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1991

BEFORE THE MONTANA BOARD OF NATURAL

RESOURCES AND CONSERVATION

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IN THE MATTER OF WATER)
RESERVATION APPLICATION NOS.)
69903-41O 71895-41I 72578-41L)
70115-41F 71966-41S 71579-41T)
70117-41H 71997-41J 72580-41A)
70118-41H 71998-41S 72581-41I)
70119-41H 72153-41P 72582-41I)
70270-41B 72154-41K 72583-41P)
71537-41P 72155-41A 72584-41S)
71688-41L 72256-41P 72585-41M)
71889-41Q 72307-41Q 72586-41P)
71890-41K 72574-41O 72587-41G)
71891-41P 72575-41K 72588-40C)
71892-41G 72576-40E 73198-41I)
71893-41K 72577-41P 73199-41S)
71894-41I IN THE UPPER)
MISSOURI RIVER BASIN)

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DEPARTMENT OF FISH, WILDLIFE AND PARKS' OBJECTOR TESTIMONY

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Objector testimony submitted in support of the Department of Fish, Wildlife and Parks' objection to reservations in the upper Missouri River Basin

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December 3, 1991

BEFORE THE MONTANA BOARD OF NATURAL

RESOURCES AND CONSERVATION

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DEPARTMENT OF FISH, WILDLIFE AND PARKS' OBJECTOR TESTIMONY

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Objector testimony submitted in support of the Department of Fish, Wildlife and Parks' objection to reservations in the upper Missouri River Basin

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December 3, 1991

LIST OF WITNESSES AND EXHIBITS FOR THE DEPARTMENT OF FISH, WILDLIFE AND PARKS PREFILED OBJECTOR'S TESTIMONY

PART I

Irrigation Projects

Fred Nelson

Liter Spence

William M. Gardner

PART II

City of Bozeman

Fred Nelson

PART III

Exhibits

Exhibit No.

1. Photographs of Jefferson River, Boulder River, and Missouri River.
2. Photograph of Smith River at Camp Baker.
3. W. Gardner and R. Berg, An Analysis of the Instream Flow Requirements for Selected Fishes in the Wild and Scenic Portion of the Missouri River (MDFWP 1982).

PART I

PRE-FILED OBJECTOR'S TESTIMONY

OF FREDERICK A. NELSON

on behalf of

MONTANA DEPARTMENT OF FISH, WILDLIFE AND PARKS (MDFWP)

Q. Please state your name and business address.

A. Fred Nelson, MDFWP, 1400 South 19th Avenue, Bozeman, Montana 59715.

Q. What is your present employment?

A. I am a fisheries biologist employed by the Montana Department of Fish, Wildlife and Parks.

Q. Please state your educational background and experience.

A. This information was already presented in previous testimony I filed for this reservation proceeding on behalf of MDFWP. That testimony included a description of my instream flow-related training and a vita.

Q. What is the purpose of this testimony?

A. The purpose is to provide the MDFWP's pre-filed objector's testimony to the applications of the Conservation Districts that impact the streamflows of the Madison, Boulder, Jefferson, and Missouri (above Canyon Ferry Dam) rivers. My testimony is organized under four headings titled Madison River, Boulder River, Jefferson River and Missouri River above Canyon Ferry Dam.

<u>Madison River</u>

Q. Which reservation application does this objection testimony pertain to?

A. This objection testimony pertains to project GA-201, submitted by the Gallatin Conservation District. The proposal is to pump up to 118.35 cfs of flow from the lower Madison River at the MDFWP's Greycliff Fishing Access Site. Water would be pumped through 37.7 miles of pipeline to irrigate 7,890 acres of benchland overlooking the Madison River.

Q. Why is the MDFWP objecting to this application?

A. MDFWP is objecting because: 1) the proposed depletion will aggravate an existing water temperature problem that already is harming the lower river's trout fishery, 2) the proposal would interfere with a prior water right of the MDFWP, 3) the proposed project conflicts with MDFWP's instream flow reservation application, and 4) the project will impact recreation lands owned by MDFWP.

Q. MDFWP objects because the proposed depletion will aggravate an existing water temperature problem. Explain this existing water temperature problem in the Madison River below Ennis Reservoir.

A. Madison River water that is stored in Ennis Reservoir - a wide, shallow impoundment having an average depth of about eight feet - is heated by solar energy. Heated water is released to the lower Madison River where it first passes through the narrow confines of the Bear Trap Canyon. Upon leaving the canyon and entering the wide Madison Valley, solar energy further heats the flow, creating summer water temperatures that are unfavorable and sometimes lethal to trout.

Q. How do these elevated summer water temperatures affect the Madison's trout fishery?

A. Elevated summer water temperatures adversely affect the survivability, growth and catchability of trout in the lower Madison River.

Q. How is survivability affected?

A. Summer water temperatures in the lower Madison River below the Bear Trap Canyon routinely reach 80°F and occasionally approach 83°F, which is the lethal water temperature for trout. In the summer of 1988, temperatures reached 83°F, causing a series of major fish kills on the river below Black's Ford, located about four miles below the mouth of the Bear Trap Canyon. Temperatures do not have to be at lethal levels to harm trout. Fish subjected to high, but sub-lethal, temperatures are highly stressed, will fail to grow, and will become vulnerable to other sources of mortality, such as disease and predation.

Q. How serious is the summer temperature problem in terms of trout survivability?

A. Summer temperatures in the lower Madison River are presently at the threshold of survivability for trout. Summer temperature increases as small as one or two degrees could be fatal.

Q. What is the current status of the trout populations in the lower Madison River?

A. Recent population studies by the MDFWP show that the stretch of river at the mouth of the Bear Trap Canyon presently supports about 3,000 brown trout and 1,000 rainbow trout of ten inches and longer per river mile. These trout numbers are relatively high for the rivers of southwest Montana. This section, along with the Bear Trap Canyon stretch, support much of the fishing pressure on the lower Madison River below Ennis Dam. In 1989, the 40 miles of river below Ennis Dam supported an estimated 38,151 angler-days of pressure, which averages about 947 angler-days per river mile. This is a high level of use for the rivers of southwest Montana.

About six miles downstream at the Greycliff Fishing Access Site, the location of the proposed project diversion, trout numbers markedly decline to about 1,000 fish per mile. This currently depressed population is believed to reflect the series of heat-related fish kills that occurred in this stretch in 1988.

Q. How is trout growth affected by elevated water temperatures?

A. The elevated summer water temperatures of the lower Madison River depress the growth rates of the larger trout (ten inches and longer). These fish grow only during the spring and fall when cooler water creates temperatures more favorable for their growth. Larger fish commonly lose weight over summer in response to the elevated temperatures. The larger trout of the lower river show about a 25% (two-three inch) growth reduction when compared to the same age fish in the upper Madison River where a summer temperature problem is absent.

Q. How is catchability affected?

A. Warmer water causes angler catch rates to decline in the lower river. At temperatures of 66°F and higher, catch rates decline to levels considered unsatisfactory by anglers in this section. Consequently, from about mid-June to early-September of each year, elevated temperatures cause fishing success to slump and anglers generally abandon the lower river for more productive waters. Further warming would worsen an existing problem.

Q. Are water temperatures in the lower Madison River affected by flows?

A. Yes. While air temperature is the major factor that influences water temperatures in the lower Madison River, the flow rate also plays an important role. Water temperature is inversely related to flow rate. Flow increases can potentially lower water temperatures the one to two degrees that could alleviate fish kills during crisis periods. The MDFWP and the Montana Power Company (MPC), the operator of

Hebgen and Ennis reservoirs on the Madison River, are presently planning to use increased flow releases as a tool for alleviating summer fish kills.

Q. Has research been conducted to predict the impact of increased flow releases on water temperatures in the lower Madison River?

A. Yes. Recent temperature/flow modeling studies funded by the MPC and conducted by researchers at Montana State University show that flow increases during crisis periods would aid in alleviating fish kills in the lower river's most heavily fished sections. When water temperatures are approaching 80°F and an extended heat spell is forecasted, upping the flow below Ennis Dam to a minimum of about 1,600 cfs would prevent lethal temperatures in that stretch of river to about the Cobblestone Fishing Access Site, located about seven miles downstream from Greycliff. This stretch bounds the most heavily fished portion of the river. Below Cobblestone Fishing Access Site, lethal temperatures would still occur. In essence, flow increases would simply move the point of occurrence of lethal water temperature downstream; it would not eliminate lethal temperatures nor would it eliminate the sub-lethal temperatures that are so stressful to trout.

Q. How would the proposed project (GA-201) affect flows and water temperatures?

A. The project would substantially reduce summer flows and aggravate an already near-critical temperature problem.

Q. Explain these adverse effects on streamflow and temperature.

A. It's unlikely little, if any, of the diverted water would return to the Madison River. Any return flows from the high benchlands being irrigated would pass into the adjacent Gallatin Drainage. Consequently, the total flow depletion would equal 118 cfs if this project was built.

Historic flow characteristics of the lower Madison River near Three Forks were provided by the USGS (see pg. D-5 of the draft EIS and Exhibit 4 of MDFWP's pre-filed direct testimony, which will be referred to in later citations as the USGS flow report). Summer flows are lowest in August, the month water temperature problems are likely to be critical and when irrigation demands are highest. August flows are:

	Percentile Flows (cfs)			
	90th	80th	50th	20th
August	1,000	1,200	1,500	1,700

In a drought (a one-in-ten-year event which is the 90th percentile flow), the project would reduce the August flow by 12%. In a normal flow year (the 50th percentile), August flow would be reduced by 8%. This is a substantial flow loss when considering the already critical state of the river's summer temperature regime. One hundred and eighteen cfs would be removed from a section already heat stressed; a section where recent heat-related fish kills are likely responsible for the current depressed population of trout; a section where summer temperature increases as little as one or two degrees could prove fatal. Added flow depletions will aggravate the present thermal problem, already of near-crisis proportions, and potentially push it over the brink and cause massive fish kills.

Q. Do the above percentile flows reflect the existing state of the flows in the lower Madison River?

A. No. The above percentile flows reflect the historic record during the 1937-86 base period. During the years from 1937 through 1986, more land was put under irrigation and reservoir operations changed. Thus, the above percentiles do not reflect today's level of irrigation development and current reservoir operations, but are an average for a period of time when depletion was increasing.

Q. What are the percentile flows for the lower Madison River under present conditions?

A. Percentile flows under the 1986 levels of irrigation development and current reservoir operations were compiled by the DNRC (see pg. C-7 of Draft EIS). These percentile flows were generated by DNRC's Missouri River basin water availability model, which mathematically adjusted the historic record to reflect current irrigation development and reservoir operations. For the Madison River near Three Forks, August percentile flows are:

	Percentile Flows (cfs)			
	90th	80th	50th	20th
August	602	724	1,227	1,647

Q. What do these percentiles show?

A. Under present levels of irrigation and current reservoir operations, current flows are far worse than previously indicated by the historic record. The project's proposed depletion of 118 cfs would reduce August flow during a normal flow year (the 50th percentile) by 10%, and during a drought year (the 90th percentile) by 20%.

Q. MDFWP also objects on the grounds that the proposed project will adversely affect recreation lands owned by MDFWP. Explain this.

A. The proposed project will use lands of the Greycliff Fishing Access Site, owned by MDFWP. In addition to being a popular angler access to the lower Madison River, the site contains two developed campgrounds, picnic areas, and boat launches. In spring and summer, Greycliff is a popular site for group functions. In fall, hunting opportunities for deer, pheasants and waterfowl are provided. Use of the site by recreationists and other users is high, amounting to about 16,000 visitor-days in 1988.

Project developments at Greycliff will potentially include an up to 60-inch diameter pipeline, an irrigation diversion, transmission lines, service roads, and a massive (and noisy) pump. Irrigation use will occur in spring and summer when the site is heavily used for recreation. MDFWP believes that these proposed developments are incompatible with the recreational purpose of the access site.

Q. The proposed project will also interfere with a prior water right of MDFWP. Explain this.

A. An act passed by the 1969 Montana Legislature enabled MDFWP to file for instream water rights for purposes of preserving fish and wildlife habitat on 12 high quality trout streams. Under SB 76, these instream rights were refiled in 1982. For the 40-mile section of the Madison River between its mouth and Ennis Dam, the amount of the instream rights of MDFWP are (claims #S41F-W-138560 through 138563):

Time Period	Amount (cfs)
Jan. 1 - May 31	1,200
June 1 - June 30	1,500
July 1 - July 15	1,423
July 16 - Dec. 31	1,300

Historic flows in the Madison River near Three Forks, near the site of the proposed project diversion, were provided by the USGS (see pg. D-5 of draft EIS and USGS flow report). During the peak of the irrigation season in August, flows near Three Forks are:

	Percentile Flows (cfs)			
	90th	80th	50th	20th
August	1,000	1,200	1,500	1,700

For August, the instream right of the MDFWP is 1,300 cfs, which falls between the 80th and 50th percentile flows. If we interpolate, 1,300 cfs would equal about the 70th percentile flow, meaning that, in about 7 years-out-of-10, average flow of the Madison River in August exceeds 1,300 cfs at this site. Conversely, in about 3 years-out-of-10, flows will be less than 1,300 cfs.

To fully meet the project's peak demand of 118 cfs and, at the same time, satisfy the MDFWP's instream right of 1,300 cfs for August, a minimum of approximately 1,418 cfs must be flowing above the proposed diversion site. Again, by interpolation, this 1,418 cfs approximately equals the 60th percentile flow, meaning that in only about 6-out-of-10 years will enough water be available to fully meet the project's peak demand of 118 cfs in August. In about 3-out-of-10 years, no water will be available for project use with MDFWP's prior instream right in place. In about 1-out-of-10 years, some water, but not the full supply of 118 cfs, will be available for project use. Thus, the project can only count on receiving its full water supply in about 6 years-out-of-10.

Q. How will water availability for the project be affected when the percentile flows that reflect present levels of irrigation development and current reservoir operations are used in the analysis?

A. Under present levels of irrigation development and current reservoir operations, August flows of the Madison River near Three Forks are far worse than previously indicated. These flows, as summarized by the DNRC on pg. C-7 of the Draft EIS, and based on their water availability model, are:

	Percentile Flows (cfs)			
	90th	80th	50th	20th
August	602	724	1,227	1,647

To satisfy MDFWP's August instream flow right of 1,300 cfs and, at the same time, supply 118 cfs for the project, a minimum of 1,418 cfs must flow above the proposed diversion site. This 1,418 cfs falls between the 50th and 20th percentile flows. By interpolation, 1,418 cfs equals about the 40th percentile flow, meaning that in about 4 years-out-of-10, flows will exceed about 1,418 cfs. Thus, in only about 4 years-out-of-10 will sufficient flow be available to fully satisfy the project's water demand.

Q. How does this level of water availability affect project feasibility?

A. GA-201 is a potential seed potato project. The project application selected a rotation pattern of one year small grain, one year potatoes, one year small grain, and three

Q. Are there other ways to assess the severity of current low flows?

A. Yes. The wetted perimeter inflection point method used by MDFWP to derive its instream flow request for the Jefferson River yielded an upper inflection point flow of 1,100 cfs (see pg. 2-348 of MDFWP's application). Eleven hundred cfs is approximately equal to the river's base winter flow. MDFWP's request equals 47% of the average annual flow (2,333 cfs) at the near Three Forks gauge site of the USGS (see pg. D-6 of the Draft EIS). (It should be noted that the average annual flow of 2,333 cfs reflects existing depletions and would be substantially higher in the virgin or undepleted state. According to a published report of the SCS, the average annual flow, without depletions, would be approximately 2,869 cfs. MDFWP's 1,100 cfs instream request equals 38% of the undepleted average annual flow).

Historic flows at the near Three Forks gauge site are summarized by the USGS (pg. D-6 of the DRAFT EIS and the USGS flow report). Annual flows are lowest in August during the peak of the irrigation season. These August flows are:

	Percentile Flows (cfs)			
	90th	80th	50th	20th
August	450	540	850	1,400

The 1,100 cfs request of MDFWP falls between the 50th and 20th percentile flows, meaning that in at least 5-out-of-10 years, August flows are less than 1,100 cfs. In 2-out-of-10 years, August flows are no more than 1/2 of 1,100 cfs.

Historic flows are also summarized for the Sappington gauge site (see pg. D-6 of Draft EIS and the USGS flow report). August flows are:

	Percentile Flows (cfs)			
	90th	80th	50th	20th
August	250	410	690	1,200

Here, the 1,100 cfs request is about equal to the 20th percentile flow. Thus, in about 8 years-out-of-10, August flows are less than the 1,100 cfs request of MDFWP. In about 1 year-out-of-10, August flows are less than 1/4 of the 1,100 cfs request.

Q. Do the above analyses indicate that MDFWP's instream flow request is excessive?

A. No. The analyses simply indicate the inadequacy of existing depleted summer flows. Existing irrigation diversions already overburden the river, creating summer flows that threaten the existence of a viable fishery resource.

Q. How much ground is irrigated above the Sappington and near Three Forks gauge sites?

A. According to published records of the USGS, about 364,700 and 390,000 acres, respectively, are irrigated upstream from the above sites. This explains why summer flows are so depleted.

Q. Are low summer flows a chronic problem on the Jefferson River?

A. Yes. Low flows caused by irrigation depletions have been a long-standing problem on the Jefferson River. Evidence of this chronic problem is provided by gauge records of the USGS. For example, a USGS gauge was operated near Silver Star from 1910-1916 and 1920-1939 (see Attachment B). Silver Star is an area of the river where present dewatering is particularly severe in summer. Minimum flows at this site were:

Year	Minimum (cfs)	Year	Minimum (cfs)
1910	-	1927	760
1911	440	1928	234
1912	-	1929	122
1913	630	1930	276
1914	460	1931	55
1915	-	1932	182
1916	465	1933	106
1920	-	1934	71
1921	571	1935	87
1922	-	1936	121
1923	780	1937	50
1924	129	1938	148
1925	647	1939	192
1926	187		

Ten percent of the average annual flow for this site was about 171 cfs. Nine of the 22 annual lows were less than the ten percent level that Tennant considers only suited for the <u>short-term survival of aquatic life</u>. Three of the annual lows were slightly greater than the ten percent level. Dewatering continues to be an ongoing problem at this site and other portions of the river as well.

Q. Does the MDFWP possess photographs that visually depict the severity of summer dewatering on the Jefferson River?

A. Yes. Some of these photos are shown in Exhibit 1. Included is a set of photos taken at the Waterloo Bridge on July 30, 1988, when flow was 4.65 cfs, and August 7, 1961. Comparison of the two photos shows that the dewatering in 1961 at this site was as extreme as that in 1988, a recent drought year.

Q. The MDFWP also objects on the grounds that the total amount of the proposed depletions is substantial and will severely reduce the river's already depressed summer flows. Explain this.

A. The ten proposed Jefferson River projects have a combined peak diversion rate of approximately 310 cfs (see below).

Project	Peak Diversion Rate (cfs)
BR-52	0.66
BR-101	77.40
JV-25	0.53
JV-55	1.86
JV-95	14.43
JV-201	80.30
JV-202	88.90
JV-203	35.80
JV-204	7.42
GA-102	2.34
Total	309.64

Taking into account potential irrigation return flows, the ten projects will reduce August flows in the Jefferson River by about 185 cfs, according to the draft EA's for the applications of the Broadwater, Jefferson Valley and Gallatin Conservation Districts. In July, flows will be reduced by about 228 cfs.

The effect of an added August flow reduction of 185 cfs on current low flows can be assessed by examining the historic flow record for the USGS gauge near Three Forks (pg. D-6 of Draft EIS and USGS flow report). Percentile flows for August, the lowest flow month for the year, are:

	Percentile Flows (cfs)			
	90th	80th	50th	20th
August	450	540	850	1400

Assuming that this gauge reflects the flows near the river's mouth, flows during a drought year (a one-in-ten year event which is the 90th percentile flow) would decrease 41%. During a normal flow year (the 50th percentile flow), August flow would decrease 22%.

Long-term historic gauge information is also available for the

Jefferson River at Sappington (pg. D-6 of Draft EIS and USGS flow report). August percentile flows at this site are:

	Percentile Flows (cfs)			
	90th	80th	50th	20th
August	250	410	690	1200

Seven of the Jefferson River projects are upstream from this gauge site. Their potential flow reductions, taking into account return flows, total 144 cfs for August (see Draft EA for the application of the Jefferson Valley Conservation District). During a drought year, August flow at the Sappington site will be reduced by 58%. In a normal water year, a 21% reduction is expected.

These are substantial flow reductions for a stream that already suffers from chronic summer dewatering.

Q. Do the above percentile flows reflect the existing state of the flows in the Jefferson River?

A. No. The above percentile flows reflect the historic record during the 1937-86 base period. During the years from 1937 through 1986, more land was put under irrigation and reservoir regulation came into play. Thus, the above percentiles do not reflect flows under today's level of irrigation development and current reservoir operations.

Q. What are the percentile flows for the Jefferson River under present conditions?

A. Percentile flows under the 1986 levels of irrigation development and current reservoir operations were computed by the DNRC (see pg. C-6 of the Draft EIS) using their water availability model. For the Jefferson River near Three Forks, these percentiles for August are:

	Percentile Flows (cfs)			
	90th	80th	50th	20th
August	0	172	727	1,160

Q. What do these percentiles show?

A. They show that, under today's conditions, the proposed Jefferson River depletions of the Conservation Districts are devastating. The potential August depletion of 185 cfs would increase the occurrence of zero flows in August to 2-out-of-10 years. During a normal flow year (the 50th percentile), existing low flows would be reduced by 25% to a level that is but 1/2 of the 1,100 cfs needed for fishery maintenance.

Q. How would these potential flow depletions affect the trout populations in the Jefferson River?

A. As discussed earlier, the existing trout populations of the Jefferson River are already depressed, a consequence of existing dewatering and other related environmental problems. Flow depletions of the magnitude being proposed would substantially reduce the present low flows and undoubtedly lead to further fish losses.

Q. At what point will the river cease to support a viable sport fishery?

A. According to angler use estimates of the MDFWP, the Jefferson River, in 1989, sustained about 15,260 angler-days of fishing pressure. This equals about 182 angler-days of use per river mile. In comparison, the neighboring Madison River, a stream without a serious dewatering problem, sustained an estimated 1,138 angler-days per mile, which is more than six times that of the Jefferson. The stretch of the Big Hole River, which includes the river's best fishing water and a chronically dewatered segment of river, supported an estimated 437 angler-days per mile, which is 2.4 times that of the Jefferson River. Clearly, angler use of the Jefferson River is well below that of neighboring rivers. This low use undoubtedly reflects the poor fish populations and other consequences of chronic dewatering. The sport fishery is already on the verge of collapse, as reflected by the low rate of use by the angling public. Added flow depletions of the magnitude being proposed will likely eliminate the sport fishery.

Q. MDFWP claims that further depletions from the Jefferson River will impact a prior water right of the MDFWP. Explain this prior right.

A. MDFWP presently holds instream water rights for the Missouri River from Toston Dam to Canyon Ferry Reservoir. The instream rights, which have a 1970 priority date, were authorized by an act passed by the 1969 Montana Legislature. Under Senate Bill 76, these instream rights were refiled in 1982 (claims S41I-W-190867 through 190872).

Q. How could depletions from the Jefferson River interfere with MDFWP's instream rights for the Missouri River?

A. Water to satisfy MDFWP's instream rights for the upper Missouri River is primarily supplied by the Madison, Gallatin and Jefferson rivers, the source waters for the Missouri River. The potential August flow reduction of 185 cfs and July reduction of 228 cfs in the Jefferson River, when combined with other depletions that could occur in the Gallatin, Boulder and Madison rivers if consumptive levels. New depletions as shown above would further lowerstreamflows at the 90th percentile and drop flows below 90 cfs in July at the 80th percentile. Only in an average year (50th percentile) would flows be about 90 cfs or above. Therefore, since DFWP considers 90 cfs the minimum required flow for fishery purposes, the new projects would adversely affect the fishery by depleting flows below this level.

The most popular fishery on the Smith River is between Camp Baker and the Eden Bridge, a distance of about 66 miles. Public access to this river reach is gained almost exclusively by floating. Floating the Smith River is currently limited to between about mid-April and the first week in July in an average water year. The minimum flow considered necessary to allow floaters to utilize this section of the river is more than 100 cfs. When streamflow at the Camp Baker gauge is 100 cfs or less, floating becomes difficult and interest drops off. The 100 cfs flow is an indicator of floating conditions, since Sheep Creek contributes additional flow just below the boat launch site. Sheep Creek flow is necessary for successful floating conditions when the Smith River above Sheep Creek reaches its minimum flow level.

As the above existing flow table shows, 100 cfs is not currently available, on the average, during July at the 90th percentile. Flows are actually lower than these average flows in any given year. For example, during the drought of 1988, daily streamflow actually measured at the USGS gauge at Camp Baker dropped as low as 35 cfs during June, 39 cfs during July, and 23 cfs during August. The actual floating season in 1988 was over for most persons by about mid June, about three weeks earlier than normal. Exhibit 2 is a 1988 photograph taken by me of the Smith River at Camp Baker at a flow of 35 cfs which illustrates the low flows which occurred that year. Continued water withdrawals on the upper Smith River will increase the frequency that such low flows will occur. Additional reductions in streamflows during drought years as occurred in 1988 would further shorten the time period that floaters can utilize this reach of the Smith River and would increase the yearly frequency of these low flows.

<u>Reach #2 - Sheep Creek to Hound Creek</u>

DFWP has requested an instream flow of 150 cfs in this river reach. Baseline (existing) flows in Reach #2 as determined by DNRC at Eden (above the mouth of Hound Creek are shown below.

Baseline Flows - Reach #2
(CFS)

	June	July	August	Sept.
90%	304	60	24	50
80%	434	129	56	62
50%	796	302	124	106

Source: DEIS, page C-8

Under the Consumptive Use Alternative described in the DEIS, streamflows would be reduced to the following levels if all five projects on the river above Hound Creek are implemented.

Depleted Flows - Consumptive Use Alternative, Reach #2
(CFS)

	June	July	August	September
90%	289 (5%)	36 (40%)	2 (92%)	43 (14%)
80%	425 (2%)	110 (15%)	34 (39%)	55 (11%)
50%	786 (1%)	283 (6%)	109 (12%)	101 (5%)

Source: DEIS, page C-12
Percent reduction from baseline flows shown in parentheses.

Existing flows during July - September at the 90th and 80th percentiles are already below the 150 cfs requested by DFWP as the amount necessary to provide a near-optimum fishery in this reach of the Smith River. Even in an average water year (50th percentile) flows are below 150 cfs in August and September. Further depletions would reduce these flows by as much as 82% in August of a drought year. In 1988, flows fell to 23 cfs in August.

Hound Creek

Q. What conservation district projects on Hound Creek would affect streamflows?

A. Hound Creek is a tributary to the Smith River entering below the Eden Bridge. The Cascade County Conservation District has proposed three projects on Hound Creek (CS-62, CS-63, and CS-64). These three projects would have a total diversion rate of 3.72 cfs (370 af/yr)(DEIS, page 14).

Existing streamflows in Hound Creek are shown below.

	July	August	September
90%	27	16	15
80%	41	22	17

Source: DEIS, page D-15

The depletions for these projects would be as follows:

Depletions - Hound Creek
(CFS)

July	August	September
1.48	1.21	0.49

Source: Cascade County CD draft EA, Table 5

DFWP has requested 35 cfs in Hound Creek from the confluence of the East Fork and Middle Creek to the mouth. Based on the existing flows, these three projects would deplete streamflows by a maximum of 6% in July of a 90th percentile flow year. This depletion would have a minor impact on the existing streamflows and would probably not noticeably affect the 35 cfs instream flow request of DFWP. However, they would add to the cumulative effect of new depletions in the Smith River and lower Missouri basin.

Sun River Basin

Q. What conservation district projects in the Sun River basin would have effects on streamflows?

A. There are 25 conservation district projects proposed in the Sun River basin by Teton County, Lewis and Clark County and Cascade County conservation districts. These requests are for a total of 125.91 cfs (18,088 af/yr). The largest project (CSS-200) would divert 65% of this amount or 82.02 cfs up to 11,885 af/yr. Project CSS-200 is located in the lower reaches of the Sun River a few miles upstream from Great Falls. This project would pump water from the Sun River to supply 43 new center pivot sprinklers, 36 of which would irrigate an area of 125 acres each.

DFWP has requested instream flows on the Sun River mainstem from the Diversion Dam to the confluence with Elk Creek (Reach

#1) and from Elk Creek to the mouth of the Sun River (Reach #2). All but five of the proposed projects in the Sun River basin are located below the USGS gauge (number 858) at Simms. The Simms gauge is located below Elk Creek. The five projects located above the Simms gauge (TEI-100, TEI-90, TEI-80, LC-131 and LC-251) would divert 6.51 cfs (974 af/yr)(DEIS pages 15, 16 and 17). Four projects are above Elk Creek and one is on Elk Creek (LE-251).

Sun River above Elk Creek

DFWP has requested an instream flow of 100 cfs in the Sun River above Elk Creek. Existing streamflows at the Simms gauge below Elk Creek are shown below.

Existing Flows at Simms
(CFS)

	July	Aug.	Sept.
90%	66	55	49
80%	96	87	68

Source: DEIS, page D-16

Total depletions of the five projects proposed above the Simms gauge are shown below:

Project Depletions
(CFS)

	July	Aug.	Sept.
Lewis and Clark County CD	3.34	2.38	0.75
Teton County CD	1.89	0.81	0.18
Total	5.23	3.19	0.93

Source: Lewis and Clark County CD, draft EA, Table 5 and Teton County CD draft EA, Table 5.

Thus, flows in both a drought and a dry year above Elk Creek are already below 100 cfs, on the average, without any new diversions. The proposed depletions would further reduce flows as shown below.

Depleted Flows at Simms
(CFS)

	July	Aug.	Sept.
90%	61 (8%)	52 (6%)	48 (2%)
80%	91 (5%)	84 (3%)	67 (1%)

Percent reduction from existing flows shown in parentheses.

Although these reductions would have only a slight additional impact on the already depleted streamflows in this reach of the Sun River, they will aggravate an already poor flow condition.

Sun River below Elk Creek

The remainder of the projects in the Sun River basin lie below Elk Creek and the Simms gauge. Two of the projects are on Big Coulee, two projects are on Muddy Creek and the remainder are along the Sun River in Cascade County. These projects would divert an additional 119.40 cfs (17,185 af/yr) above the amounts already noted for projects above the Simms gauge.

DFWP has requested an instream flow of 130 cfs in Reach #2 of the Sun River. The lower Sun River experiences severe dewatering during the summer when irrigation demand is at its peak. Poor flows and elevated water temperatures during this period have limited the fishery to short river segments where irrigation return flows and seepage provide only marginal flow conditions for trout. With adequate flow, there is an excellent potential to improve the fishery (DFWP Appl. page 3-195).

Baseline flows in the lower Sun River were determined at the USGS gauge near Vaughn, which is located below the mouth of Muddy Creek. These flows are as follows:

Baseline Flows - Sun River near Vaughn
(CFS)

	July	Aug.	Sept.
90%	42	224	239
80%	240	312	303
50%	430	493	426

Source: DEIS, page C-8

In the driest one and two years in 10 (90th and 80th percentiles respectively,) flows in the Sun River near Vaughn would be reduced under the Consumptive Use Alternative to the following quantities:

Depleted Flows - Sun River near Vaughn
(CFS)

	July	August	September
90%	0 (100%)	158 (30%)	239 (0%)
80%	137 (43%)	265 (15%)	288 (5%)
50%	345 (20%)	447 (9%)	412 (3%)

Percentage reductions from baseline flows shown in parentheses.

DFWP has requested 130 cfs in the lower reach of the Sun River. The principal impact of the Consumptive Use Alternative on streamflows would occur in July at the 80th percentile and in July and August at the 90th percentile. Flows in July at the 90th percentile would be reduced to zero. Only during average years (50th percentile) are flows available to meet the instream flow request of 130 cfs. Thus, new depletions will only make worse an already poor flow condition in the lower Sun River where only a marginal fishery currently exists.

Project CSS-200 is the largest proposed project on the Sun River. The diversion point of this project is below the Vaughn gauge. Assuming water is still available, this project would deplete flows in the Sun River below the point of diversion by an additional 53.54 cfs in July; 30.48 cfs in August and 6.53 cfs in September (Cascade County CD draft EA, Table 5, page 12). Under the Consumptive Use Alternative, this would result in the following flows below the point of diversion:

Depleted flows below Project CSS-200
(CFS)

	July	August	September
90%	0[1]	128	232
80%	83	235	281
50%	291	416	405

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[1]Flow is already zero at the Vaughn gauge upstream.

Thus flows in the Sun River below the diversion point would be even less than those shown at the Vaughn gauge and, in July, would be well below the 130 cfs recommended by DFWP to maintain the lower Sun River fishery. There does not appear to be any water available for project CSS-200 in July, on the average, at the 90th percentile flow level.

Elk Creek

Q. What conservation district projects are on Elk Creek that would affect streamflows?

A. Elk Creek is a tributary to the Sun River that has only one new irrigation project proposed by the Lewis and Clark County Conservation District. DFWP has requested 16 cfs for instream flows on Elk Creek. Flows in July, August and September at the 90th percentile range between 20 and 32 cfs. At the 80th percentile, they range between 23 and 52 cfs (DEIS, page D-16). The proposed depletions on Elk Creek from the single project would be a maximum of 0.64 cfs in July. Thus, it is not expected this project will significantly affect streamflows on Elk Creek but would contribute to the cumulative depletions in the Sun River.

Belt Creek

Q. What conservation district projects in Belt Creek would have an effect on streamflows?

A. There are seven proposed new irrigation projects in the Belt Creek drainage (JB-61, JB-281, CS-43, CS-42, CS-159, CS-44, and CHS-1). These projects would divert a total of 34.05 cfs (4,659 af/yr)(DEIS, pages 14, 15 and 16). Project JB-281 is on Big Otter Creek (Referred to as Otter Creek in DEIS). Project JB-61 is on Little Otter Creek, a tributary to Big Otter Creek.

DFWP has requested 35 cfs for instream flows in Belt Creek from the mouth of Big Otter Creek to the confluence with the Missouri River. The proposed projects would affect flows only below the mouth of Big Otter Creek. There are no projects in Belt Creek above the mouth of Big Otter Creek.

Existing flows near the mouth of Belt Creek, measured at the USGS gauge near Portage are shown below.

Existing Flows - Belt Creek
(CFS)

	July	August	September
90%	57	16	14
80%	85	27	18

Source: (DEIS, page D-17).

The anticipated depletions of the proposed projects on streamflows in Belt Creek are shown in the following table:

Project Depletions - Belt Creek
(CFS)

	July	August	September	
Cascade County CD	4.25	2.63	1.00	Draft EA, Table 5
Chouteau County CD	15.07	9.71	3.92	Draft Ea, Table 5
Judith Basin Co. CD	1.51	0.94	0.35	Draft EA, Table 5
Total	20.83	13.28	5.27	

The above depletions would reduce existing streamflows to those shown below.

Depleted Flows - Belt Creek
(CFS)

	July	August	September
90%	36 (37%)	3 (81%)	9 (36%)
80%	64 (25%)	14 (48%)	13 (28%)

Numbers in parentheses are the percent reduction from existing flows.

The proposed projects would have severe effects on existing streamflows, particularly during August and September at both the 90th and 80th percentiles. Flows during these months are well below the 35 cfs requested by DFWP. The requested 35 cfs is the wetted perimeter <u>low inflection point</u> flow and has been requested because aquatic habitat values in this reach of Belt Creek are low, due partly to low streamflows (DFWP application page 3-217). The additional depletions will cause habitat conditions to become even worse than they are at the present time, adversely affecting the resident trout fishery and the spring spawning migrations of sauger which enter from the

Missouri River (DFWP application page 3-217).

Big Otter Creek

Q. What conservation district projects would affect the streamflows in the Big Otter Creek drainage?

A. There are two projects proposed by Judith Basin County Conservation District. Project JB-61 would divert 2.15 cfs (275 af/yr) from Little Otter Creek which is a tributary to Big Otter Creek. Project JB-281 would divert 0.44 cfs (28 af/yr) from Big Otter Creek. DFWP has an instream flow request of 5 cfs on Big Otter Creek but has no request on Little Otter Creek. However, the proposed diversion from Little Otter Creek would adversely affect streamflows in Big Otter Creek. The combined diversion requested on both projects is 2.59 cfs (303 af/yr).

The existing flows in Big Otter Creek, as determined above Never Sweat Creek near Raynesford, are shown below:

Existing Flows - Big Otter Creek
(CFS)

	June	July	August	September
90%	14	6	2	1
80%	17	7	4	2
50%	29	10	6	5

Source: DEIS, page D-17.

The combined depletions of these two projects on Big Otter and Little Otter creeks are shown below:

Depletions - Big and Little Otter Creeks
(CFS)

	June	July	August	September
Otter Creek	0.04	0.09	0.06	0.02
Little Otter Creek	0.74	1.42	0.88	0.33
Total	0.78	1.51	0.94	0.35

Source: Judith Basin County CD draft EA, Table 5.

DFWP has requested 5 cfs in Big Otter Creek. Because of an artesian aquifer, Big Otter Creek is able to maintain a consistent perennial flow even though these flows are of low magnitude most of the year (DFWP application, page 3-235; DEIS page D-17). During high flow periods in a wet year, streamflows are 50 cfs or less on the average. During the drier times of the year, flows are normally less than 15 cfs even in a wet year (DEIS page D-17).

If the projects on Big Otter Creek and Little Otter Creek are implemented, streamflows in Big Otter Creek would be reduced to the levels shown below.

Depleted Flows - Big Otter Creek
(CFS)

	June	July	August	September
90%	13 (6%)	4.5 (25%)	1.1 (47%)	0.6 (35%)
80%	16 (5%)	5.5 (22%)	3.1 (23%)	1.6 (17%)
50%	28 (3%)	8.5 (15%)	5.1 (16%)	4.6 (7%)

Percent reduction from existing flows is shown in parentheses.

The above information shows that the two projects would not significantly affect streamflows in June of any year and would have varying effects during July, August and September of average, dry and drought years. In a drought year (90th percentile), flows would be nearly cut in half in August and would be below the DFWP flow request in July, August and September. In a dry year (80th percentile), flows would be less affected but would still be below the 5 cfs flow request in August and September. The same would be true in an average year (50th percentile) for August and September. The overall impact of new depletions, therefore, would be to reduce flows in Big Otter Creek in dry and average years to levels that fall below the minimum instream flows needed and, thus, adversely impact the stream's fishery.

Teton River Basin

Q. Please describe how proposed conservation district projects in the Teton River basin will affect streamflows.

A. DFWP has an instream flow request for 35 cfs in the Teton River in the reach from the headwaters to the discharge from Priest Butte Lake near Choteau. Instream flow requests have also been submitted on several of its tributaries. No instream flow requests have been submitted for the Teton River below the Choteau area. No conservation district projects are proposed for the tributary streams where DFWP has flow requests, but only for the Teton River itself. In the reach where DFWP has a flow request, there are four projects proposed by Teton County Conservation District (TEI-70, TEI-60, TEI-50, and TE-321). These four projects would divert a total of 25.33 cfs from the Teton River (DEIS, page 17). The largest of these projects (TEI-60) would divert 10.99 cfs.

Depletions by these four projects are shown in the following table:

(CFS) Project Depletions - Teton County CD

	July	August	September
TEI-50	1.43	0.46	0.15
TEI-60	4.57	1.43	0.48
TEI-70	1.82	0.58	0.19
TE-321	2.81	0.90	0.29
Total	10.63	3.37	1.11

Source: Teton County CD draft EA, page 10, Table 5.

The most significant effect of these depletions will be in July. July flows in a drought year (90th percentile) are currently 32 cfs, on the average. In a dry year (80th percentile) flows are 64 cfs, on the average, at the USGS gauge near Dutton, which is downstream from the lowermost reach of the DFWP instream flow request (DEIS, Table D-1, page D-18).

Upper Teton River flows before and after depletions by these four proposed projects are shown below.

Teton River near Dutton

	Baseline Flow[1]			Depleted Flow[2]		
	July	Aug.	Sep.	July	Aug.	Sept.
90%	32	16	26	21 (34%)	13 (19%)	25 (4%)
80%	64	45	39	53 (17%)	42 (7%)	38 (3%)

[1]DEIS, page D-18
[2]Baseline flows minus project depletions
Percent reduction from baseline flows shown in parentheses.

DFWP has requested 35 cfs in the upper reach of the Teton

River. An additional depletion of approximately 11 cfs would reduce existing July flows at the 90th percentile level by 34% and at the 80th percentile level by 17%. It would produce a flow that is 30% below the flow requested by DFWP to maintain the fishery resources of this reach of the river. About 43% of the overall depletion would occur from project TEI-60.

According to the DEIS (page 166), existing flows in the Teton River are insufficient to support all water uses included in any of the three alternatives. According to DNRC's water availability model, July flows at the mouth of the Teton River near Loma already cease during the driest two years out of 10 (80th percentile) during all months except March and June. Flows already cease in August and September of average years (50th percentile). Under the Consumptive Use Alternative, June flows would cease during dry years, July flows would cease in average years, and August flows would drop to three cfs during wet years. Therefore, even under baseline conditions (without any new diversions) flows are not available for new projects during most months in a dry year (DEIS pages 166 through 169). DFWP has not requested instream flows in the lower Teton River. However, it is apparent that additional upstream depletions will only further aggravate an already poor streamflow condition in the lower Teton River and contribute to lower flows in the Missouri River.

Marias River Basin

Q. Please describe the conservation district projects in the Marias River basin which will affect streamflows.

A. The first part of my testimony will be for that portion of the Marias River basin lying above Tiber Reservoir followed by the Marias River below Tiber Reservoir.

Marias River above Tiber Reservoir

Three conservation districts have proposed projects in the basin above Tiber Reservoir. These projects are GL-11, GL-221, GL-201, POI-10, PO-421, PO-251, PO-91, PO-171, PO-211, PO-411, PO-271 and TO-221. The eight projects proposed by Pondera County CD would require a total of 16.05 cfs (2,092 af/yr) to irrigate 1,058.3 acres of land using wheel lines, hand lines and center pivot sprinkler systems. Toole County CD proposes one project which would divert 1.26 cfs (153 af/yr). The three projects proposed by Glacier County CD would divert a total of 11.44 cfs (1,271 af/yr)(DEIS Table 3-1, page 14).

The conservation district projects would deplete flows in the basin by the following amounts.

Project Depletions (cfs)

	July	August	September
Glacier County CD	11.92	6.52	2.76
Pondera County CD	8.15	4.35	1.83
Toole County CD	0.47	0.24	0.10
Total	20.54	11.11	4.69

Source: Glacier County CD draft EA, Table 4; Pondera County CD draft EA, Table 5; and Toole County CD draft EA, Table 5.

Existing streamflows on the Marias River above Tiber Reservoir near Shelby are as follows:

Existing Streamflows (cfs)

Percentile Flow	July	August	September
90%	370	180	150
80%	570	220	220

Source: DEIS, page D-17

DFWP has requested 200 cfs in the Marias River above Tiber Reservoir. Flows in the Marias River above Tiber Reservoir are already below 200 cfs in August and September in a drought year (90th percentile). Reductions in streamflow of the above amounts from these existing flows would reduce streamflows an additional 11 cfs in August and 5 cfs in September. In a dry year (80th percentile), August flows would be reduced to about 209 cfs. On the average, project depletions would reduce streamflows in August and September in a drought year (90th percentile) even further below the 200 cfs instream flow DFWP considers necessary in this stream reach during those months.

Marias River below Tiber Reservoir

In the Marias River basin below Tiber Reservoir and including Tiber Reservoir, five conservation districts have submitted project applications. These projects are TO-211, TO-341, TO-342, TO-421, LI-161, LI-162, LI-261, LI-91, LI-262, LI-263, HI-269, BSS-2, BS-32, BS-31, CHI-52, CH-53, CH-51.

The four largest projects and their diversion rates are BSS-2, 289.61 cfs (44,608 af/yr); HI-269, 18.82 cfs (2,708 af/yr); LI-261, 24.31 cfs (3,241 af/yr); and LI-262, 10.51 cfs (1,401 af/yr). All four projects divert water from the Marias River. BSS-2 would supply water to 135 new center pivot sprinklers.

Project BSS-2 would have a major impact on streamflows. In the driest two years in ten (80th percentile) measured at the USGS gauge on the Marias River near Loma (gauge number 1020.5), this project alone would reduce July baseline streamflows by 33%, August streamflows by 25% and September streamflows by 13%. In a drought year [driest one year in 10 (90th percentile)], July flows would be reduced by 86%, August flows by 36% and September flows by 20%. This information is summarized below:

Baseline Flows
(CFS)

	July	August	September
90%	228	366	287
80%	596	472	426

Source: DEIS, Table C-1, pages C-9, C-13.

Flow Depletions by BSS-2
(CFS)

July	August	September
196.23	132.89	55.66

Source: Big Sandy CD draft EA, Table 4

Flows Remaining after BSS-2 Depletions
(CFS)

	July	August	September
90%	32 (86%)	233 (36%)	231 (20%)
80%	400 (33%)	339 (28%)	370 (13%)

Percent reduction from baseline flows shown in parentheses.

DFWP has requested 560 cfs in the lowermost reach of the Marias River (Reach #3). With the exception of the month of July at the 80th percentile level, streamflows are already below the requested amount in August and September and at the

90th percentile level are below that amount in all three months. Thus, project BSS-2 alone would reduce streamflows well below those necessary for the fishery of the lower reach of the Marias River. If projects HI-269, LI-261 and LI-262 are included, streamflows would be even further reduced than shown above since, together, they would deplete an additional 36 cfs in July, 24 cfs in August and 10 cfs in September (Hill and Liberty county CD draft EA's, Table 4).

Q. What are the cumulative effects of the proposed conservation district projects on streamflows at the mouth of the Marias River.

A. The table below shows baseline flow conditions in the Marias River at the USGS gauge near Loma (near the mouth) and flows which would occur under the Consumptive Use Alternative at the same site.

	Baseline Flow[1]			Consumptive Use Alternative Depleted Flow[2]		
	July	Aug	Sept	July	Aug	Sept
90%	228	366	287	0 (100%)	169 (54%)	186 (35%)
80%	596	472	426	310 (48%)	294 (38%)	351 (18%)
50%	1079	1012	782	785 (27%)	785 (22%)	698 (11%)

[1]DEIS, Table C-2, page C-9
[2]DEIS, Table C-2, page C-13

Percent reduction from baseline flows shown in parentheses.

DFWP has requested 560 cfs in the lower Marias River. Baseline flows in the lower Marias River are already below this flow during low flow periods during drought years (90th percentile) and dry years (80th percentile). Even without proposed new depletions, existing flows are poor.

As can be seen from the above tables, the lowermost reach of the Marias River (Reach #3) would be severely affected by the Consumptive Use Alternative depletions at the 80th and 90th percentile flow levels. No flow would occur in July one year in 10. July and August flows would be only 30% - 33% of the required flow level of 560 cfs. Only during an average year (50th percentile) or better would the requested flow be met.

Other than on the Marias River itself, DFWP has no instream flow requests for any other streams in the basin where conservation district projects are proposed except on Birch Creek, where Pondera County CD has three projects. However, compared to the existing flows in Birch Creek, these projects would have only minor effects on streamflows due to their small depletion levels.

Judith River Basin

Q. What conservation district projects in the Judith River basin would affect streamflows in the basin?

A. There are a total of 21 projects proposed by Judith Basin CD and Fergus County CD in the Judith River basin. These projects would divert a total of 103.62 cfs (12,060 af/yr). (DEIS pages 15 and 16).

DFWP has requested instream flows on 10 streams in the basin. Conservation districts have requested water reservations on three of those streams (Judith River, Big Spring Creek, Warm Spring Creek). I will evaluate the effects of these projects separately on these streams as follows: Judith River above the mouth of Big Spring Creek; Big Spring Creek; Warm Spring Creek; and Judith River below the mouth of Big Spring Creek.

Judith River above the Mouth of Big Spring Creek

There are seven projects which would affect streamflows in the Judith River above its confluence with Big Spring Creek (JBI-2, JB-231, JB-309, FE-673, FE-672, FE-671, and FEI-50. These projects would divert 89.11 cfs (10,456 af/yr)(DEIS, pages 15 and 16).

DNRC has determined the depletions these projects would have on streamflows of the Judith River above its confluence with Big Spring Creek. The total depletions for projects proposed by the two conservation districts are shown by month in the following table.

Project Depletions - Judith River above Big Spring Creek (CFS)

	July	August	September
Fergus County CD	46.81	38.75	7.83
Judith Basin County CD	9.08	7.52	1.52
Total	55.89	46.27	9.35

Source: Fergus County CD draft EA, Table 5 and Judith Basin CD draft EA, Table 5.

There are no flow estimates or gauging station data available to determine the existing streamflows in the Judith River just above the mouth of Big Spring Creek. DFWP has requested 25 cfs in the Judith River from the confluence of the South and Middle forks to Big Spring Creek. The depletions for irrigation in July and August are about twice as much as the requested instream flow and the resulting flow reduction will adversely affect the fishery.

Water used by project FEI-50 alone would comprise 71% of the total depletions in each of the months July through September. This project would pump water from the Judith River to service 33 new center pivot sprinklers to irrigate lands just above the mouth of Big Spring Creek.

<u>Big Spring Creek</u>

There are four projects proposed in the Big Spring Creek basin (FE-141, FE-431, FE-111 and FE-401). These projects range in size from 0.21 cfs to 3.23 cfs. The total request for all four of these streams is 5.05 cfs (DEIS page 15). The total depletions of these four projects on Big Spring Creek are shown below:

Project Depletions - Big Spring Creek Basin
(CFS)

July	August	September
3.11	2.62	0.56

Source: Fergus County CD draft EA, Table 5.

DFWP has requested an instream flow of 110 cfs from the state fish hatchery to the confluence with Cottonwood Creek. DFWP also has a Murphy Right in the amount of 110 cfs in this same reach. The priority date of the Murphy Right is December 21, 1970. Existing streamflows in Big Spring Creek above the mouth of Cottonwood Creek (near Hanover) are shown below:

	July	August	September
90%	140	120	120
80%	160	130	120

Source: DEIS, Table D-1, page D-18.

Big Spring Creek has relatively stable flows throughout the year. Slight increases in flow occur in May and June and portions of July. During the rest of the year flows remain between 110 and 130 cfs. Because of the stable flows and the small depletions expected to occur from the four Fergus County CD projects, little impact to the fishery at Big Spring Creek is expected to occur although the depletions will contribute to the cumulative depletion in the Judith River. Also, any reservations granted for these projects will be junior to DFWP's instream Murphy Right.

Warm Spring Creek

There are three proposed projects on Warm Spring Creek (FE-161, FE-561 and FEI-40). These projects range in size from 2.16 cfs to 13.69 cfs. The total request for all three projects is 19.15 cfs (DEIS, pages 15 and 16). The largest individual project (FEI-40) would pump 13.69 cfs from Warm Spring Creek to service six new center pivot sprinklers (Fergus County CD draft EA, Table 2). DNRC has estimated the depletions which would occur in Warm Spring Creek from these projects as shown below.

July	August	September
12.76	10.73	2.36

Source: Fergus County CD draft EA, Table 5.

Estimates of streamflow have been made for the lower reach of Warm Spring Creek. The estimated flows are as follows:

Existing Flows - Warm Springs Creek
(CFS)

	July	August	September
90%	98	100	100
80%	100	100	110

Source: DEIS, Table D-1, Page D-19.

DFWP has requested 110 cfs on Warm Spring Creek from its origin to its confluence with the Judith River. Streamflows are already below 110 cfs in all months except September at the 80th percentile. The projects would further reduce streamflows below that requested by DFWP in July through September of both dry and drought years.

Judith River below Big Spring Creek

As mentioned earlier, there are 21 proposed new irrigation projects in the Judith River basin. These projects will deplete existing streamflows as they exist at the mouth of the Judith River. The total amount of water requested for all 21 projects is 128.37 cfs (14,691 af/yr); 103.62 cfs (12,060 af/yr) in Fergus County Conservation District and 24.75 cfs (2,631 af/yr) in Judith Basin Conservation District. The three largest projects are FEI-40 on Warm Spring Creek, FEI-50 on the Judith River and JBI-2 on the Judith River. These three projects would divert 90.28 cfs (10,588 af/yr) which is 70% of the total diversions for the 21 projects.

Baseline (existing) streamflows were determined for the Judith River near its mouth as follows:

Baseline Flows - Judith River near mouth (CFS)

	July	August	September
90%	266	226	236
80%	308	238	238

Source: DEIS, page C-9.

Under the Consumptive Use Alternative described in the DEIS, flows on the lower Judith River would be reduced by upstream depletions to the following amounts.

Depleted Flows - Judith River near mouth (CFS)

	July	August	Sept.
90%	182 (32%)	151 (33%)	213 (10%)
80%	226 (27%)	168 (29%)	218 (8%)

Source: DEIS, page C-14

Percent reduction from baseline flows shown in parentheses.

DFWP has requested 160 cfs in the Judith River from the confluence with Big Spring Creek to the confluence with the Missouri River. This flow quantity is the wetted perimeter low inflection point flow. This reach of the Judith River has a low level of aquatic habitat potential. Present fish populations are not exceptionally high. Reducing the flows in the Judith River by as much as 33% in July of a drought year and 29% in August in a dry year could cause habitat conditions to further deteriorate for fish populations. The flows shown above are the average flows at each of the percentile flow levels. It is expected that daily flows lower than those shown above may occur in any given year in this reach of the Judith River. Except for August in a drought year, flows, on the average, do not drop below the instream flow request of DFWP. However, it is expected that daily flows could drop to 160 cfs or below in any given dry or drought year.

Bureau of Reclamation

Q. Will the Bureau of Reclamation's reservation application on the Missouri River have any effect upon streamflows?

A. Yes. The Bureau of Reclamation has applied for up to 280 cfs (89,000 af/yr) from April 1 to October 30 to provide supplemental and new full service irrigation in the Milk River drainage, including two Indian reservations, the Lake Bowdoin National Wildlife Refuge and the Town of Chinook. Water would be diverted from the Missouri River about two miles above the town of Virgelle and transported through a canal to a point on the Milk River about four miles upstream from the City of Havre (USBR draft EA, pages 1 and 2).

Depletions from this project would reduce fish habitat in side channels of the Missouri River. These side channels are important rearing areas for sauger, goldeye, smallmouth buffalo and bigmouth buffalo. DFWP has requested 5,400 cfs for instream flows in the Missouri River from the mouth of the Marias River to the mouth of the Judith River to maintain adequate flow in the side channels during the period July 6 - August 31. (See Exhibit 3 and objector's testimony of Bill Gardner (DFWP) for a further explanation of the flow needs of side channels.) The USGS gauge on the Missouri River at Virgelle records streamflows in this reach and is just downstream from the proposed Bureau of Reclamation diversion. Since the proposed diversion would be used to transport Missouri River water to the Milk River basin, the 280 cfs is completely removed from this portion of the Missouri River basin. Thus, there are no return flows to consider in determining the water depletion from this project in this reach of the Missouri River.

The following table shows the baseline (existing) streamflow conditions for average, dry and drought water years.

Baseline Flows - Missouri River at Virgelle
(CFS)

	April	May	June	July	Aug.	Sept.
90%	4890	7340	6192	3986	3683	4127
80%	6521	8930	8145	4414	3879	4356
50%	8968	12,577	13,252	7323	5399	5162

Source: DEIS, page C-9

Baseline flows are already below 5400 cfs in July and August at the 90th and 80th percentile. In July of an average water year (50th percentile), flows are above 5400 cfs and in August, about 5400 cfs.

The next table shows what flows would occur at Virgelle if 280 cfs is diverted during the months shown.

Depleted Flows - Missouri River at Virgelle
(CFS)

	April	May	June	July	Aug.	Sept.
90%	4610	7060	5912	3706	3403	3847
80%	6241	8650	7865	4134	3599	4076
50%	8688	12,297	12,972	7043	5119	4882

At the 90th and 80th percentiles, already inadequate flows are further reduced below 5400 cfs in July and August. In an average year (50th percentile) flows fall below 5400 cfs in August.

DFWP has requested 4300 cfs to maintain the main channel riffle areas between September 1 and March 14. The above table shows that this flow is not currently present in September at the 90th percentile and would not be present in September at either the 90th or 80th percentile with an additional 280 cfs withdrawal.

Musselshell River Basin

Q. What conservation district requests on the Musselshell River would affect streamflows?

A. The Lower Musselshell Conservation District has proposed one project (LM-20) on the Musselshell River near Roundup. This is the only conservation district request in the Musselshell River basin.

Project LM-20 would involve pumping water from abandoned underground coal mines to supplement late summer flows in the Musselshell River. The requested amount is 90 cfs (8,150 af/yr). Water would be pumped from the abandoned coal mines into the Musselshell River during the irrigation season as needed to supplement water supplies. The project may also divert water from the Musselshell back into the coal mines throughout the year if water is available. Pumping the Jeffrey Mine, which is connected to the Musselshell River alluvial aquifer, could lower aquifer water levels and induce infiltration of river water into the mine. Thus, augmenting river flows in summer could be somewhat offset by losses in river flow (DEIS, page 175).

No specific projects for the use of this supplemental water are identified in the CD application or in DNRC's environmental assessment on this project. This lack of information makes predictions of the effects of this project on streamflow in the Musselshell River difficult to make. DEIS, page 175).

__**Cumulative Effects of all projects on Missouri River**__

Q. Eighteen conservation districts and 18 municipalities and the Bureau of Reclamation have submitted applications for new consumptive uses. Can the cumulative effects of these new uses on Missouri River streamflow be determined?

A. Yes, by using the information from the DNRC's Missouri basin water availability model, the results of which are included in the DEIS.

Q. Please describe these effects.

A. The effects can be shown by comparing the baseline flows on the Missouri River at the USGS gauge near Landusky to the flows which would occur at this same site under the Consumptive Use, Combination and Instream alternatives. The Landusky gauge is the lowermost flow measuring point on the Missouri River above Fort Peck Reservoir. The Musselshell River is not included since it directly enters Fort Peck Reservoir at another location.

The baseline flows and flows which would occur under each of the three alternatives are shown in the following table for the 90th, 80th and 50th percentiles.

Baseline Flows

	June	July	August	Sept.	Oct.	12-Month Average
90%	6781	4323	3907	4368	4525	5043
80%	8989	4972	4100	4799	5411	6021
50%	15,554	8313	5875	5639	4118	8591

Source: DEIS page C-9

Consumptive Use Alternative Flows

	June	July	August	Sept.	Oct.	12-Month Average
90%	5973	3288	3097	3865	4530	4727
80%	8448	3784	3456	4368	5204	5681
50%	14,850	6944	5137	5367	6901	8291

Source: DEIS, page C-14

Combination Alternative Flows

	June	July	August	Sept.	Oct.	12-Month Average
90%	6453	3924	3584	4095	4529	4926
80%	8768	4428	3829	4617	5681	5888
50%	15,279	7800	5556	5502	6994	8475

Source: DEIS, page C-18

Instream Alternative Flows

	June	July	August	Sept.	Oct.	12-Month Average
90%	6705	4211	3828	4279	4527	5014
80%	8922	4829	4031	4746	5736	5983
50%	15,477	8171	5806	5604	7032	8560

Source: DEIS, page C-23

Under all three alternatives the greatest reduction in flow will occur in July followed by August and September. The table below summarizes those reductions.

Flow Reductions at Landusky Under Three Alternatives
(CFS)

Consumptive Use Alternative

	July	August	September
90%	1,035 (24%)	810 (21%)	503 (12%)
80%	1,188 (24%)	644 (16%)	431 (9%)
50%	1,369 (16%)	738 (13%)	272 (5%)

Combination Alternative

	July	August	September
90%	399 (9%)	323 (8%)	273 (6%)
80%	544 (11%)	271 (7%)	182 (4%)
50%	513 (6%)	319 (5%)	137 (2%)

Instream Alternative

	July	August	September
90%	112 (3%)	79 (2%)	89 (2%)
80%	143 (3%)	69 (2%)	53 (1%)
50%	142 (2%)	69 (1%)	35 (1%)

The greatest flow reductions would occur under the Consumptive Use Alternative in July under both the 90th and 80th percentile flow levels. A 24% reduction (1,035 cfs) would occur in July at the 90th percentile and a 24% reduction (1,188 cfs) would occur in July at the 80th percentile. The next highest reductions would occur in August at the 90th percentile where a 21% reduction (810 cfs) would occur and at the 80th percentile where a 16% reduction (644 cfs) would occur. Even in an average water year (50th percentile), July flow reductions would be 1,369 cfs (16% reduction) with a lesser reduction in August and September.

Under the Combination Alternative, flows in July would be reduced 9% (399 cfs) and 11% (544 cfs), respectively, for the 90th and 80th percentile flows.

Flow reductions are least for the Instream Alternative, the greatest reduction being 3% (112 cfs) at the 90th percentile and 3% (143 cfs) at the 80th percentile in July.

DFWP has requested 5,800 cfs as an instream flow in Reach #6 of the Missouri River from July 6 to August 31 to maintain proper flow in side channels. At the 90th and 80th percentile, flows are already below that amount by about 800 to 1500 cfs. Only in an average water year (50th percentile) are flows above this amount, on the average. During August, flows are well below 5400 cfs at both the 90th and 80th percentile by about 1700 to 1900 cfs. Even in an average water year, baseline flows are already approaching 5800 cfs. Further reduction in the flow levels can only cause more frequent periods when flow levels in side channels will be inadequate to maintain these important fish habitats.

Liter E. Spence, being first duly sworn, states that the foregoing testimony is true.

DATED this 2nd day of December, 1991.

Liter E. Spence

Liter E. Spence

Subscribed and sworn to before me this 2nd day of December, 1991.

Debra K. McRae

Notary Public for the State of Montana
Residing at Helena, Montana
My commission expires May 14, 1994

PRE-FILED OBJECTOR'S TESTIMONY
OF WILLIAM M. GARDNER
ON BEHALF OF THE MONTANA DEPARTMENT OF
FISH, WILDLIFE AND PARKS

Q. Please state your name and business address?

A. William M. Gardner
Montana Department of Fish, Wildlife and Parks
P.O. Box 1088
Fort Benton, MT 59442

Q. What is your present employment?

A. I am a fisheries biologist employed by the Montana Department of Fish, Wildlife and Parks (MDFWP).

Q. Have you provided previous testimony in this proceeding?

A. Yes, I provided pre-filed direct testimony on behalf of DFWP which was filed on November 1, 1991. That testimony contained a statement of my education and work experience and a biography.

Q. What is the purpose of your objector's testimony?

A. The purpose of my testimony is to describe the effects that proposed new water withdrawals under the Consumptive Use and Combination alternatives described in the Draft Environmental Impact Statement will have on streamflows and the fisheries resources in Reaches 4, 5 and 6 of the Missouri River below Great Falls (see DFWP application pages 3-22 through 3-38 for a description of these reaches). These reaches are downstream from most of the proposed projects in the Missouri River basin.

Q. Please explain what these effects will be on the fisheries in these reaches.

A. Under the Consumptive Use and Combination alternatives, there is the potential to severely reduce summer flows. The reduced flows will cause dewatering of important fish habitat in side channels and, during low water years, also dewater riffle habitat of the main channel.

Q. What is the ecological importance of these two habitats to the fisheries in the Missouri River?

A. A side channel is defined as a channel diverging from the main channel and containing less than 20 percent of the river's flow. In Reaches 4, 5 and 6 of the Missouri River there are about 70 side channels, ranging in length from .2 to 1.4 miles. The side channels provide important rearing habitat for fish such as sauger, buffalo and goldeye. Side channels provide spawning area for buffalo. Side channels are also important for production of forage fish. Riffle habitat is essential for forage food production. Forage food organisms include aquatic insects and small riffle fish such as sculpin, dace and stonecat.

Q. What is the source of your information on the ecological value of side channel and riffle habitats?

A. During the period between April, 1979 and March, 1981, DFWP biologist, Rod Berg, and I conducted a study of the Wild and Scenic portion of the Missouri River to determine instream flow requirements for this river reach. The study was done in cooperation with the U.S. Bureau of Land Management.

Q. Are the results of the study published?

A. Yes. The study is published as: Gardner, W.M. and R.K. Berg. 1982. "An analysis of the instream flow requirements for selected fishes in the wild and scenic portion of the Missouri River. MT DFWP, Great Falls, MT. 111 pp. This publication is Exhibit 3 of DFWP's objector's testimony.

Q. What are the conditions which occur in side channels that cause them to be considered dewatered?

A. Side channels are dewatered when water levels become too shallow to support fish (see page 39 of above report for criteria used in this determination) or contain only pools which are disconnected from the main channel due to declining river flow. Pools of standing water often remain but can eventually dry up or become unsuitable for fish life due to high water temperatures and low dissolved oxygen levels. The loss of side channel habitat would mean less food production for fish, and fewer numbers of species that depend on the side channels for rearing of fish, notably the sauger.

Q. Please explain how the Consumptive Use and Combination alternatives conflict with the MDFWP's instream flow requests for maintaining side channel and riffle habitats?

A. These alternatives will increase the frequency of low flows in the Missouri River, thereby affecting the use and value of side channel and riffle habitats. Since these two habitats are essential for the fisheries, I believe overall fish populations in the Missouri River would decline.

The current baseline flow conditions are just barely enough to maintain the side channel habitat during the late summer in average water years. This is shown by comparing DFWP's instream flow request for side channels with the 50 percentile baseline flow conditions (Table 1).

August is the month when the river can barely meet its flow requirements. Table 1 also shows that, under the Consumptive Use Alternative at the 50 percentile flow level during August, the river will be short by an average of 640 cfs (Range: 487 to 722 cfs) of meeting the instream flow needs for side channels in the three reaches. At an 80 percentile flow, the flow shortage would be far greater, with an average reduction of 1855 cfs for the three reaches combined (Range: 1133 to 2344 cfs).

For the Combination Alternative, the dewatering impacts on side channels is also significant. During August in a 50 percentile water year, the average monthly flow shortage for the three reaches combined is 297 cfs (Range: 244 to 368 cfs). In an 80 percentile year, the average shortage is 1606 cfs (Range: 1093 to 1971 cfs).

Q. What happens to these side channels under the Consumptive Use and Combination alternatives?

A. In our 1982 study, we studied a total of 12 different side channels which we considered representative of those found in Reaches 4, 5 and 6. According to the information in the draft EIS, the following effects of flow depletions would occur under the two alternatives.

<u>Consumptive Use Alternative</u>
50 percentile - 9 of 12 side channels dewatered
80 percentile - 11 of 12 side channels dewatered

<u>Combination Alternative</u>
50 percentile - 7 of 12 side channels dewatered
80 percentile - 11 of 12 side channels dewatered

Even under present conditions and under the Instream Alternative, which provides for some project development, 5 out of 12 side channels were dewatered at the 50th percentile and 10 out of 12 would be dewatered at the 80th percentile flow level. This indicates there is not much room for additional upstream water development in August if these river features are to be maintained.

Flows reserved for riffle maintenance are less than those required for side channels. Flows in riffles are the higher inflection point flows determined by the wetted perimeter inflection point method. During the study, riffles were also shown to produce the small forage fish selected by sauger, the principal sport fish in this part of the Missouri River.

The instream flows requested for riffles are affected by the two alternatives only during an 80 percentile or lower flows. During these years, riffle habitats are reduced throughout the summer to a level which do not allow food production to reach near optimum levels.

Table 1. Monthly streamflow percentile distributions (in cfs). Flows below DFWP instream flow requests are underlined.

Missouri River - Reach #4 (Great Falls to Marias River)

	Jul	Aug	Sep	Oct
Instream flow request for side channels and riffles	4500	4500	-	-
Instream flow request for riffles	-	-	3700	3700

Source: DFWP application page 3-26

	Jul	Aug	Sep	Oct
50% baseline conditions	6104	4318	4629	5696
80% baseline conditions	3814	3543	3905	4610
50% Consumptive alt.	5343	4013	4356	5649
80% Consumptive alt.	3508	3367	3758	4316
50% Combination alt.	5696	4132	4399	5659
80% Combination alt.	3598	3407	3812	4633

Source: DEIS, Table C-2, Missouri River at Fort Benton

Missouri River - Reach #5 (Marias River to Judith River)

	Jul	Aug	Sep	Oct
Instream flow request for side channels and riffles	5400	5400	-	-
Instream flow request for riffles	-	-	4300	4300

Source: DFWP application, page 3-32

	Jul	Aug	Sep	Oct
50% baseline conditions	7323	5399	5162	6609
80% baseline conditions	4414	3879	4356	5363
50% Consumptive alt.	5926	4628	4875	6478
80% Consumptive alt.	3359	3312	3988	4715
50% Combination alt.	6768	5120	5017	6578
80% Combination alt.	4014	3646	4182	5331

Source: DEIS, Table C-2, Missouri River at Virgelle

Missouri River - Reach #6 (Judith River to Fort Peck Reservoir)

	Jul	Aug	Sep	Oct
Instream flow request for side channels and riffles	5800	5800	-	-
Instream flow request for riffles	-	-	4700	4700

Source: DFWP application, page 3-37

	Jul	Aug	Sep	Oct
50% baseline conditions	8313	5875	5639	7045
80% baseline conditions	4972	4100	4799	5757
50% Consumptive alt.	6944	5137	5367	6901
80% Consumptive alt.	3784	3456	4368	5204
50% Combination alt.	7800	5556	5502	6994
80% Combination alt.	4428	3829	4617	5681

Source: DEIS, Table C-2, Missouri River at Landusky

William M. Gardner, being duly sworn, states that the foregoing testimony is true.

Dated this 2nd day of December, 1991.

William M. Gardner
William M. Gardner

Subscribed and sworn before me this 2nd day of December, 1991.

(NOTARY SEAL)

Cheryl L. Johnson
Notary Public for the State of Montana
residing at Montana NOTARY PUBLIC for the State of Montana
Residing at Fort Benton, Montana
My commission expires My Commission Expires December 1, 1994

PART II

PART II

City of Bozeman

Fred Nelson

PRE-FILED OBJECTOR'S TESTIMONY

OF FREDERICK A. NELSON

on behalf of

MONTANA DEPARTMENT OF FISH, WILDLIFE AND PARKS (MDFWP)

Q. Please state your name and business address.

A. Fred Nelson, MDFWP, 1400 South 19th Avenue, Bozeman, Montana 59715.

Q. What is your present employment?

A. I am a fisheries biologist employed by the Montana Department of Fish, Wildlife and Parks.

Q. Please state your educational background and experience.

A. This information was already presented in previous testimony I filed for the reservation proceeding on behalf of MDFWP. That testimony included a description of my instream flow-related training and a vita.

Q. What is the purpose of this testimony?

A. The purpose is to provide the MDFWP's pre-filed objector's testimony to the City of Bozeman's application for a municipal storage reservoir on Sourdough Creek, also known as Bozeman Creek.

Q. What is the purpose of this proposed reservoir?

A. The purpose is to meet the city's projected water shortfall in the year 2025.

Q. Briefly describe this proposed reservoir.

A. The proposed 152-foot-high dam will be located upstream of Bozeman in the Gallatin National Forest at about stream mile 13 of Sourdough Creek. The reservoir's total storage potential is about 6,000 acre-feet (af). About 188 acres will be inundated by the project.

Q. How much water will the reservoir supply to the city?

A. Bozeman proposes to construct this 6,000 af impoundment to meet a projected annual deficit of 4,030 af by the year 2025. An additional 1,970 af capacity will be available to provide water in dry years, giving a total potential withdrawal of up to 6,000 af/yr.

Q. Why is MDFWP objecting to the city's application?

A. MDFWP is objecting because: 1) Bozeman's application conflicts with the instream flow application of MDFWP for Sourdough Creek, 2) the proposed project could damage the fishery of Sourdough Creek, 3) MDFWP believes that the city's projected water needs are inflated, and 4) other sources of supply are available to help meet the city's future needs.

Q. How does Bozeman's application conflict with the instream flow application of MDFWP?

A. MDFWP requested that all remaining unappropriated water in Sourdough Creek be reserved instream to dilute the various urban pollutants that enter the creek as it passes through Bozeman. These pollutants are passed onto the East Gallatin River - a river with a history of pollution problems. Recent upgrades of Bozeman's sewage treatment plant have improved water quality, allowing the trout fishery of the East Gallatin River to blossom once again. However, periodic pollution problems persist. An example occurred in 1983 when the river's trout population crashed (see pg. 2-570 through 2-575 of MDFWP's application). While the cause has not been identified, a fire in an industrial storage area containing hazardous chemicals is suspected of causing a toxic spill that entered the river. The key to stemming ongoing pollution is dilution. Adverse effects will be minimized if sufficient flow can be maintained to dilute the hazardous materials and everyday pollutants, such as salt, grease and oil from roadway runoff and fertilizers and insecticides from streamside gardens, that eventually end up in the city's waterways. City storm drains that feed Sourdough creek are another source of pollution.

Q. How serious is the water pollution problem at Bozeman?

A. We are not aware of any comprehensive monitoring programs to measure water quality impacts to streams in the Bozeman area. However, given that pollutants have been detected at measurable concentrations in Bozeman streams (e.g. seepage of contaminants from the Idaho Pole "superfund" site at Bozeman and nutrients, sediments, and other non-point source pollutants), it logically follows that further depletion of streamflow will cause concentrations of pollutants to increase in the remaining streamflows. Such depletions increase the likelihood of deleterious effects on fishes and other aquatic life.

Q. How would the city's proposed storage reservoir affect dilution flows in Sourdough Creek?

A. Bozeman's water will be diverted year-round from Sourdough Creek at about stream mile 11 downstream from the proposed reservoir. Peak use will occur primarily in summer during the lawn irrigation season when streamflows through the city are already diminished, sometimes severely, by existing consumptive users. Return water will enter the East Gallatin River downstream from Bozeman at the city's sewage treatment plant. Thus, diverted water will bypass about 11 miles of Sourdough Creek and 5.1 miles of the East Gallatin River, causing current streamflows to diminish even further.

Q. Could the city's withdrawals drastically reduce the existing streamflows of Sourdough Creek?

A. Yes. The estimated flows of Sourdough Creek in the vicinity of the proposed diversion site are shown on page D-4 of the Draft EIS. These flows were derived by the USGS using simulation procedures that incorporated existing USGS gauge data for Sourdough Creek. Sourdough Creek has an average annual flow of about 26 cfs (18,823 af/yr). During drought (a one-in-ten year event), flow annually averages about 15 cfs (10,859 af/yr).

The city could potentially remove up to 6,000 af/yr from Sourdough Creek. This equals 32% of the annual streamflow in a normal water year and 55% during a drought year. This is a substantial block of water that would no longer be available for dilution purposes in 11 miles of Sourdough Creek and the 5.1 miles of the East Gallatin River upstream from the city's sewage treatment plant.

Q. Is instream flow needed in Sourdough Creek for purposes other than the dilution of urban pollutants?

A. Yes. Sourdough Creek also supports a noteworthy small stream fishery for rainbow, brook, and a few brown trout that reside yearlong in the creek. Based on my personal observations, kids are the primary users of the fishery. The various stretches of the creek support from 28 to 104 pounds of trout per 1,000 feet of stream. Trout populations within the urban stretches are characterized by fewer fish as compared to the non-urban sections and by an age structure in which older fish predominate. This is indicative of poor reproduction, a probable consequence of poorer water quality and other related problems.

Q. Does Sourdough Creek currently suffer from dewatering?

A. Yes. Sourdough Creek presently supplies the City of Bozeman with about 3,724 af of water annually, according to the city's application. Flow in Sourdough Creek is also diminished by summer irrigation depletions. According to the Water

Resources Survey for Gallatin County, Montana, water diverted from the Sourdough Creek drainage irrigates up to 2,287.5 acres. During years of below normal snowpack, the public commonly contacts MDFWP's Bozeman office to report low summer flows in Sourdough Creek. MDFWP includes Sourdough Creek on its list of streams having periodic dewatering problems.

Q. Could the releases at the proposed dam be regulated to provide acceptable fishery maintenance flows in Sourdough Creek?

A. The potential exists to guarantee flow releases that will maintain the fishery of Sourdough Creek. Because a reservoir operations plan is not a part of the city's application, assessing how the creek's fishery would fare if the reservoir is built is not possible. The fact that the city's application makes no mention of the fishery or of the need to pass instream flows to ensure its survival appears to demonstrate that these impacts have not yet been considered.

Q. Are there other aspects of the proposed storage project that could harm other interests of MDFWP?

A. Yes. If a significant willow community was inundated by the reservoir, impacts would be detrimental to wintering moose and beaver. Impacts on wildlife have not been assessed in the city's application.

Q. MDFWP also objects on the grounds that the city's projected future water demand is inflated. How is it inflated?

A. The city's reservation request predicts a city population of 37,000 in the year 2025. The DNRC in its draft Environmental Assessment (EA) for the city's application considers this population forecast to be higher than the current trend justifies. Continuation of this current trend yields a population of 31,800 in 2025, according to the draft EA.

The city's request also assumes an average daily water use of 310 gallons per capita per day (gpcd), which the draft EA considers high when compared to other Montana communities in the Missouri River basin (200-250 gpcd). A variety of reasons were given in the city's application to explain the high average use. These include:

1. Water mains are old and pressures are very high in parts of the city, causing considerable leakage.

2. Diversions have been constant but hourly and daily demands of the city are variable, necessitating overflow from reservoirs. This overflow is essentially wasted, but is reflected in use figures.

3. Cold weather does not allow manipulation of the diversion gates on Bozeman and Hyalite creeks. The gates are set in late fall so that adequate water can be provided throughout the winter. This results in a diversion rate that exceeds the use rate or cannot be stored and is therefore wasted.

4. Releases from storage in Hyalite Reservoir are relatively constant. Because of the remote location, releases cannot be responsive to rapidly changing demands for water.

Improvements in the existing delivery and diversion systems could save considerable water, thus lowering the future gpcd to a more reasonable level. According to the draft EA, the city already plans to construct a surge pond that could reduce the amount of additional water needed in the future by limiting losses caused by the lack of control of the stream diversion gates and the overflows resulting from the lack of adequate storage. The draft EA also states that a previous study by the city recommended splitting the present distribution system into two pressure districts to reduce leakage caused by high pressures in the north portion of the city. Other system improvements that could conserve water and lower future needs are also possible, such as the replacement of leaking water mains. These system improvements are not considered in the city's application.

Q. MDFWP also objects on the grounds that other sources of supply are available to help meet the city's future needs. Explain these sources.

A. The city's application mentioned the enlargement of Hyalite Reservoir as a means to partially meet future municipal needs. This project has been funded and construction is under way. When completed in two years, 2,334 af/yr will be available for use by the city, according to the draft EA. Other sources of supply include the conservation of existing supplies. Some of these conservation measures, such as the construction of a surge pool, were previously discussed.

Q. How does MDFWP believe the city's reservation request should be considered?

A. MDFWP is not advocating that the City of Bozeman be denied water for future municipal use. Rather, MDFWP believes that the facts do not justify the amount being requested by the city. MDFWP believes that the city's water needs should be recalculated using a more reasonable population forecast and a gpcd that is more in-line with other communities of the Missouri basin. Improvements in Bozeman's water delivery and diversion systems will undoubtedly lower the future gpcd.

Granting a reservation request that's based on the continuation of current wasteful practices into the future is unreasonable, particularly when another user group is competing for Sourdough's limited water resource.

The new water being supplied by an enlarged Hyalite Reservoir should also be incorporated into the calculations.

Q. How much water is needed by the City of Bozeman?

A. If the future water need of Bozeman is recalculated using a forecasted population of 31,800 in 2025 (the application used 37,000) and a gpcd of 250, which is in-line with other Missouri basin communities (the application used 310), the future need is 8,907 af/yr. According to the city's application, the annual reliable yield from the present water supply system is:

Lyman Creek	1,283 af
Bozeman Creek	3,724 af
Hyalite Reservoir	2,324 af
Middle Creek	1,487 af
Total	8,818 af

An enlarged Hyalite Reservoir will supply an additional 2,334 af, yielding a total supply of 11,152 af. The existing supply exceeds the future need by 2,245 af, according to our calculations.

If we assume that the current waste continues into the future by assigning a gpcd of 310, as used in the city's calculations, a population of 31,800 in 2025, as forecasted by the DNRC in the draft EA for the city's application, will require 11,044 af/yr. The existing supply still exceeds this future need by 108 af.

Q. Does the city need a new storage reservoir to supply future municipal needs?

A. The above calculations by MDFWP using information provided in the city's application and the draft EA raise doubts regarding the need for a municipal storage reservoir on Sourdough Creek.

Q. How should the city's reservation request be reconciled with the competing instream flow application of the MDFWP?

If the City of Bozeman is granted a reservation, the city's request should be pared to a more reasonable amount that reflects the facts previously discussed, including conservation measures. Once a reasonable amount has been established, all remaining unappropriated flow should be reserved for the needs of the fishery; the most important consideration being the dilution of the urban pollutants that enter Sourdough Creek at Bozeman and are passed onto the East Gallatin River. Further, the operation of the dam should be conditioned to mitigate impacts on the fishery and streamflows of Sourdough Creek.

Frederick A. Nelson, being duly sworn, states that the foregoing testimony is true.

Dated this 29th day of November 1991.

Frederick A. Nelson

Frederick A. Nelson

Subscribed and sworn to before me this 29th day of November 1991.

Curtis E. Larsen

Notary Public for the State of Montana
Residing at Helena, Montana
My commission expires July 6, 1994

517.7

PART III

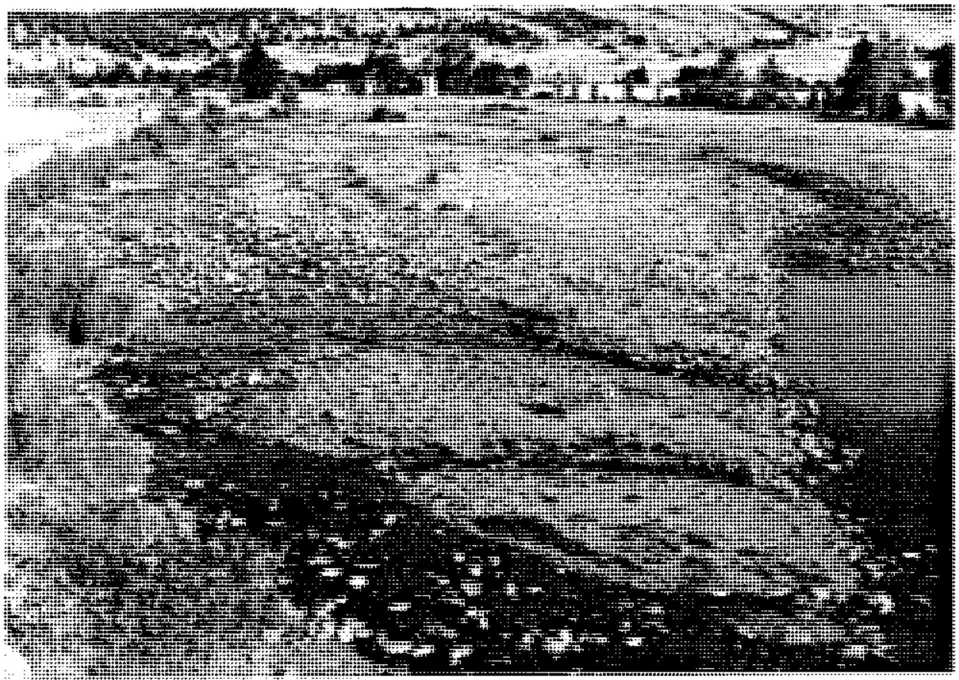
PART III

Exhibits

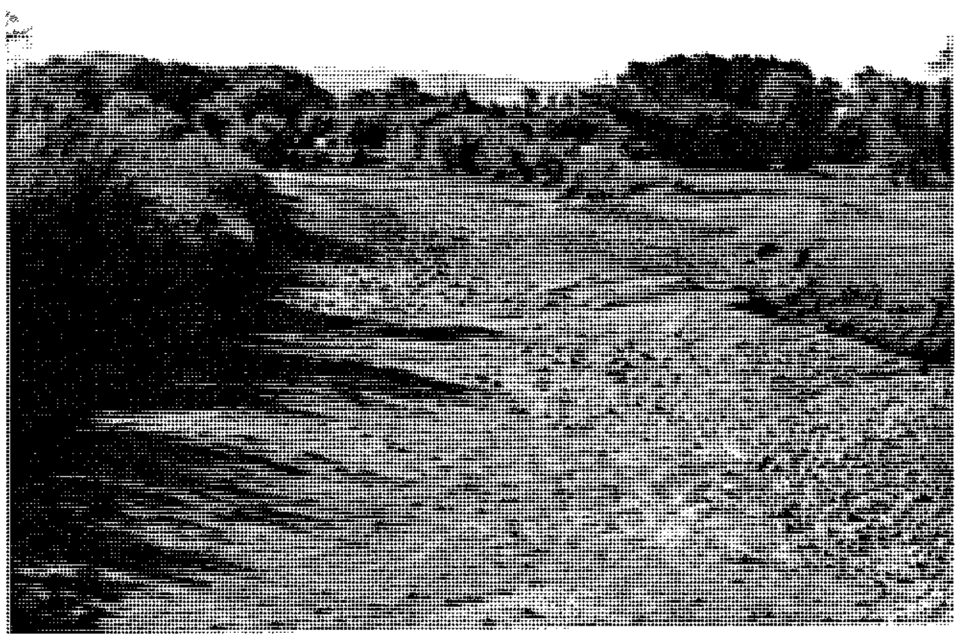
Exhibit No.

1. Photographs of Jefferson River, Boulder River, and Missouri River.
2. Photograph of Smith River at Camp Baker.
3. W. Gardner and R. Berg, An Analysis of the Instream Flow Requirements for Selected Fishes in the Wild and Scenic Portion of the Missouri River (MDFWP 1982).

EXHIBIT 1



Boulder River at Highway 69 Bridge at Boulder. Photo taken by Bob Martinka, DFWP, on August 9, 1988.



Boulder River at Quaintance Lane Bridge 15 miles downstream from Boulder. Photo taken by Bob Martinka, DFWP, on August 9, 1988.

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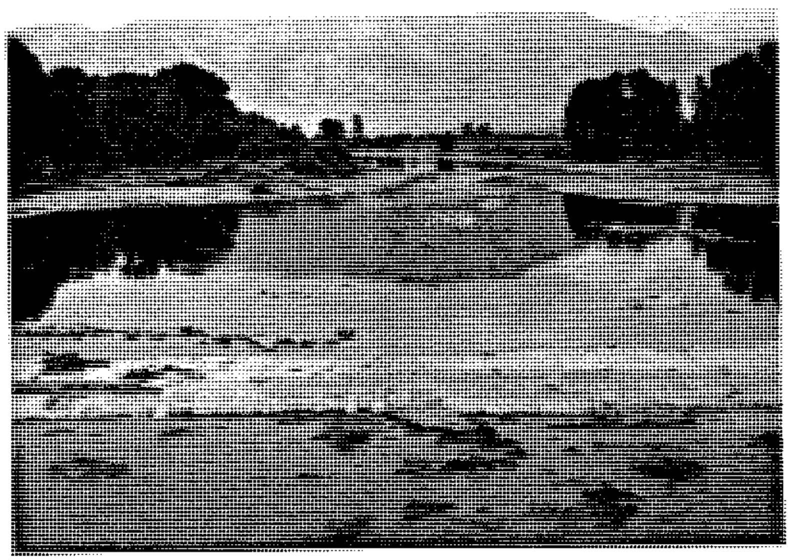

Jefferson River below the Waterloo Bridge. Photo taken by Joe Halterman (deceased), USFWS, Billings, on August 7, 1961.

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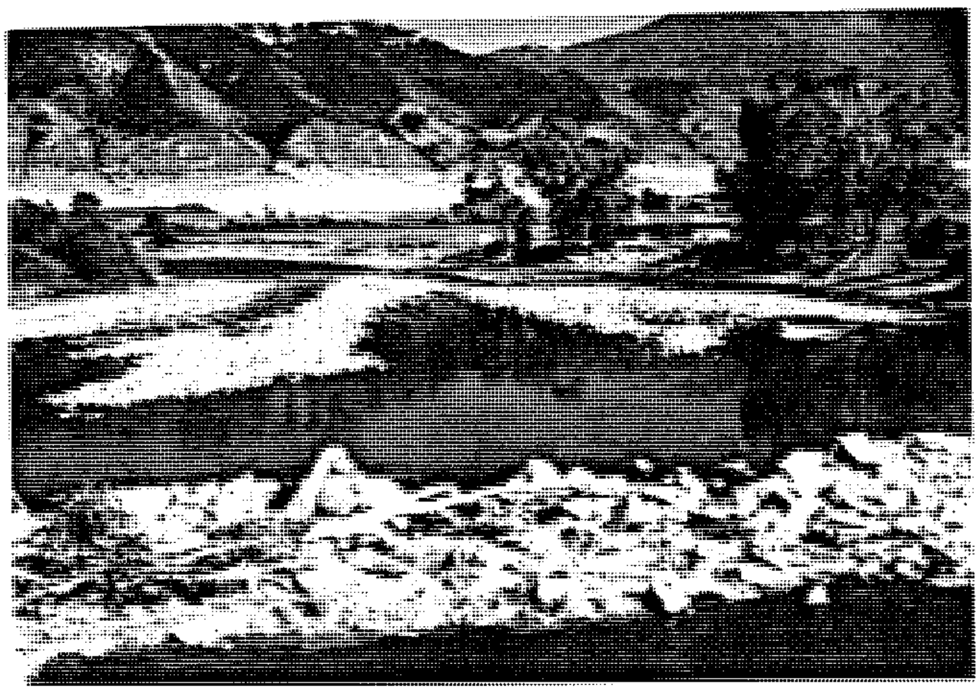
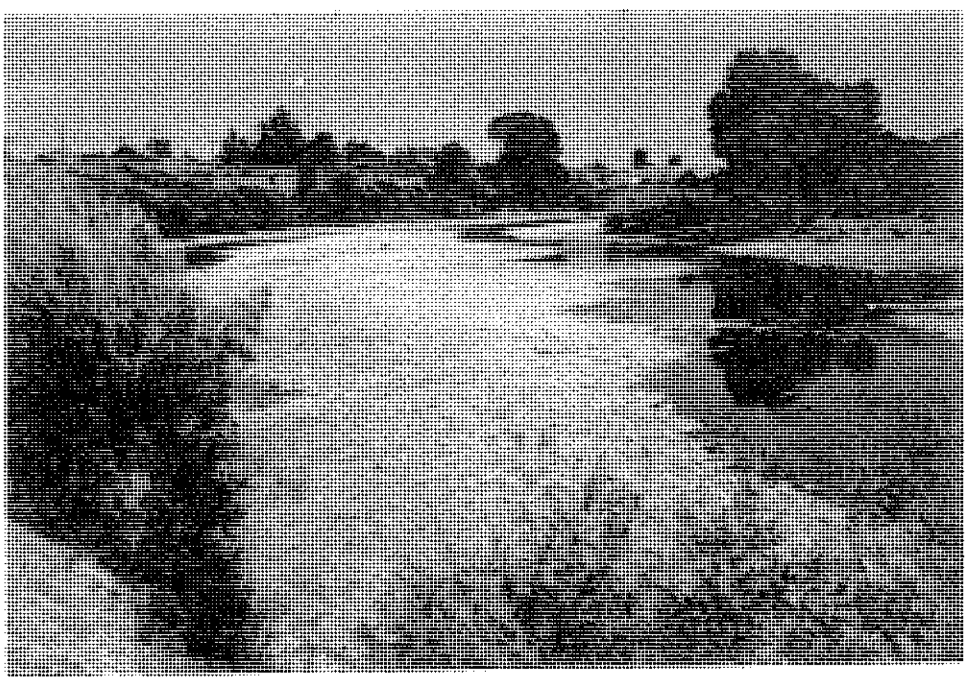


Jefferson River below the Waterloo Bridge. Photo taken by Liter Spence, DFWP, on July 30, 1988. Flow shown is 4.65 cfs.

EXHIBIT 1

Jefferson River below the Parrott Diversion. Photo taken by Joe Halterman (deceased) USFWS, Billings, on August 10, 1961.



Jefferson River below the Silver Star Bridge. Photo taken by Joe Halterman (decreased), USFWS, Billings, on August 10, 1961.

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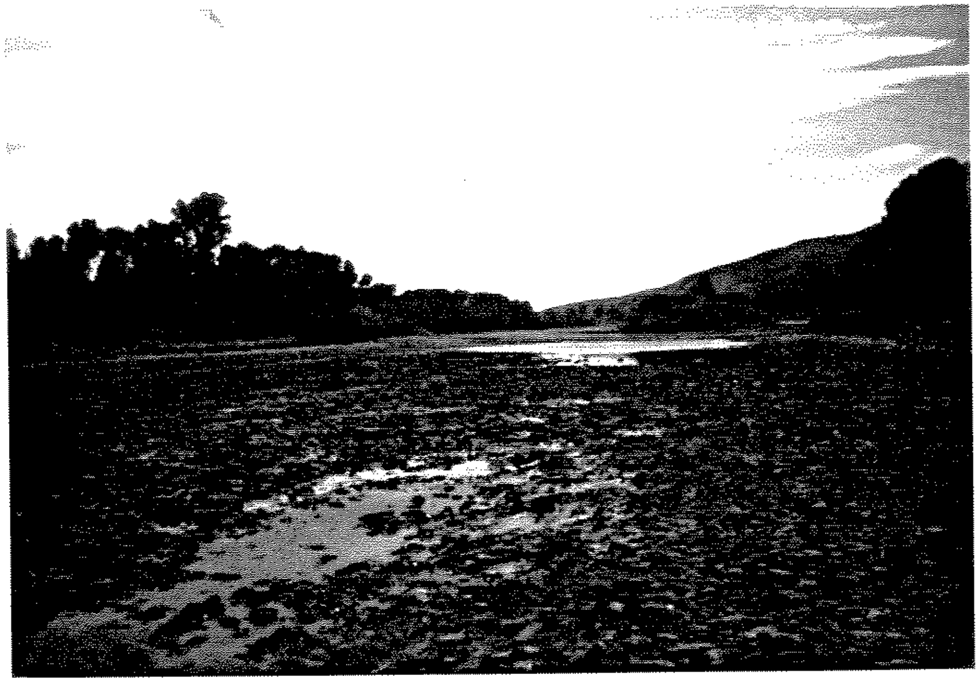
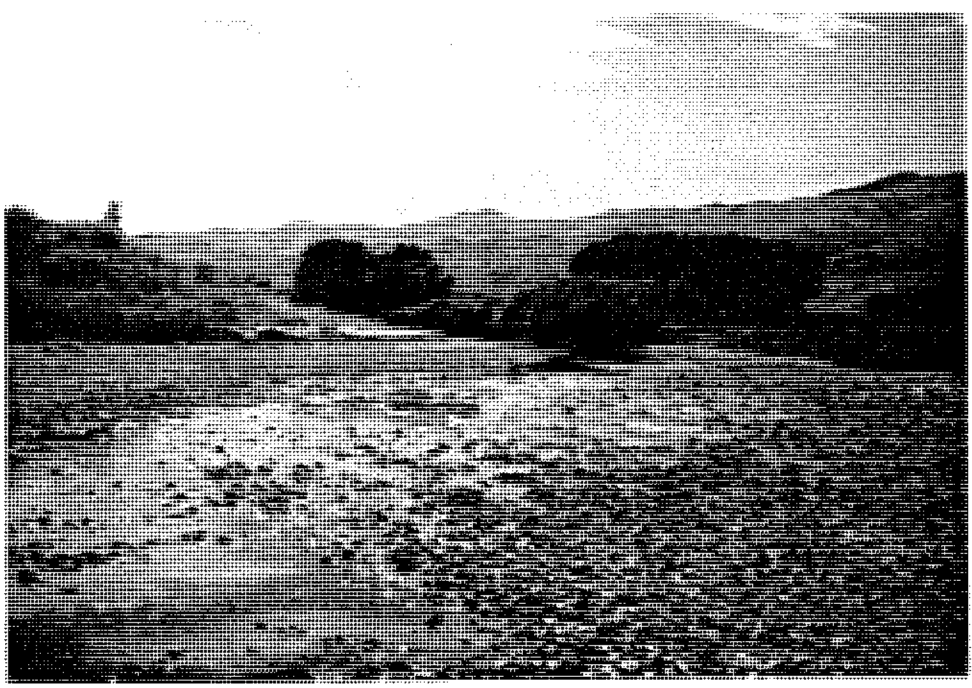
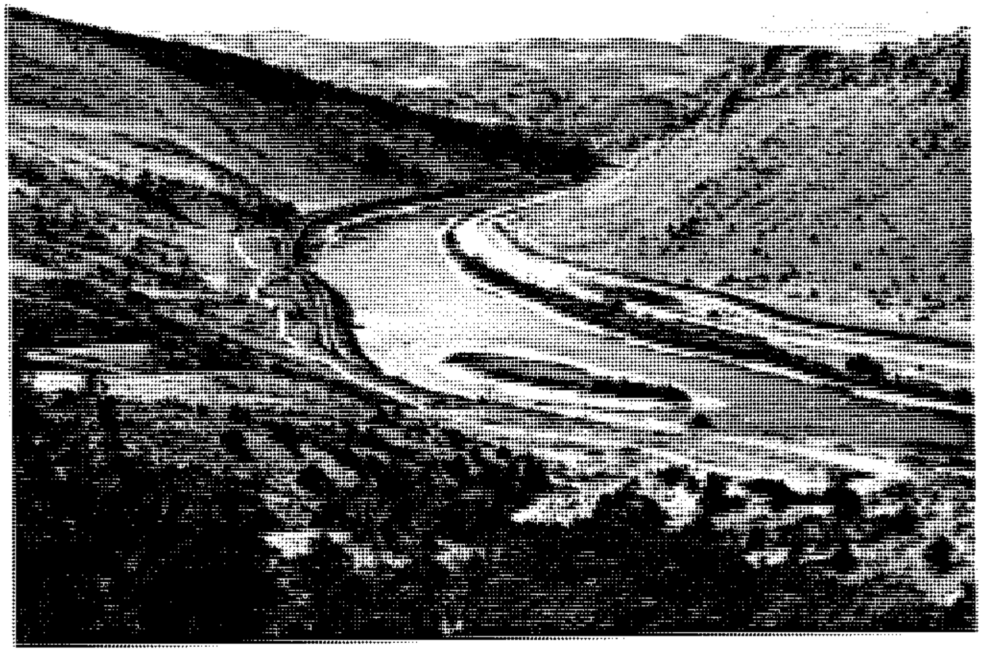


Jefferson River between Silver Star and Iron Rod Bridge, looking downstream. Photo taken by Brad Shepard, DFWP, in August, 1988.

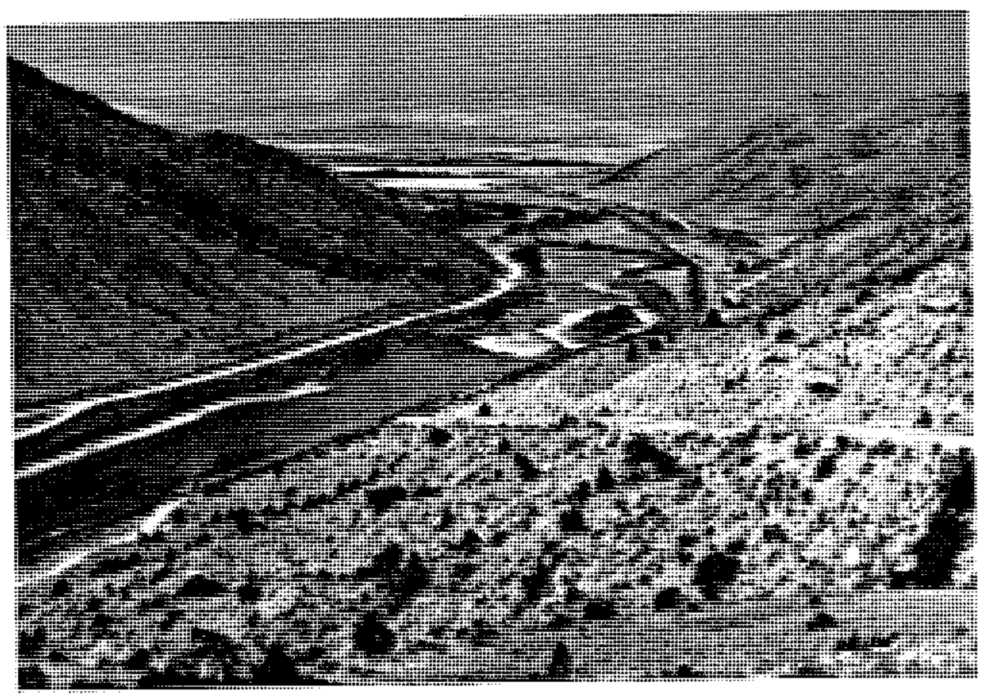


Jefferson River between Silver Star and Iron Rod Bridge looking upstream. Photo taken by Brad Shepard, DFWP, in August, 1988.

EXHIBIT 1

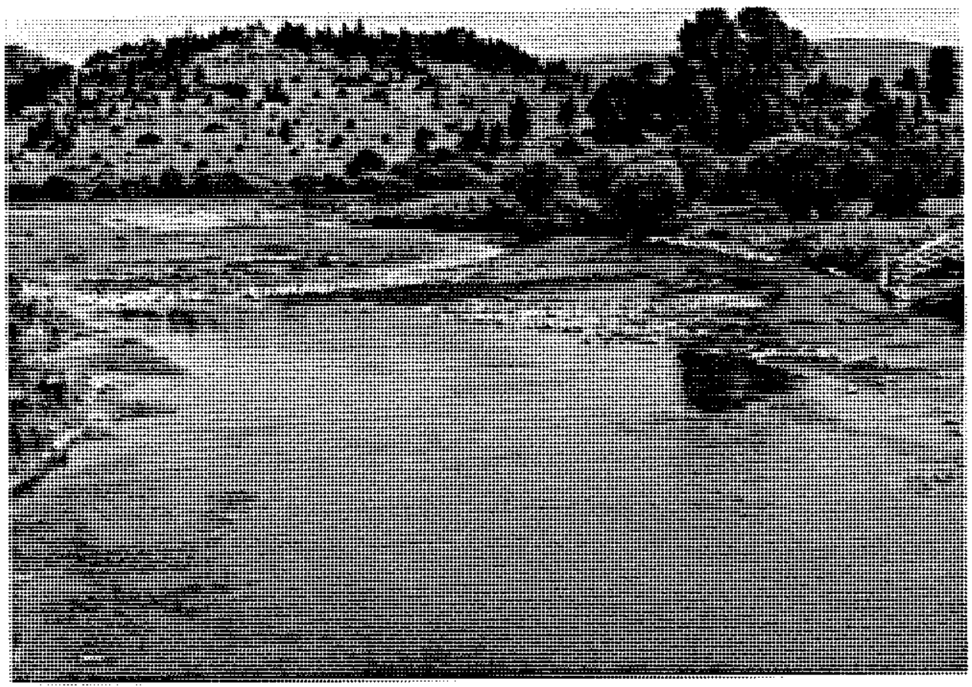


Missouri River near Toston. Photo taken by Fred Nelson, DFWP, on August 11, 1988. Flow shown is 835 cfs.



Missouri River near Toston. Photo taken by Fred Nelson, DFWP, on August 11, 1988. Flow shown is 835 cfs.

EXHIBIT 2



Smith River below bridge at Camp Baker. This is site of USGS gauge "near Fort Logan". Photo taken by Liter Spence, DFWP on June 25, 1988. Flow shown is 35 cfs.

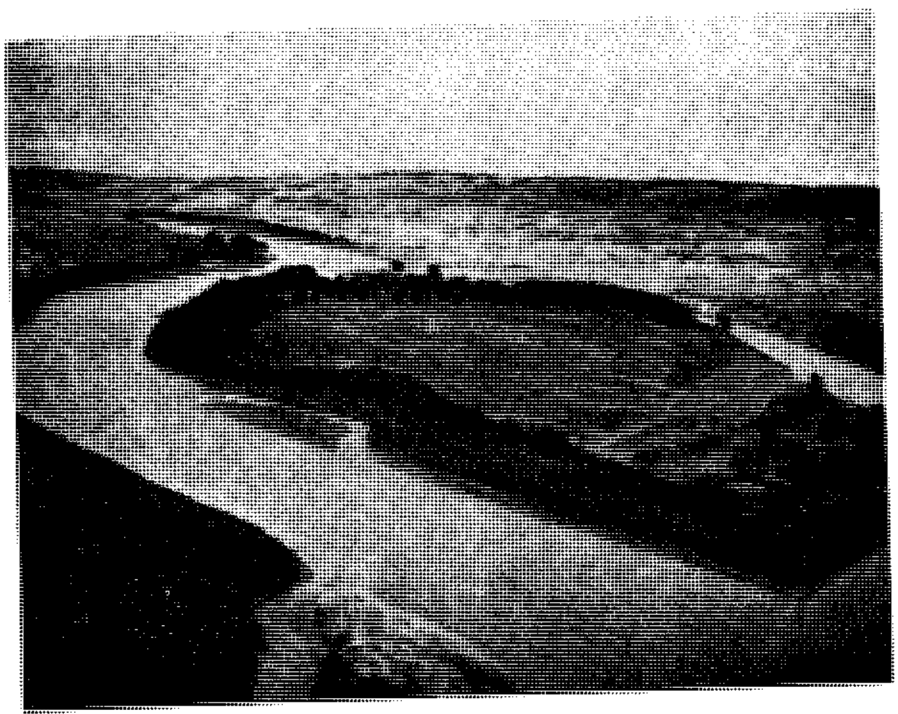
AN ANALYSIS OF THE INSTREAM FLOW REQUIREMENTS FOR SELECTED FISHES IN THE WILD & SCENIC PORTION OF THE MISSOURI RIVER

Research Conducted by:

Montana Department of Fish, Wildlife and Parks
Ecological Services Division

Sponsored by:

Bureau of Land Management
U.S. Department of Interior



By:

William M. Gardner

Rodney K. Berg

MARCH 1982

AN ANALYSIS OF THE INSTREAM FLOW REQUIREMENTS FOR SELECTED FISHES IN THE WILD & SCENIC PORTION OF THE MISSOURI RIVER

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ABSTRACT

This study was initiated on the Wild and Scenic portion of the Missouri River to determine instream flow requirements of selected fish species. The study will form a basis for the Bureau of Land Management in quantifying instream flows necessary to maintain the values associated with the Wild and Scenic reach of river.

Rearing areas and habitat preference studies conducted from July through September indicated that young-of-the-year sauger selected protected habitat in peripheral areas of the stream. Although young-of-the-year sauger were found throughout most of the study area, 70 percent of the total numbers sampled in 1979 were taken in a 77-km reach of the river below Cow Island. The preference for this particular area was attributed to the greater development of side channel pool habitat which was the most desirable rearing habitat. Peripheral habitat areas were also heavily utilized by forage fish. An average of 125,104 and 81 forage fish per seine haul was taken in the backwater, main channel pool and side channel pool habitat types, respectively. During 1980, 12 representative side channels were monitored to determine the amount of instream flow required to maintain sauger rearing and forage fish habitats. Based on the utilization by the fish and the channels' water level and connection to the main channel, minimum instream flows were determined.

Food habits studies of adult shovelnose sturgeon and sauger revealed that food organisms in the riffle areas comprised major portions of their diet. Using the WETP program, the amount of instream flow required to maintain riffle areas was determined.

Resident fish populations were inventoried in the lower reaches of three major tributaries of the middle Missouri River. A total of 24, 21 and 15 species was sampled in the Marias, Teton and Judith Rivers, respectively. Sauger was the most common game fish found in all three tributaries.

Movements of radio tagged paddlefish during the spring and early summer of 1980 were correlated with high flows. When the river was at lower flows, movements were confined to their staging area immediately above the Ft. Peck Reservoir pool. Significant upstream movement did not begin until higher flows occurred during the spring runoff period.

The minimum instream flows required to maintain the middle Missouri River fishery were based on:

(1) Side channel threshold flows during July 6-August 31
(2) Wetted perimeter/inflection point flows of riffles during September 1-May 18
(3) Paddlefish migration flows during May 19-July 5
(4) Channel morphology maintenance flows (24 hours) staged during May 19-July 5

and MDFWP should cooperate to develop a suitable methodology to determine instream flow requirements for the Wild and Scenic Missouri River. This study, funded by the BLM and conducted by the MDFWP, was initiated on April 1, 1979.

DESCRIPTION OF STUDY AREA AND HABITAT TYPES

The study area consists of a 333 km reach of the mainstem of the middle Missouri River in northcentral Montana from Morony Dam near Great Falls to the headwaters of Fort Peck Reservoir near Landusky. The general basin characteristics, hydrogeology and physical/chemical characteristics of the river have been adequately described by Berg (1981) and Kaiser and Botz (1975). The two major tributaries entering the Missouri River in this reach are the Marias River from the north and the Judith River from the south. The present day flow regimen of the Missouri River in this study area is not entirely natural because of regulation and storage at several dams in the drainage upstream from the study area.

Fifty-three species, representing 14 families of fish, are known to occur in the middle Missouri River drainage between Morony and Fort Peck dams (Berg 1981). Basically, two fishery zones occur on the mainstem Missouri. In the upper reach, from Morony Dam to the confluence of the Marias River, a cold water/warm water fisheries transitional zone exists. Sauger is by far the predominant game fish species found in this reach, but significant numbers of trout, mountain whitefish, sculpins, longnose dace and suckers also occur. A warm water fisheries zone extends from the confluence of the Marias River downstream to the headwaters of Fort Peck Reservoir. Sauger, shovelnose sturgeon, paddlefish, channel catfish and a variety of chubs, minnows, suckers and shiners are the predominant species in this zone.

Eleven sampling sections were established on the mainstem Missouri in the study area (Fig. 1). The Morony Dam and Carter Ferry study sections contain rocky substrate and have very few islands and side channels. Stream gradients are relatively high, ranging from 0.76 to 3.4 m/km. The Fort Benton, Loma Ferry, Coal Banks Landing and Judith Landing study sections have considerably more islands and side channels. Stream gradients in those study sections range from 0.38 to 0.76 m/km. The Hole-in-the-Wall and Stafford Ferry study sections have similar gradients, but the river in these study sections is confined by steep, narrow canyons, and consequently, very few islands and side channels occur. The lowest three study sections, Cow Island, Robinson Bridge and Turkey Joe, are in a reach of river characterized by a wide, meandering channel which contains numerous shifting sandbars and large developed islands.

Nine study sections were established on three tributaries of the middle Missouri River in the study area (Fig.1).

To facilitate interpretation of rearing area and forage fish data, the river channel was categorized into five major habitat types which could be effectively seined. The habitat types were main channel border, main channel pool, side channel chute, side channel pool and backwaters (Fig.2).

The main channel border habitat type was defined as a zone adjacent to the main channel bank which had an average current velocity of 15 to 45 cm/sec and a

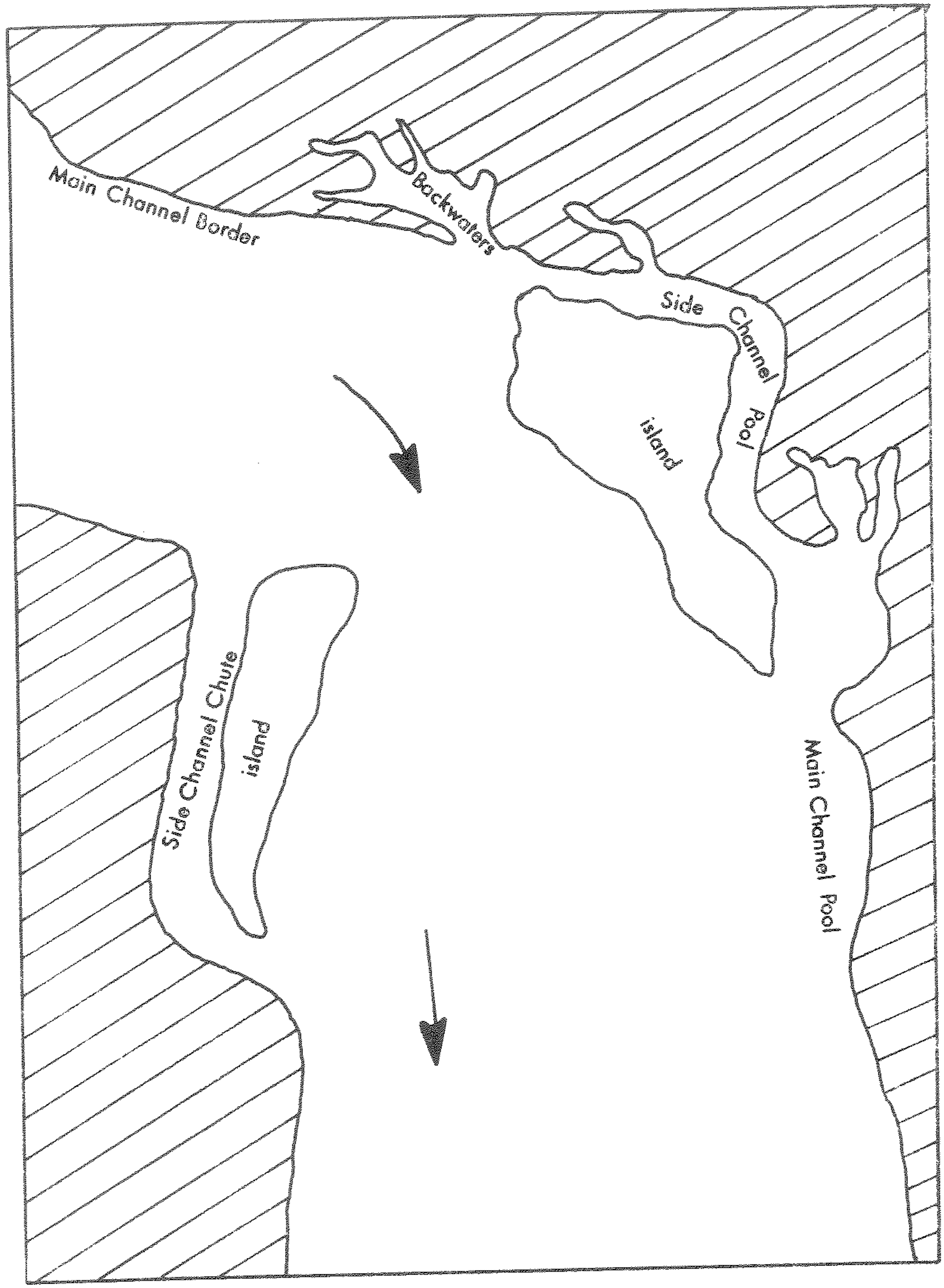

Figure 2. Diagrammatic representation of peripheral habitats in the middle Missouri River. (modified from Kallemeyn and Novotny 1977).

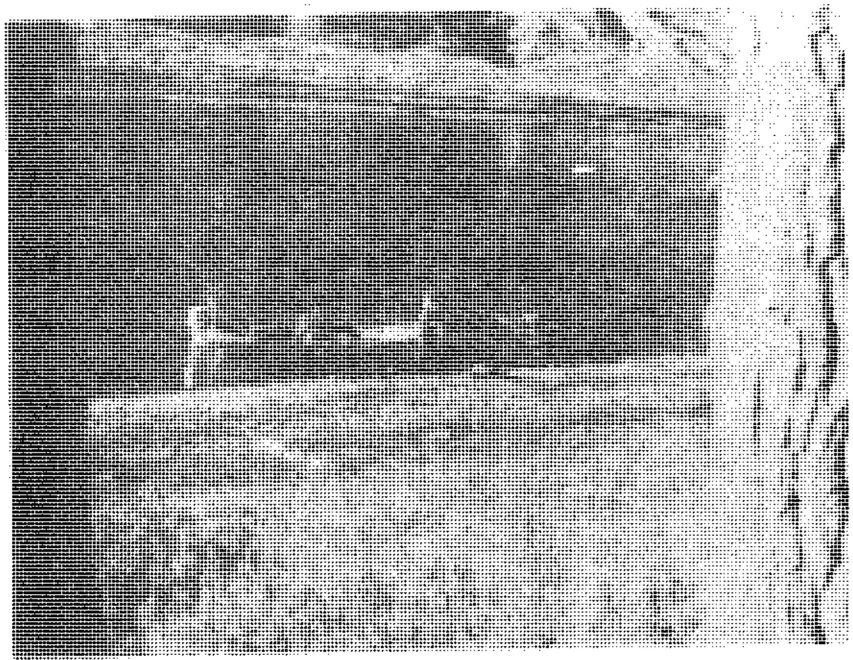

Figure 3. Electrofishing collections were made from a 5.2 m aluminum boat.

Figure 4. A screened scoop was utilized to sample incubating eggs of important fish species.

After the 0.5 m net was retrieved from the stationary set or integrated width tows, its contents were thoroughly washed into the collection jar. All samples were preserved in a 10 percent solution of formaldehyde colored with phloxine-B dye. In the laboratory, the samples were washed on a U.S. series No. 30 screen. Material retained by the screen was transferred to an enamel sorting pan where the larval fish were extracted. Larvae were identified to the lowest taxon practical using taxonomic keys by Hogue et al. (1976) and May and Gasaway (1967). For purposes of this study, larval fish were defined as those fish exhibiting underdeveloped pectoral and dorsal fin rays; essentially as suggested by May and Gasaway (1967).

Young-of-the-Year Fish and Minnows

Young-of-the-year (YOY) fish and minnows were sampled with a 15.2 x 1.2 m beach seine with 3.2 mm square mesh (Fig. 6). The seine was operated by two men and worked in as many different habitat types as the current and bottom characteristics allowed. Fish collected were identified, and associated habitat type was recorded. All comparisons between study areas or habitat types for fish sampled by seining were based on catch per unit effort. A unit effort was accomplished by dragging the seine 10-20 m through an area.

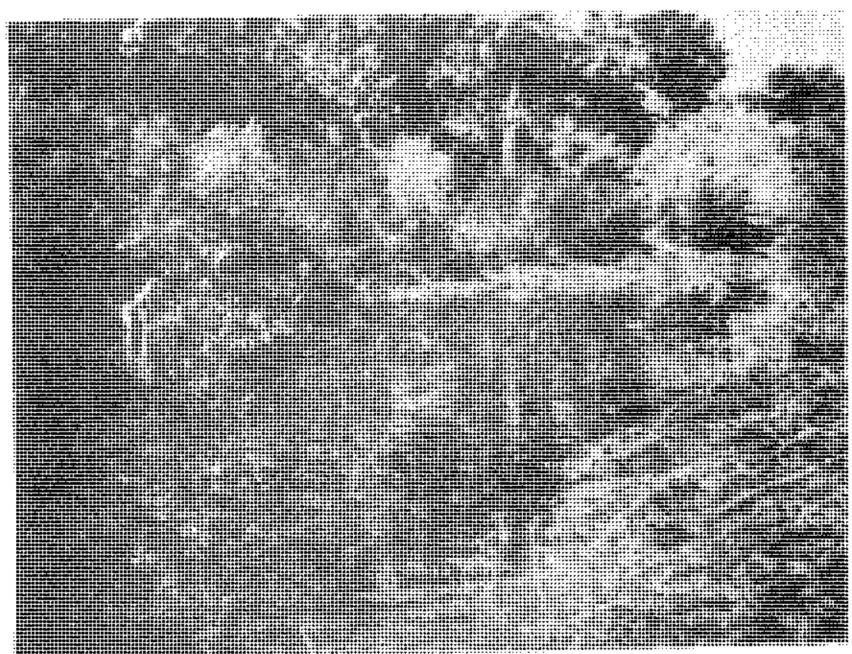

Figure 6. A beach seine was an effective device used to sample for young-of-the-year fish and minnows.

RESULTS

Life Cycle Stages

To determine instream flow requirements for the maintenance of a fish species, each life cycle stage and its requirements should be evaluated. The life cycle stages include: spawning, incubation, larval development, rearing and development to a mature adult. Each of these life cycle stages may require different habitat conditions which in some cases are related to the flow regime of the river. Because of the importance of the early life stages, the main effort of this study was directed in this area.

Spawning

Attempts were made in the study area to locate spawning sites of shovelnose sturgeon and sauger. It is generally accepted that spawning for these species does not occur randomly, but at specific sites or spawning grounds. Electrofishing was utilized during the spawning period in an effort to locate possible concentrations of fish and identify spawning sites. Because of sampling limitations, this effort was made only on shovelnose sturgeon and sauger.

No unusually large concentrations of adult shovelnose sturgeon or sauger were observed in the study area during their reported spawning seasons in 1979 and 1980. The inability to locate concentrations of these fish species is probably related in part to efficiency of the electrofishing sampling equipment. However, it is also possible that large concentrations of the spawning fish do not exist, and that spawning occurs in smaller concentrations over a wide area in the mainstem or in tributaries.

The range of the spawning period for shovelnose sturgeon and sauger in the study area was determined by examining a sample of sexually mature fish captured in the electrofishing surveys. Results of these observations are presented in Tables 1 and 2.

For shovelnose sturgeon, the spawning period was difficult to define. Moos (1978) reported that female shovelnose may take up to 3 years following spawning before their ovaries are again mature. Consequently, there are probably several different stages of ovarian development among adult female shovelnose sturgeon present in the Missouri River population. Thus, it is difficult to determine sex and spawning condition of the fish. For the purposes of this study, sturgeon with distended and turgid abdomens were classified as gravid females, fish with very flaccid abdomens and of a large size were considered spent females, fish with a tight, flat abdomen were left unclassified, and if milt could be stripped the sturgeon was considered a ripe male. No ripe females, as evident by stripping eggs, were observed during the spawning period in this study area. The scarcity of ripe females with strippable eggs has also been reported by Moos (1978) and Elser et al. (1977).

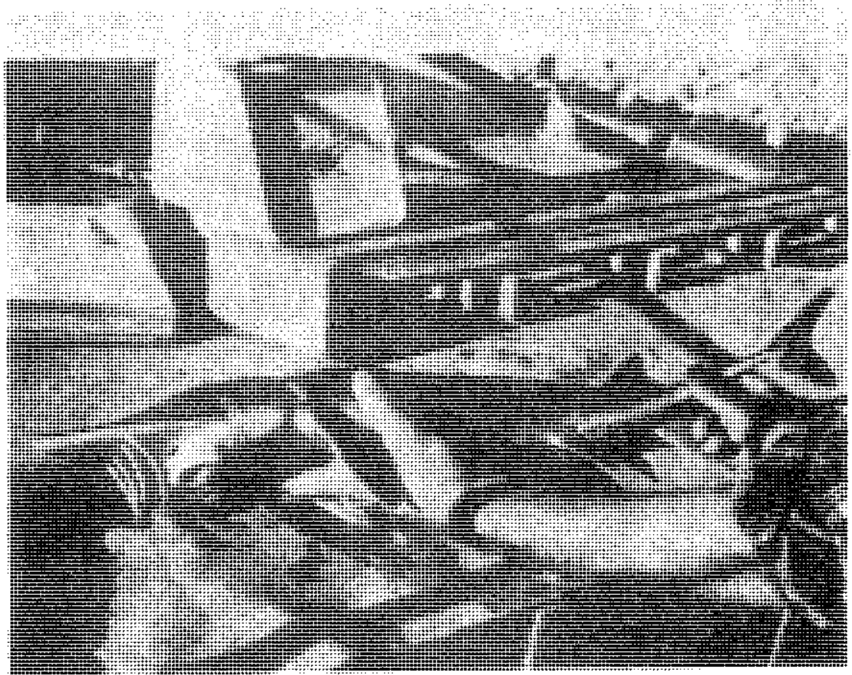

Figure 7. Shovelnose sturgeon were in spawning condition from early June to early July.

To verify our judgment of sex and spawning condition of female shovelnose sturgeon based on external characteristics, a technique for internal examination of the fish was developed. Internal examination provides positive confirmation of sex and spawning condition. The technique consisted of a 50 mm surgical incision of the abdomen to examine the gonads. After examination, the surgery was completed by closing the incision with five sutures. A number of shovelnose sturgeon were examined in this manner, and all appeared to be fully recovered within 24 hours. There appeared to be several stages of ovarian development among the female shovelnose examined during the spawning period. The stages included 1) ovaries developed into small size eggs, barely distinguishable, white to pink in color, 2) ovaries developed into small size eggs approximately 1 mm in diameter, white with an occasional black egg, and 3) mature ovarian development consisting of all black eggs approximately 3 mm in diameter.

In 1979 the first occurrence of ripe male shovelnose sturgeon in the study area was during the first week of June, and the last ripe male was collected in mid July (Fig. 7). Sampling for shovelnose sturgeon was terminated on July 16. Spent female shovelnose sturgeon were noted during the third week in June and the second week in July. A shovelnose sturgeon stomach sample collected on June 5, 1979, for food habits analyses contained three unfertilized shovelnose sturgeon eggs. These observations indicate that spawning of shovelnose sturgeon in the Missouri River in 1979 occurred primarily during a period from early June through early July.

To insure successful sauger spawning instream flows should remain steady with minimal fluctuations early in May, then flow should gradually rise until the peak of the runoff in June. If flow is significantly reduced after sauger spawn in early and mid-May, embryo incubation and hatching success will probably be impaired. Nelson (1968) investigated the effects of water fluctuations on the Missouri River sauger population below Fort Randall Dam. He reported that sharp water level changes over sauger spawning bars during the incubation period were the major reason for a poor reproductive success. Furthermore, the loss of recruitment was reflected as weak adult sauger year-class strength during the following years.

Incubation

An attempt was made to locate fertilized eggs of shovelnose sturgeon, paddlefish and sauger at anticipated or known spawning sites for these species in the study area. Types of areas sampled were similar to those described by Purkett (1961) for paddlefish, Nelson (1968) and Graham and Penkal (1978) for sauger. In general, these areas were usually shallow bars consisting of small gravel. Table 3 indicates the effort and number of eggs sampled in four study sections on the middle Missouri River during 1979. Although most of the incubating eggs collected were identified as goldeye, sucker or cyprinid eggs, one incubating paddlefish egg was collected near Stafford Ferry on June 12, 1979. This was approximately a 55-hour embryo as described by Ballard and Needham (1964). The embryo was sent to the TVA fish repository in Norris, Tennessee, and identification was verified by Bob Wallus. Berg (1981), previously reported that the Stafford Ferry area, with its numerous submerged gravel bars, was one of the most important spawning sites utilized by migrating paddlefish in the Missouri River upstream from Cow Island.

Some fish species are known to spawn on sites which are inundated only during the high flow period. Purkett (1961) indicated paddlefish in the Osage River, Missouri, spawned at least in part on gravel bars which were inundated only during high spring flows. Nelson (1980) found bigmouth buffalo embryos attached to inundated terrestrial vegetation and debris in Lewis and Clark Reservoir, South Dakota.

Paddlefish, bigmouth and smallmouth buffalo and river carpsucker in this study area also spawn, in part, in habitat inundated only during the high flow period. A substantial reduction in the magnitude of runoff during the normal high water period would obviously result in a significant loss of spawning and egg incubation habitat for paddlefish, buffalo, river carpsuckers and possibly other species.

Table 3. Number of egg samples taken and number of eggs collected (in parentheses) in four study sections on the middle Missouri River during 1979.

	Loma Ferry	Coal Banks	Stafford Ferry	Cow Island
May 22-Jun 6	16(6)	3(0)	7(0)	17(1)
Jun 12-Jun 20	4(7)	8(17)	18(12)*	24(17)
Jun 27-Jul 3	15(44)	14(0)	17(0)	15(2)
Jul 10-Jul 17	7(0)	6(0)	14(0)	-
Total No.	42(57)	31(17)	56(12)	56(20)

* One paddlefish egg collected June 12

Table 4. Taxonomic composition of fish larvae sampled by both stationary and integrated width tows in the middle Missouri River during late May - late July 1979.

		Total number of larvae sampled						
Study Section	Number of Tows	Goldeye	Mountain whitefish	Catostominae	Ictiobinae/ Cyprinidae group	Stonecat	Sauger	Sculpin
Carter Ferry	4		1	36				
Fort Benton	5			81	1			
Loma Ferry	9	6		734	130		1	
Coal Banks	9			152	32			
Judith Landing	5	1		40	21	1	1	
Stafford Ferry	7	2		205	33		1	1
Cow Island	14	1		143	192		1	
Robinson Bridge	2			15	4		5	

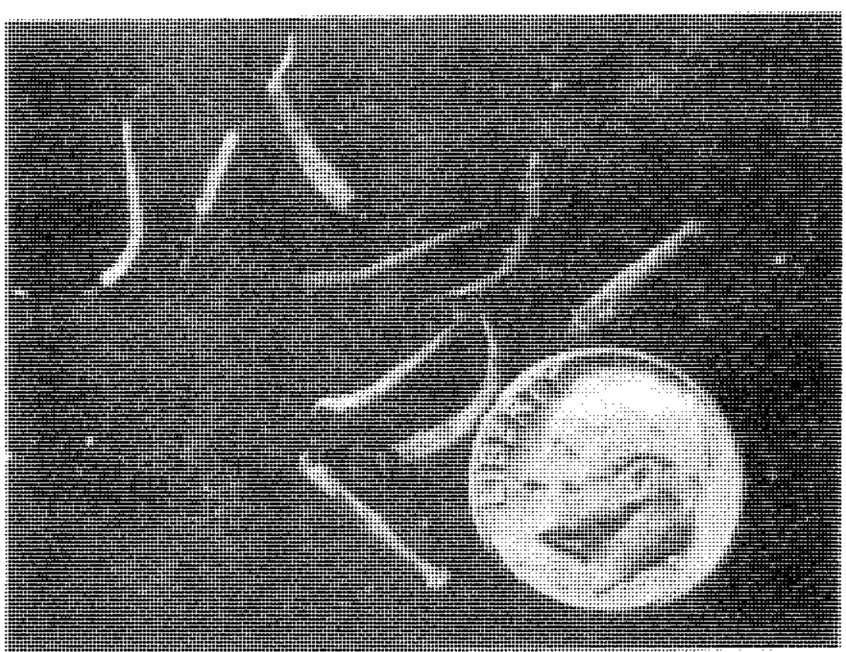

Figure 9. Fish larvae of eight subordinal taxa were collected in the middle Missouri River and its major tributaries.

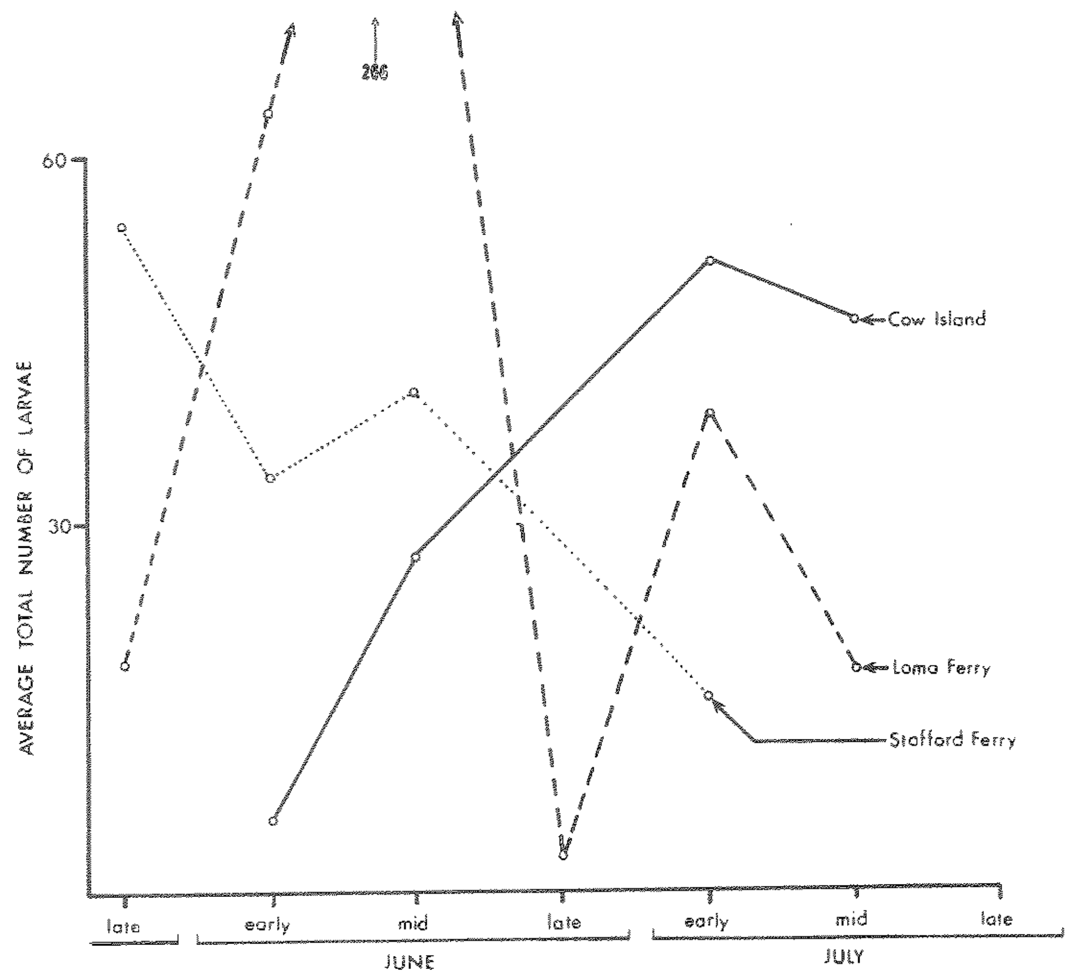

Figure 10. Average total number of fish larvae collected from 20-minute integrated width tows taken in three sections of the middle Missouri River during late May - mid-July, 1979.

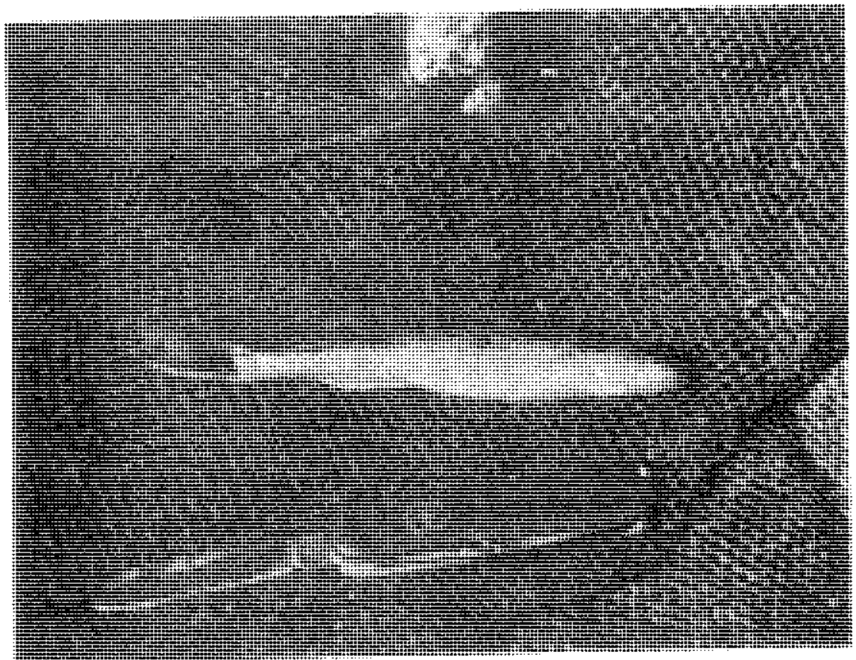

Figure 11. Young-of-the-year sauger ranging in length from 40 to 188 millimeters were collected in various peripheral habitat types on the middle Missouri River.

The Hole-in-the-Wall study section also contained a significant amount of sauger rearing habitat. Eighteen percent of the YOY sauger sampled during July, August and September were found in this study section, and catch rates averaged 0.74 YOY sauger per seine haul.

Results of sauger rearing habitat preference studies conducted in 1979 indicated YOY sauger selected protected habitats in peripheral areas of the river. During July, August and September, most YOY sauger were found in the side channel pool habitat types. Figure 12 illustrates the average catch rates of YOY sauger in each of the five habitat types. In the seven study sections where YOY sauger were found, the side channel pool habitat type accounted for a weighted average of 74 percent of the YOY sauger catch rate. The remaining habitat types, main channel pool, main channel borders, backwaters and side channel chutes were less important, and they accounted for averages of 27, 6, 3 and 1 percent of the YOY sauger catch rates.

Habitat preferences probably had a large influence on the longitudinal distribution of YOY sauger during 1979. The Robinson Bridge study section contained an extensive amount of side channel pools which are the most preferred sauger rearing habitat type (Figure 13). The Hole-in-the-Wall study section contained a

Figure 13. This typical side channel pool, 2 kilometers in length, was intensively utilized by rearing young-of-the-year sauger in 1979 (upstream view).

considerable number of main channel "pocket pools" which provided important sauger rearing habitat. The "pocket pools" are formed by small peninsulas extending perpendicular to the channel margin. The pools are located immediately downstream from and behind the peninsulas (Figure 14).

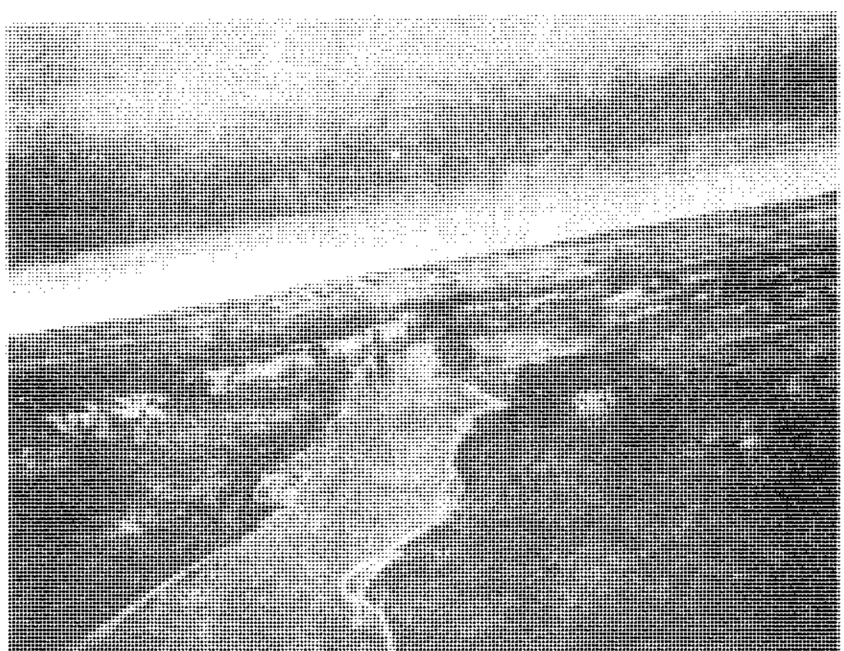

Figure 14. The Hole-in-the-Wall section exhibited extensive channel margin development, several peninsulas perpendicular to the margin formed important sauger rearing "pocket pools."

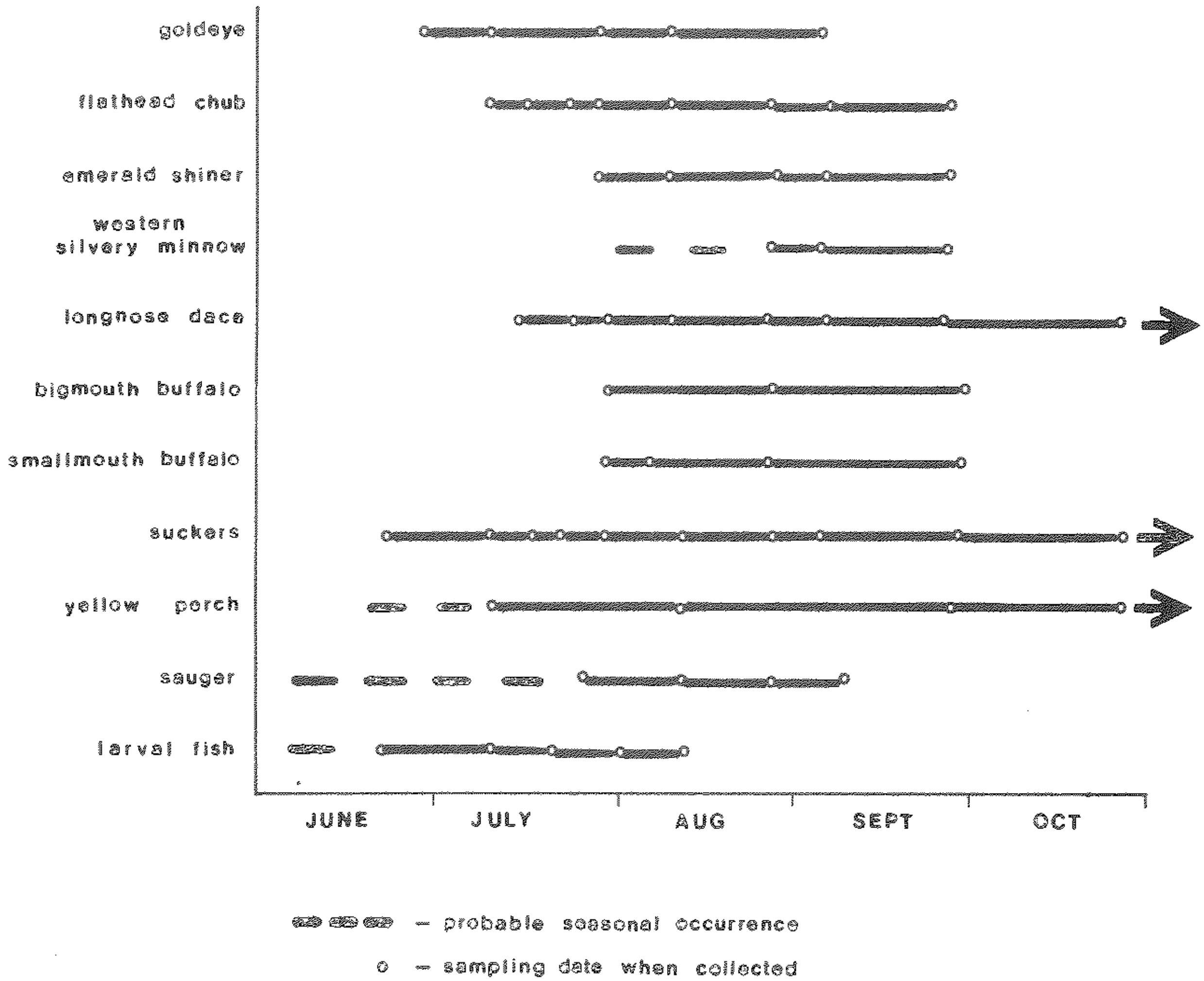

Figure 15. Seasonal occurrence of YOY fishes in the side channels of the middle Missouri River 1979-80.

Very little has been reported about the spawning habits or early life history of the goldeye. During this study, no exceptionally large numbers of sexually mature goldeye were sampled in the side channels; however, numerous ripe males and females were collected in calm main channel pools during late May. While sampling for incubating fish eggs in riffle areas during 1979, goldeye were the most numerous fish eggs collected. When trawling and seining some side channels during this period, substantially greater numbers of goldeye eggs were collected. This may indicate that many of the semi-buoyant goldeye eggs spawned in the main channel were carried into the side channels where they incubated.

Forage Fish

The forage fish community of the Missouri River plays a very important role in providing an adequate food base for piscivorous fish species such as sauger, northern pike, burbot, walleye and channel catfish. Therefore, it is important that habitat requirements are met to maintain forage fish for the welfare of the sport fishery as well as for the present fish fauna diversity of the river. This phase of the investigation was conducted to determine longitudinal distribution of forage fish species in the middle Missouri River, identify their preferred habitat types and monitor the forage fish communities of selected side channel pools during declining instream flows. For purposes of this study, a forage fish was broadly defined as any fish utilized by another fish as a food source. This would include most age 0 fish and nearly all adult minnows (Figure 17).

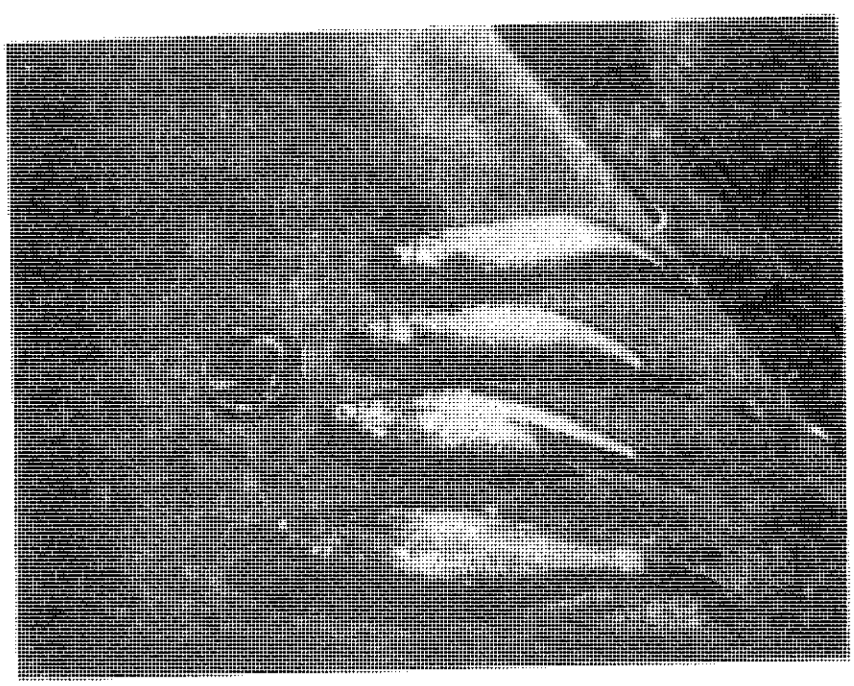

Figure 17. Forage fish distribution and abundance and their significance as a food source of sport fish were investigated during 1979-81.

Table 6. Longitudinal distribution of forage fish species seined in the middle Missouri River during 1979 and 1980. 1/

	Morony Dam	Carter Ferry	Fort Benton	Loma Ferry	Coal Banks Landing	Hole-in-the-Wall	Judith Landing	Stafford Ferry	Cow Island Landing	Robinson Bridge	Turkey Joe	Marias River	Teton River
Goldeye				*	*	*	*		*	*	*		
Mountain Whitefish		*			*								
Carp	*	*	*	*	*	*	*	*	*	*	*	*	
Flathead chub	*	*	*	*	*	*	*	*	*	*	*	*	*
Sturgeon chub							*		*	*			*
Sicklefin chub									*	*			
Lake chub	*	*	*	*	*	*	*					*	
Emerald shiner	*	*	*	*	*	*	*	*	*	*	*	*	*
Brassy minnow											*		*
Plains minnow	*	*		*					*	*		*	*
Western silvery minnow	*	*	*	*	*	*	*	*	*	*	*	*	
Fathead minnow	*	*	*	*	*	*	*			*		*	
Longnose dace	*	*	*	*	*	*	*	*	*	*	*	*	*
River carpsucker				*	*	*	*	*	*	*	*		*
Smallmouth buffalo			*	*			*		*		*		
Bigmouth buffalo			*	*			*						
Shorthead redhorse	*	*	*	*	*	*	*	*	*	*	*	*	*
Longnose sucker	*	*	*	*	*	*	*		*	*	*	*	*
White sucker	*	*	*	*		*						*	
Channel catfish									*	*			*
Stonecat		*		*		*	*	*	*	*			*
Smallmouth bass					*								
Pumpkinseed				*									
Yellow perch		*	*	*			*						
Sauger				*	*	*	*	*	*	*	*		
Walleye				*					*				
Iowa darter		*	*										
Freshwater drum											*		
Mottled sculpin	*	*		*		*				*			

1/ - Fish larger than 140 mm were not included.

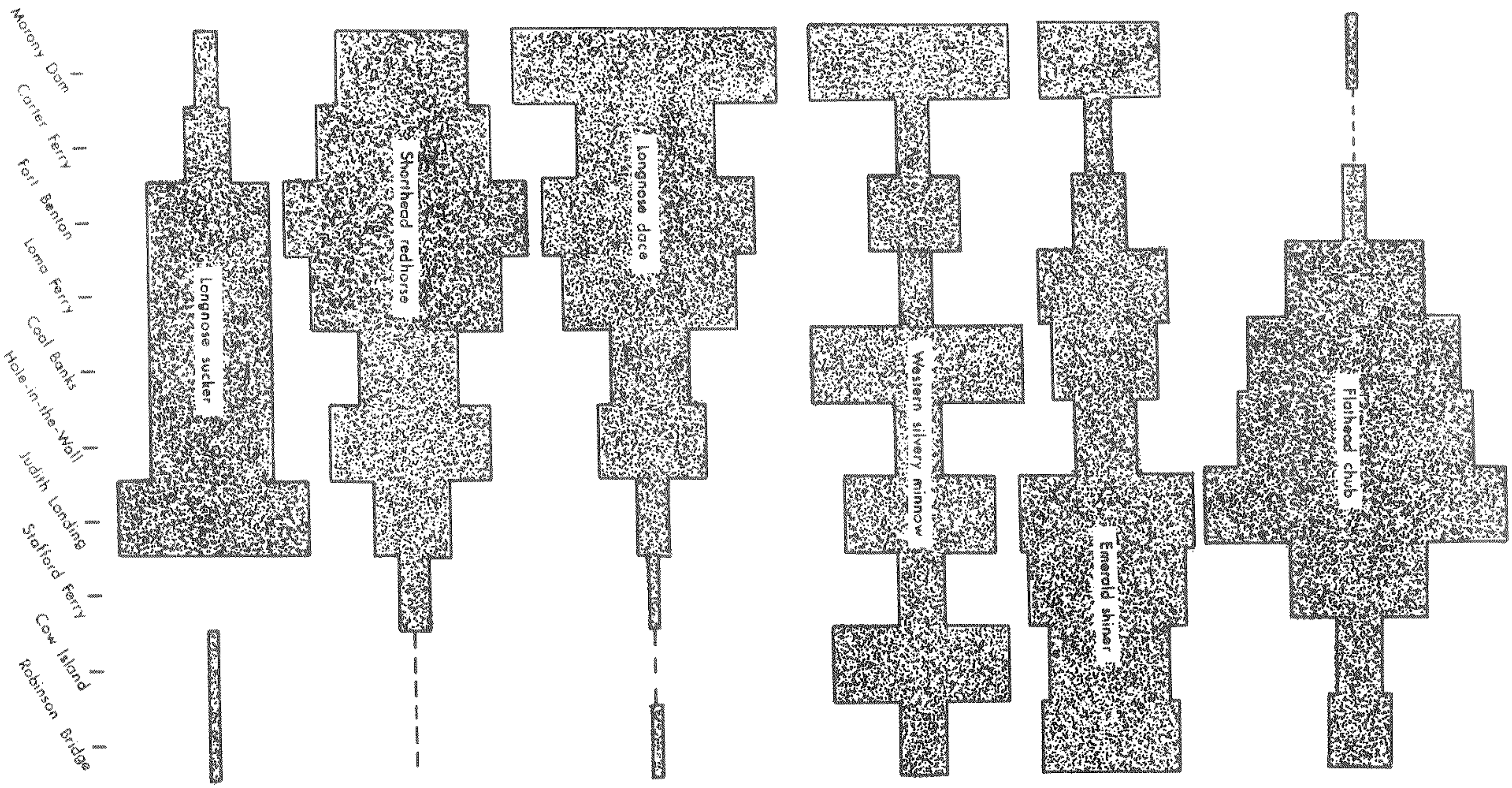

Figure 18. Longitudinal distribution and relative abundance (ave. catch rate) of six common forage fish species seined in the middle Missouri River during 1979. (10 mm on the vertical equals an average catch rate of eight fish per seine haul.)

suitable habitat conditions in the side channel. The flow requirements vary from one side channel to another; some side channels require more flow than others to maintain suitable habitat. The flow required to maintain each side channel is indicated by a threshold point. Above the threshold point, reductions in flow of the main channel caused only very small losses of habitat in the side channels. Below the threshold point, habitat conditions in the side channel deteriorated, making it inadequate for rearing or shelter. Threshold points determined for individual side channels were grouped together to formulate flow recommendations for a reach of stream.

A variety of physical characteristics were monitored in 12 typical side channels of the Missouri River in 1980, as flow receded from the seasonal high point to the low point. The locations and physical aspects of the side channels are shown in Figure 1 and Table 8. Cross-sectional transects were established in the side channel pool habitat type, which, as shown previously, was the most important habitat for rearing and forage fish. Measurements of width and depth were made at a variety of flow levels for each of the side channel pool transects. Side channel inlet flow and length of the channel were also measured and descriptive notes were recorded on the physical characteristics of the outlet of the side channel. The 12 side channels were surveyed by seining to monitor their utilization for rearing and forage fish.

Physical Characteristics of the Side Channels

Tables 9 through 11 summarize various physical parameters measured in each side channel during declining flows. To facilitate interpretation of instream flow data, the river was separated into three reaches. The reaches extended from Morony Dam to the confluence of the Marias River, from the confluence of the Marias to the confluence of the Judith River and from the confluence of the Judith River to Fort Peck Reservoir. Stream flow in these reaches was monitored by the Fort Benton, Virgelle and Robinson Bridge gage stations, respectively.

Influent surface flow ceased in 7 of the 12 side channels at an intermediate point of the declining surface runoff period (July 18-29, 1980). Even though there was no influent surface flow to the side channels, they did not entirely dewater, but were then supplied by subsurface seepage and a backwater flow from the main channel. Consequently, the water level in the side channels continued to decline in response to the decreasing instream flows even after influent surface flow had ceased.

The influent surface flow of a side channel was a major factor controlling both the channel length and depth (Figure 20). For example, average channel length decreased from 1.2 to 0.5 km, or by 58 percent, in side channels 2, 4, 7, 9 and 11 between the time the side channels had an influent flow and when the flow recently had ceased.

Water depth is the physical dimension of habitat most important for the fish communities in these side channels. In several of the side channels the depths throughout the channel were not uniform, but exhibited shallow, wide segments (Figure 21) as well as deep segments. For transects located in these shallower portions of the side channels, mean depth declined from 0.59 to 0.18 meters, or a 70 percent loss between the time the side channels had an influent flow and when the flow recently had ceased. For the same side channels and period, the deeper portions of the side channels exhibited only a 32 percent average decline.

Table 9. Physical characteristics of side channels in the Fort Benton gaged reach compared to flow of the Missouri River in 1980.

Side Ch. No.	Date	Missouri River flow (m 3/s)	Channel influent flow (m 3/s)	Total channel length (km)	Transect 1 Ave. Depth	Transect 1 Max. Depth (meters)	Transect 1 Width	Transect 2 Ave. Depth	Transect 2 Max. Depth (meters)	Transect 2 Width	Transect 3 Ave. Depth	Transect 3 Max. Depth (meters)	Transect 3 Width
#1	7/17	277	5.5	1.3	0.49	0.76	23.4	0.88	1.40	23.1	0.76	0.97	20.4
	8/20	172.2	1.4	1.3	0.24	0.52	21.0	0.76	1.09	21.6	0.52	0.73	20.1
	9/10	117.0	tr 1/	1.3	0.06	0.33	17.9	0.64	0.94	20.4	0.36	0.55	18.5
#2	7/18	257.7	tr	1.1	0.76	1.04	15.2	0.55	1.03	14.9	0.70	0.88	18.8
	8/25	130.6	- 2/	0.5	-	-	-	0.43	0.73	10.3	0.46	0.64	17.3
	9/24	119.5	-	0.4	-	-	-	0.40	0.67	9.1	0.33	0.49	16.1
#3	7/19	218.1	-	1.6	0.27	0.40	14.9	0.46	0.64	22.2	0.46	0.64	25.2
	8/26	123.5	-	1.0	0.15	0.18	11.6	0.09	0.12	13.1	0.12	0.18	14.0
	9/25	109.3	-	1.0	-	-	-	0.06	0.09	11.9	0.09	0.15	12.8
#4	7/19	218.1	tr	1.4	0.88	1.34	27.7	0.36	0.52	28.3			
	8/26	123.5	-	0.4	0.58	0.91	23.7	0.06	0.09	12.2			
	9/25	109.3	-	0.4	0.58	0.88	23.7	0.06	0.09	8.8			

1/ - Flow less than 0.14 m 3/s
2/ - Denotes zero flow or depth

Table 11. Physical characteristics of side channels in the Fred Robinson Bridge gaged reach compared to flow of the Missouri River in 1980.

Side Ch. No.	Date	Missouri River flow (m 3/s)	Channel influent flow (m 3/s)	Total channel length (km)	Transect 1 Ave. depth (meters)	Transect 1 Max. depth (meters)	Transect 1 width (meters)	Transect 2 Ave. depth (meters)	Transect 2 Max. depth (meters)	Transect 2 width (meters)	Transect 3 Ave. depth (meters)	Transect 3 Max. depth (meters)	Transect 3 width (meters)	Transect 4 Ave. depth (meters)	Transect 4 Max. depth (meters)	Transect 4 width (meters)
8	7/9	436.1	- 1/	1.7	0.49	0.70	10.9	0.67	0.82	13.4						
	7/27	268.8	-	1.6	0.24	0.40	7.9		2/							
	9/5	158.6	-	1.1	-	-	-	0.12	0.18	9.1						
9	7/10	413.5	2.0	1.0	0.43	0.67	13.1	0.85	0.97	16.7	0.97	1.28	20.4			
	7/28	262.5	-	0.9	0.21	0.36	8.5	0.54	0.64	15.8	0.73	0.94	18.8			
	9/6	149.8	-	0.3	0.06	0.09	4.0	0.40	0.49	15.2	0.40	0.61	17.3			
10	7/10	413.5	20.6	1.1	0.97	1.37	26.1	1.28	1.58	28.3	1.22	1.64	29.8			
	7/28	262.5	9.9	1.1	0.64	0.91	25.2	0.91	1.16	27.7	0.82	1.22	29.2			
	9/6	149.8	2.0	1.1	0.36	0.61	22.2	0.64	0.85	26.8	0.54	0.82	24.3			
11	7/12	439.0	6.9	1.2	0.79	1.06	17.0	0.52	0.64	21.3	1.09	1.58	19.2			
	7/29	258.8	tr 3/	1.2	0.33	0.54	14.9	0.12	0.18	18.5	0.73	1.19	17.3			
	9/7	159.7	-	0.7	0.27	0.49	14.9	0.06	0.06	11.2	0.54	0.91	15.8			
12	7/13	385.2	6.9	1.7	0.70	0.94	20.4	0.76	1.12	26.8	0.94	1.16	21.0	0.76	1.00	25.5
	7/30	248.6	2.5	1.7	0.52	0.67	17.3	0.54	0.85	24.3	0.61	0.76	19.8	0.46	0.54	23.7
	9/7	159.7	tr	0.5	0.27	0.33	14.3	0.30	0.58	20.7	0.30	0.46	19.2	0.15	0.33	23.2

1/ Denotes zero flow or depth
2/ Did not take depth measurement at transect
3/ tr denotes a flow less than 0.14 m 3/s

This illustrates that the shallower portions of the channel were more susceptible to dewatering and this dewatering occurred to a greater degree between the period when there was an inlet flow and when the inlet flow recently had ceased. In some cases where segments of shallow pool areas were completely dewatered, the loss of channel length was large. Dewatering of these shallower pool areas occurred in side channels 4, 9, 11 and 12 during low instream flows. It was noted at this time that many of the disconnected large pools (isolated from river) with moderate depths were warmer than the ambient river temperature. With the increase in water temperature of the pools, the dissolved oxygen probably declined to low levels. It is evident that a side channel must at least be connected at the outlet to allow for adequate circulation of the side channel water.

The channel width did not appear to change at the same rate as average depth. This was because most of the transects in the side channels had steep channel banks.

The 12 side channels were assessed in terms of suitability of the habitat for the fish fauna at declining instream flows. The criteria used were average depth, length of channel loss and depth of channel at outlet. An average depth of at least 0.2 m with maximum depths of 0.4-0.5 m was considered the minimum criteria required for adequate cover in the side channels. This criteria was based on fish sampling in these areas during 1979 and 1980. Table 12 is an evaluation of the side channels' suitability at the instream flow levels when they were surveyed. It was evident that at instream flows of 123.5 m 3/s (4360 cfs) in the Fort Benton gaged reach, serious losses of habitat had occurred and habitat conditions in two of the four side channels were inadequate. At 117.0 m 3/s (4130 cfs), habitat in three of the four side channels was considered inadequate. In the Virgelle gaged reach, only one of the three side channels was severely affected by the lower base flows. This side channel was disconnected from the river. Consequently, habitat conditions were inadequate when flow had reached 141.0 m 3/s. The other two side channels in this reach were in satisfactory condition at the low flow of 127.7 m 3/s gaged on September 25, 1980.

Four of the five side channels surveyed in the Robinson Bridge gaged reach were classified as inadequate at the lower instream flows of 159.7 m 3/s (5640 cfs) recorded September 7, 1980.

In summary, habitat conditions in 8 of the 12 monitored side channels were inadequate at the lower instream flows experienced in 1980.

The 12 side channels which were selected for monitoring in 1980 represented the various types found throughout the study area. Therefore, the effects of flow reductions on these 12 side channels exemplified the effects on the unmonitored side channels and backwaters. From this it was concluded that during the lower flow period when many of the monitored side channels were inadequate for rearing and shelter, so were most of the unmonitored side channels and backwaters. At this flow, the river's capabilities for rearing of important sport and commercial fish (i.e., sauger, buffalo, goldeye) and forage fish had been seriously reduced.

Fish Communities of the Side Channels

The monitored side channels were sampled to determine the utilization by forage fish and their capabilities for rearing fish. The 11 side channels could be separated into two different community types (Table 13) based on fish species associations. The major differences in fish communities were the abundance of suckers, fathead minnows and the occurrence of both YOY smallmouth and bigmouth buffalo in the upper side channels. In contrast, YOY sauger and goldeye were mostly found in the lower three side channels and the catch rates for the widely distributed common fish were reduced (Appendix Tables B and C). These differences in the fish communities were probably related to the physical characteristics of the side channels. Such a feature as an influent flow in the side channels during the period when YOY sauger are emerging from gravel bars and drifting down river is probably important for entry into the side channel. In contrast, lack of an influent flow when YOY buffalo emerge and move away from submerged vegetation would enable them to maintain themselves in the side channel.

Table 13. A simplified schematic assemblage of the common fish seined in the monitored side channels of the Missouri River during 1979-80. Species are listed according to numerical abundances.

Common fish sampled in side channels 1-8	Common fish sampled in side channels 9-12
Suckers[1/]	Flathead chub
Flathead chub	Western silvery minnow
Western silvery minnow	Emerald shiner
Fathead minnow	Suckers
Longnose dace	Longnose dace
Emerald shiner	Sauger
Smallmouth buffalo	Goldeye
Bigmouth buffalo	

1/- Comprised of shorthead redhorse, longnose and white suckers.

Seasonal utilization of these side channels was determined. Highwater conditions prevented seining of the side channels during June and early July. Circumstantial evidence (known hatching periods) would depict the onset for rearing of YOY fish to be about mid-June. For forage fish, utilization of side channels probably is initiated when adequate water levels in the side channels are reestablished. Most of the YOY fish did not continue to rear in these side channels, nor did most forage fish utilize the side channels during the autumn and presumably winter periods. Table 14 depicts species diversity and catch rates in the side channels as being the highest from mid-July through late August. By early September, substantial reductions of the fish communities were noted, both in diversity and catch rates. It was believed that a general emigration occurred by the forage and YOY fish to the more open waters of the main channel. This change in utilization happened before flows in the river, and consequently the side channels, were at their lower levels. Four of the 12 side channels with adequate water levels during late September exhibited little utilization by forage and YOY fish, indicating that a reason other than water level decreases in the side channels was responsible for this decline. Schmulbach (1974), evaluating the off-channel areas of the Missouri River below Gavin's Point Dam, also noticed a decline of utilization by forage fish in these areas during early autumn. In summary, it can be concluded that utilization of side channels by forage and YOY fish occurs from mid-June through August.

During 1980, the summer flows in the Missouri River were near normal, and there were suitable water levels in the side channels for rearing capabilities and forage fish production throughout the summer. However, a few conditions existed where segments of side channels were nearly isolated or severely dewatered. In those situations, fish species were sampled. The reaction of the fish communities to dewatering of some side channel segments was a retreat to deeper waters of the connected side channel. Therefore, in these cases it was apparent that the fish communities responded to the decreases of water levels in the side channels.

Instream Flow Recommendations for Side Channels

Side channels are important as rearing areas for YOY goldeye, buffalo, sauger and various forage fish species from early July through August. Goldeye and buffalo are most important commercial fish in Fort Peck Reservoir (J. Liebelt, MDFWP, pers. com.). Sauger are the most abundant sport fish found in the study area, and comprise a large portion of the sport fishery (Berg 1981). Forage fish (chiefly the flathead chub and western silvery minnow) are one of the principal food items consumed by the sauger. Instream flows are recommended to maintain suitable conditions in side channels for maintaining rearing capabilities and forage fish production.

The relationship between the monitored side channels' habitat condition and mainstem flows indicated that flows of 127.4 (4500), 152.9 (5400) and 164.2 m^3/s (5800 cfs) at Fort Benton, Virgelle and Robinson Bridge gaged sections, respectively, are the minimum flows required to maintain suitable conditions in these side channels for rearing and forage fish production (Table 15). The mainstem flow, and consequently channel dimensions, increases substantially between reaches; therefore, one recommended minimum flow for the entire study section would not be adequate. The recommended increases in flow correspond to the normal water accretion as reported by USGS surface water runoff monitoring (Missouri River Basin Commission 1978). Since the side channel habitat is used for rearing and forage fish production from early June through August, the recommended flows should be maintained during this period.

Food Habits

Shovelnose Sturgeon

Food habits analyses were completed for 68 adult shovelnose sturgeon collected by electrofishing in the Loma Ferry and Coal Banks Landing study sections. The sturgeon were collected during the autumn of 1978 and spring, summer and autumn of 1979. They ranged in weight from 1200 to 4680 grams.

Results of the shovelnose sturgeon food habits analyses are presented in Table 16. The diet was basically comprised of a wide variety of aquatic insects. Twenty-three subordinal taxa of aquatic insects were observed in the diet.

Table 16. Percentages of occurrence (O), average total numbers (N) and volumes (vol.) and the relative importance values (RI) of the food items found in the diets of adult shovelnose sturgeon in the Missouri River during 1978-79.

	1978 Autumn				1979 Spring				1979 Summer				1979 Autumn			
	%O	%N	%Vol	RI	%O	%N	%Vol	RI	%O	%N	%Vol	RI	%O	%N	%Vol	RI
Mayfly																
Rhithrogena	65	2	1	7.4	73	8	9	8.4	100	9	15	11.0	29	1	tr	4.1
Heptagenia	70	1	1	8.0	45	1	1	4.4	20	tr	tr	1.8	43	1	tr	6.1
Baetis	53	2	1	6.1	73	18	6	9.0	100	13	5	10.5	43	tr	tr	5.9
Tricorythodes	33	tr	tr	3.6	0	-	-	-	50	tr	tr	4.4	29	tr	tr	4.0
Ephron	10	tr	tr	1.1	0	-	-	-	80	6	8	8.3	0	-	-	-
Ephemera	0	-	-	-	0	-	-	-	0	-	-	-	14	tr	tr	1.9
Traverella	30	1	tr	3.4	0	-	-	-	100	29	43	15.3	29	1	tr	4.1
Ephemerella	23	tr	tr	2.5	100	16	26	13.2	30	tr	tr	2.7	14	tr	tr	1.9
				32.1				35.0				54.0				28.0
Stonefly																
Isogenus	38	1	2	4.5	45	1	1	4.4	30	tr	1	2.8	57	7	13	10.6
Isoperla	5	tr	tr	0.5	64	2	1	6.2	10	tr	tr	0.9	0	-	-	-
Acroneuria	23	1	3	3.0	27	tr	1	2.6	10	tr	tr	0.9	0	-	-	-
Claassenia	5	tr	tr	0.5	9	tr	1	0.9	0	-	-	-	0	-	-	-
Unidentified	13	tr	tr	1.4	18	tr	tr	1.7	60	tr	tr	5.3	14	tr	tr	1.9
				9.9				15.8				9.9				12.5
Caddisfly																
Hydropsychidae*	100	73	87	28.4	100	36	52	17.5	100	18	22	12.4	100	74	81	35.1
Oecetis	45	tr	tr	4.9	73	tr	tr	6.8	10	tr	tr	0.9	14	tr	tr	1.9
Brachycentrus	68	1	1	7.7	45	tr	tr	4.2	20	tr	tr	1.8	29	5	4	5.2
Glossosoma	0	-	-	-	0	-	-	-	10	tr	tr	0.9	0	-	-	-
Hydroptila	5	tr	tr	0.5	0	-	-	-	0	-	-	-	0	-	-	-
				41.5				28.5				16.0				42.2
Truefly																
Chironomidae (midge)	95	17	2	12.5	91	10	tr	9.4	100	12	3	10.2	86	8	tr	12.9
Simulium	18	1	tr	2.1	91	6	tr	9.0	90	9	3	9.1	29	1	tr	4.1
Tipula	3	tr	tr	0.3	18	tr	tr	1.7	0	-	-	-	0	-	-	-
Empididae	0	-	-	-	9	tr	tr	0.8	0	-	-	-	0	-	-	-
				14.9				20.9				19.3				17.0

The relative importance (RI) of mayflies was high during all seasons. Mayflies were the most important order in the diet during the spring and summer, with an average RI of 44 percent. Eight subordinal taxa of mayflies were observed.

The stonefly order, represented by at least four subordinal taxa, exhibited an average seasonal RI of 12 percent, which was considered a moderate representation in the diets. The caddisfly order was also heavily utilized as food by shovelnose sturgeon. Represented by six subordinal taxa, caddisflies had an average RI of 29 percent for all seasons combined. Caddisflies were the most important order in the diet in the autumn, with an average RI of 42 percent. The volumetric percentages of caddisflies in the diet were always high, averaging 63 percent for all seasons combined. Mayflies, by comparison, averaged 29 percent of the volume in the diet for all seasons combined.

The trueflies, represented by at least four subordinal taxa, were the third most important food group in the diet of shovelnose sturgeon. Their average seasonal RI was 19 percent. Miscellaneous taxa were of little significance in the diets of shovelnose sturgeon, but it was interesting that fish tissue, as evident by skeletal features, was consumed.

Seasonal comparisons of the relative importance (RI) of six major food groups utilized by adult shovelnose sturgeon are shown in Figure 22. It is particularly interesting to compare the relative seasonal importance of the mayfly and caddisfly orders. During spring, mayflies were only slightly more important than caddisflies in the shovelnose diet. However, during the summer months, shovelnose fed much more heavily on mayflies than caddisflies. The RI of mayflies in the summer diet was 54 percent. Two mayfly taxa, *Rhithrogena* and *Traverella,* alone had an RI of 26 percent. In the autumn, the RI of the mayfly taxa was substantially reduced. Hydropsychidae, a caddisfly taxa, clearly dominated in the autumn diet of shovelnose sturgeon with an RI of 32 percent.

The seasonal diets of shovelnose sturgeon have been reported by other investigators. Walburg et al. (1971) and Modde and Schmulbach (1977) found the shovelnose opportunistic feeders, and in the Yellowstone River, Elser et al. (1977) reported nonselective foraging for *Traverella* during the summer followed by a resumption of feeding on hydropsychids in the autumn. No selectivity analysis was conducted for this investigation; however, based on the distribution and composition of the aquatic insect fauna as described by Berg (1981), it appears adult shovelnose sturgeon forage nonselectively on insects in swift current habitats in this study area. Furthermore, the seasonal diets of shovelnose sturgeon in the middle Missouri River correspond closely to the emergence of several major food taxa. For example, *Rhithrogena* and *Traverella* emerge mainly during the summer, and they are prominent in the summer diet of shovelnose sturgeon. *Ephemerella* and most of the species of Hydropsychidae had previously emerged during the spring and were unavailable as a food item during the summer.

Newell (1976) reported that the mayflies *Rhithrogena* and *Traverella* are insects which inhabit swift current areas. The four remaining taxa shown in Figure 19 frequent a wide array of habitats, also including the swift current areas. Berg (1981) indicated *Heptagenia* was a common insect in the study area. However, this insect was not an important food item in the diet of shovelnose sturgeon. Newell (1976) reported the velocity requirement for *Heptagenia* is substantially less than that of *Rhithrogenia* and *Traverella.* This observation provides further evidence to support the idea that shovelnose sturgeon feed nonselectively in swift current areas in the middle Missouri River.

Fish growth rates follow a seasonal pattern in response to temperature changes and food availability. For a warm water species like the shovelnose, the summer period is probably the season when maximum utilization of food organisms occurs. Helms (1974) described the shovelnose sturgeon of the Mississippi River as having a low body condition value from February to mid-June, increasing to a peak value in early September, thereafter declining to the low winter levels. Brett et al. (1969) reported a relationship between growth of sockeye salmon with that of varying temperatures and ration size. They concluded there was not only an optimal temperature for maximum utilization of food organisms by a fish, but also, at higher temperatures (which could be optimal temperatures for that species' growth) the requirements for a given quantity of food were increased.

With these reported findings in mind, it is believed the summer diet is the most critical diet for the maintenance of the high quality shovelnose sturgeon fishery which exists in the middle Missouri River. Since the two mayflies *Rhithrogena* and *Traverella* together comprised 26 and 58 percent of the total RI and volume, respectively, in the summer diets, it is apparent that these two taxa are very important food sources for shovelnose sturgeon in this area. It should also be noted that these two taxa exhibit relatively little tolerance to alterations of physical and chemical characteristics of a river. It is essential that adequate flow be maintained in riffle areas so that *Rhithrogena* and *Traverella* can continue to provide the significant food base for shovelnose sturgeon as well as other species.

Sauger

Food habit analyses were completed for sauger sampled during the months of August to November 1980. The sauger ranged in length from 160-678 mm and were representative of the size structure normally found in the river (Appendix Table E). Of the 638 fish pumped for stomach contents, 185 yielded identifiable contents which consisted entirely of fish matter. A minimum of 12 fish species was found in the sauger diet, although 91 percent of the individual sauger stomachs contained single item contents (Table 17).

The principal food items for sauger were stonecats, "shoal" minnows (flathead chub, western silvery minnows, emerald shiner and fathead minnows), longnose dace and sculpins, having an overall average relative importance value of 26.8, 24.0, 23.2 and 11.0, respectively. When examined for each particular reach of river, differences in the diet were evident. For the relatively swift, cool water reach of river consisting of the Morony Dam and Carter Ferry sections, longnose dace, mottled sculpins and minnows comprised the major portion of the sauger's diet with RI values of 28.3, 26.0 and 22.3 percent, respectively. In the warmer, lower reach of the river from the Coal Banks Landing section downstream, the stonecat constituted the major portion of the diet with an RI value of 29.4 percent, followed by sicklefin/sturgeon chubs, channel catfish and longnose dace with RI values of 18.7, 13.0 and 11.7, respectively.

The diet of the piscivorous sauger was apparently influenced to a great degree by availability of food items. For example, in the upper reach, mottled sculpins were abundant, but rare in downstream areas. This distribution of sculpins was distinctly reflected in the diet of the sauger. Similarly, availability limited the importance of YOY channel catfish, sicklefin and sturgeon chubs and stonecats to the lower reach of river. Even though fishes associated with swift current areas comprised much of the sauger's diet, a substantial portion of the ration was comprised of minnows which prefer the slower, more protected areas (shoals) of the river.

When comparing the size of sauger to the type of food constituting their diet, it was noteworthy that sauger less than 250 mm selected the small-sized longnose dace, sicklefin and sturgeon chubs and YOY channel catfish which all prefer swift current. This was also the area where most of the juvenile sauger were sampled in the autumn. The other size groups did not appear to exhibit such selection. Flathead chub, longnose dace and YOY channel catfish comprised the major portion of the sauger's diet in the Yellowstone River (Elser et al. 1977). Also, the stonecat comprised a substantial portion of the diet in terms of volume, but they were not consumed as frequently as other food items. Basically, the sauger diet described by Elser et al. for the Yellowstone River resembles the middle Missouri River sauger's diet, with the exception of the stonecat being more prominent and young channel catfish being less important in the Missouri. It is evident that sauger feed extensively in the riffle areas where many forage fish are found. The importance of "shoal minnow" types in their diets also verifies the significance of side channels and other peripheral habitat areas as essential food producing areas for sauger.

Young-of-the-Year Fish

Limited studies were made during 1979 on the food habits of young-of-the-year (YOY) sauger, goldeye and freshwater drum. Results of diet analyses for these species are shown in Table 18.

Findings indicated that the diet of YOY sauger in the middle Missouri River was chiefly piscivorous. Priegel (1969) reported that YOY sauger less than 50 mm in size fed chiefly on cladocerans, and those larger than 50 mm preferred YOY troutperch, freshwater drum and white bass. However, when the YOY forage fish were not abundant or available, the YOY sauger larger than 50 mm continued with the plankton diet.

In the earlier discussion concerning larval fish, it was indicated that the peak of abundance of larval fish in the upper study sections occurred in late May and early June. A later peak in early July was observed in the lower river. It was also found that there was a selection by YOY sauger for rearing sites in the lower river. Growth rates for YOY sauger sampled during 1979 were highest during July. An adequate food supply is necessary during this period. This requirement is probably best fulfilled at the lower sites where larval fish are still available. Walburg (1976) reported the greatest growth increases occurred during July, and further comparisons between years indicated the greatest growth was realized in years when forage fish were available by mid-July and then utilized by YOY sauger.

The diets of YOY goldeye were the most diversified of the three fish species investigated. *Baetis*, corixids, and cladocerans comprised 69 percent of the diet during late July. In mid-October, Hymenoptera, corixids and cladocerans accounted for 71 percent of the diet. Food habits of the YOY goldeye appear to be correlated with the backwater and side channel pool habitats which they prefer as rearing areas. Since the rearing habitat preferences of YOY goldeye and sauger overlap to some extent, the invertebrate food items available to goldeye are also available to sauger. In spite of this abundant invertebrate food supply, the YOY sauger selected a diet comprised primarily of YOY forage fish.

Little is known about the resident fish populations in these tributaries. This phase of the study was conducted to determine species composition, longitudinal distribution, relative abundance and size composition of the resident fish populations in the tributaries.

A total of 24, 21 and 15 fish species was observed in the Marias, Teton and Judith rivers, respectively, during electrofishing and seining surveys conducted in 1979 (Table 19). Most of these species are also found on the mainstem between Morony Dam and Fort Peck Reservoir (Berg 1981).

Table 19. A list of fish species sampled by electrofishing and seining in the three major tributaries of the middle Missouri River during August-October 1979.

	Marias	Teton	Judith
Goldeye	*	*	*
Mountain whitefish	*	*	*
Rainbow trout	*		
Brown trout	*		
Carp	*	*	*
Sturgeon chub		*	
Flathead chub	*	*	*
Lake chub	*	*	
Emerald shiner	*	*	
Brassy minnow		*	
Plains minnow	*	*	
Western silvery minnow	*	*	*
Fathead minnow	*		
Longnose dace	*	*	*
River carpsucker	*	*	
Blue sucker	*		
Smallmouth buffalo	*		
Shorthead redhorse sucker	*	*	*
Longnose sucker	*	*	*
White sucker	*	*	*
Mountain sucker	*	*	*
Channel catfish	*	*	*
Stonecat	*	*	*
Burbot	*	*	*
Sauger	*	*	*
Walleye	*		
Freshwater drum		*	
Mottled sculpin			*

Table 20. Catch statistics of fish sampled by electrofishing in the Tiber Dam section of the Marias River during August and October 1979.

Species	Number Sampled	Average Length (mm)	Length Range (mm)	Average Weight (gm)	Weight Range (gm)	Catch per unit effort
Goldeye	13	330	320-350	375	300- 430	3.7
Mountain whitefish	236	360	110-500	695	20-1840	26.7
Rainbow trout	13	338	80-530	899	10-2470	1.5
Brown trout	2	401	360-440	994	830-1160	0.2
Carp	36	485	420-650	1540	930-4130	10.3
Longnose dace	4	81	60-100	14	5- 20	2.9
River carpsucker	9	445	420- 510	1076	930-1570	2.6
Blue sucker	1	660	-	2860	-	0.1
Smallmouth buffalo	3	605	570-650	3314	2630-3860	0.3
Shorthead redhorse	6	448	380-490	1058	550-1520	5.7
Longnose sucker	34	371	130-490	785	30-1450	9.7
White sucker	5	395	310-470	763	280-1140	4.0
Burbot	12	427	170-770	654	40-2910	1.4
Sauger	36	377	280-510	427	150-1070	4.1

Table 21. Catch statistics of fish sampled by electrofishing in the High Rock Canyon section of the Marias River during October 1979.

Species	Number Sampled	Average Length (mm)	Length Range (mm)	Average Weight (gm)	Weight Range (gm)	Catch per unit effort
Mountain whitefish	27	266	100-420	268	20- 770	9.8
Carp	12	472	420-530	1466	960-1990	6.9
River carpsucker	1	390	-	670	-	0.6
Shorthead redhorse	16	452	390-480	1058	640-1400	9.1
Longnose sucker	13	417	140-480	876	30-1130	7.4
White sucker	2	318	250-380	418	190- 640	1.1
Sauger	17	384	310-560	440	230- 840	6.2

Table 24. Catch statistics of fish sampled by electrofishing in the Collins section of the Marias River during October 1979.

Species	Number Sampled	Average Length (mm)	Length Range (mm)	Average Weight (gm)	Weight Range (gm)	Catch per unit effort
Goldeye	6	325	310-350	291	240- 340	3.0
Mountain whitefish	24	279	150-360	250	20- 540	5.7
Brown trout	2	351	300-400	508	290- 720	0.5
Carp	3	471	460-480	1402	1210-1660	1.5
Shorthead redhorse	3	216	120-400	277	10-810	1.5
Longnose sucker	20	298	200-420	286	270-780	10.0
White sucker	2	304	240-360	341	160-520	1.0
Mountain sucker	1	140	-	30	-	0.5
Stonecat	1	180	-	20	-	0.5
Burbot	1	320	-	170	-	0.2
Sauger	137	326	150-530	286	20-1230	32.2
Walleye	1	430	-	700	-	0.2

effort for this species was substantially reduced downstream from the Tiber Dam study section. Rainbow trout were very ephemeral in their longitudinal distribution, being confined exclusively to the Tiber Dam section. A few YOY rainbow trout and many YOY mountain whitefish were found in the surveys, indicating that successful natural reproduction of these species occurs in the Marias River below Tiber Dam.

The abundance of sauger in the Marias River increased gradually from Tiber Dam to the mouth of the Teton River. Sauger catch increased from 4.1 fish per electrofishing hour in the Tiber Dam section to 32.2 fish per hour in the Collins section. A number of YOY sauger were collected in the Badlands and Collins study sections, indicating that spawning and rearing of this species occurs in the lower Marias. Sauger are the most common game fish below Tiber Dam, and comprise the bulk of the sport fishery.

Other common game fish found in the Marias River between Tiber Dam and the mouth of the Teton River include burbot, walleye, northern pike and channel catfish. These fish are known to permanently reside in this reach. The scarcity of northern pike, channel catfish and burbot in the electrofishing sample is partly due to the poor response of these species to electrofishing. Posewitz (1962), utilizing frame traps as a sampling technique, found substantial populations of sauger, burbot and channel catfish throughout the Marias River below Tiber Dam. Berg (1981) reported significant annual spawning migrations of several fish species from the Missouri River into the lower Marias. The most important migrant species included sauger, shovelnose sturgeon, blue suckers and smallmouth and bigmouth buffalo.

Table 25. Catch statistics of the fish sampled by electrofishing in the Bootlegger section of the Teton River during September and October 1979.

Species	Number Sampled	Average Length (mm)	Length Range (mm)	Average Weight (gm)	Weight Range (gm)	Catch per unit effort
Goldeye	35	327	300-370	272	190- 380	4.9
Carp	8	489	450-520	1430	1130-1870	1.1
Flathead chub	195	99	70-140	20	10- 20	-
Lake chub	1	80	-	10	-	-
Brassy minnow	2	-	-	-	-	-
Plains minnow	1	-	-	-	-	-
Western silvery minnow	75	136	130-150	20	20- 30	-
Longnose dace	19	-	-	-	-	-
River carpsucker	1	460	-	1050	-	0.1
Shorthead redhorse	31	266	60-360	200	10- 360	4.4
Longnose sucker	26	236	70-340	160	10- 380	3.7
White sucker	53	240	130-370	190	10- 540	7.5
Mountain sucker	39	113	70-220	20	10- 40	5.5
Channel catfish	1	50	-	10	-	0.1
Stonecat	4	119	70-150	20	10- 40	0.6
Burbot	1	530	-	800	-	0.1
Sauger	25	406	340-510	550	270-1080	3.5

Table 26. Catch statistics of fish sampled by electrofishing in the Wood section of the Teton River during September 1979.

Species	Number Sampled	Average Length (mm)	Length Range (mm)	Average Weight (gm)	Weight Range (gm)	Catch per unit effort
Goldeye	5	340	320-370	341	260- 480	0.5
Mountain whitefish	1	160	-	20	-	0.1
Carp	24	483	100-640	1390	20-2210	2.6
Flathead chub	276	96	40-250	20	10- 140	-
Western silvery minnow	5	106	90-130	20	10- 20	-
Longnose dace	55	57	40- 80	10	10- 20	-
River carpsucker	7	432	390-510	917	710-1250	0.8
Shorthead redhorse	13	350	50-470	540	10-1020	1.4
Longnose sucker	47	111	60-240	27	10- 160	5.0
White sucker	4	214	120-300	150	10- 300	0.4
Mountain sucker	18	96	50-140	14	10- 20	1.9
Channel catfish	3	686	640-710	3677	3000-4540	0.3
Stonecat	19	144	40-220	45	10- 130	2.0
Burbot	3	357	250-460	268	80- 480	0.3
Sauger	28	394	320-530	520	230-1210	2.5
Freshwater drum	1	380	-	610	-	0.1

Table 27. Catch statistics of fish sampled by electrofishing in the Anderson Bridge section of the Judith River during September 1979.

Species	Number Sampled	Average Length (mm)	Length Range (mm)	Average Weight (gm)	Weight Range (gm)	Catch per unit effort
Goldeye	3	338	320-360	436	380- 490	0.7
Carp	3	503	490-510	1748	1540-2010	0.7
Flathead chub	31	122	50-160	23	10- 60	-
Longnose dace	21	73	50- 90	10	10	-
Longnose sucker	24	310	160-420	350	40- 740	5.7
White sucker	1	300	-	300	-	0.2
Mountain sucker	18	154	120-220	36	20- 100	4.3
Stonecat	16	158	130-190	23	10- 90	3.8
Burbot	3	396	260-510	404	80- 780	0.7
Sauger	7	294	240-370	236	130- 420	1.7
Mottled sculpin	1	70	-	10	-	0.2

Table 28. Catch statistics of the fish sampled by electrofishing in the PN Ranch section of the Judith River during September 1979.

Species	Number Sampled	Average Length (mm)	Length Range (mm)	Average Weight (gm)	Weight Range (gm)	Catch per unit effort
Goldeye	1	320	-	230	-	0.3
Mountain whitefish	1	120	-	20	-	0.3
Carp	3	492	460-500	1575	1370-1850	0.8
Flathead chub	100	130	510-730	32	10- 120	-
Longnose dace	3	67	60- 80	10	10	-
Shorthead redhorse	3	214	60-380	245	10- 620	0.8
Longnose sucker	30	274	80-360	232	10- 410	8.1
White sucker	1	220	-	130	-	0.3
Mountain sucker	9	134	80-200	36	10- 110	2.4
Channel catfish	1	680	-	3810	-	0.3
Stonecat	4	139	120-160	23	10- 30	1.1
Burbot	3	415	390-430	300	300	0.8
Sauger	19	233	120-510	200	20-1090	5.1

The middle Missouri River is a large river with deep pools, and contains water of a relatively high ionic conductivity. It is difficult to develop an aquatic radiotelemetry system which functions adequately in this situation. Only limited success has been attained by researchers attempting to utilize radiotelemetry in streams similar to the middle Missouri River. Therefore, all of our effort in 1979 was spent in developing a radio-telemetry system which would be suitable for our requirements. In 1980 the actual tracking of paddlefish took place.

Equipment

A Smith-Root SR-40, 10 channel search receiver with a frequency range between 40.000 and 41.000 MH_z was used to simultaneously monitor the radio-instrumented fish. An omnidirectional whip antenna was matched with the receiving unit and mounted to the wing strut of a Supercub airplane.

Radio transmitters from three different commercial suppliers were used to increase the probability of success. In 1979, the Smith-Root P-40-1000L, a radio transmitter powered by a lithium battery, was superior in performance to its mercury battery powered counterpart. Because of this, the Smith-Root P-40-1000L transmitters were used in 1980. In addition, transmitters manufactured by Dav Tron and Wyoming Biotelemetry were used in 1980. These transmitters were also powered by lithium batteries. The Dav Tron LF-815 transmitter was very similar in design to the Smith-Root, but the Wyoming Biotelemetry transmitter consisted of an enclosed antenna on a circuit board and its basic component was all micro-circuitry.

The Smith-Root transmitter was approximately 85 grams, cylindrical in shape, measuring 190x19 mm with a 150 mm external antenna. Dav Tron radio transmitters were approximately the weight and size of a "D"-cell battery, 100 gms and 70x35 mm dimensions with a 250 mm external antenna. Wyoming Biotelemetry transmitters were not entirely symmetrical; however, their overall length was 155 mm with a maximum diameter of 20 mm and weight of 50 grams (Figure 23). The three companies adjusted the current drain of the transmitters to meet the environmental conditions, yet transmit a strong signal for 90 days. Each radio transmitter was individually identified by the channel frequency and a specified pulse rate. During feasibility tests conducted in 1979, it was determined the Smith-Root P-40-1000L transmitter's signal could be relocated at an accuracy of $\pm$ 50 m and received at a maximum distance of approximately 1.5 km from the airplane.

Implantation and Attachment of Transmitters

Radio transmitters were attached to paddlefish using both internal and external plants. Internal plants were surgically implanted in the peritoneal cavity of paddlefish (Figure 24). Using standard surgical procedures, a 70 mm incision was made with a scalpel along the upper right ventrum immediately posterior to the pectoral fin (Figure 25). The incision was made at this site to avoid severing major vessels present along the ventral axis. After the incision was completed, a transmitter dipped in parafin was inserted into the peritoneal cavity with the external antenna (plastic coated copper wire 1 mm diameter) extending outside the body. The incision was then closed with

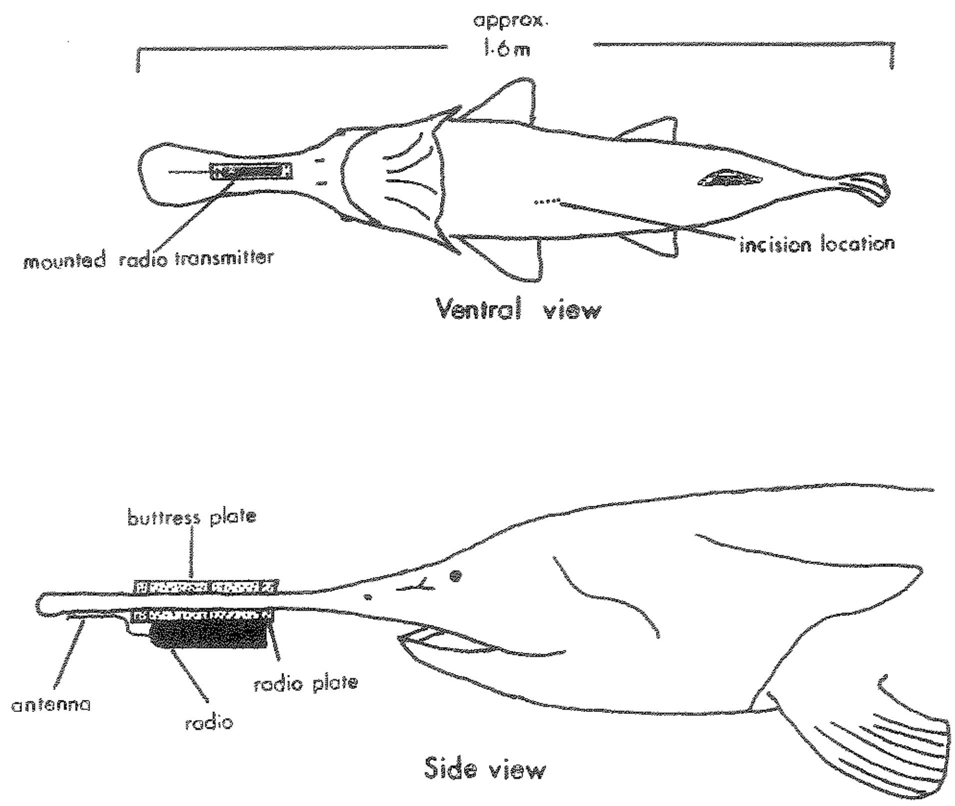

Figure 24. Attachment and implant sites for the paddlefish radio transmitters.

Table 29. Performances of radio tags used in the 1980 middle Missouri River paddlefish radiotelemetry study.

	Companies/Placement				
	Smith-Root		Dav Tron	Wyoming	
	Internal	Rostrum	Internal	Internal	Rostrum
Total number radios attached	9	3	9	2	5
Percent of radios which worked	78	67	22	0	0
Average number relocations for each working radio	7.0	2.0	1.5	-	-
Range:number relocations	2-11	1-3	1-2		
Average radio life (days)	56.3	41	29		
Radio life range (days)	14-87	7-76	29		

Some problems were also encountered with internally planted tags. Apparently, because of the large amount of tension on the sutures, the skin could not hold the strain; consequently, some of the sutures tore through. This problem was observed on two of the paddlefish with internal radio transmitter placements. The problem could be easily alleviated by placing wider sutures in addition to the primary, medium width ones. Another problem encountered with the surgically implanted radio transmitters was associated with the external antenna. The connection between the base of the antenna to the component was sound; however, a length of antenna was sheared off on two of the recovered radio transmitters. The shearing could have been related to abrasion caused by the fish rubbing the bottom, or corrosion caused by a chemical reaction with the fishes' mucous covering. Stainless steel antenna or other noncorrosive materials would probably remedy this problem.

There is little doubt that successful radio tracking of a large fish under these conditions can be achieved. Dennis Unkenholtz (South Dakota Dept. of Game, Fish & Parks pers. com.), using a similar radio telemetry system for studying movements of paddlefish in the Missouri River below Ft. Randall Dam, has achieved very encouraging results. During the present study, one paddlefish instrumented with an internally implanted radio transmitter in 1979 was recovered 1 year later and exhibited no apparent abnormalities. This fish gained 2.3 kg in weight during an 11-month period after the radio was implanted.

Table 30. Paddlefish radiotelemetry relocations in the middle Missouri River during April 15-July 16, 1980.

	Individual Radio Transmitters[a/]											Average Paddlefish Location (km)[b/]	Discharge[c/] (m3/sec)
	1/1	2/1	3/1	5/1	8/1	9/1	10/1	1/2	2/2	3/2	4/2		
April 15			5R[d/]		-14R								243.8
22			17		-14							2	265.3
May 1	-1R	-1R	17	-1R		-1R	-1R	-1R	-1R	-1R	-1R	17	285.3
7	7	7	5	4		-14	-13	4	-14	-14		-3	276.6
15			7		8	-12	7	4	-2			3	242.4
26	15				-14			10	8	-17	20	4	454.8
29	21[e/]				57	28		30	67			41	802.3
June 2			-30		-13	27		-30	21			-5	638.4
5		20	-13		49			45				25	655.4
8			45		75	73						64	731.7
10					78							78	768.4
16					44							44	802.3
30					75							75	743.0
July 7					9							9	435.0
16		18				22		13				18	324.9

a/ Radio transmitters were coded $\frac{\text{channel (MH}_z\text{)}}{\text{pulse rate}}$

b/ River kilometer 0 was located where the river ends and reservoir resumes. (Negative km value indicates location in reservoir.)

c/ River discharge as gaged at the Fred Robinson Bridge near Landusky, MT.

d/ R denotes release site and date after being instrumented with a radio transmitter.

e/ This fish was harvested at river km 43 on May 30, 1980.

distance upstream from the paddlefish staging area in the vicinity of known spawning sites. The presence of paddlefish in spawning areas through the runoff period has been extensively documented by other researchers (Elser 1976, Purkett 1961, Berg 1981). Purkett (1961) indicated paddlefish prefer spawning areas on shallow gravel bars which are inundated to the proper depth and velocity during the runoff period.

Because of the rapid increase in flow late in May, no evaluation could be made concerning possible migratory barriers. It is possible that the inception of the paddlefish migration to upstream spawning sites is related more to behavioral motivation than the presence of physical barriers. In other words, when the flow which motivates paddlefish to migrate upstream is attained there may be no physical barriers to navigate.

Radiotelemetry provided little information on possible paddlefish spawning sites because only one paddlefish could be monitored during the entire spawning period. Paddlefish spawning sites on the middle Missouri River have been previously identified by Berg (1981).

Along with the tracking of radio-equipped fish, electrofishing was used as a method to monitor and census the paddlefish migratory run in 1980. Electrofishing provided a significantly better appraisal of the relative abundance and distribution of migratory paddlefish than radiotelemetry. An electrofishing census run was made from June 3 through 8, 1980, to monitor paddlefish distribution after the high flows were attained. The result of this electrofishing run is presented in Table 31. The observed distribution and relative abundance of paddlefish were similar to previous years (Berg 1981). Results of censusing the upper river from Fort Benton to Coal Banks Landing on four occasions from June 3 to July 1 (Table 32) indicate substantial numbers of paddlefish were distributed up to 251 km above Fort Peck Reservoir, peaking in numbers slightly after the crest of the runoff, but persisting until at least July 1.

Instream Flow Assessment for Paddlefish

Berg (1981) found that paddlefish require a flow of 396.5 m^3/sec (14,000 cfs) in the Virgelle gaged reach of the Missouri River to complete their annual spring migration to spawning sites. To maintain the paddlefish migration, flow should remain at or above 396.5 m^3/sec for 48 consecutive days from May 19 through July 5 in the Virgelle gaged reach. This time period was selected because it satisfies the biological requirements of paddlefish. It also conforms to the time period when median flow historically reaches or exceeds 396.5 m^3/sec at the Virgelle gage.

Results of paddlefish radiotelemetry studies conducted in 1980 firmly support these conclusions. Movement of radio-tagged paddlefish to spawning sites occurred during the high flow period from late May through early June (Figure 26).

Table 32. Seasonal distribution of paddlefish in the upper section of the middle Missouri River as determined by four electrofishing "census" runs taken during the peak runoff period June 3-July 1, 1980.

Location of Reach Electrofished	River km	No. of Paddlefish Observed			
		6/3 & 4	6/10 & 11	6/25	7/1
Ft Benton Community-Evans Bend	281-272	0	0	0	0
Evans Bend-Brule Bottoms	272-251	0	0	0	0
Brule Bottoms-Marias R confluence	251-246	0	0	7	0
Marias R confluence-Crow Id	246-228	2	7	19	21 1/
Crow Id-Boggs Id	228-220	3	10	11	9
Boggs Id-Coal Banks Landing	220-212	3	6	3	2
Total		8	23	40	32

1/ Six of these 21 paddlefish were censused in the mouth of the Marias River.

Based on these considerations, a flow of 396.5 m^3/sec is recommended for the Virgelle gaged reach of the Missouri River. This reach extends from the confluence of the Marias to the confluence of the Judith River. The Missouri River upstream from the confluence of the Marias River is the source of most of the water downstream from the Marias. The reach of the Missouri River from the confluence of Belt Creek to the confluence of the Marias River is gaged by the Fort Benton USGS station. Based on calculations made from USGS data gathered at the Virgelle and Fort Benton gage stations, it was determined that the Missouri River at Fort Benton contributes 80.6 percent of the median flow of the Missouri River at Virgelle during the paddlefish spawning period from May 19 through July 5. Therefore, to maintain the annual spring paddlefish migration in the Missouri River, a flow of 319.6 m^3/sec (11,284 cfs) is recommended for the reach of the Missouri River from the confluence of Belt Creek to the confluence of the Marias River. This flow must be maintained from May 19 through July 5.

The reach of the Missouri River from the confluence of the Judith River to Fort Peck Reservoir is gaged by the Robinson Bridge (Landusky) USGS station. Flow accretion in this reach of the river during the paddlefish spawning period is mostly attributable to the contribution of the Judith River. Based on calculations made from USGS data gathered at the Virgelle and Robinson Bridge gage stations, it was determined that median flow of the Missouri River at Robinson Bridge amounts to 109.3 percent of the median flow of the Missouri River at Virgelle during the paddlefish spawning period from May 19 through July 5. Therefore, to maintain the annual spring paddlefish migration in the Missouri River, a flow of 433.4 m^3/sec

USGS Gage Station	Dominant Discharge	
Fort Benton	614.6 m^3/sec	(21,700 cfs)
Virgelle	606.1 m^3/sec	(21,400 cfs)
Robinson Bridge	664.6 m^3/sec	(23,466 cfs)

Therefore, dominant discharge flow recommendations are:

Missouri River Reach	Flow Recommendation	
Confluence of Belt Creek to confluence of Marias R	614.6 m^3/sec	(21,700 cfs)
Confluence of Marias River to confluence of Judith R	606.1 m^3/sec	(21,400 cfs)
Confluence of Judith River to Fort Peck Reservoir	664.6 m^3/sec	(23,466 cfs)

It is not presently known how long the bankful flow must be maintained to accomplish the necessary channel formation processes. Until further studies clarify the necessary duration of the bankful discharge, a duration period of 24 hours was chosen.

Instream Flow Assessment for Riffles

Wetted Perimeter/Inflection Point Method

Flow recommendations from September 1 through March 23 were based on the wetted perimeter/inflection point method. Wetted perimeter is the distance along the bottom and sides of a channel cross-section in contact with water. As the flow in the stream channel decreases, the wetted perimeter also decreases, but the rate of loss of wetted perimeter is not constant throughout the entire range of flows. There is a point, called an inflection point, on the curve of wetted perimeter versus flow at which the rate of loss of wetted perimeter is significantly changed. Above the inflection point, large changes in flow cause only very small changes in wetted perimeter. Below the inflection point, the river begins to pull away from the riffle bottom, exposing the bottom at an accelerated rate. The flow recommendation is selected at or beyond this inflection point.

The maintenance of suitable flows in riffles is essential for the Missouri River fish populations. Four apparent reasons are:

1. Riffles contain substantial standing crops of aquatic invertebrates and forage fish, the principal food organisms of important fish species in the Missouri River.
2. Production of aquatic invertebrates occurs primarily in riffle areas (Hynes 1970).
3. Adequate flow must be maintained in riffle areas to allow for passage of migratory fish species.
4. Riffle areas provide critical habitat for the rare sicklefin and sturgeon chub populations of the Missouri River.

If flows in the Missouri River were reduced below the inflection point, the riffle bottom would be exposed at an accelerated rate, causing a decrease in riffle area and channel depth.

Riffles are also the area of a stream most affected by flow reductions (Bovee 1974, Nelson 1977). Consequently, the maintenance of suitable riffle conditions in pools and runs, areas normally inhabited by adult fish.

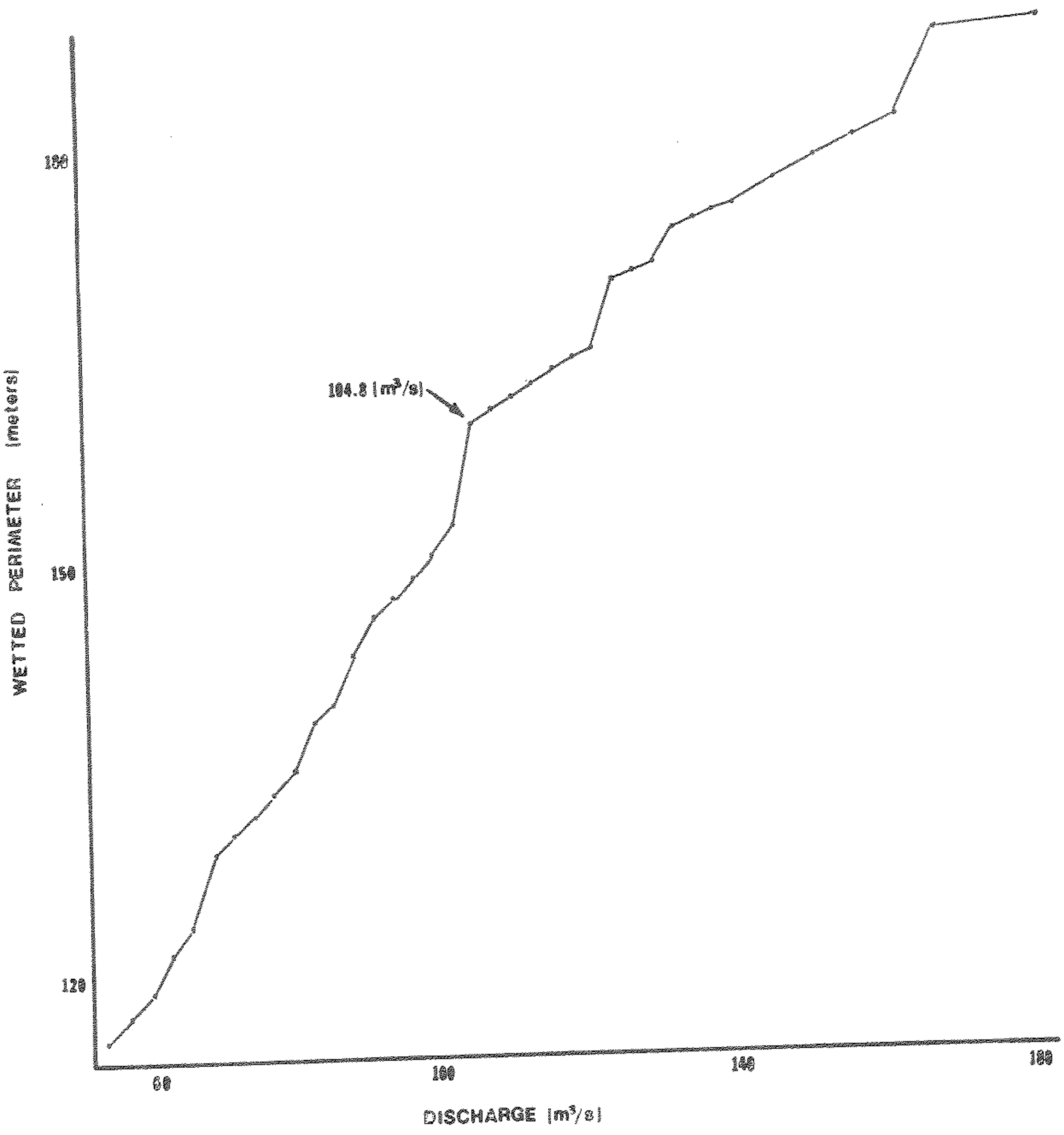

Figure 27. Wetted perimeter-discharge relationship for a composite of seven riffle transects located on the Missouri River in the Fort Benton gaged reach, 1980.

the median flow of the Missouri River at Robinson Bridge during the base flow period from September 1 through late March. Therefore, a flow of 121.9 m^3/sec (4305 cfs) is recommended for this reach.

Flow recommendations for riffle maintenance are:

Missouri River Reach	Flow Recommendation	
Confluence of Belt Creek to confluence of Marias River	104.8 m^3/sec	(3700 cfs)
Confluence of Marias River to confluence of Judith R	121.9 m^3/sec	(4305 cfs)
Confluence of Judith River to Fort Peck Reservoir	133.1 m^3/sec	(4700 cfs)

The wetted perimeter riffle maintenance flows may not be adequate during the early portion of the runoff period from late March through May 18. Sauger, walleye, northern pike and other early spring spawners probably require a higher flow for spawning, but their flow requirement was not assessed during this study. Since this assessment was not made, the riffle maintenance flow is recommended until the paddlefish migration flow recommendation commences on May 19.

Summary of Minimum Instream Flow Requirements

Assessed minimum instream flows for the middle Missouri River are given according to the seasonal schedule in Table 33. These are the flows necessary for the species with the highest requirements for that particular season. Using the Robinson Bridge gaging station as an example, it is evident the instream flows requested are less than the median flows (Figure 29). The median flow provides a measure of water availability during a normal or typical water year. The median is the flow that is exceeded in 5 of 10 years or, in other terms, in 5 years out of 10 there is more water than the median flowing in the river.

Table 33. The schedule of the assessed minimum instream flows for the middle Missouri River.

Period	Assessed Minimum Instream Flow			Concept Based on
	Gage St.	m^3/s	cfs	
Sept. 1-May 18	Ft Benton	104.8	3700	Wetted perimeter/inflection point of riffles
	Virgelle	121.9	4305	
	Robinson Br	133.1	4700	
May 19-July 5	Ft Benton	319.6	11,284	Paddlefish migration flows
	Virgelle	396.5	14,000	
	Robinson Br	433.4	15,302	
24 hours between May 19-July 5	Ft Benton	614.6	21,700	Maintenance of channel morphology
	Virgelle	606.1	21,400	
	Robinson Br	664.6	23,466	
July 6-August 31	Ft Benton	127.5	4500	Maintenance of side channel water levels above threshold value.
	Virgelle	152.9	5400	
	Robinson Br	164.3	5800	

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Appendix Table A. An example of relative importance (RI) calculation for food habits analyses.

Example:

To calculate the relative importance (RI) for a food item in a diet, first find the absolute importance (AI).

1. AI = % occurrence + % numbers + % volume
   (found in diet)

The percent of occurrence of each food item is simply the percentage of fish which consumed that particular food item. The average percent composition by number and volume is the average number or volume of that food item in the sample divided by the average total number or volume of all the food items in that sample, expressed as a percentage.

If,

AI item a = 2
AI item b = 6
AI item c = 1

The RI for a particular food item is obtained by summing the numerical percentage, volumetric percentage and percentage of occurrence of the food item in the diet, then dividing by the summation of all the food items in the diet.

Then,

$$RI_a = 100\ AIa/\sum_{a=1}^{n} AI_a$$

(Where a = food item a)
(n = number of different food types)

$$= 100(2) \div (2+6+1)$$
$$= 200 \div 9$$
$$RI_a = 22.2$$

Appendix Table C-1. Catch rates (number of fish per seine haul) of forage fish species in side channel 1 (Fort Benton section) of the middle Missouri River, 1980.

	Early August
Carp	0.3
Flathead chub	13.7
Lake chub	10.7
Emerald shiner	1.7
Western silvery minnow	3.0
Fathead minnow	5.7
Longnose dace	14.3
Suckers[a]	17.7
Number seine hauls	3
Range of catch	22-148

a/ This group was not separated into shorthead redhorse, white and longnose suckers.

Appendix Table C-2. Catch rates (number of fish per seine haul) of forage fish species in side channel 2 (Fort Benton section) of the middle Missouri River, 1980.

	Late July	Early August	Late August	Late Sept.	Late October
Carp	0.75				
Lake chub	0.2	1.0			
Flathead chub		4.0	0.3	0.3	
Emerald shiner	1.0	1.5	0.7		
Fathead minnow	49.3		0.7	2.3	2.5
Longnose dace	0.2	17.0	10.3	4.3	4.0
Smallmouth buffalo		5.8			
Suckers[a]	34.2	25.3	5.3	2.0	1.0
Yellow perch				0.3	
Larvae	0.8				
Number seine hauls	4	4	3	3	4
Range of catch	51-210	22-108	2-33	1-12	1-20

a/ This group was not separated into shorthead redhorse, white and longnose suckers.

Appendix Table C-5. Catch rate (number of fish per seine haul) of forage fish species in side channel 5 (Loma Ferry section) of the middle Missouri River, 1980.

	Late July	Early Aug.	Late Aug.	Late Sept.
Flathead chub	4.9	38.7	14.4	
Emerald shiner	14.9	5.0	0.4	0.8
Western silvery minnow	0.3		8.2	20.5
Fathead minnow	1.1	0.3		
Longnose dace	0.1	20.0	6.8	0.8
Smallmouth buffalo			0.4	
Suckers[a/]	6.7	12.0	15.4	1.2
Yellow perch			0.8	
Larvae		2.3		
Number seine hauls	7	3	5	4
Range of catch	3-64	66-101	16-104	2-80

a/ This group was not separated into shorthead redhorse, white and longnose suckers.

Appendix Table C-6. Catch rate (number of fish per seine haul) of forage fish species in side channel 6 (Loma Ferry section) of the middle Missouri River, 1980.

	Late July	Early Aug.	Late Aug.	Late Sept.
Carp		0.4		
Flathead chub	1.7	35.2	38.5	7.8
Emerald shiner	14.7	1.0	0.5	2.5
Western silvery minnow	0.3	84.4	19.0	21.2
Fathead minnow	0.3	6.4	1.2	
Longnose dace		17.2	30.7	14.2
Smallmouth Buffalo		0.8	1.2	
Suckers[a/]	12.3	20.2	97.5	6.2
Number seine hauls	3	5	6	4
Range of catch	18-35	16-354	24-396	4-190

a/ This group was not separated into shorthead redhorse, white and longnose suckers.

Appendix Table C-9. Catch rate (number of fish per seine haul) of forage fish species in side channel 9 (Cow Island Section) of the middle Missouri River, 1980.

	Early July	Late July	Early September
Goldeye	0.2	18.0	
Flathead chub	2.8	61.8	2.0
Emerald shiner	1.8	3.8	
Western silvery minnow	1.8	0.6	2.5
Longnose dace	0.2	7.5	
Suckers[a/]	0.8	6.0	0.5
Yellow perch	0.2	0.5	
Larvae	1.2		
Number seine hauls	5	4	2
Range of catch	2-15	29-200	1-9

a/ This group was not separated into shorthead redhorse, white and longnose suckers.

Appendix Table C-10. Catch rate (number of fish per seine haul) of forage fish species in side channel 11 (Robinson Bridge section) of the middle Missouri River, 1980.

	Early July	Late July	Early September
Goldeye	0.2		0.5
Carp	0.2		
Flathead chub	6.0	4.5	24.8
Emerald shiner	5.2		1.8
Western silvery minnow	61.8	0.5	10.5
Fathead minnow	1.0		
Longnose dace	0.4	0.5	0.2
Suckers[a/]		0.5	12.0
Larvae	5.2		
Number seine hauls	5	2	4
Range of catch	8-316	1-11	14-89

a/ This group was not separated into shorthead redhorse, white and longnose suckers.

Appendix Table D-1. Catch rates (number of fish per seine haul) of forage fish species in the Morony Dam section, middle Missouri River during late July-early September 1979.

	Main Channel Border	Main Channel Pool	Backwater
Carp			1.0
Flathead chub		1.5	
Lake chub		1.3	
Emerald shiner	1.5	34.2	11.0
Plains minnow		0.5	
Western silvery minnow		76.7	4.5
Fathead minnow			1.2
Longnose dace	40.5	19.0	44.0
Shorthead redhorse	9.5	34.5	5.7
Longnose sucker	1.0	4.7	3.8
White sucker	4.5	14.7	57.8
Ave. CPUE 1/	57.0	187.1	129.0
Range	51-63	23-300	18-300
Number of seine hauls	2	6	6

1/ Catch rate - catch per unit effort

Appendix Table D-2. Catch rates (number of fish per seine haul) of forage fish species in the Carter Ferry section, middle Missouri River during late July-early September 1979.

	Main Channel Border	Main Channel Pool	Backwater
Mountain whitefish		0.2	
Carp			2.2
Flathead chub	0.2	0.5	
Lake chub			0.2
Emerald shiner	3.8		3.8
Plains minnow		0.2	
Western silvery minnow		9.2	2.0
Fathead minnow	21.5		95.5
Longnose dace	17.5	32.2	3.8
Shorthead redhorse	8.0	35.7	26.8
Longnose sucker	4.2	6.2	6.2
White sucker	4.8	2.1	8.5
Yellow perch			0.2
Iowa darter			0.2
Ave. CPUE 1/	60.0	86.3	149.4
Range	11-110	9-302	24-300
Number of seine hauls	4	6	4

1/ Catch rate, catch per unit effort

Appendix Table D-5. Catch rates (number of fish per seine haul) of forage fish species in the Coal Banks section, middle Missouri River during late July-early September 1979.

	Main Channel Border	Main Channel Pool	Side Channel Chute	Side Channel Pool	Backwaters
Mountain whitefish		0.2			
Carp		0.1			5
Flathead chub	56.5	20.3	5.0	8.5	45
Lake chub	0.4			0.5	
Emerald shiner	9.7	7.4	7.0		45
Western silvery minnow	1.0	4.6		1.0	135
Fathead minnow					15
Longnose dace	11.0	23.7		10.0	5
River carpsucker	0.3	0.4			3
Shorthead redhorse	5.4	22.0	8.0	1.5	28
Longnose sucker	35.6	40.7		6.0	2
Sauger					1
Mottled sculpin	0.1				
Ave. CPUE[1/]	120.0	119.4	20.0	27.5	284.0
Range	9-300	6-300	7-33	8-47	
Number of seine hauls	10	7	2	2	1

1/ Catch rate, catch per unit effort.

Appendix Table D-6. Catch rates (number of fish per seine haul) of forage fish species in the Hole-in-the-Wall section, middle Missouri River during late July-early September 1979.

	Main Channel Border	Main Channel Pool	Side Channel Chute	Side Channel Pool	Backwaters
Goldeye				0.2	
Carp	0.2	0.1		0.4	72.0
Flathead chub	6.2	38.6	54.5	38.4	17.0
Lake chub		2.0			0.3
Emerald shiner	3.5	2.5	1.3	4.6	27.0
Western silvery minnow	0.2	8.0	0.8	20.2	2.3
Fathead minnow					6.0
Longnose dace	14.1	29.6	4.5	5.0	17.7
River carpsucker		1.4	0.8	2.0	3.3
Shorthead redhorse	4.0	16.1	4.0	25.2	55.7
Longnose sucker	1.0	4.9		3.4	61.7
White sucker		0.4			
Stonecat	0.1		0.2	0.2	
Sauger	0.2	1.0		1.8	1.3
Ave. CPUE[1/]	29.5	104.6	66.1	101.4	264.3
Range	3-95	15-231	6-193	11-293	36-504
Number of seine hauls	11	8	4	5	3

1/ Catch rate, catch per unit effort.

Appendix Table D-9. Catch rates (number of fish per seine haul) of forage fish species in the Cow Island section, middle Missouri River during late July-early September 1979.

	Main Channel Border	Main Channel Pool	Side Channel Chute	Side Channel Pool	Backwaters
Goldeye					9.6
Carp					0.2
Flathead chub	3.9	10.6	3.3	2.5	10.5
Sicklefin chub	0.4	0.9	0.3		
Emerald shiner	22.2	32.0	2.3	0.7	24.2
Western silvery minnow	2.9	58.9	3.2	7.3	42.4
Longnose dace		0.1	0.1	0.2	
River carpsucker		0.1		0.2	0.6
Shorthead redhorse	0.4	0.2		1.0	
Longnose sucker	0.7	2.3	0.2	0.4	2.6
Channel catfish		0.1			
Stonecat			0.1		
Yellow perch					0.8
Sauger	0.4	0.8	0.1	1.3	0.1
Ave. CPUE[1/]	30.9	106.0	9.6	13.2	91.0
Range	2-202	14-300	1-24	2-32	23-237
Number of seine hauls	14	8	9	8	4

1/ Catch rate; catch per unit effort.

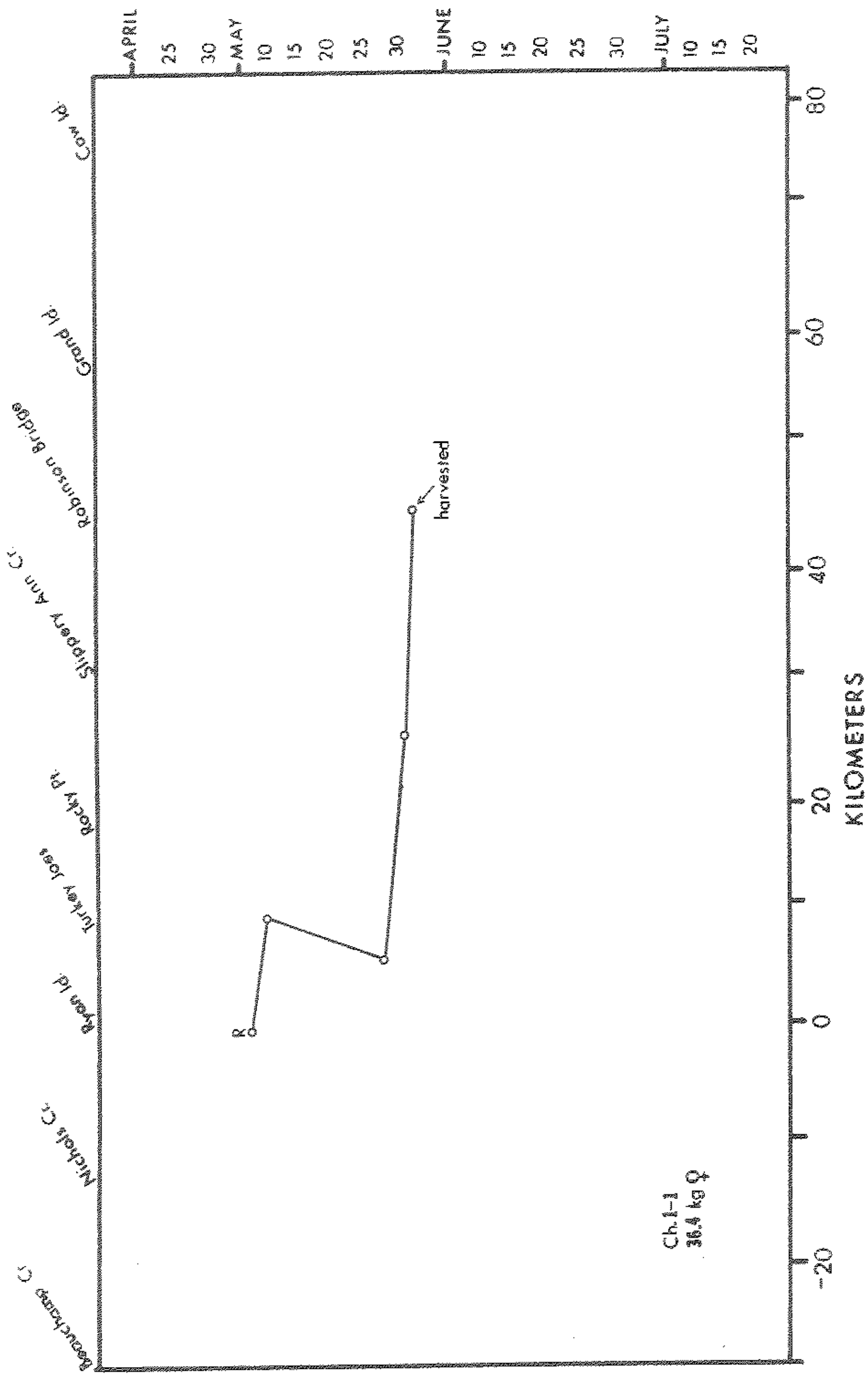
Appendix Table D-10. Catch rates (number of fish per seine haul) of forage fish species in the Robinson Bridge section, middle Missouri River during late July-early September 1979.

	Main Channel Border	Main Channel Pool	Side Channel Chute	Side Channel Pool	Backwaters
Goldeye	0.2	0.8		40.5	1.4
Carp				1.0	
Flathead chub	11.3	12.2	8.7	7.5	1.4
Sicklefin chub	1.6	0.7			
Emerald shiner	4.2	10.8	33.7	5.0	36.9
Plains minnow		0.2		0.5	
Western silvery minnow	0.9	5.4	0.7	12.8	11.5
Longnose dace	0.2	0.1	2.7	0.2	
River carpsucker					0.2
Shorthead redhorse	0.1	1.4			
Longnose sucker	0.3	0.4	0.7	5.5	0.5
Channel catfish	0.1				
Sauger	0.3	2.2		9.2	
Mottled sculpin	0.1				
Ave. CPUE[1/]	19.3	34.2	46.5	82.2	51.9
Range	1-109	2-85	7-107	12-178	3-103
Number of seine hauls	18	9	3	4	8

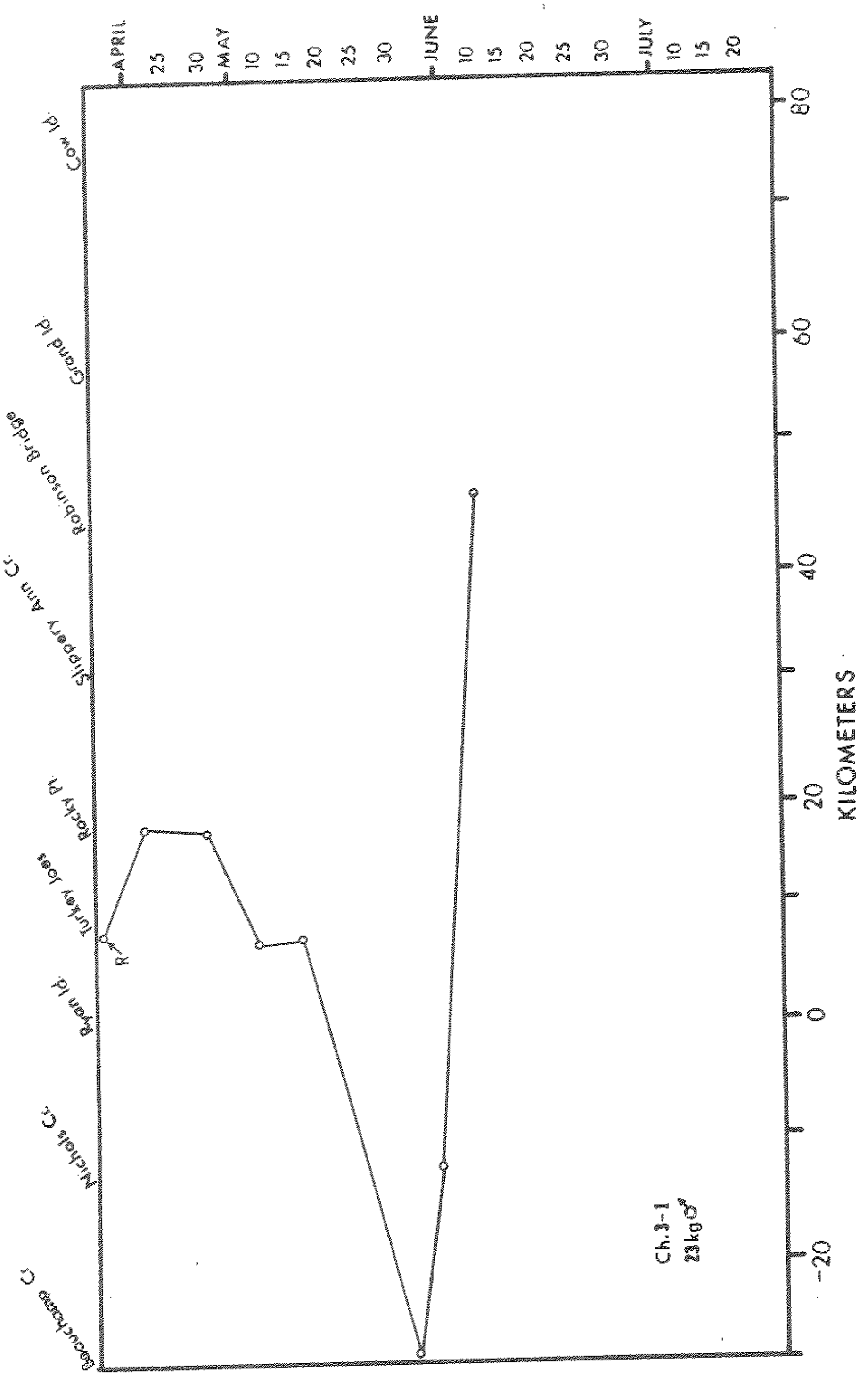
1/ Catch rate; catch per unit effort.

Appendix Table F. Daily minimum and maximum water temperatures (degrees C) for the Missouri River at Virgelle (Coal Banks Landing section) during 1980.

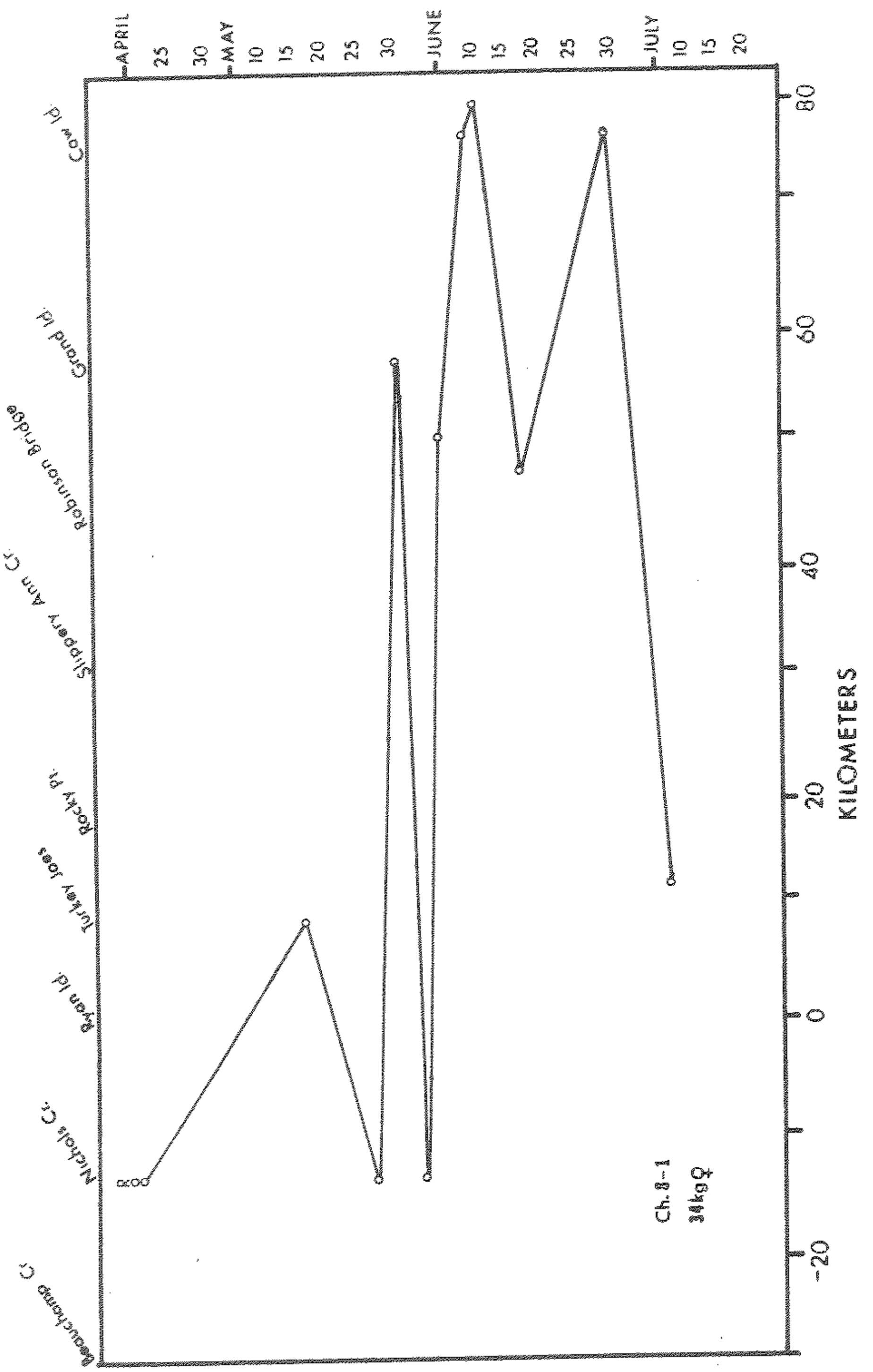
	April		May		June		July		Aug.		Sept.		Oct.	
Day	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1	4.0	5.0	14.0	16.5	14.1	15.4	17.9	19.6	21.3	22.7	15.4	18.0	12.2	14.0
2	4.5	5.5	15.0	17.5	14.2	15.4	18.8	20.3	20.0	21.7	16.6	18.5	11.4	14.0
3	4.0	6.0	14.0	15.5	13.7	14.4	19.2	20.2	18.2	21.0	15.5	17.2	12.1	14.7
4	5.0	8.0	12.5	15.5	13.8	15.0	18.7	20.2	16.8	19.0	14.2	16.5	12.9	15.0
5	6.0	8.5	14.0	17.0	13.4	14.7	19.8	20.9	17.9	20.2	14.9	18.0	13.1	15.1
6	7.0	9.5	13.5	16.0	12.9	14.6	19.7	21.0	18.0	19.8	15.7	19.1	12.7	15.1
7	7.0	8.0	12.5	14.5	12.9	14.2	19.2	20.9	18.3	19.8	17.2	18.7	13.2	15.4
8	6.0	9.0	12.5	14.5	12.9	14.5	20.4	21.9	17.8	20.1	15.6	17.9	13.7	15.6
9	7.0	9.0	14.0	15.5	13.4	15.9	20.7	22.2	18.8	20.4	15.4	18.1	12.6	14.7
10	7.0	8.0	13.0	14.5	15.4	17.2	20.4	22.1	18.3	20.9	16.4	18.9	10.9	12.7
11	6.5	9.0	12.0	15.0	16.6	17.6	19.9	21.1	19.2	21.3	17.6	19.2	10.0	11.6
12	7.5	10.5	12.5	15.0			20.1	21.5	19.2	20.2	16.3	18.5	10.6	12.7
13	8.0	11.0	12.5	15.5			19.4	20.7	18.3	20.7	15.8	17.0	11.8	13.1
14	9.0	12.0	13.0	16.0			18.6	19.7	17.9	20.9	15.1	17.8	10.4	11.8
15	10.0	11.5	13.0	16.5			18.0	19.4	19.7	21.4	14.6	17.1	8.2	10.2
16	9.0	12.0	14.0	17.0			17.5	20.1	19.5	21.5	12.6	14.9	8.1	8.6
17	10.0	13.5	15.0	18.0			18.4	20.2			14.0	14.8	8.3	9.1
18	11.5	14.0	16.0	19.5			18.5	20.2			13.5	14.2	7.9	9.6
19	12.0	14.0	17.0	18.0			18.7	20.4			13.3	15.1	8.4	9.9
20	12.0	15.0	16.0	19.0			17.6	20.3	17.5	19.8	13.2	15.1	8.4	9.7
21	13.0	15.5	18.2	19.8			18.9	22.0	17.6	19.7	12.8	14.3	9.0	10.0
22	11.0	13.0	19.2	22.1			20.0	22.0	17.1	18.3	11.8	13.3	6.9	9.2
23	10.0	12.5	16.9	20.0			21.2	23.5	16.3	18.4	11.8	13.0	6.4	7.8
24	12.0	14.5	15.5	17.4			20.7	21.8	16.6	19.4	11.1	12.6	6.7	8.0
25	13.0	15.5	14.4	16.6			19.5	22.2	15.7	18.7	10.2	12.7	6.0	6.8
26	13.0	14.5	12.4	14.3	17.0	18.3	21.2	23.2	15.4	18.8	11.3	13.7	5.7	6.2
27	12.5	15.5	11.4	12.9	16.5	18.2	20.9	22.9	16.7	18.7	12.2	14.7	5.4	6.1
28	14.0	16.5	11.7	13.0	15.9	17.2	20.9	23.5	16.2	17.7	12.5	13.6	5.0	6.5
29	14.5	17.0	12.0	14.2	15.9	18.1	21.2	22.8	15.6	17.3	12.0	14.2	5.9	6.8
30	15.0	16.5	13.6	14.6	17.2	18.5	20.3	22.8	15.2	18.0	12.9	13.9	6.0	7.3
31			13.7	14.9			20.6	23.4	15.7	17.2			6.8	7.8



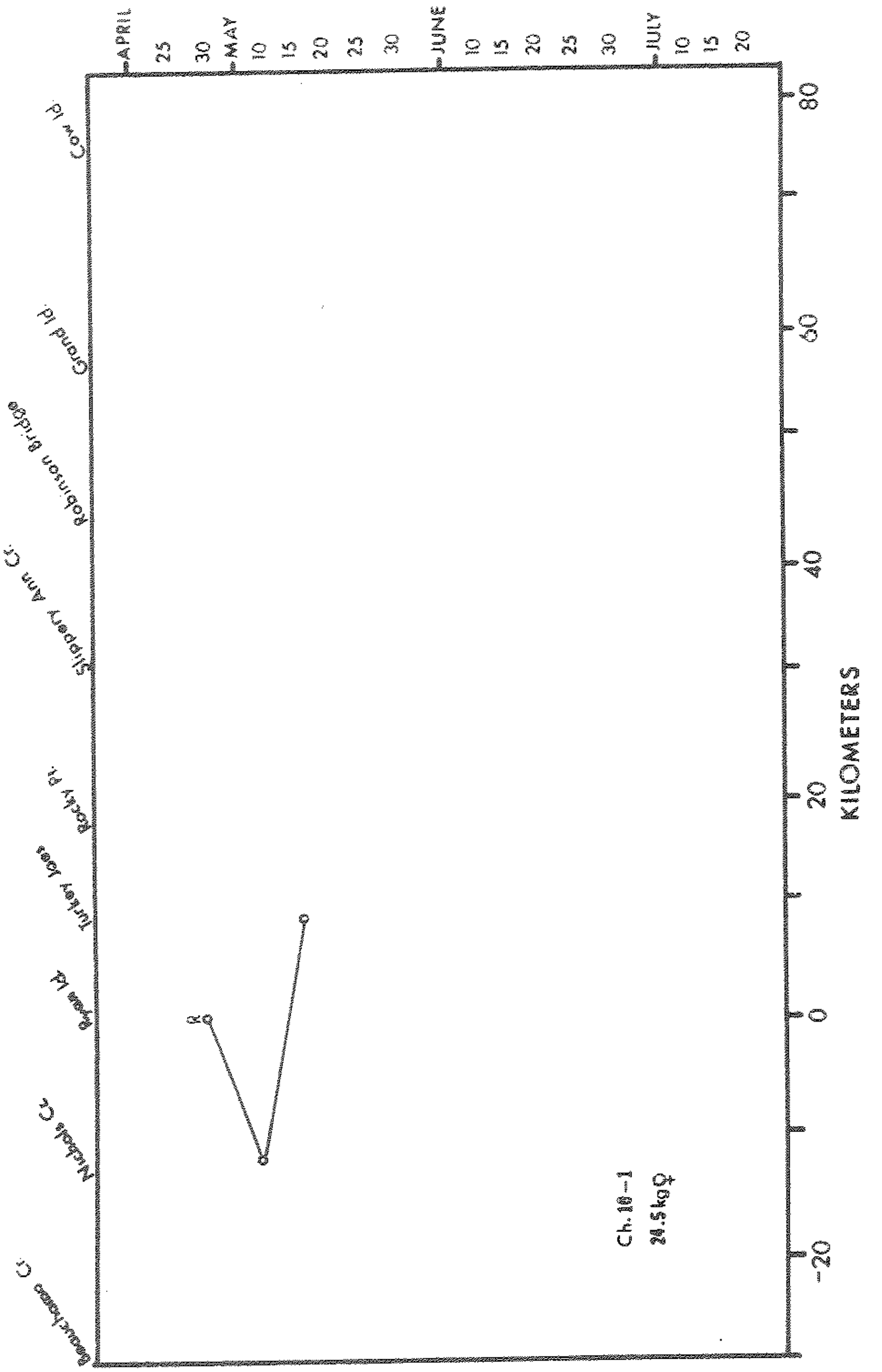
Appendix Figure B-1 . Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



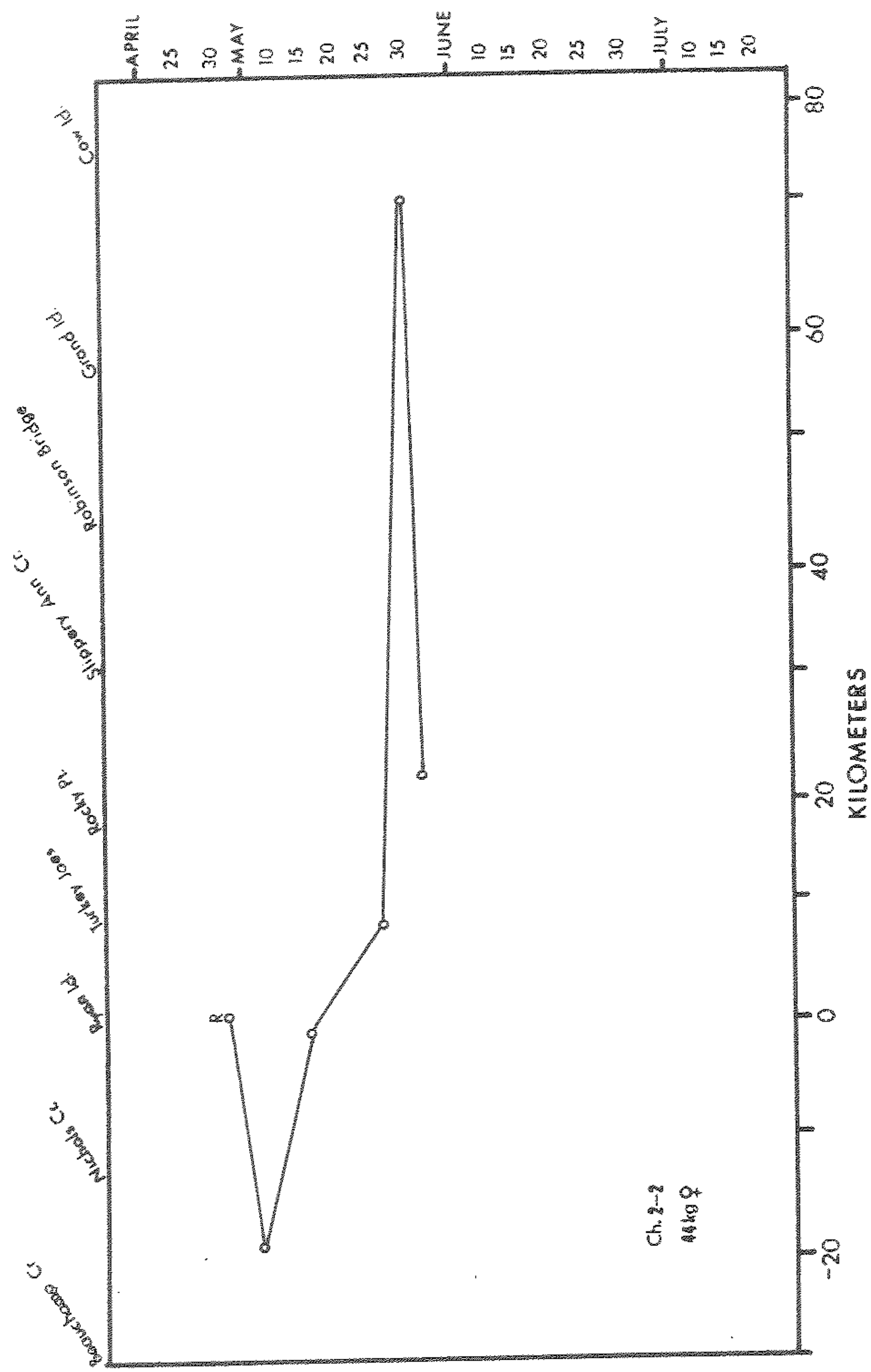
Appendix Figure B-3 . Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



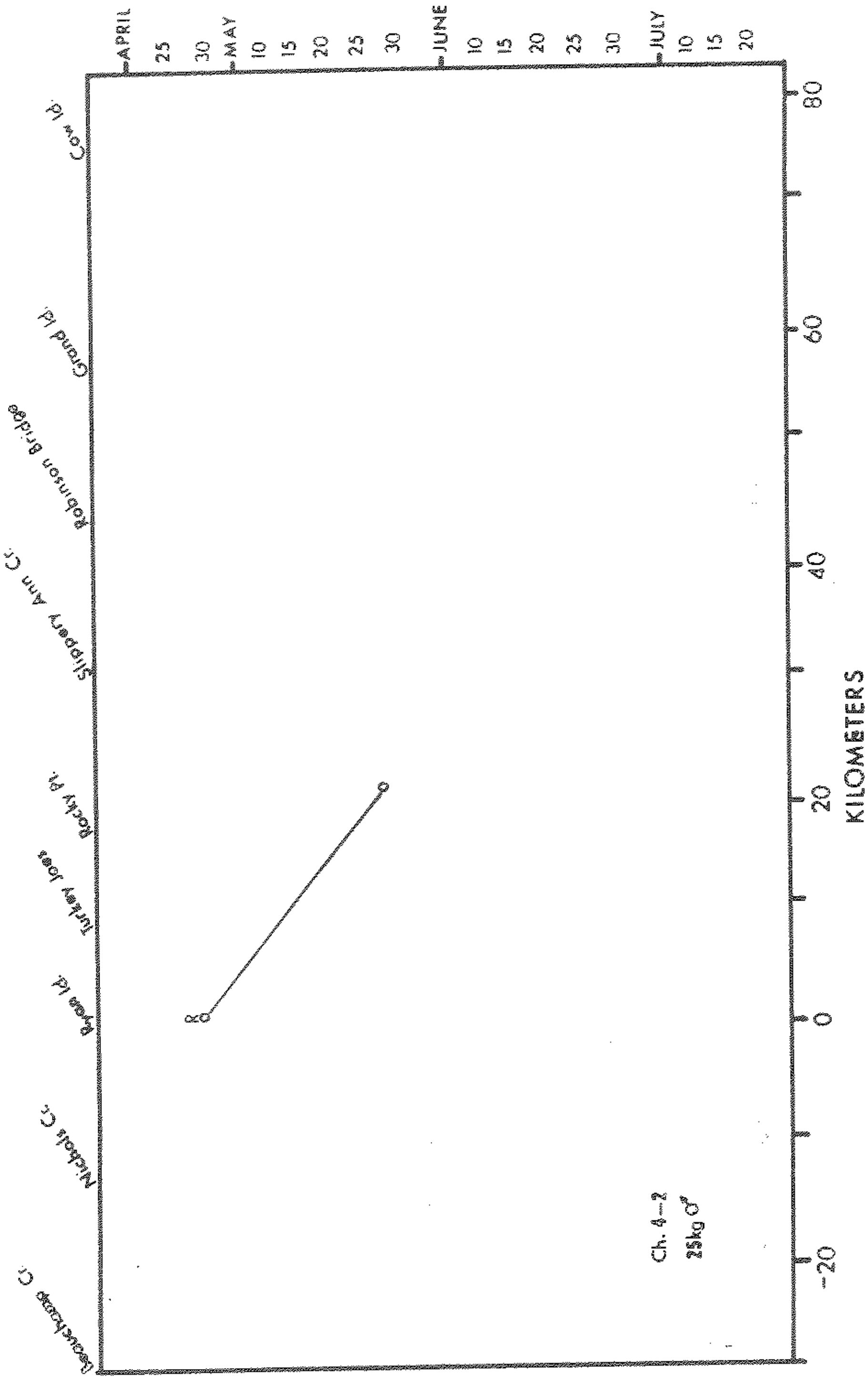
Appendix Figure B-5. Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



Appendix Figure B-7. Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



Appendix Figure B-9. Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



Appendix Figure B-11. Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.

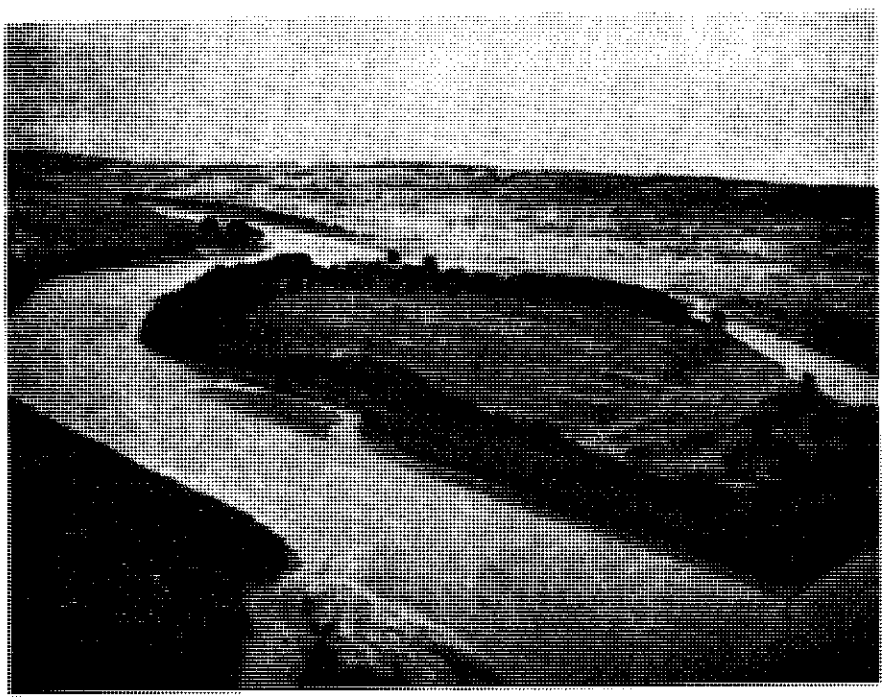
AN ANALYSIS OF THE INSTREAM FLOW REQUIREMENTS FOR SELECTED FISHES IN THE WILD & SCENIC PORTION OF THE MISSOURI RIVER

Research Conducted by:

Montana Department of Fish, Wildlife and Parks
Ecological Services Division

Sponsored by:

Bureau of Land Management
U.S. Department of Interior



By:

William M. Gardner

Rodney K. Berg

MARCH 1982

AN ANALYSIS OF THE INSTREAM FLOW REQUIREMENTS FOR SELECTED FISHES IN THE WILD & SCENIC PORTION OF THE MISSOURI RIVER

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ABSTRACT

This study was initiated on the Wild and Scenic portion of the Missouri River to determine instream flow requirements of selected fish species. The study will form a basis for the Bureau of Land Management in quantifying instream flows necessary to maintain the values associated with the Wild and Scenic reach of river.

Rearing areas and habitat preference studies conducted from July through September indicated that young-of-the-year sauger selected protected habitat in peripheral areas of the stream. Although young-of-the-year sauger were found throughout most of the study area, 70 percent of the total numbers sampled in 1979 were taken in a 77-km reach of the river below Cow Island. The preference for this particular area was attributed to the greater development of side channel pool habitat which was the most desirable rearing habitat. Peripheral habitat areas were also heavily utilized by forage fish. An average of 125,104 and 81 forage fish per seine haul was taken in the backwater, main channel pool and side channel pool habitat types, respectively. During 1980, 12 representative side channels were monitored to determine the amount of instream flow required to maintain sauger rearing and forage fish habitats. Based on the utilization by the fish and the channels' water level and connection to the main channel, minimum instream flows were determined.

Food habits studies of adult shovelnose sturgeon and sauger revealed that food organisms in the riffle areas comprised major portions of their diet. Using the WETP program, the amount of instream flow required to maintain riffle areas was determined.

Resident fish populations were inventoried in the lower reaches of three major tributaries of the middle Missouri River. A total of 24, 21 and 15 species was sampled in the Marias, Teton and Judith Rivers, respectively. Sauger was the most common game fish found in all three tributaries.

Movements of radio tagged paddlefish during the spring and early summer of 1980 were correlated with high flows. When the river was at lower flows, movements were confined to their staging area immediately above the Ft. Peck Reservoir pool. Significant upstream movement did not begin until higher flows occurred during the spring runoff period.

The minimum instream flows required to maintain the middle Missouri River fishery were based on:

(1) Side channel threshold flows during July 6-August 31
(2) Wetted perimeter/inflection point flows of riffles during September 1-May 18
(3) Paddlefish migration flows during May 19-July 5
(4) Channel morphology maintenance flows (24 hours) staged during May 19-July 5

INTRODUCTION

The middle Missouri River in northcentral Montana abounds with historical, scenic, recreational and natural values. The river is freeflowing in a 333 km reach from Morony Dam near Great Falls, Montana, to the headwaters of Fort Peck Reservoir. In addition, the land contiguous to the river in this area has retained most of its primitive characteristics. These qualities are rarely found in a river of this magnitude. Because of these considerations a 240 km section of the river from Fort Benton to Robinson Bridge was recently designated as part of the National Wild and Scenic Rivers System (US Congress 1975a). This inclusion, signed into law on October 13, 1976, affords considerable protection for the last major free-flowing portion of the Missouri River. Under provisions of this legislation, no dams may be built on any of the protected waters, and specific protective regulations would be imposed on any new commercial development in designated areas surrounding the protected waters (US Congress 1975b). The law does allow minor diversions and pumping of water from the protected area for agricultural uses. Private landowners in the area can continue with traditional grazing, farming, recreational and residential uses.

The enacting legislation also assigned the Bureau of Land Management (BLM) the responsibility to manage the river. In 1978, the BLM drafted a management plan which included an objective of determining instream flows required to maintain the river, commensurate with the purposes of the act (BLM 1978). Specifically, the determination was to be based on instream flow needs required to maintain fish and wildlife, vegetative, recreational and water quality benefits.

There is little need to review the circumstances which make the instream flow determination study particularly important at this time. It is sufficient to note that because of the increasing demand for Montana's limited water supplies for industrial, agricultural and domestic uses, water resource development proposals on the Missouri River are imminent. On October 1, 1979, the US Bureau of Reclamation (USBR) began an appraisal study for potential damsites on or adjacent to the Missouri River between Fort Benton and Morony Dam. Montana Power Company (MPC) has applied to the Federal Energy Regulatory Commission for a preliminary permit to study feasibility of building a hydropower dam in the Carter Ferry area 22 km upstream of Fort Benton. Also, MPC plans to construct a 250 megawatt coal-fired power generating plant near Morony Dam.

The proposed projects have the potential to impact the aquatic fauna. Unless streamflow levels necessary to maintain the aquatic resources of the middle Missouri River are determined, little can be done to evaluate conflicting resource demands and minimize adverse impacts on the aquatic resources.

Since October 1, 1975, the Montana Department of Fish, Wildlife and Parks (MDFWP) has been conducting a fisheries inventory and planning study in the Wild and Scenic Missouri River. The MDFWP has expended considerable time and effort in becoming familiar with proven sampling methods on large rivers and in developing equipment and techniques adaptable to the Missouri River. The MDFWP study efforts parallel to some extent the effort to be made by the BLM on instream flow quantification. Based on these considerations, it was decided that the BLM and MDFWP should cooperate to develop a suitable methodology to determine instream flow requirements for the Wild and Scenic Missouri River. This study, funded by the BLM and conducted by the MDFWP, was initiated on April 1, 1979.

DESCRIPTION OF STUDY AREA AND HABITAT TYPES

The study area consists of a 333 km reach of the mainstem of the middle Missouri River in northcentral Montana from Morony Dam near Great Falls to the headwaters of Fort Peck Reservoir near Landusky. The general basin characteristics, hydrogeology and physical/chemical characteristics of the river have been adequately described by Berg (1981) and Kaiser and Botz (1975). The two major tributaries entering the Missouri River in this reach are the Marias River from the north and the Judith River from the south. The present day flow regimen of the Missouri River in this study area is not entirely natural because of regulation and storage at several dams in the drainage upstream from the study area.

Fifty-three species, representing 14 families of fish, are known to occur in the middle Missouri River drainage between Morony and Fort Peck dams (Berg 1981). Basically, two fishery zones occur on the mainstem Missouri. In the upper reach, from Morony Dam to the confluence of the Marias River, a cold water/warm water fisheries transitional zone exists. Sauger is by far the predominant game fish species found in this reach, but significant numbers of trout, mountain whitefish, sculpins, longnose dace and suckers also occur. A warm water fisheries zone extends from the confluence of the Marias River downstream to the headwaters of Fort Peck Reservoir. Sauger, shovelnose sturgeon, paddlefish, channel catfish and a variety of chubs, minnows, suckers and shiners are the predominant species in this zone.

Eleven sampling sections were established on the mainstem Missouri in the study area (Fig. 1). The Morony Dam and Carter Ferry study sections contain rocky substrate and have very few islands and side channels. Stream gradients are relatively high, ranging from 0.76 to 3.4 m/km. The Fort Benton, Loma Ferry, Coal Banks Landing and Judith Landing study sections have considerably more islands and side channels. Stream gradients in those study sections range from 0.38 to 0.76 m/km. The Hole-in-the-Wall and Stafford Ferry study sections have similar gradients, but the river in these study sections is confined by steep, narrow canyons, and consequently, very few islands and side channels occur. The lowest three study sections, Cow Island, Robinson Bridge and Turkey Joe, are in a reach of river characterized by a wide, meandering channel which contains numerous shifting sandbars and large developed islands.

Nine study sections were established on three tributaries of the middle Missouri River in the study area (Fig.1).

To facilitate interpretation of rearing area and forage fish data, the river channel was categorized into five major habitat types which could be effectively seined. The habitat types were main channel border, main channel pool, side channel chute, side channel pool and backwaters (Fig.2).

The main channel border habitat type was defined as a zone adjacent to the main channel bank which had an average current velocity of 15 to 45 cm/sec and a

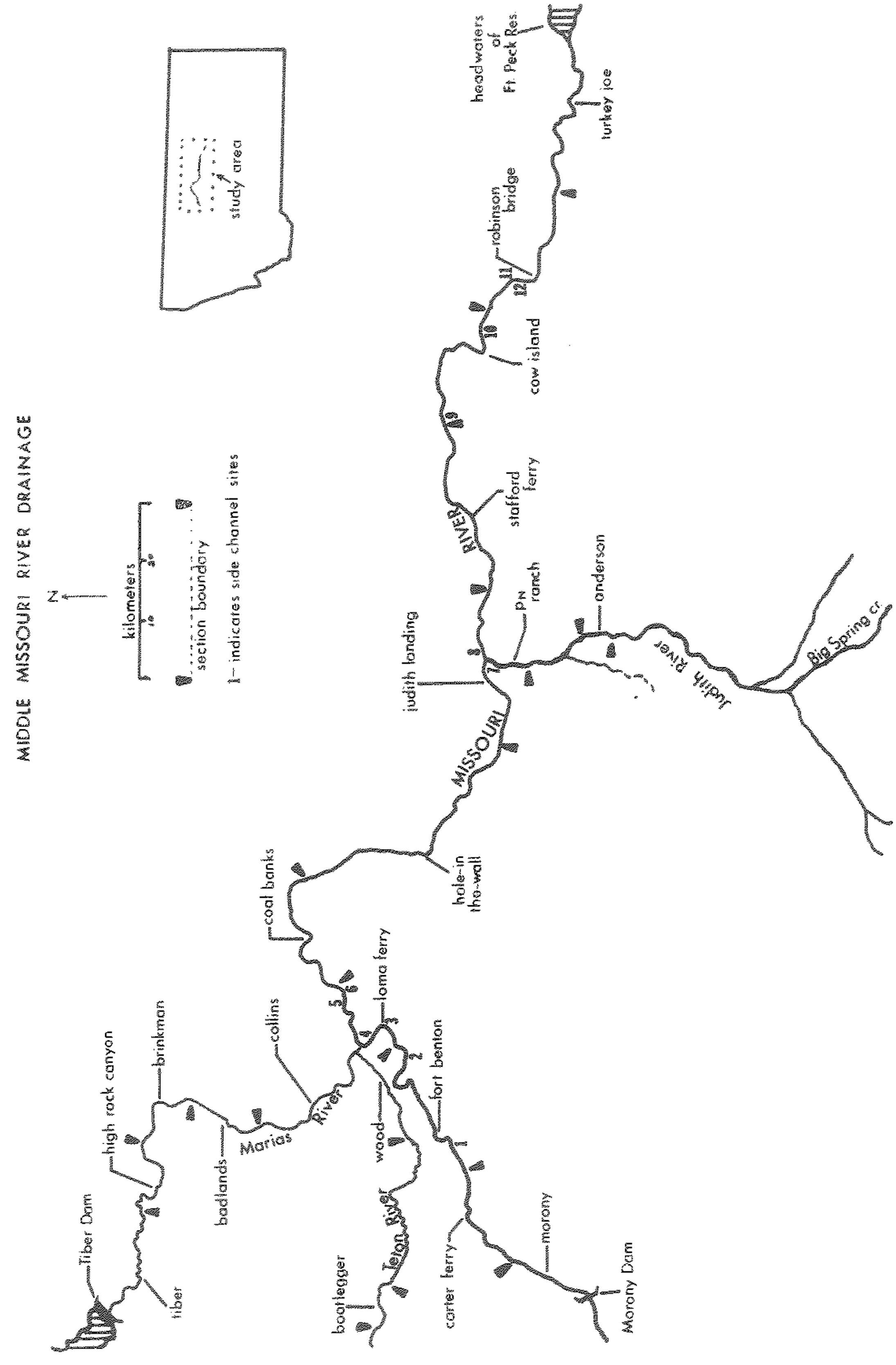

Figure 1. Map of middle Missouri River drainage and study area.

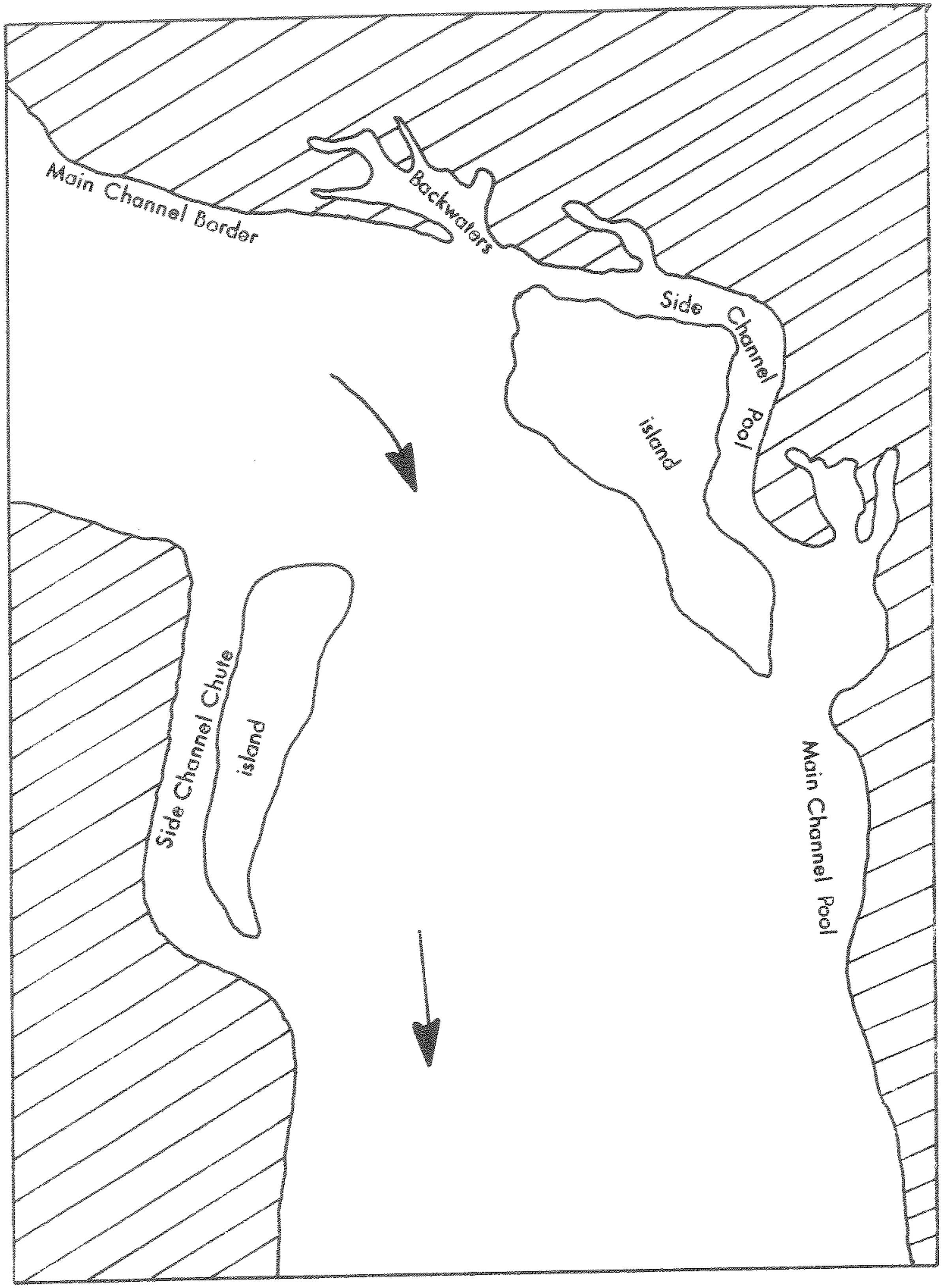

Figure 2. Diagrammatic representation of peripheral habitats in the middle Missouri River. (modified from Kallemeyn and Novotny 1977).

depth of 1 m or less. This habitat type included slow runs, gravel bars and sandbars.

The main channel pool habitat type was defined as an area in the main channel along side the bank which had little current. Depth ranged from 0.4 to 1.0 m. This habitat type included large wide pools and "pocket pools." "Pocket pools" are described in greater detail in the Results section.

Side channels, islands and backwaters are prominent features of river sections where peripheral channel development occurs. A side channel was defined as a channel diverging from the main channel and containing less than 20 percent of the river's flow. A developed island was common with this type of channel divergence. The side channel chute habitat type was defined as a side channel without development of pools. This habitat type was equivalent to the main channel border type in current velocity and depth. The side channel pool habitat type was defined as a side channel with well defined pools and few riffles. Some side channels did not maintain an influent and effluent flow through the entire year but continued to be submerged in part. These were still considered side channels if they contained influent and effluent flow during the high flow period.

The backwater habitat type exhibited no perceptible current velocity and only a single connection to the main or side channel of the river. Because of the narrow floodplain, the backwater habitat type was limited.

METHODS

Adult fish were collected by boom electrofishing in a 5.2 m flat-bottomed aluminum boat powered by an 85 hp outboard motor equipped with a jet propulsion lower unit (Fig. 3). The electrode system and operation was similar to that described by Berg (1981). The boom electrofishing unit was utilized on the mainstem of the Missouri River during all flows and on the lower Marias River during the spring flows. During summer flows, the Teton and Judith Rivers were sampled with a mobile electrofishing unit as described by Berg (1981), and the Marias River was sampled with a boom electrofishing unit mounted on a 4.2 m fiberglass boat. All comparisons between study areas or habitat types for fish sampled by electrofishing were based on catch per unit effort. A unit of effort was accomplished by electrofishing for one hour.

Fish Eggs

Sampling for incubating fish eggs was accomplished with a screened 50 cm square, 13 cm deep handled scoop, similar to that described by Priegel (1969) (Fig. 4). With the scoop positioned in the current, a person kicked downward into the substrate, moving toward the scoop from a distance of approximately 3 m. Gravel bars where known concentrations of sport fish were observed were sampled randomly at various depths up to 1 m. The samples were sorted at the site, and the eggs were preserved in a 5 percent solution of formaldehyde. Eggs which could not be identified were sent to Mr. Bob Wallus, an early life stage fish taxonomist, at the TVA fish repository in Norris, Tennessee.

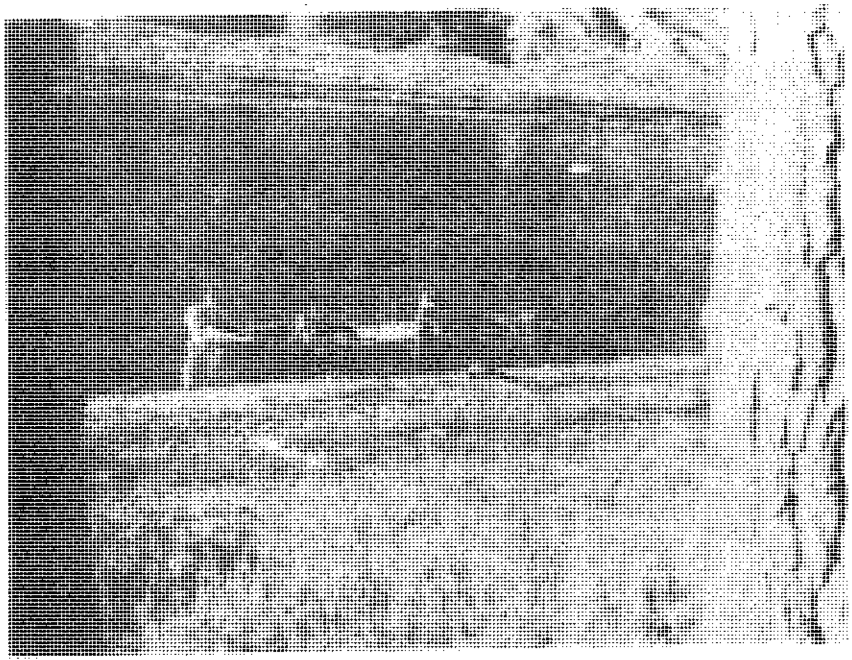

Figure 3. Electrofishing collections were made from a 5.2 m aluminum boat.

Figure 4. A screened scoop was utilized to sample incubating eggs of important fish species.

Larval Fish

Larval fish were sampled with a 0.5 m diameter by 1.6 m long Nitex plankton net (0.75 mm mesh) fitted with a threaded ring sewn at the distal end to accommodate a widemouth pint mason jar as the collecting bucket (Fig. 5). Two methods of collecting larval fish samples with the 0.5 m net were employed, stationary sets and integrated width tows.

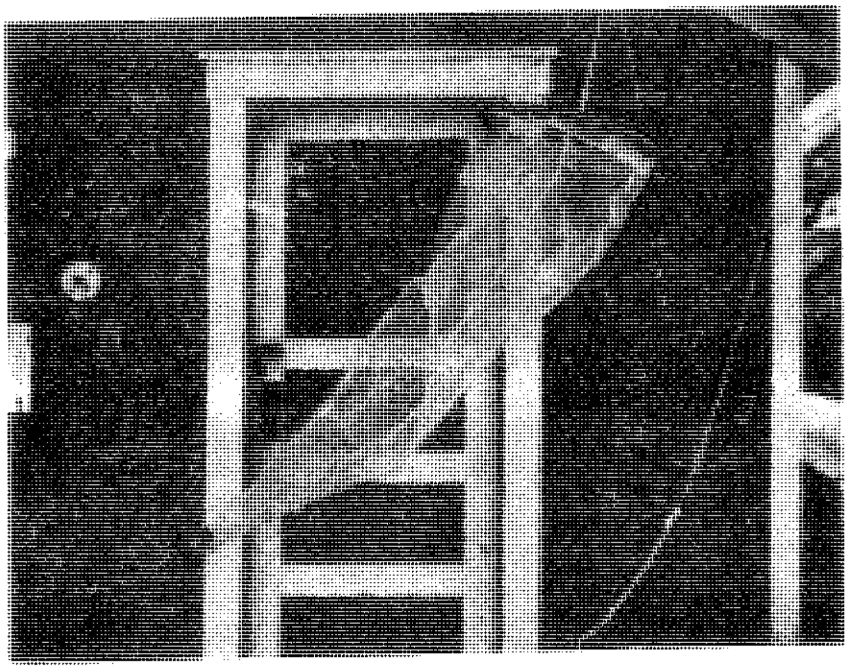

Figure 5. A 0.5 m diameter larval fish net was used to collect drifting fish larvae in the middle Missouri River and its major tributaries.

The stationary sets involved fishing the 0.5 m net immediately below the surface of the water in main channel border areas of the river. The net was held in position in the current by a 4 m length of rope tied to an anchored post. The volume of water filtered was measured with a Price type AA current meter positioned at the center of the net orifice. The net was fished for a measured period of time, usually 30 minutes. On some occasions the net was fished for less than 30 minutes because of excessive amounts of debris collecting in the nets. Stationary set samples were taken at 2-week intervals at five established study stations. The samples were usually collected during the dusk to dawn hours of the day.

The second technique for collecting larval fish samples was the integrated width tows. This technique involved towing the 0.5 m larval fish net under a boat while traversing the width of the river. The net was towed in this manner for 20 minutes. This method allowed a larger cross-sectional area of the river to be sampled. The integrated width samples were taken immediately downstream from several sites on the river where spawning of sauger, shovelnose sturgeon or paddlefish was considered to be likely. Again, the samples were usually collected during the dusk or dawn hours of the day.

After the 0.5 m net was retrieved from the stationary set or integrated width tows, its contents were thoroughly washed into the collection jar. All samples were preserved in a 10 percent solution of formaldehyde colored with phloxine-B dye. In the laboratory, the samples were washed on a U.S. series No. 30 screen. Material retained by the screen was transferred to an enamel sorting pan where the larval fish were extracted. Larvae were identified to the lowest taxon practical using taxonomic keys by Hogue et al. (1976) and May and Gasaway (1967). For purposes of this study, larval fish were defined as those fish exhibiting underdeveloped pectoral and dorsal fin rays; essentially as suggested by May and Gasaway (1967).

Young-of-the-Year Fish and Minnows

Young-of-the-year (YOY) fish and minnows were sampled with a 15.2 x 1.2 m beach seine with 3.2 mm square mesh (Fig. 6). The seine was operated by two men and worked in as many different habitat types as the current and bottom characteristics allowed. Fish collected were identified, and associated habitat type was recorded. All comparisons between study areas or habitat types for fish sampled by seining were based on catch per unit effort. A unit effort was accomplished by dragging the seine 10-20 m through an area.

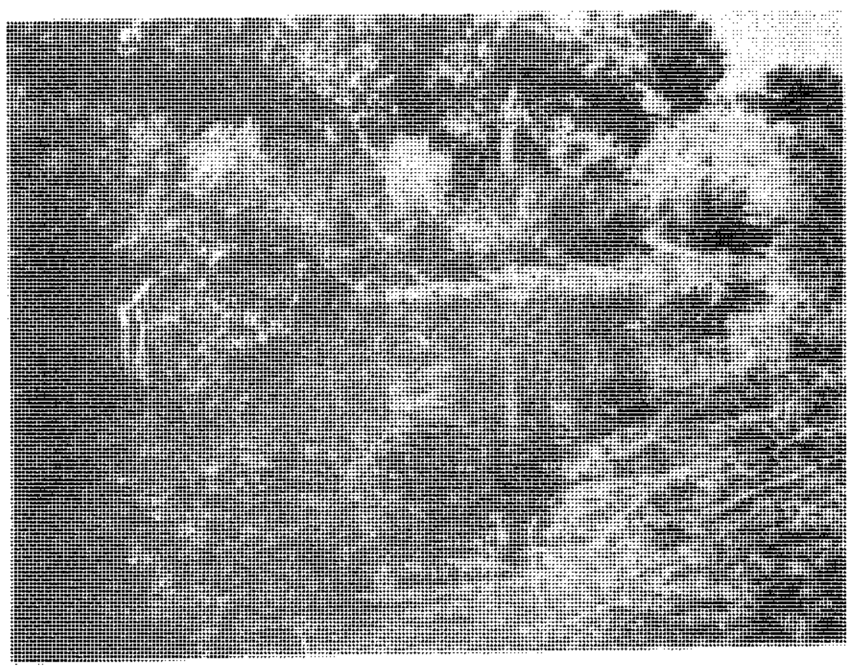

Figure 6. A beach seine was an effective device used to sample for young-of-the-year fish and minnows.

An attempt was also made to sample young-of-the-year fish and minnows with a 2.4 m wide semi-balloon fry trawl fitted with 3.2 mm square mesh Ace webbing in the cod end. The trawl was used in deeper areas of the river which could not be effectively sampled by seining. Results of sampling with the trawl in 1980 were poor. Very few fish were collected unless the trawl was dragged close to the bank of a side channel. The trawl was usually towed downstream to increase mobility and speed. Since data gathered by trawling were not sufficient enough to warrant interpretation, findings are not included in this report. It is recommended that a larger trawl should probably be used in the Missouri River since most investigators in the Missouri River impoundments used 4.9 to 8.2 m beam trawls (Walburg 1976).

Instream Flow Assessment

Side channel pools were surveyed to monitor their physical characteristics as flow in the Missouri River receded. Cross-sectional transects were established in side channel pools and measurements of width and mean depth were made at a variety of flow levels. Side channel influent flows and length of submerged channel were also measured and descriptive notes were recorded on the physical characteristics of the outlet of the side channel.

To evaluate the main channel riffle areas the Wetted Perimeter (WETP) computer program was used. This program is described in detail by Nelson (1980). Using standard surveying techniques, water surface elevations at several discharges were measured with a level and stadia rod. The channel profile was measured at low flow. A Lietz, model SD-5F range finder was used to determine distances and keep the boat on the transect line. Range finder accuracy was ±1, ±3 and ±5 percent at a distance from 0-90, 90-150 and +150 m, respectively. To measure depths along the transect a portable, constant recording fathometer (Raytheon, model DE-719 B) was used. The depth sounder print-out was calibrated in increments of 0.3 m and could be interpolated to 0.03 m. Graham and Penkal (1978) used similar procedures to measure channel profiles of the lower Yellowstone River, Montana.

Food Habits

Food habits were determined for adult shovelnose sturgeon, one-year-old and older sauger and YOY fish of several species. To study the food habits of shovelnose sturgeon and YOY fish the entire stomach was collected and stored in a 10 percent solution of formaldehyde. For sauger, the stomach contents were collected by pumping the stomachs with water, causing them to regurgitate the contents. The contents were then transferred to a labeled plastic package containing a 10 percent solution of formaldehyde. In the laboratory, stomach contents were sorted and volumetrically measured. Insects found in sturgeon stomachs were identified to the lowest taxon practical using Edmondson's (1959) key. Fish found in sauger stomachs were identified using Brown (1971). Some partly digested fish had to be identified using parts of the skeletal features, such as pharyngeal teeth and fin rays.

To facilitate interpretation of the shovelnose sturgeon food habits, a relative importance index (RI) as described by George and Hadley (1979), was utilized. Refer to Appendix Table A for an example of this calculation.

RESULTS

Life Cycle Stages

To determine instream flow requirements for the maintenance of a fish species, each life cycle stage and its requirements should be evaluated. The life cycle stages include: spawning, incubation, larval development, rearing and development to a mature adult. Each of these life cycle stages may require different habitat conditions which in some cases are related to the flow regime of the river. Because of the importance of the early life stages, the main effort of this study was directed in this area.

Spawning

Attempts were made in the study area to locate spawning sites of shovelnose sturgeon and sauger. It is generally accepted that spawning for these species does not occur randomly, but at specific sites or spawning grounds. Electrofishing was utilized during the spawning period in an effort to locate possible concentrations of fish and identify spawning sites. Because of sampling limitations, this effort was made only on shovelnose sturgeon and sauger.

No unusually large concentrations of adult shovelnose sturgeon or sauger were observed in the study area during their reported spawning seasons in 1979 and 1980. The inability to locate concentrations of these fish species is probably related in part to efficiency of the electrofishing sampling equipment. However, it is also possible that large concentrations of the spawning fish do not exist, and that spawning occurs in smaller concentrations over a wide area in the mainstem or in tributaries.

The range of the spawning period for shovelnose sturgeon and sauger in the study area was determined by examining a sample of sexually mature fish captured in the electrofishing surveys. Results of these observations are presented in Tables 1 and 2.

For shovelnose sturgeon, the spawning period was difficult to define. Moos (1978) reported that female shovelnose may take up to 3 years following spawning before their ovaries are again mature. Consequently, there are probably several different stages of ovarian development among adult female shovelnose sturgeon present in the Missouri River population. Thus, it is difficult to determine sex and spawning condition of the fish. For the purposes of this study, sturgeon with distended and turgid abdomens were classified as gravid females, fish with very flaccid abdomens and of a large size were considered spent females, fish with a tight, flat abdomen were left unclassified, and if milt could be stripped the sturgeon was considered a ripe male. No ripe females, as evident by stripping eggs, were observed during the spawning period in this study area. The scarcity of ripe females with strippable eggs has also been reported by Moos (1978) and Elser et al. (1977).

Table 1. Spawning conditions of shovelnose sturgeon sampled in the Loma Ferry and Coal Banks Landing study sections of the middle Missouri River during late spring and summer 1979.

Date	Spawning Condition
May 19 - May 24	52 observed; 17 examined 2 gravid females and 15 not ripe
June 4 - June 6	46 observed; 10 examined 3 gravid females; 5 ripe males; 2 not ripe
June 5	unfertilized shovelnose eggs taken from a collected shovelnose stomach
June 16 - June 19	77 observed; 18 examined 5 gravid females; 1 spent female; 6 ripe males; 6 not ripe
June 28	25 observed; 10 examined 2 spent females; 4 ripe males; 6 not ripe
July 9 - July 16	65 observed; 22 examined 4 gravid females; 3 spent females; 9 ripe males; 6 not ripe

Table 2. Spawning conditions of sauger sampled in the Morony Dam through Coal Banks Landing study sections of the middle Missouri River during spring 1980.

Date	Spawning Condition
April 8 - April 10	10 gravid females; 1 spent female; 3 ripe males; 4 unclassified fish
April 29 - April 30	11 gravid females; 4 spent females; 32 unclassified fish
May 10 - May 13	12 gravid females; 6 ripe females; 8 spent females; 2 ripe males; 220 unclassified fish
May 24 - June 9	2 spent females; 81 ripe males; 79 unclassified fish

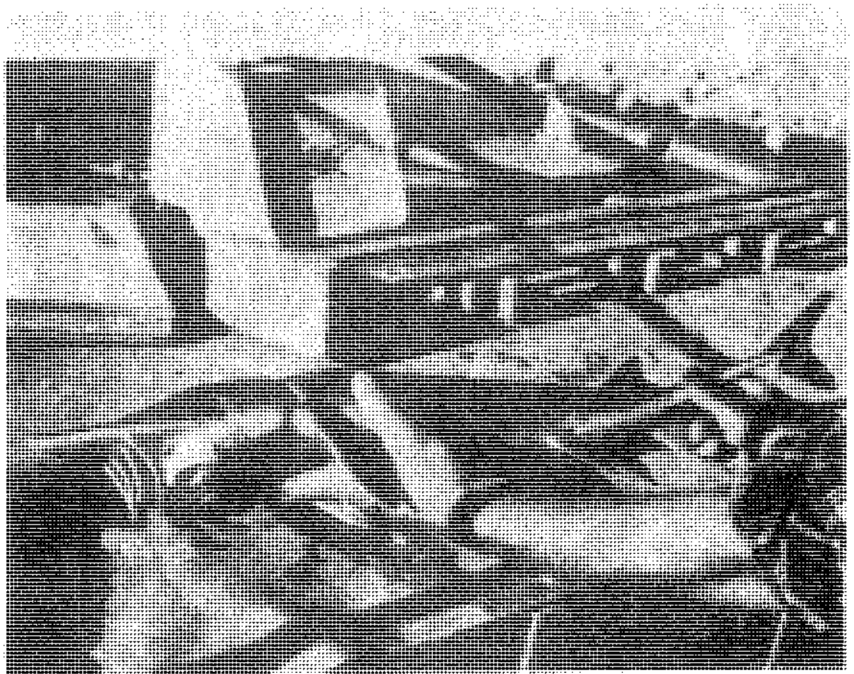

Figure 7. Shovelnose sturgeon were in spawning condition from early June to early July.

To verify our judgment of sex and spawning condition of female shovelnose sturgeon based on external characteristics, a technique for internal examination of the fish was developed. Internal examination provides positive confirmation of sex and spawning condition. The technique consisted of a 50 mm surgical incision of the abdomen to examine the gonads. After examination, the surgery was completed by closing the incision with five sutures. A number of shovelnose sturgeon were examined in this manner, and all appeared to be fully recovered within 24 hours. There appeared to be several stages of ovarian development among the female shovelnose examined during the spawning period. The stages included 1) ovaries developed into small size eggs, barely distinguishable, white to pink in color, 2) ovaries developed into small size eggs approximately 1 mm in diameter, white with an occasional black egg, and 3) mature ovarian development consisting of all black eggs approximately 3 mm in diameter.

In 1979 the first occurrence of ripe male shovelnose sturgeon in the study area was during the first week of June, and the last ripe male was collected in mid July (Fig. 7). Sampling for shovelnose sturgeon was terminated on July 16. Spent female shovelnose sturgeon were noted during the third week in June and the second week in July. A shovelnose sturgeon stomach sample collected on June 5, 1979, for food habits analyses contained three unfertilized shovelnose sturgeon eggs. These observations indicate that spawning of shovelnose sturgeon in the Missouri River in 1979 occurred primarily during a period from early June through early July.

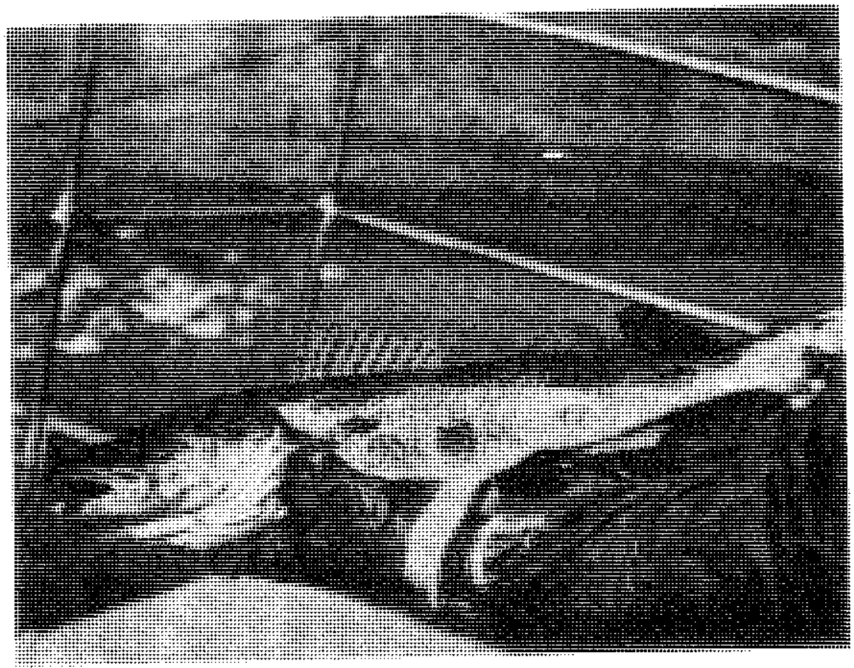

Figure 8. The sauger's spawning peak occurred in early May.

Internal examinations were made on several shovelnose sturgeon sampled during late August 1979. A number of females contained large black eggs which were quite flaccid in nature. Others had smaller, more firm black eggs. It was believed that the former sturgeon were resorbing their eggs, while the latter were at the end of the second year of development.

Observations of sex and spawning condition of shovelnose sturgeon examined during the spawning period in 1979 on the Missouri River largely coincide with those reported by Moos (1978), for the Missouri River below Gavins Point Dam, and Elser et al. (1977) for the Tongue River in Montana.

Shovelnose sturgeon spawn during the high flows and rising water temperatures of June and early July. To sustain a healthy sturgeon population, such as the one found in the middle Missouri River, the natural flow and temperature regimens should be maintained.

The spawning period for sauger during 1980 commenced with the occurrence of a few spent females sampled at the end of April (Table 2). By May 13 several spent females were found as were a number of ripe males and females. During the electrofishing run completed May 24 no gravid females were sampled and only male sauger remained in a ripe spawning condition. These observations indicate that the peak of sauger spawning during 1980 occurred from the beginning to middle of May. The observations of spawning conditions of sauger in the Missouri are similar to those reported by Haddix and Estes (1976) for the Yellowstone River, Elser et al. (1977) for the Tongue River and Berg (1981) for the Marias River.

To insure successful sauger spawning instream flows should remain steady with minimal fluctuations early in May, then flow should gradually rise until the peak of the runoff in June. If flow is significantly reduced after sauger spawn in early and mid-May, embryo incubation and hatching success will probably be impaired. Nelson (1968) investigated the effects of water fluctuations on the Missouri River sauger population below Fort Randall Dam. He reported that sharp water level changes over sauger spawning bars during the incubation period were the major reason for a poor reproductive success. Furthermore, the loss of recruitment was reflected as weak adult sauger year-class strength during the following years.

Incubation

An attempt was made to locate fertilized eggs of shovelnose sturgeon, paddlefish and sauger at anticipated or known spawning sites for these species in the study area. Types of areas sampled were similar to those described by Purkett (1961) for paddlefish, Nelson (1968) and Graham and Penkal (1978) for sauger. In general, these areas were usually shallow bars consisting of small gravel. Table 3 indicates the effort and number of eggs sampled in four study sections on the middle Missouri River during 1979. Although most of the incubating eggs collected were identified as goldeye, sucker or cyprinid eggs, one incubating paddlefish egg was collected near Stafford Ferry on June 12, 1979. This was approximately a 55-hour embryo as described by Ballard and Needham (1964). The embryo was sent to the TVA fish repository in Norris, Tennessee, and identification was verified by Bob Wallus. Berg (1981), previously reported that the Stafford Ferry area, with its numerous submerged gravel bars, was one of the most important spawning sites utilized by migrating paddlefish in the Missouri River upstream from Cow Island.

Some fish species are known to spawn on sites which are inundated only during the high flow period. Purkett (1961) indicated paddlefish in the Osage River, Missouri, spawned at least in part on gravel bars which were inundated only during high spring flows. Nelson (1980) found bigmouth buffalo embryos attached to inundated terrestrial vegetation and debris in Lewis and Clark Reservoir, South Dakota.

Paddlefish, bigmouth and smallmouth buffalo and river carpsucker in this study area also spawn, in part, in habitat inundated only during the high flow period. A substantial reduction in the magnitude of runoff during the normal high water period would obviously result in a significant loss of spawning and egg incubation habitat for paddlefish, buffalo, river carpsuckers and possibly other species.

Table 3. Number of egg samples taken and number of eggs collected (in parentheses) in four study sections on the middle Missouri River during 1979.

	Loma Ferry	Coal Banks	Stafford Ferry	Cow Island
May 22-Jun 6	16(6)	3(0)	7(0)	17(1)
Jun 12-Jun 20	4(7)	8(17)	18(12)*	24(17)
Jun 27-Jul 3	15(44)	14(0)	17(0)	15(2)
Jul 10-Jul 17	7(0)	6(0)	14(0)	-
Total No.	42(57)	31(17)	56(12)	56(20)

* One paddlefish egg collected June 12

Larval Fish

Larval fish (Fig. 9) were sampled in eight study sections from late May through early July 1979. Results of the sampling are shown in Table 4. The larval fish sampling was conducted to determine timing and location of successful hatching and emergence of important fish species.

Nine sauger and one salmonid were the only game fish collected in the larval fish samples taken in 1979. Of the nine sauger sampled, all were collected between May 28 and June 5. Assuming an incubation period of 13 to 21 days as described by Nelson (1968), sauger spawning occurred on May 7 at the earliest and May 23 at the latest.

Figure 10 indicates that at least two different seasonal distributions of larval fish existed in the study area during 1979. The curves for the Loma Ferry and Stafford Ferry study sections indicate a peak in the abundance of larval fish occurring between late May and mid-June. In contrast, the abundance of larval fish in the Cow Island study section gradually increases to a peak in early July. The relatively early peaks at Loma Ferry and Stafford Ferry are related to the dominance of Catostominae in the larval fish samples taken in these study sections. The predominance of cyprinid larvae explains the later peak in the Cow Island study section. Berg (1981) observed similar seasonal distributions of larval fish in the middle Missouri River in 1978. Brown (1971) indicates that suckers spawn earlier and prefer swifter waters for spawning than cyprinids. The cyprinids show a preference for slower protected waters, and this type of habitat is prevalent in the Cow Island study section.

In a study of larval fish distribution and abundance for the Missouri River below Gavins Point Dam, Kallemeyn and Novotony (1977) observed noticeable increases of larval cyprinid catches during July and August. Disregarding the obvious effects of the dam, they observed a seasonal curve of larval fish abundance similar to that of the Loma Ferry or Stafford Ferry sites in this study area.

The larval fish stage represents the transition period from the inactive embryo to the mobile juvenile fish. Therefore, a specific habitat is also transient. For the paddlefish it is high water which carries the larvae from gravel bars and transports them to large backwaters or oxbows in the Missouri River or the headwaters of Fort Peck Reservoir. In these calmer waters the larvae grow to a size enabling them to negotiate a swift current. For the larval sauger it is similarly the high water which enables the larvae to drift into side channels of the Missouri River or the headwaters of Fort Peck Reservoir. Without a sustained high flow period, drift of larval fish would be diminished, and recruitment of young sauger and paddlefish into the population would be reduced.

Larval fish were sampled near the mouths of the Marias, Teton and Judith Rivers from late May through early August 1979. The sampling was conducted to evaluate success of spawning in the tributaries and to determine importance of the tributaries in providing recruitment of larval fish to the mainstem of the middle Missouri River. Results of the sampling are shown in Table 5.

Ninety-one percent of the 1,026 fish larvae collected from the Marias River in 1979 were Catostominae. The remainder were primarily from the Ictiobinae/Cyprinidae group. Substantial spawning runs of sauger and shovelnose sturgeon were observed in the lower Marias River in 1979 (Berg 1981), but only one sauger

Table 4. Taxonomic composition of fish larvae sampled by both stationary and integrated width tows in the middle Missouri River during late May - late July 1979.

Study Section	Number of Tows	Goldeye	Mountain whitefish	Catostominae	Ictiobinae/ Cyprinidae group	Stonecat	Sauger	Sculpin
		Total number of larvae sampled						
Carter Ferry	4		1	36				
Fort Benton	5			81	1			
Loma Ferry	9	6		734	130		1	
Coal Banks	9			152	32			
Judith Landing	5	1		40	21	1	1	
Stafford Ferry	7	2		205	33		1	1
Cow Island	14	1		143	192		1	
Robinson Bridge	2			15	4		5	

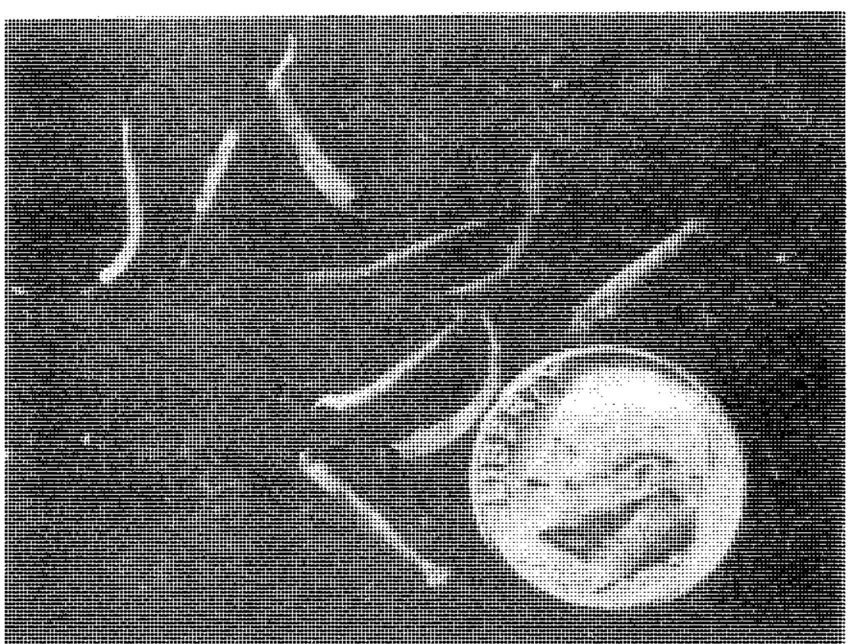

Figure 9. Fish larvae of eight subordinal taxa were collected in the middle Missouri River and its major tributaries.

Table 5. Taxonomic composition and seasonal densities (number per 100 m^3 of river filtered) of fish larvae sampled in the three major tributaries of the middle Missouri River during 1979.

Total Number of Larvae Sampled	Marias	Teton	Judith
Goldeye		1	1
Catostominae	938	446	5
Ictiobinae/Cyprinidae	87	218	18
Channel Catfish			33
Stonecat		1	
Sauger	1		
Total	1026	666	57

Density of Larvae Sampled (No./100 m^3)	Marias	Teton	Judith
Late May	114	169	1
Early June	38	11	3
Mid-June			
Late June	68	137	1
Early July	92	189	3
Mid-July			
Late July	285	57	
Early August	14	3	18

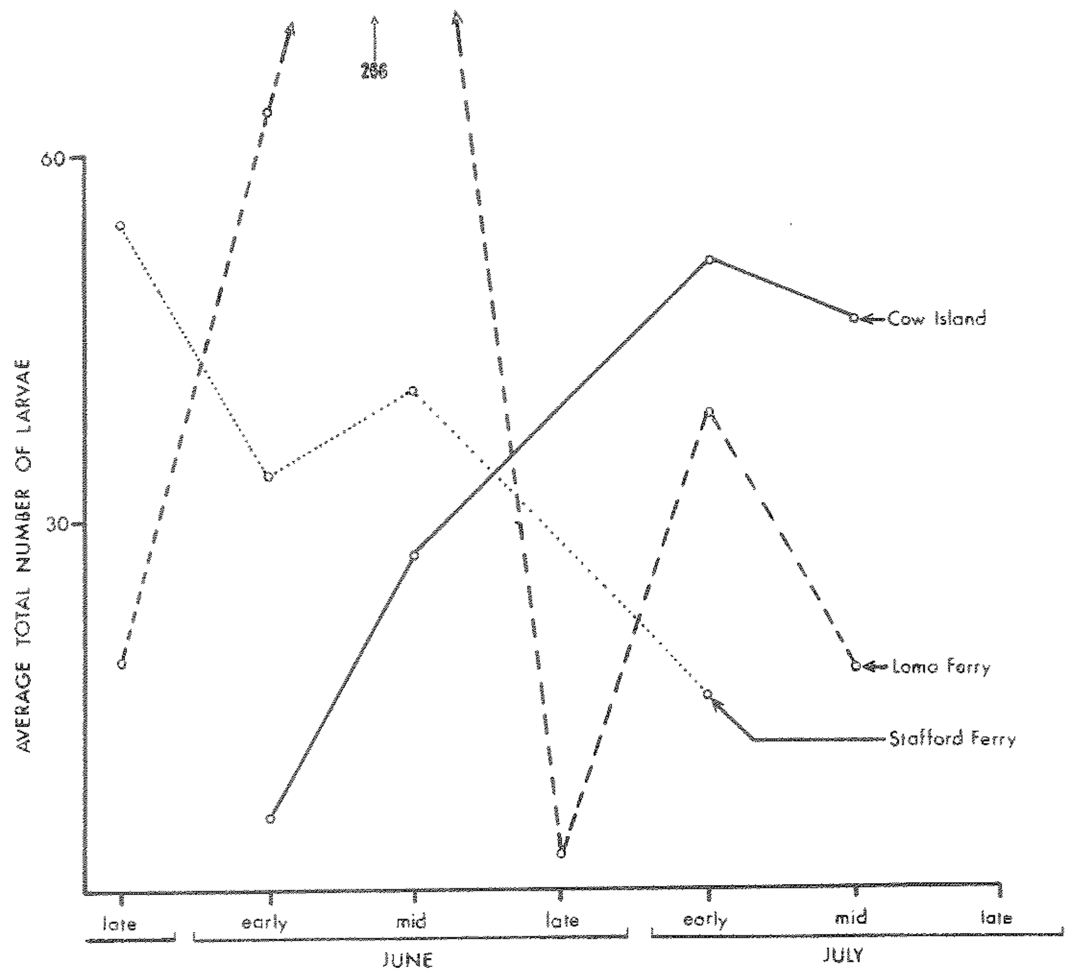

Figure 10. Average total number of fish larvae collected from 20-minute integrated width tows taken in three sections of the middle Missouri River during late May - mid-July, 1979.

larva and no sturgeon were collected. The scarcity of sauger and sturgeon larvae in the collections was probably related more to sampling efficiency than to lack of spawning success. Berg (1981) collected a large variety of fish larvae near the mouth of the Marias River in 1978. In addition to the species listed in Table 4, he collected channel catfish, stonecat, goldeye and shovelnose sturgeon larvae. Peak densities of larval fish in the lower Marias River in 1979 occurred from late June through July. Very few larvae were collected before late May.

Sixty-seven percent of the 666 fish larvae collected from the Teton River in 1979 were Catostominae, and 33 percent were Ictiobinae/Cyprinidae. The percentage of Ictiobinae/Cyprinidae in the larval fish samples was substantially greater for the Teton River than for the Marias River. Goldeye and stonecat larvae were sampled in the Teton River in 1979, but they were sampled only once each. Peak densities of larval fish in the Teton River in 1979 were similar to the Marias River. A substantial spawning run of channel catfish was observed in the lower Teton River in 1979 (Berg 1981), but no catfish alevins were collected in the larval fish samples. The scarcity of catfish alevins is probably related more to insufficient sampling frequency than to lack of spawning success.

Fifty-eight percent of 57 fish larvae collected from the Judith River in 1979 were catfish alevins, 32 percent were Ictiobinae/Cyprinidae and 9 percent were suckers. Goldeye larvae were sampled on one occasion. The 33 catfish alevins collected on August 2 indicate that the Judith River is probably an important tributary for spawning of channel catfish. The catfish alevins were collected when water temperature of the Judith River was near its annual maximum. A water temperature of 25C was recorded at 2200 hours on August 2.

The predominance of Ictiobinae/Cyprinidae over Catostominae in the Judith River is in contrast to findings on the Marias and Teton rivers. Also, total numbers and densities of larval fish collected in the Judith River were less than in the Marias and Teton rivers. However, the large amount of suspended organic material carried by the Judith River probably reduced sampling efficiency. The relatively low larval fish densities could be a reflection of this problem.

Rearing Areas

Ten study sections were sampled during 1979 in an effort to determine rearing habitat preferences of important fish species. Samples were collected in peripheral habitat areas such as side channels and backwaters, as well as in nonperipheral habitat areas such as main channel pools. Peripheral habitat areas are affected by reductions of stream flow levels much sooner than nonperipheral areas. If peripheral habitat areas are important in the life cycle of important fish species, minimum flows required to maintain these habitats should be determined. If adequate flows are secured to maintain peripheral habitat areas, flow in nonperipheral habitat areas should be more than adequate.

Results of survey sampling during 1979 indicated that most young-of-the-year (YOY) sauger reared in a 47 km reach of the Missouri River from Sturgeon Island to Robinson Bridge (Figure 11). Seventy percent of the YOY sauger sampled during July, August and September were found in the Cow Island and Robinson Bridge study sections. Catch rates were highest in the Robinson Bridge study section, averaging 1.50 YOY sauger per seine haul (Figure 12 and Appendix Table B). This indicates that the Cow Island and Robinson Bridge study sections provide a substantial amount of sauger rearing habitat.

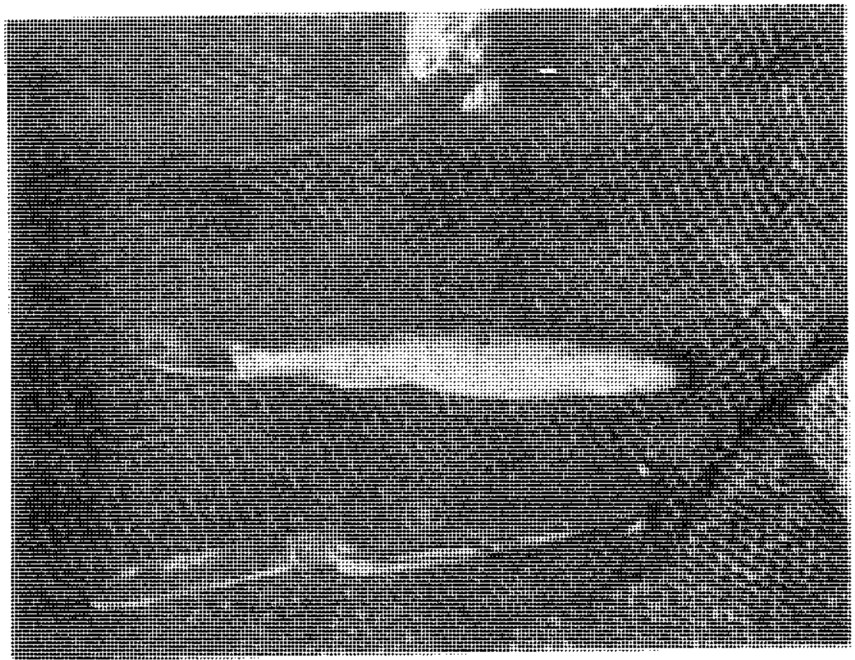

Figure 11. Young-of-the-year sauger ranging in length from 40 to 188 millimeters were collected in various peripheral habitat types on the middle Missouri River.

The Hole-in-the-Wall study section also contained a significant amount of sauger rearing habitat. Eighteen percent of the YOY sauger sampled during July, August and September were found in this study section, and catch rates averaged 0.74 YOY sauger per seine haul.

Results of sauger rearing habitat preference studies conducted in 1979 indicated YOY sauger selected protected habitats in peripheral areas of the river. During July, August and September, most YOY sauger were found in the side channel pool habitat types. Figure 12 illustrates the average catch rates of YOY sauger in each of the five habitat types. In the seven study sections where YOY sauger were found, the side channel pool habitat type accounted for a weighted average of 74 percent of the YOY sauger catch rate. The remaining habitat types, main channel pool, main channel borders, backwaters and side channel chutes were less important, and they accounted for averages of 27, 6, 3 and 1 percent of the YOY sauger catch rates.

Habitat preferences probably had a large influence on the longitudinal distribution of YOY sauger during 1979. The Robinson Bridge study section contained an extensive amount of side channel pools which are the most preferred sauger rearing habitat type (Figure 13). The Hole-in-the-Wall study section contained a

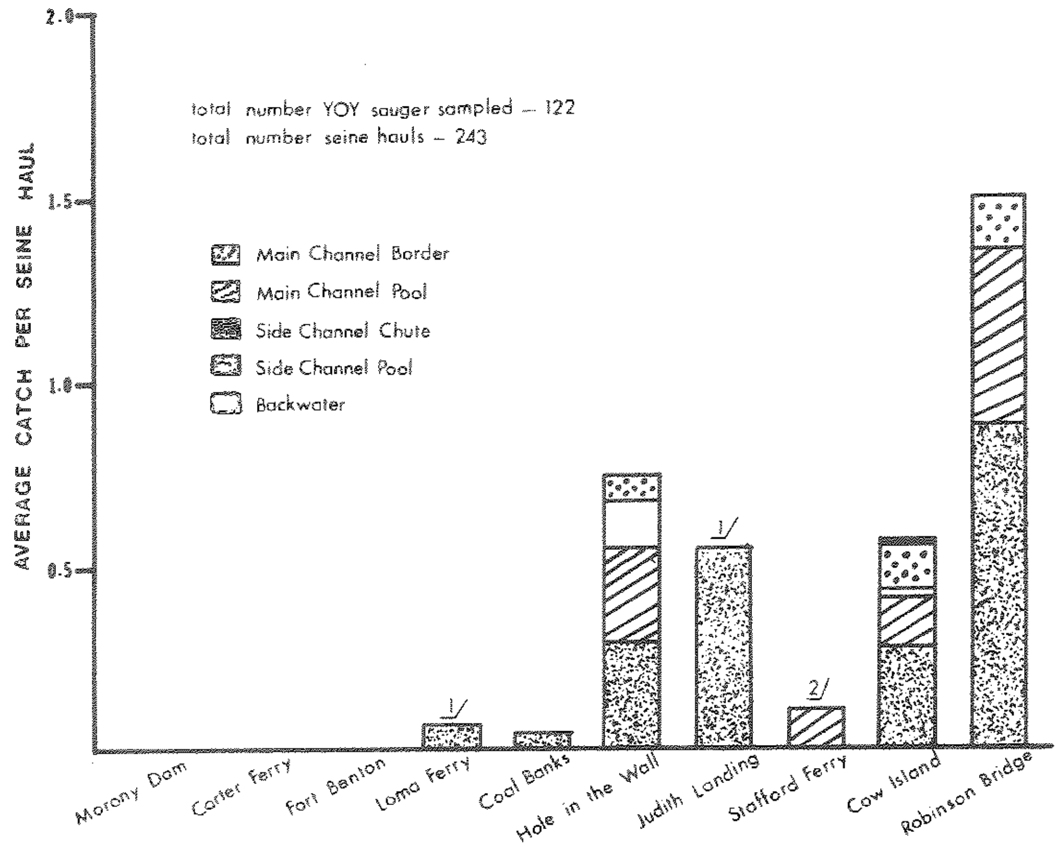

Figure 12. Longitudinal distribution, relative abundance and habitat preference of young-of-the-year (YOY) sauger seined in the middle Missouri River during 1979.

1/ - Side channel chute habitat type not sampled.
2/ - Side channel chute and pool habitat types not sampled.

Figure 13. This typical side channel pool, 2 kilometers in length, was intensively utilized by rearing young-of-the-year sauger in 1979 (upstream view).

considerable number of main channel "pocket pools" which provided important sauger rearing habitat. The "pocket pools" are formed by small peninsulas extending perpendicular to the channel margin. The pools are located immediately downstream from and behind the peninsulas (Figure 14).

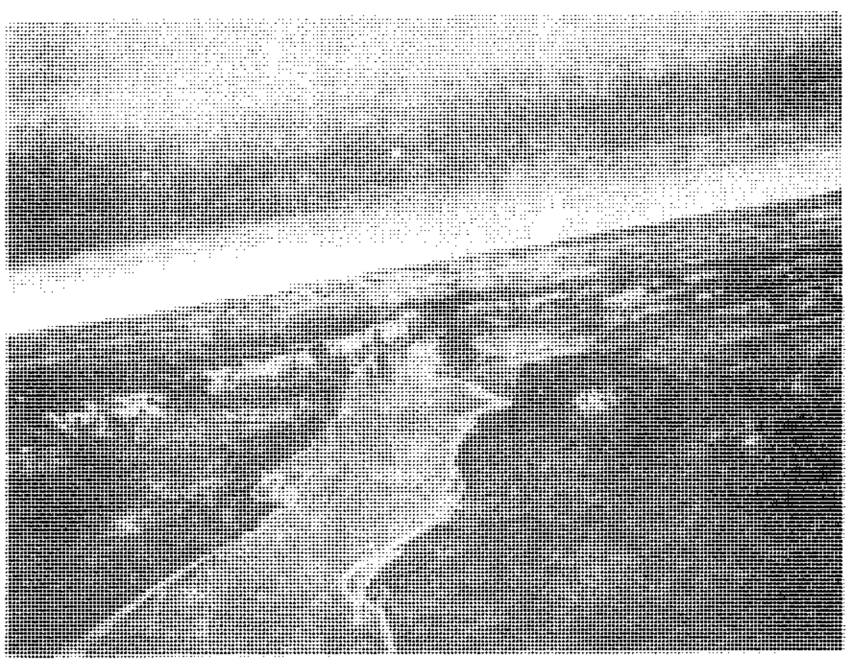

Figure 14. The Hole-in-the-Wall section exhibited extensive channel margin development, several peninsulas perpendicular to the margin formed important sauger rearing "pocket pools."

In the fall of 1979, there was a change in sauger rearing habitat preferences in the study area. Catch rates in rearing areas which could be effectively seined decreased noticeably during October when compared to catch rates in the same areas during July, August and September. The preferred rearing areas apparently shifted to main channel areas during October, and most of these areas could not be effectively seined. During this time, electrofishing in main channel riffle areas produced a number of YOY sauger, verifying a shift of habitat preference from side channels to the main channel.

During 1980, efforts were made to collect YOY sauger in habitat areas where they were commonly sampled the preceding year; however, very few YOY sauger were found. Since YOY sauger were not found in anticipated rearing areas, the "delta-like" portion of the Missouri River in the Turkey Joe section near the headwaters of Fort Peck Reservoir was also seined in 1980. An average of 2.5 YOY sauger per seine haul was sampled in this area, indicating that it provided significant rearing habitat. Since Fort Peck Reservoir is located immediately below the Turkey Joe section, it is also likely that a significant number of YOY sauger reared in the headwaters of Fort Peck Reservoir itself in 1980. However, since the reservoir could not be effectively sampled with our equipment, this hypothesis could not be verified.

In late July 1981, attempts again were made to collect YOY sauger in areas where they were commonly sampled in 1979, but again very few YOY sauger were found. In 1980 and 1981, peak flows in the Missouri River were well above normal, whereas in 1979 peak flows were about normal (Appendix Figure A). Based on these observations, it can be concluded when flows in the Missouri River are significantly above normal, larval or YOY sauger are apparently carried through or past side channel rearing habitat areas downriver into the headwaters of Fort Peck Reservoir where they rear. In years when flow of the Missouri River during the runoff period is about normal, side channels provide a very substantial amount of rearing habitat, and substantially fewer sauger larvae drift into the reservoir. Since our flow recommendations must be based on flow available during a normal water year, it is essential to maintain adequate flow in side channels for sauger rearing. Without side channel rearing habitat areas, recruitment of YOY sauger into the population would be severely impaired in normal water years.

Of the major sport fish found in the middle Missouri River, sauger appears to be the only species which rears in shallow water habitat. Kallemeyn and Novotny (1977) and Kozel (1974) reported that of the few YOY sauger collected, most were found off shallow sandbars or in the backwater habitats. Walburg (1976) reported that most of the YOY sauger which he collected were found in the shallow floodplain (shoals) of Lewis and Clark Reservoir.

The seasonal occurrence of YOY fish in side channels of the Missouri River is illustrated in Figure 15. Young-of-the-year goldeye and sauger were most abundant in the Cow Island and downstream sections, while the YOY smallmouth and bigmouth buffalo were most common in the Fort Benton and Loma Ferry sections (Appendix Table C). The other species listed were generally found throughout the study area. From early July through early September, side channels were heavily utilized by YOY and forage fish.

Explanations for the occurrence of YOY and larval fishes in side channels are well understood for some species and poorly understood for others. Cyprinidae,

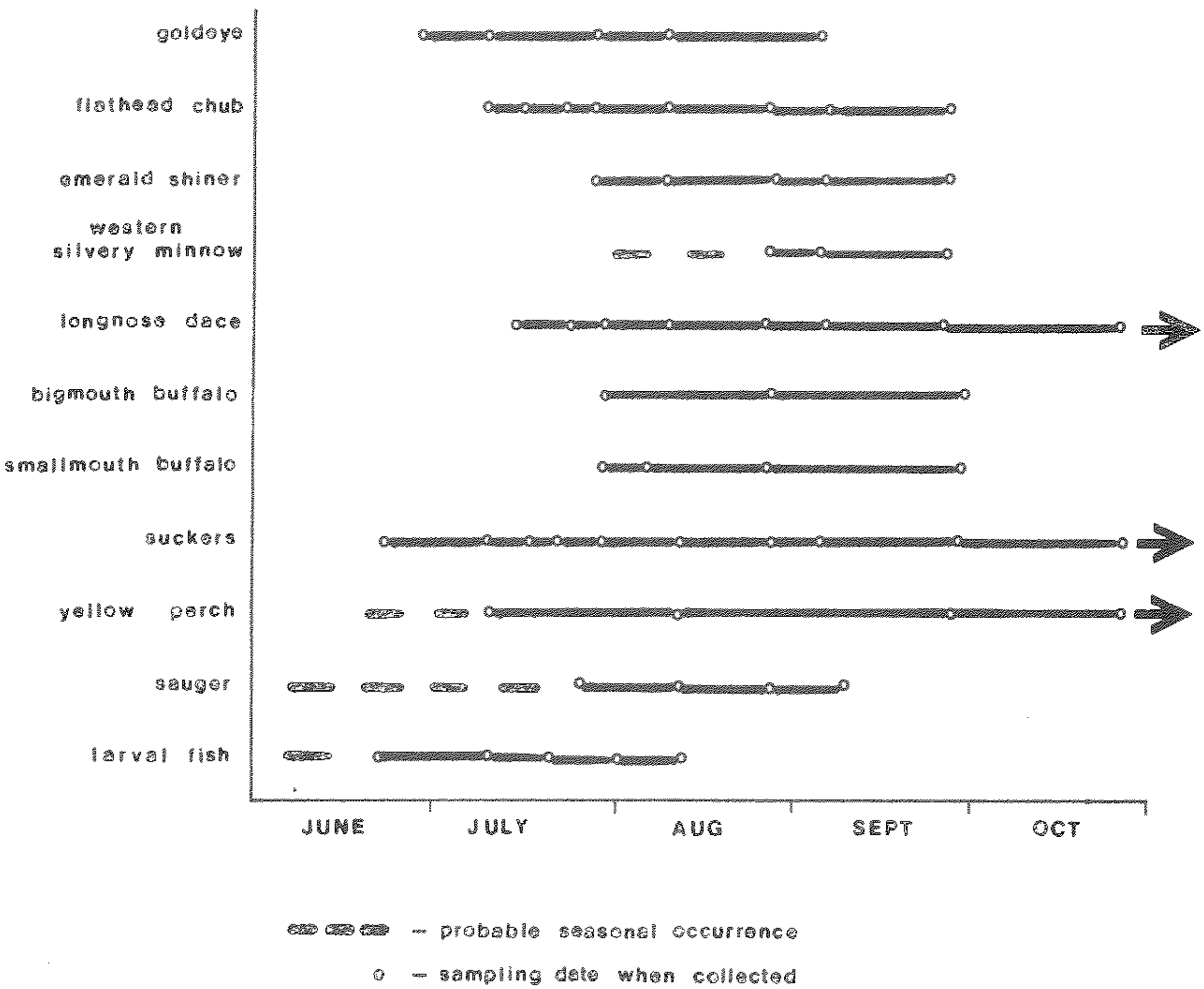

Figure 15. Seasonal occurrence of YOY fishes in the side channels of the middle Missouri River 1979-80.

Ictiobinae and yellow perch undoubtedly are found in side channels at least in part, because adults spawn there. The Flathead chub and emerald shiner spawn near the head of side channels in protected areas on firm substrate (Pflieger 1975). Western silvery minnows spawn in the lower end of side channels in calm water on soft substrate. Substantial concentrations of ripe bigmouth and smallmouth buffalo have been observed in backwaters and side channels of the Missouri River during the spawning period (Figure 16). Similarly, Nelson (1980) and Johnson (1963) found large concentrations of bigmouth buffalo during the spawning period in vegetated shoal and backwater areas of Lewis & Clark Reservoir, South Dakota. Yellow perch usually spawn in vegetated, calm habitat found in side channels or backwaters (Pflieger 1975). Suckers, longnose dace, goldeye and sauger also may spawn, in part, in side channels. However, the majority of spawning and incubation for these species probably occurs in riffle areas of the main channel. Emergent larvae from the main channel apparently enter side channels by drifting through the inlets, then establishing themselves in the calmer waters of the side channels.

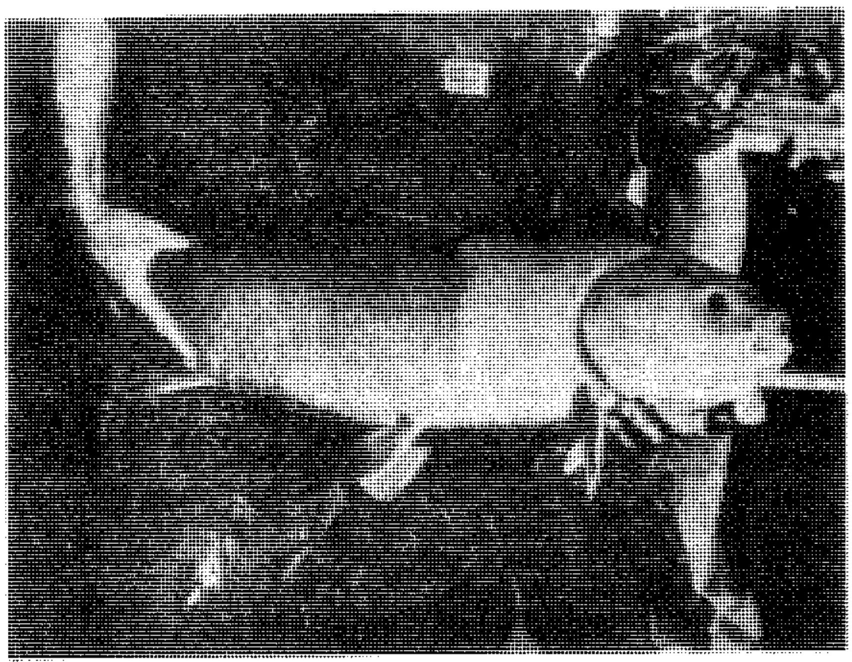

Figure 16. Bigmouth buffalo spawned in side channels and backwaters of the Missouri River.

Nelson (1968) reported that sauger spawned along rubble shorelines of the Missouri River below Fort Randall Dam, South Dakota, and after incubation the larvae drifted downstream into Lewis & Clark Lake.

Very little has been reported about the spawning habits or early life history of the goldeye. During this study, no exceptionally large numbers of sexually mature goldeye were sampled in the side channels; however, numerous ripe males and females were collected in calm main channel pools during late May. While sampling for incubating fish eggs in riffle areas during 1979, goldeye were the most numerous fish eggs collected. When trawling and seining some side channels during this period, substantially greater numbers of goldeye eggs were collected. This may indicate that many of the semi-buoyant goldeye eggs spawned in the main channel were carried into the side channels where they incubated.

Forage Fish

The forage fish community of the Missouri River plays a very important role in providing an adequate food base for piscivorous fish species such as sauger, northern pike, burbot, walleye and channel catfish. Therefore, it is important that habitat requirements are met to maintain forage fish for the welfare of the sport fishery as well as for the present fish fauna diversity of the river. This phase of the investigation was conducted to determine longitudinal distribution of forage fish species in the middle Missouri River, identify their preferred habitat types and monitor the forage fish communities of selected side channel pools during declining instream flows. For purposes of this study, a forage fish was broadly defined as any fish utilized by another fish as a food source. This would include most age 0 fish and nearly all adult minnows (Figure 17).

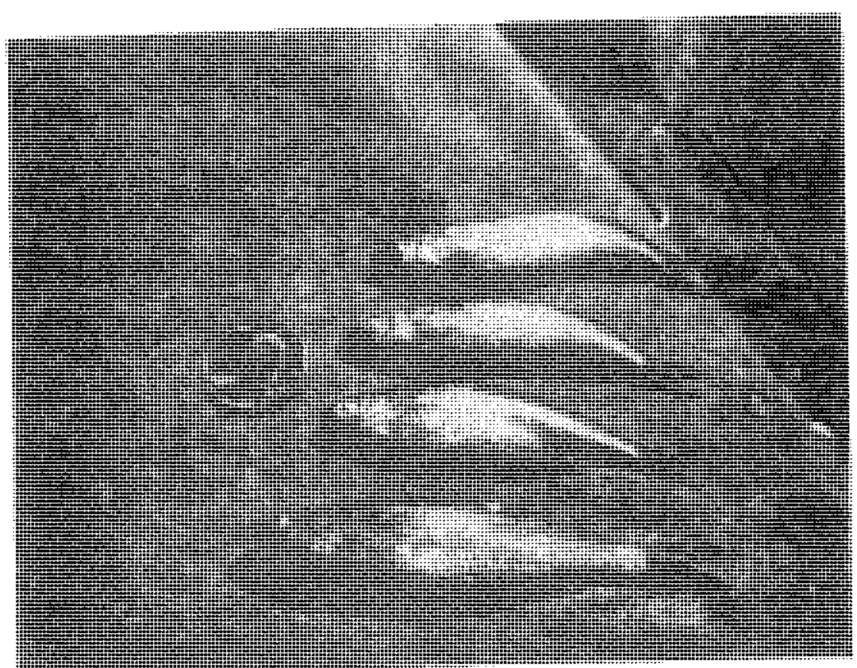

Figure 17. Forage fish distribution and abundance and their significance as a food source of sport fish were investigated during 1979-81.

The longitudinal distribution of forage fish sampled during 1979 is shown in Table 6. Twenty-nine species were collected. Considering the minnow family only, all of the species reported by Brown (1971) were collected. Notable additions were the collection of several sicklefin *(Hybopsis meeki)* and sturgeon *(Hybopsis gelida)* chubs. The sicklefin chub had previously been reported to be in the Missouri River only as far upstream as the confluence of the Little Missouri River in North Dakota (R. Bailey, pers. com.) and the sturgeon chub had been found in Montana only in the lower Yellowstone and Powder rivers (Brown 1971). Both of these chubs were collected in fair numbers in the 70 km reach from Cow Island to the headwaters of Fort Peck Reservoir. This reach contains many sand and gravel bar areas which Pflieger (1975) describes as being their preferred habitat. Another notable extension of a forage fish distribution was the collection of Iowa darters in the Carter Ferry and Fort Benton study sections. Previous to this collection, the known range of Iowa darters in Montana was limited to tributaries of the Little Missouri River and Missouri River and its tributaries below Fort Peck Dam (Brown 1971). Most of the darters were found in the sheltered peripheral areas of the channel, which was similar to Brown's description of their basic habitat preference.

Peripheral areas of the stream channel appear to play an important role in the relative abundance and diversification of forage fish populations in the study area. The average number of forage fish captured was greatest in the backwaters, main channel pools and side channel pools (Table 7). An average of 125, 104 and 81 fish per seine haul was captured in each of these habitat types, respectively. Main channel border and side channel chute habitat types averaged 45 and 31 forage fish per seine haul, respectively. The backwaters habitat type had the greatest variety of forage fish species, averaging 5.8 different species per seine haul. Side channel pools, main channel pools, main channel borders and side channel chutes averaged 5.5, 4.8, 3.6 and 3.3 species per seine haul, respectively. Considering both relative abundance and diversity, the backwaters were the most preferred forage fish habitat type, and side channel chutes were the least preferred. It was apparent that forage fish in the middle Missouri River prefer protected slow water habitat types.

The longitudinal distribution and relative abundance of six of the most widely distributed forage fish in the study area are presented in Figure 18 and Appendix Table D. The suckers (shorthead redhorse and longnose sucker), collectively, were the most abundant forage fish, with an average catch rate of 24 fish per seine haul. Catch rates for flathead chubs, emerald shiners, western silvery minnows and longnose dace averaged 16, 14, 14 and 13 fish per seine haul, respectively. Suckers and longnose dace were most abundant in the relatively swift upstream study sections, while the flathead chub and emerald shiner were more prevalent in the lower gradient downstream study sections. The western silvery minnow did not appear to show any longitudinal preference. Catch rates for western silvery minnow were highest in the Morony Dam, Coal Banks Landing and Cow Island study sections.

Specific habitat preferences of the six common forage fish species are shown in Figure 19. Basically, all six forage species were found in high numbers in the main channel pool, side channel pool and backwater habitats. The emerald shiner preferred the backwaters, whereas the flathead chub was common in all habitat types.

Table 6. Longitudinal distribution of forage fish species seined in the middle Missouri River during 1979 and 1980. 1/

	Morony Dam	Carter Ferry	Fort Benton	Loma Ferry	Coal Banks Landing	Hole-in-the-Wall	Judith Landing	Stafford Ferry	Cow Island Landing	Robinson Bridge	Turkey Joe	Marias River	Teton River
Goldeye				*	*	*	*		*	*	*		
Mountain Whitefish		*			*								
Carp	*	*	*	*	*	*	*	*	*	*	*	*	
Flathead chub	*	*	*	*	*	*	*	*	*	*	*	*	*
Sturgeon chub							*		*	*			*
Sicklefin chub									*	*			
Lake chub	*	*	*	*	*	*	*					*	
Emerald shiner	*	*	*	*	*	*	*	*	*	*	*	*	*
Brassy minnow											*		*
Plains minnow	*	*		*					*	*		*	*
Western silvery minnow	*	*	*	*	*	*	*	*	*	*	*	*	
Fathead minnow	*	*	*	*	*	*	*			*		*	
Longnose dace	*	*	*	*	*	*	*	*	*	*	*	*	*
River carpsucker				*	*	*	*	*	*	*	*		*
Smallmouth buffalo			*	*			*		*		*		
Bigmouth buffalo			*	*			*						
Shorthead redhorse	*	*	*	*	*	*	*	*	*	*	*	*	*
Longnose sucker	*	*	*	*	*	*	*		*	*	*	*	*
White sucker	*	*	*	*		*						*	
Channel catfish									*	*			*
Stonecat		*		*		*	*	*	*	*			*
Smallmouth bass					*								
Pumpkinseed				*									
Yellow perch		*	*	*			*						
Sauger				*	*	*	*	*	*	*	*		
Walleye				*					*				
Iowa darter		*	*										
Freshwater drum											*		
Mottled sculpin	*	*		*		*				*			

1/ - Fish larger than 140 mm were not included.

Table 7. Relative abundance and diversity of forage fish seined in five habitat types of the middle Missouri River during 1979.

Habitat Type	Ave. number fish/haul	Median number fish/haul	Ave. number species/haul	Mode of number species/haul	Total number of hauls
Main Channel Border	45.2	19	3.6	3	84
Main Channel Pool	104.2	56	4.8	4	68
Side Channel Chute	30.6	10	3.3	3	18
Side Channel Pool	81.3	33	5.5	5	26
Backwaters	125.2	95	5.8	7	46

Instream Flow Assessment for Side Channels

Methodology

Results of rearing and forage fish studies conducted on the Missouri River from 1979 through 1981 indicated side channels provided critical habitat for rearing of several important fish species as well as habitat vital for producing forage fish. Other investigators have found similar results: Ellis et al. 1979, Funk and Robinson 1974, and Kallemeyn and Novotny 1977.

Islands and associated side channels are a major feature of the Missouri River in this study area. Much of the diversity of fishes found here is related to habitat varieties in side channels. Side channels enable fish which require calmer, more protected water during some or all of their life cycle to extend their distribution into reaches of the river which would provide very little habitat if only the main channel of the river were available. Since side channels are essential for maintaining the integrity of fish populations, extensive studies were made in 1980 to determine the amount of flow required to maintain suitable habitat conditions in side channels for rearing capabilities and forage fish production.

As flow in the river recedes from high to low flows, the amount of suitable habitat in side channels for rearing and forage fish generally declines, but the rate of habitat loss is not constant throughout the entire range of flows. For each side channel there is a certain instream flow which is required to maintain

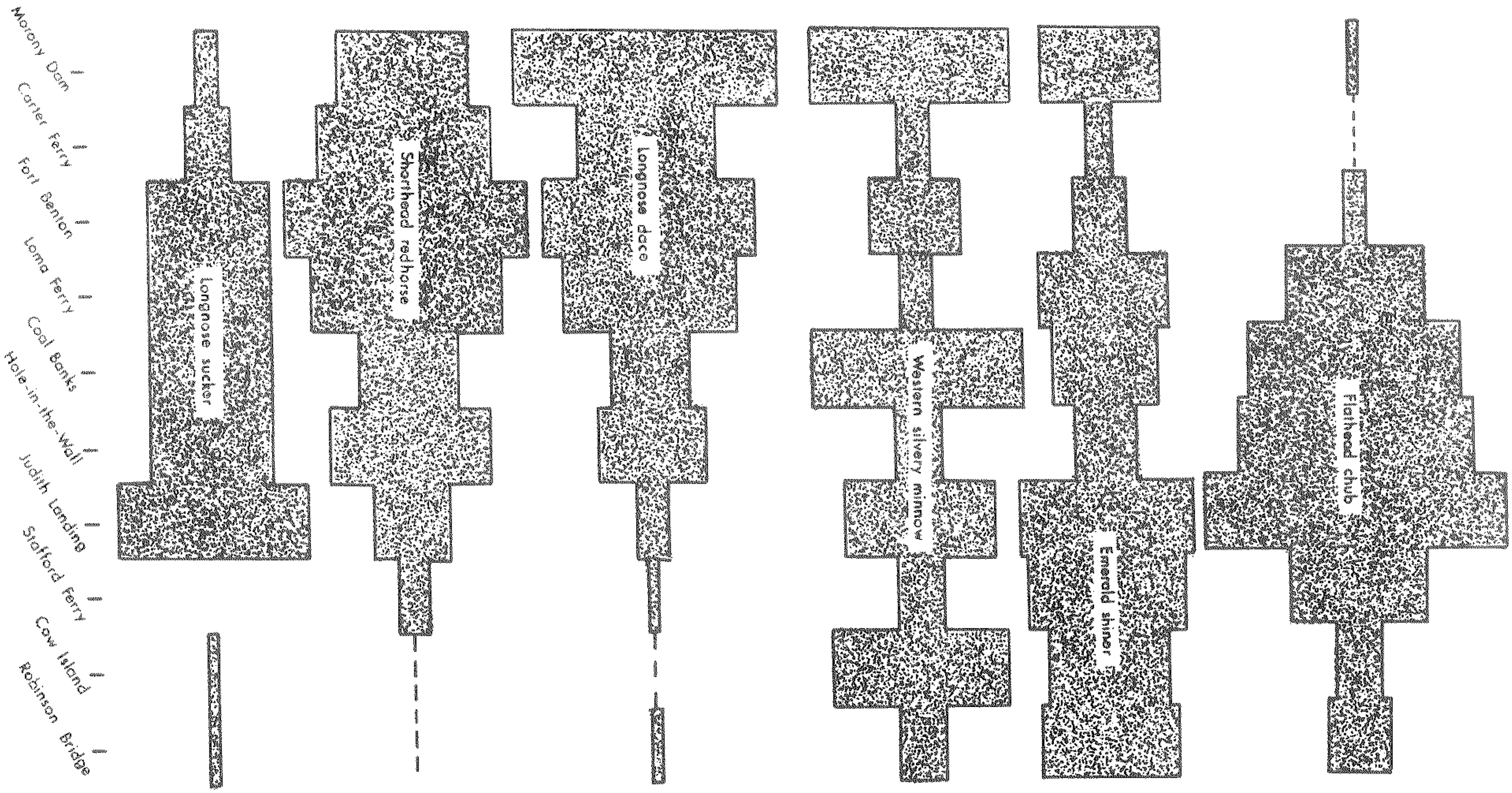

Figure 18. Longitudinal distribution and relative abundance (ave. catch rate) of six common forage fish species seined in the middle Missouri River during 1979. (10 mm on the vertical equals an average catch rate of eight fish per seine haul.)

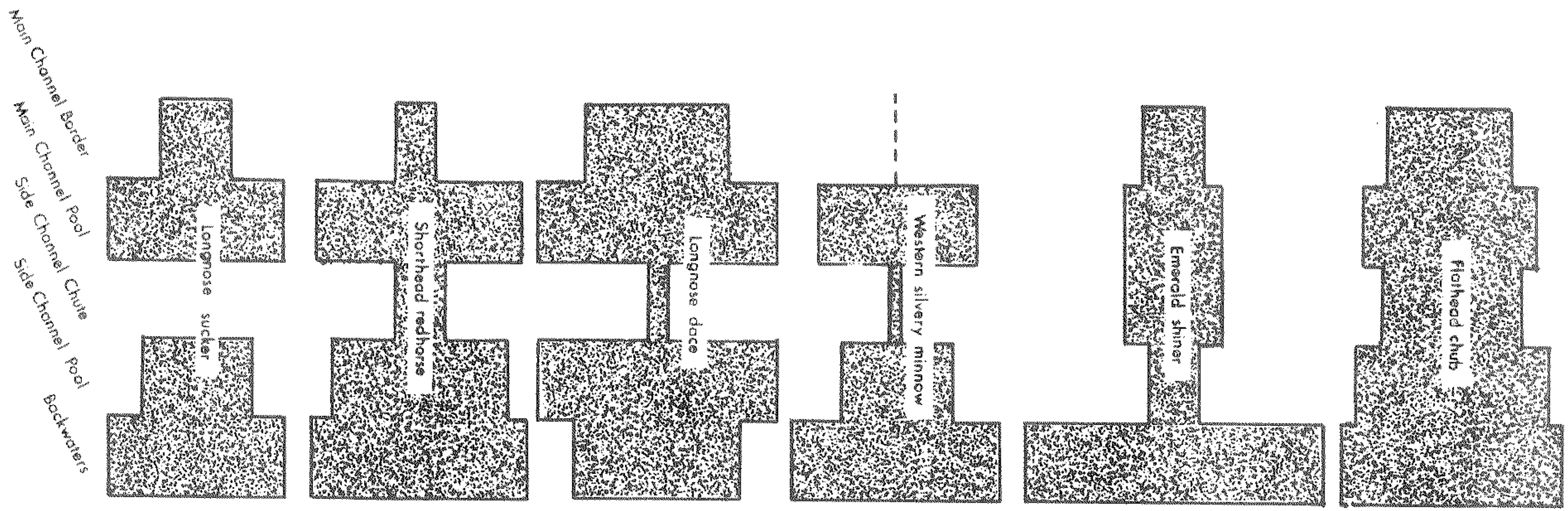

Figure 19. Forage fish habitat type preferences as described by the relative abundance (average catch rate) of six common forage species seined in five habitat types of the middle Missouri River during 1979. (10mm on the vertical equals an average catch rate of eight fish per haul.)

suitable habitat conditions in the side channel. The flow requirements vary from one side channel to another; some side channels require more flow than others to maintain suitable habitat. The flow required to maintain each side channel is indicated by a threshold point. Above the threshold point, reductions in flow of the main channel caused only very small losses of habitat in the side channels. Below the threshold point, habitat conditions in the side channel deteriorated, making it inadequate for rearing or shelter. Threshold points determined for individual side channels were grouped together to formulate flow recommendations for a reach of stream.

A variety of physical characteristics were monitored in 12 typical side channels of the Missouri River in 1980, as flow receded from the seasonal high point to the low point. The locations and physical aspects of the side channels are shown in Figure 1 and Table 8. Cross-sectional transects were established in the side channel pool habitat type, which, as shown previously, was the most important habitat for rearing and forage fish. Measurements of width and depth were made at a variety of flow levels for each of the side channel pool transects. Side channel inlet flow and length of the channel were also measured and descriptive notes were recorded on the physical characteristics of the outlet of the side channel. The 12 side channels were surveyed by seining to monitor their utilization for rearing and forage fish.

Physical Characteristics of the Side Channels

Tables 9 through 11 summarize various physical parameters measured in each side channel during declining flows. To facilitate interpretation of instream flow data, the river was separated into three reaches. The reaches extended from Morony Dam to the confluence of the Marias River, from the confluence of the Marias to the confluence of the Judith River and from the confluence of the Judith River to Fort Peck Reservoir. Stream flow in these reaches was monitored by the Fort Benton, Virgelle and Robinson Bridge gage stations, respectively.

Influent surface flow ceased in 7 of the 12 side channels at an intermediate point of the declining surface runoff period (July 18-29, 1980). Even though there was no influent surface flow to the side channels, they did not entirely dewater, but were then supplied by subsurface seepage and a backwater flow from the main channel. Consequently, the water level in the side channels continued to decline in response to the decreasing instream flows even after influent surface flow had ceased.

The influent surface flow of a side channel was a major factor controlling both the channel length and depth (Figure 20). For example, average channel length decreased from 1.2 to 0.5 km, or by 58 percent, in side channels 2, 4, 7, 9 and 11 between the time the side channels had an influent flow and when the flow recently had ceased.

Water depth is the physical dimension of habitat most important for the fish communities in these side channels. In several of the side channels the depths throughout the channel were not uniform, but exhibited shallow, wide segments (Figure 21) as well as deep segments. For transects located in these shallower portions of the side channels, mean depth declined from 0.59 to 0.18 meters, or a 70 percent loss between the time the side channels had an influent flow and when the flow recently had ceased. For the same side channels and period, the deeper portions of the side channels exhibited only a 32 percent average decline.

Table 8. Location, channel length and Missouri River flow at which the side channel begins to flow water and nearest USGS gaging station for the 12 side channels on the middle Missouri River monitored during 1980.

No.	Name	Location T	Location R	Location S	River km[1/]	Channel Length (km)	Missouri R. flow at inception of influent Surface Flow (m^3/s)	Missouri R. flow at inception of influent Surface Flow (cfs)	Nearest Gaging Station
1.	Roosevelt Island	24N	8E	23	281	1.3	117.0	4,130	Ft. Benton[1/] Rkm 281
2.	Pimperton Island	24N	9E	4	269	1.1	257.7	9,100	Ft. Benton Rkm 281
3.	Rowe Bayou	25N	10E	21	254	1.7	Approximately 339.0	Approximately 12,000	Ft. Benton Rkm 281
4.	Loma Ferry Is.	25N	10E	18	247	1.4	218.1	7,700	Ft. Benton Rkm 281
5.	Spanish Island	25N	10E	1	235	2.3	Approximately 339.8	Approximately 12,000	Virgelle Rkm 217
6.	Three Islands	25N	11E	31	233	2.3	Approximately 107.6	Approximately 3,800	Virgelle Rkm 217
7.	Judith Island	23N	16E	26	139	1.1	Between (141.6-254.0)	Between (5,000-8970)	Virgelle, Rkm 217
8.	Norris Island	23N	16E	25	138	2.0	Approximately 452.0	Approximately 16,000	Fred Robinson Br. Rkm 40
9.	Lower Sturgeon Is.	23N	21E	6	89	1.0	Approximately 271.2	Approximately 9,600	Fred Robinson Br. Rkm 40
10.	Snake Point Island	23N	21E	1	81	1.1	Approximately 107.6	Approximately 3,800	Fred Robinson Br. Rkm 40
11.	Dillon Island	23N	23E	31	57	1.2	258.8	9,140	Fred Robinson Br. Rkm 40
12.	Hammond Island	22N	23E	6	56	1.7	159.7	5,640	Fred Robinson Br. Rkm 40

1/ Rkm = River kilometer; Rkm 0 = Ft. Peck Reservoir

Table 9. Physical characteristics of side channels in the Fort Benton gaged reach compared to flow of the Missouri River in 1980.

Side Ch. No.	Date	Missouri River flow (m 3/s)	Channel influent flow (m 3/s)	Total channel length (km)	Transect 1 Ave. Depth	Transect 1 Max. Depth (meters)	Transect 1 Width	Transect 2 Ave. Depth	Transect 2 Max. Depth (meters)	Transect 2 Width	Transect 3 Ave. Depth	Transect 3 Max. Depth (meters)	Transect 3 Width
#1	7/17	277	5.5	1.3	0.49	0.76	23.4	0.88	1.40	23.1	0.76	0.97	20.4
	8/20	172.2	1.4	1.3	0.24	0.52	21.0	0.76	1.09	21.6	0.52	0.73	20.1
	9/10	117.0	tr[1]	1.3	0.06	0.33	17.9	0.64	0.94	20.4	0.36	0.55	18.5
#2	7/18	257.7	tr	1.1	0.76	1.04	15.2	0.55	1.03	14.9	0.70	0.88	18.8
	8/25	130.6	-[2]	0.5	-	-	-	0.43	0.73	10.3	0.46	0.64	17.3
	9/24	119.5	-	0.4	-	-	-	0.40	0.67	9.1	0.33	0.49	16.1
#3	7/19	218.1	-	1.6	0.27	0.40	14.9	0.46	0.64	22.2	0.46	0.64	25.2
	8/26	123.5	-	1.0	0.15	0.18	11.6	0.09	0.12	13.1	0.12	0.18	14.0
	9/25	109.3	-	1.0	-	-	-	0.06	0.09	11.9	0.09	0.15	12.8
#4	7/19	218.1	tr	1.4	0.88	1.34	27.7	0.36	0.52	28.3			
	8/26	123.5	-	0.4	0.58	0.91	23.7	0.06	0.09	12.2			
	9/25	109.3	-	0.4	0.58	0.88	23.7	0.06	0.09	8.8			

1/ - Flow less than 0.14 m 3/s
2/ - Denotes zero flow or depth

Table 10. Physical characteristics of side channels in the Virgelle gaged reach compared to flow of the Missouri River in 1980.

Side Ch. No.	Date	Missouri River flow (m 3/s)	Channel influent flow (m 3/s)	Total channel length (km)	Transect 1 Ave. depth	Transect 1 Max. depth (meters)	Transect 1 width	Transect 2 Ave. depth	Transect 2 Max. depth (meters)	Transect 2 width	Transect 3 Ave. depth	Transect 3 Max. depth (meters)	Transect 3 width
#5	7/20	256.6	1/	1.8	0.67	0.91	23.7		2/		0.76	1.12	30.1
	8/27	154.1	-	1.8	0.40	0.58	20.4	0.46	0.64	22.8	0.49	0.85	28.0
	9/25	127.7	-	1.8	0.36	0.52	20.1	0.43	0.54	22.5	0.43	0.73	27.1
#6	7/20	256.6	13.5	2.3	1.40	1.88	42.3	0.58	0.70	34.4	1.25	1.73	21.9
	8/27	154.1	2.3	2.2	0.85	1.16	39.5	0.30	0.40	30.7	0.94	1.37	21.0
	9/26	135.1	0.9	2.2	0.76	1.03	38.6	0.21	0.27	28.3	0.79	1.22	20.1
#7	7/8	379.5	6.0	1.1	0.54	0.73	19.5	0.88	1.22	21.6	0.70	0.79	20.1
	7/27	254	0.8	0.7	0.27	0.36	17.0	0.73	0.91	15.5	0.36	0.46	19.2
	9/5	141	-	0		3/			3/			3/	

1/ Denotes zero flow
2/ Did not take depth measurements at transect
3/ Side channel's outlet and inlet dry

Table 11. Physical characteristics of side channels in the Fred Robinson Bridge gaged reach compared to flow of the Missouri River in 1980.

Side Ch. No.	Date	Missouri River flow (m 3/s)	Channel influent flow (m 3/s)	Total channel length (km)	Transect 1 Ave. depth (meters)	Transect 1 Max. depth (meters)	Transect 1 width (meters)	Transect 2 Ave. depth (meters)	Transect 2 Max. depth (meters)	Transect 2 width (meters)	Transect 3 Ave. depth (meters)	Transect 3 Max. depth (meters)	Transect 3 width (meters)	Transect 4 Ave. depth (meters)	Transect 4 Max. depth (meters)	Transect 4 width (meters)
8	7/9	436.1	1/	1.7	0.49	0.70	10.9	0.67	0.82	13.4						
	7/27	268.8	-	1.6	0.24	0.40	7.9		2/							
	9/5	158.6	-	1.1	-	-	-	0.12	0.18	9.1						
9	7/10	413.5	2.0	1.0	0.43	0.67	13.1	0.85	0.97	16.7	0.97	1.28	20.4			
	7/28	262.5	-	0.9	0.21	0.36	8.5	0.54	0.64	15.8	0.73	0.94	18.8			
	9/6	149.8	-	0.3	0.06	0.09	4.0	0.40	0.49	15.2	0.40	0.61	17.3			
10	7/10	413.5	20.6	1.1	0.97	1.37	26.1	1.28	1.58	28.3	1.22	1.64	29.8			
	7/28	262.5	9.9	1.1	0.64	0.91	25.2	0.91	1.16	27.7	0.82	1.22	29.2			
	9/6	149.8	2.0	1.1	0.36	0.61	22.2	0.64	0.85	26.8	0.54	0.82	24.3			
11	7/12	439.0	6.9	1.2	0.79	1.06	17.0	0.52	0.64	21.3	1.09	1.58	19.2			
	7/29	258.8	tr 3/	1.2	0.33	0.54	14.9	0.12	0.18	18.5	0.73	1.19	17.3			
	9/7	159.7	-	0.7	0.27	0.49	14.9	0.06	0.06	11.2	0.54	0.91	15.8			
12	7/13	385.2	6.9	1.7	0.70	0.94	20.4	0.76	1.12	26.8	0.94	1.16	21.0	0.76	1.00	25.5
	7/30	248.6	2.5	1.7	0.52	0.67	17.3	0.54	0.85	24.3	0.61	0.76	19.8	0.46	0.54	23.7
	9/7	159.7	tr	0.5	0.27	0.33	14.3	0.30	0.58	20.7	0.30	0.46	19.2	0.15	0.33	23.2

1/ Denotes zero flow or depth
2/ Did not take depth measurement at transect
3/ tr denotes a flow less than 0.14 m 3/s

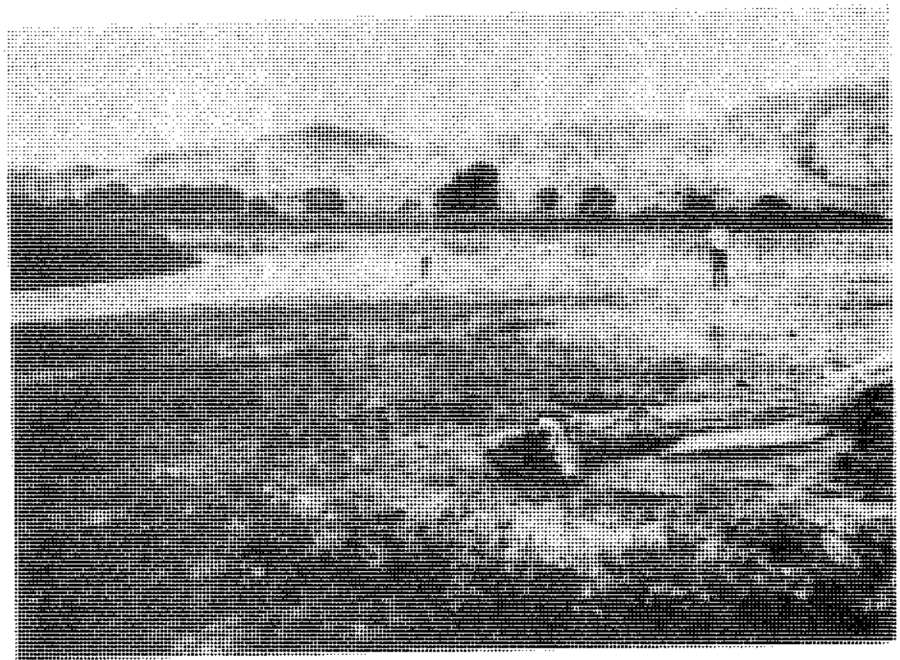

Figure 20. The influent flow of side channels (left) was an important factor maintaining both physical channel features and the fish communities utilizing this habitat.

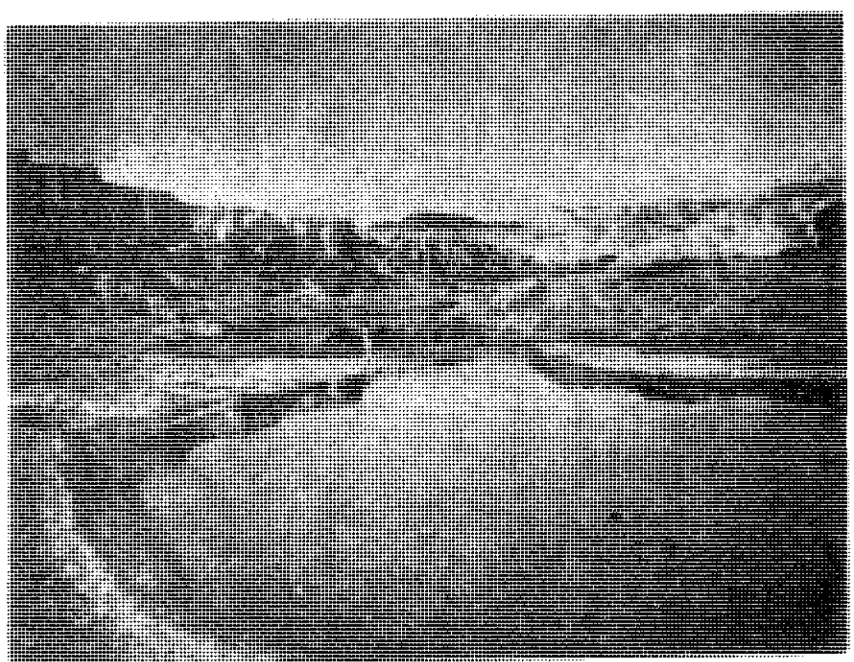

Figure 21. Example of a side channel with a nearly dewatered mid-section.

This illustrates that the shallower portions of the channel were more susceptible to dewatering and this dewatering occurred to a greater degree between the period when there was an inlet flow and when the inlet flow recently had ceased. In some cases where segments of shallow pool areas were completely dewatered, the loss of channel length was large. Dewatering of these shallower pool areas occurred in side channels 4, 9, 11 and 12 during low instream flows. It was noted at this time that many of the disconnected large pools (isolated from river) with moderate depths were warmer than the ambient river temperature. With the increase in water temperature of the pools, the dissolved oxygen probably declined to low levels. It is evident that a side channel must at least be connected at the outlet to allow for adequate circulation of the side channel water.

The channel width did not appear to change at the same rate as average depth. This was because most of the transects in the side channels had steep channel banks.

The 12 side channels were assessed in terms of suitability of the habitat for the fish fauna at declining instream flows. The criteria used were average depth, length of channel loss and depth of channel at outlet. An average depth of at least 0.2 m with maximum depths of 0.4-0.5 m was considered the minimum criteria required for adequate cover in the side channels. This criteria was based on fish sampling in these areas during 1979 and 1980. Table 12 is an evaluation of the side channels' suitability at the instream flow levels when they were surveyed. It was evident that at instream flows of 123.5 m 3/s (4360 cfs) in the Fort Benton gaged reach, serious losses of habitat had occurred and habitat conditions in two of the four side channels were inadequate. At 117.0 m 3/s (4130 cfs), habitat in three of the four side channels was considered inadequate. In the Virgelle gaged reach, only one of the three side channels was severely affected by the lower base flows. This side channel was disconnected from the river. Consequently, habitat conditions were inadequate when flow had reached 141.0 m 3/s. The other two side channels in this reach were in satisfactory condition at the low flow of 127.7 m 3/s gaged on September 25, 1980.

Four of the five side channels surveyed in the Robinson Bridge gaged reach were classified as inadequate at the lower instream flows of 159.7 m 3/s (5640 cfs) recorded September 7, 1980.

In summary, habitat conditions in 8 of the 12 monitored side channels were inadequate at the lower instream flows experienced in 1980.

The 12 side channels which were selected for monitoring in 1980 represented the various types found throughout the study area. Therefore, the effects of flow reductions on these 12 side channels exemplified the effects on the unmonitored side channels and backwaters. From this it was concluded that during the lower flow period when many of the monitored side channels were inadequate for rearing and shelter, so were most of the unmonitored side channels and backwaters. At this flow, the river's capabilities for rearing of important sport and commercial fish (i.e., sauger, buffalo, goldeye) and forage fish had been seriously reduced.

Fish Communities of the Side Channels

The monitored side channels were sampled to determine the utilization by forage fish and their capabilities for rearing fish. The 11 side channels could be

Table 12. A summary of habitat conditions in monitored side channels at declining instream flows, 1980.

Side Channel No.	Reach of River	Date	Missouri River gaged flow (m 3/s)	(cfs)	Condition of side channel habitat[1/]
1	Fort Benton	7/17	277.0	9780	Suitable
		8/20	172.2	6080	Suitable
		9/10	117.0	4130	Inadequate
2	Fort Benton	7/18	257.7	9100	Suitable
		8/25	130.6	4610	Suitable
		9/24	119.5	4220	Suitable
3	Fort Benton	7/19	218.1	7700	Suitable
		8/26	123.5	4360	Inadequate
		9/25	109.3	3860	Inadequate
4	Fort Benton	7/19	218.1	7700	Suitable
		8/26	123.5	4360	Inadequate
		9/25	109.3	3860	Inadequate
5	Virgelle	7/20	256.6	9060	Suitable
		8/27	154.7	5440	Suitable
		9/25	127.7	4510	Suitable
6	Virgelle	7/20	256.6	9060	Suitable
		8/27	154.7	5440	Suitable
		9/26	135.1	4770	Suitable
7	Virgelle	7/8	379.5	13400	Suitable
		7/25	254.0	8970	Suitable
		9/25	141.0	4980	Inadequate
8	Robinson Bridge	7/9	436.1	15400	Suitable
		7/27	268.8	9490	Suitable
		9/5	158.6	5600	Inadequate
9	Robinson Bridge	7/10	413.5	14600	Suitable
		7/28	262.5	9270	Suitable
		9/6	149.8	5290	Inadequate
10	Robinson Bridge	7/10	413.5	14600	Suitable
		7/28	262.5	9270	Suitable
		9/6	149.8	5290	Suitable
11	Robinson Bridge	7/12	439.0	15500	Suitable
		7/29	258.8	9140	Suitable
		9/7	159.7	5640	Inadequate
12	Robinson Bridge	7/13	385.2	13600	Suitable
		7/30	248.6	8780	Suitable
		9/7	159.7	5640	Inadequate

1/ Suitable rating = at or above the threshold point;
Inadequate rating = below the threshold point

separated into two different community types (Table 13) based on fish species associations. The major differences in fish communities were the abundance of suckers, fathead minnows and the occurrence of both YOY smallmouth and bigmouth buffalo in the upper side channels. In contrast, YOY sauger and goldeye were mostly found in the lower three side channels and the catch rates for the widely distributed common fish were reduced (Appendix Tables B and C). These differences in the fish communities were probably related to the physical characteristics of the side channels. Such a feature as an influent flow in the side channels during the period when YOY sauger are emerging from gravel bars and drifting down river is probably important for entry into the side channel. In contrast, lack of an influent flow when YOY buffalo emerge and move away from submerged vegetation would enable them to maintain themselves in the side channel.

Table 13. A simplified schematic assemblage of the common fish seined in the monitored side channels of the Missouri River during 1979-80. Species are listed according to numerical abundances.

Common fish sampled in side channels 1-8	Common fish sampled in side channels 9-12
Suckers[1/]	Flathead chub
Flathead chub	Western silvery minnow
Western silvery minnow	Emerald shiner
Fathead minnow	Suckers
Longnose dace	Longnose dace
Emerald shiner	Sauger
Smallmouth buffalo	Goldeye
Bigmouth buffalo	

1/- Comprised of shorthead redhorse, longnose and white suckers.

Seasonal utilization of these side channels was determined. Highwater conditions prevented seining of the side channels during June and early July. Circumstantial evidence (known hatching periods) would depict the onset for rearing of YOY fish to be about mid-June. For forage fish, utilization of side channels probably is initiated when adequate water levels in the side channels are reestablished. Most of the YOY fish did not continue to rear in these side channels, nor did most forage fish utilize the side channels during the autumn and presumably winter periods. Table 14 depicts species diversity and catch rates in the side channels as being the highest from mid-July through late August. By early September, substantial reductions of the fish communities were noted, both in diversity and catch rates. It was believed that a general emigration occurred by the forage and YOY fish to the more open waters of the main channel. This change in utilization happened before flows in the river, and consequently the side channels, were at their lower levels. Four of the 12 side channels with adequate water levels during late September exhibited little utilization by forage and YOY fish, indicating that

Table 14. The variety and abundance of YOY and forage fish seined in the 11 monitored side channels, Missouri River, 1980.

Side Channel No.	Date	Total No. of Species	Average Catch Rate	Range	Number of Hauls
2	7/18	7	86	(39-210)	4
	8/8	7	54	(22-108)	4
	8/25	6	17	(2- 33)	3
	9/20	6	10	(1- 16)	3
3	7/18	7	107	(37-248)	4
	8/8	8	54	(30- 71)	3
	8/25	11	140	(105-197)	3
	9/24	7	25	(23- 26)	2
4	7/18	6	35	(8- 94)	5
	8/9	9	102	(62-154)	3
	8/26	6	76	-	1
	9/24	4	22	(11- 33)	3
5	7/18	7	28	(3- 64)	7
	8/9	5	79	(66-101)	3
	8/26	8	46	(16-104)	5
	9/24	4	23	(2- 80)	4
6	7/19	5	29	(18 -35)	3
	8/10	8	166	(16-354)	5
	8/27	8	189	(24-396)	6
	9/26	5	52	(4-190)	4
9	7/10	6	9	(2- 15)	5
	7/28	7	88	(29-200)	4
	9/6	3	5	(1- 9)	2
11	7/12	6	80	(8-316)	5
	7/29	6	50	(14- 89)	4
	9/8	4	6	(1- 11)	2
12	7/13	7	41	(7-124)	6
	7/30	6	26	(5- 49)	5
	9/8	4	6	(1- 13)	3

Note: Only 8 of the 12 side channels were routinely sampled for fish.

a reason other than water level decreases in the side channels was responsible for this decline. Schmulbach (1974), evaluating the off-channel areas of the Missouri River below Gavin's Point Dam, also noticed a decline of utilization by forage fish in these areas during early autumn. In summary, it can be concluded that utilization of side channels by forage and YOY fish occurs from mid-June through August.

During 1980, the summer flows in the Missouri River were near normal, and there were suitable water levels in the side channels for rearing capabilities and forage fish production throughout the summer. However, a few conditions existed where segments of side channels were nearly isolated or severely dewatered. In those situations, fish species were sampled. The reaction of the fish communities to dewatering of some side channel segments was a retreat to deeper waters of the connected side channel. Therefore, in these cases it was apparent that the fish communities responded to the decreases of water levels in the side channels.

Instream Flow Recommendations for Side Channels

Side channels are important as rearing areas for YOY goldeye, buffalo, sauger and various forage fish species from early July through August. Goldeye and buffalo are most important commercial fish in Fort Peck Reservoir (J. Liebelt, MDFWP, pers. com.). Sauger are the most abundant sport fish found in the study area, and comprise a large portion of the sport fishery (Berg 1981). Forage fish (chiefly the flathead chub and western silvery minnow) are one of the principal food items consumed by the sauger. Instream flows are recommended to maintain suitable conditions in side channels for maintaining rearing capabilities and forage fish production.

The relationship between the monitored side channels' habitat condition and mainstem flows indicated that flows of 127.4 (4500), 152.9 (5400) and 164.2 m^3/s (5800 cfs) at Fort Benton, Virgelle and Robinson Bridge gaged sections, respectively, are the minimum flows required to maintain suitable conditions in these side channels for rearing and forage fish production (Table 15). The mainstem flow, and consequently channel dimensions, increases substantially between reaches; therefore, one recommended minimum flow for the entire study section would not be adequate. The recommended increases in flow correspond to the normal water accretion as reported by USGS surface water runoff monitoring (Missouri River Basin Commission 1978). Since the side channel habitat is used for rearing and forage fish production from early June through August, the recommended flows should be maintained during this period.

Food Habits

Shovelnose Sturgeon

Food habits analyses were completed for 68 adult shovelnose sturgeon collected by electrofishing in the Loma Ferry and Coal Banks Landing study sections. The sturgeon were collected during the autumn of 1978 and spring, summer and autumn of 1979. They ranged in weight from 1200 to 4680 grams.

Results of the shovelnose sturgeon food habits analyses are presented in Table 16. The diet was basically comprised of a wide variety of aquatic insects. Twenty-three subordinal taxa of aquatic insects were observed in the diet.

Table 15. The condition of the monitored side channels habitat at the recommended minimum flow and their threshold points.

Side Channel Number	Threshold Flow	Condition of side channel habitat at recommended minimum flow
	Fort Benton Gaged Reach Recommended minimum flow = 127.5 m^3/s (4500 cfs)	
	(m^3/s) (cfs)	
1	118.9 ← Approx. → 4200	Suitable
2	118.9 ← Less than → 4200	Suitable
3	127.4 ← Approx. → 4500	Suitable
4	141.6 ← Approx. → 5000	Inadequate
	Virgelle Gaged Reach Recommended minimum flow = 152.9 m^3/s (5400 cfs)	
	(m^3/s) (cfs)	
5	127.7 ← Less than → 4510	Suitable
6	107.6 ← Approx. → 3800	Suitable
7	(141.0-254.0) ← Between → (4980-8970)	Inadequate
	Fred Robinson Bridge Reach Recommended minimum flow - 164.3 m^3/s (5800 cfs)	
	(m^3/s) (cfs)	
8	(158.6-268.8) ← Between → (5600-9490)	Suitable
9	(149.8-262.5) ← Between → (5290-9270)	Suitable
10	107.6 ← Approx. → 3800	Suitable
11	(159.7-258.8) ← Between → (5640-9140)	Suitable
12	164.3 ← Approx. → 5800	Suitable

Table 16. Percentages of occurrence (O), average total numbers (N) and volumes (vol.) and the relative importance values (RI) of the food items found in the diets of adult shovelnose sturgeon in the Missouri River during 1978-79.

	1978 Autumn				1979 Spring				1979 Summer				1979 Autumn			
	%O	%N	%Vol	RI	%O	%N	%Vol	RI	%O	%N	%Vol	RI	%O	%N	%Vol	RI
Mayfly																
Rhithrogena	65	2	1	7.4	73	8	9	8.4	100	9	15	11.0	29	1	tr	4.1
Heptagenia	70	1	1	8.0	45	1	1	4.4	20	tr	tr	1.8	43	1	tr	6.1
Baetis	53	2	1	6.1	73	18	6	9.0	100	13	5	10.5	43	tr	tr	5.9
Tricorythodes	33	tr	tr	3.6	0	-	-	-	50	tr	tr	4.4	29	tr	tr	4.0
Ephron	10	tr	tr	1.1	0	-	-	-	80	6	8	8.3	0	-	-	-
Ephemera	0	-	-	-	0	-	-	-	0	-	-	-	14	tr	tr	1.9
Traverella	30	1	tr	3.4	0	-	-	-	100	29	43	15.3	29	1	tr	4.1
Ephemerella	23	tr	tr	2.5	100	16	26	13.2	30	tr	tr	2.7	14	tr	tr	1.9
				32.1				35.0				54.0				28.0
Stonefly																
Isogenus	38	1	2	4.5	45	1	1	4.4	30	tr	1	2.8	57	7	13	10.6
Isoperla	5	tr	tr	0.5	64	2	1	6.2	10	tr	tr	0.9	0	-	-	-
Acroneuria	23	1	3	3.0	27	tr	1	2.6	10	tr	tr	0.9	0	-	-	-
Claassenia	5	tr	tr	0.5	9	tr	1	0.9	0	-	-	-	0	-	-	-
Unidentified	13	tr	tr	1.4	18	tr	tr	1.7	60	tr	tr	5.3	14	tr	tr	1.9
				9.9				15.8				9.9				12.5
Caddisfly																
Hydropsychidae*	100	73	87	28.4	100	36	52	17.5	100	18	22	12.4	100	74	81	35.1
Oecetis	45	tr	tr	4.9	73	tr	tr	6.8	10	tr	tr	0.9	14	tr	tr	1.9
Brachycentrus	68	1	1	7.7	45	tr	tr	4.2	20	tr	tr	1.8	29	5	4	5.2
Glossosoma	0	-	-	-	0	-	-	-	10	tr	tr	0.9	0	-	-	-
Hydroptila	5	tr	tr	0.5	0	-	-	-	0	-	-	-	0	-	-	-
				41.5				28.5				16.0				42.2
Truefly																
Chironomidae (midge)	95	17	2	12.5	91	10	tr	9.4	100	12	3	10.2	86	8	tr	12.9
Simulium	18	1	tr	2.1	91	6	tr	9.0	90	9	3	9.1	29	1	tr	4.1
Tipula	3	tr	tr	0.3	18	tr	tr	1.7	0	-	-	-	0	-	-	-
Empididae	0	-	-	-	9	tr	tr	0.8	0	-	-	-	0	-	-	-
				14.9				20.9				19.3				17.0

Table 16 continued.

	1978 Autumn				1979 Spring				1979 Summer				1979 Autumn			
	0%	%N	%Vol	RI	%0	%N	%Vol	RI	%0	%N	%Vol	RI	%0	%N	%Vol	RI
Others																
Elmidae	3	tr	tr	0.3	0	-	-	-	0	-	-	-	0	-	-	-
Coleoptera	8	tr	tr	0.9	0	-	-	-	0	-	-	-	0	-	-	-
Corixidae	3	tr	tr	0.3	0	-	-	-	10	tr	tr	0.9	0	-	-	-
Fish eggs	0	-	-	-	9	-	tr	-	0	-	-	-	0	-	-	-
Fish tissue	45	-	tr	-	18	-	tr	-	10	-	tr	-	14	-	2	tr
				1.5				0.0				0.9				tr

*Includes both *Cheumatopsyche* and *Hydropsyche* genera.

- Denotes zero values
tr denotes values less than 0.5%

The relative importance (RI) of mayflies was high during all seasons. Mayflies were the most important order in the diet during the spring and summer, with an average RI of 44 percent. Eight subordinal taxa of mayflies were observed.

The stonefly order, represented by at least four subordinal taxa, exhibited an average seasonal RI of 12 percent, which was considered a moderate representation in the diets. The caddisfly order was also heavily utilized as food by shovelnose sturgeon. Represented by six subordinal taxa, caddisflies had an average RI of 29 percent for all seasons combined. Caddisflies were the most important order in the diet in the autumn, with an average RI of 42 percent. The volumetric percentages of caddisflies in the diet were always high, averaging 63 percent for all seasons combined. Mayflies, by comparison, averaged 29 percent of the volume in the diet for all seasons combined.

The trueflies, represented by at least four subordinal taxa, were the third most important food group in the diet of shovelnose sturgeon. Their average seasonal RI was 19 percent. Miscellaneous taxa were of little significance in the diets of shovelnose sturgeon, but it was interesting that fish tissue, as evident by skeletal features, was consumed.

Seasonal comparisons of the relative importance (RI) of six major food groups utilized by adult shovelnose sturgeon are shown in Figure 22. It is particularly interesting to compare the relative seasonal importance of the mayfly and caddisfly orders. During spring, mayflies were only slightly more important than caddisflies in the shovelnose diet. However, during the summer months, shovelnose fed much more heavily on mayflies than caddisflies. The RI of mayflies in the summer diet was 54 percent. Two mayfly taxa, *Rhithrogena* and *Traverella,* alone had an RI of 26 percent. In the autumn, the RI of the mayfly taxa was substantially reduced. Hydropsychidae, a caddisfly taxa, clearly dominated in the autumn diet of shovelnose sturgeon with an RI of 32 percent.

The seasonal diets of shovelnose sturgeon have been reported by other investigators. Walburg et al. (1971) and Modde and Schmulbach (1977) found the shovelnose opportunistic feeders, and in the Yellowstone River, Elser et al. (1977) reported nonselective foraging for *Traverella* during the summer followed by a resumption of feeding on hydropsychids in the autumn. No selectivity analysis was conducted for this investigation; however, based on the distribution and composition of the aquatic insect fauna as described by Berg (1981), it appears adult shovelnose sturgeon forage nonselectively on insects in swift current habitats in this study area. Furthermore, the seasonal diets of shovelnose sturgeon in the middle Missouri River correspond closely to the emergence of several major food taxa. For example, *Rhithrogena* and *Traverella* emerge mainly during the summer, and they are prominent in the summer diet of shovelnose sturgeon. *Ephemerella* and most of the species of Hydropsychidae had previously emerged during the spring and were unavailable as a food item during the summer.

Newell (1976) reported that the mayflies *Rhithrogena* and *Traverella* are insects which inhabit swift current areas. The four remaining taxa shown in Figure 19 frequent a wide array of habitats, also including the swift current areas. Berg (1981) indicated *Heptagenia* was a common insect in the study area. However, this insect was not an important food item in the diet of shovelnose sturgeon. Newell (1976) reported the velocity requirement for *Heptagenia* is substantially less than that of *Rhithrogenia* and *Traverella*. This observation provides further evidence to support the idea that shovelnose sturgeon feed nonselectively in swift current areas in the middle Missouri River.

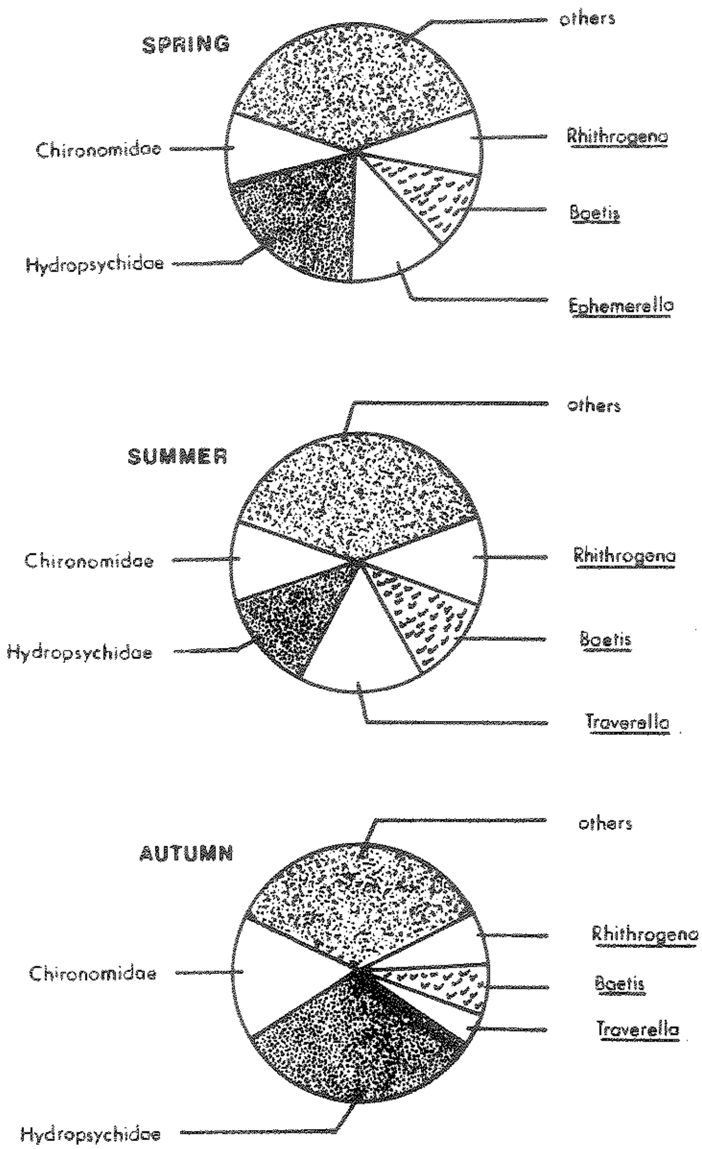

Figure 22. Seasonal comparisons of relative importance values (RI) of the six major food groups utilized by adult shovelnose sturgeon in the Loma Ferry and Coal Banks Landing sections of the middle Missouri River, 1978-79.

Fish growth rates follow a seasonal pattern in response to temperature changes and food availability. For a warm water species like the shovelnose, the summer period is probably the season when maximum utilization of food organisms occurs. Helms (1974) described the shovelnose sturgeon of the Mississippi River as having a low body condition value from February to mid-June, increasing to a peak value in early September, thereafter declining to the low winter levels. Brett et al. (1969) reported a relationship between growth of sockeye salmon with that of varying temperatures and ration size. They concluded there was not only an optimal temperature for maximum utilization of food organisms by a fish, but also, at higher temperatures (which could be optimal temperatures for that species' growth) the requirements for a given quantity of food were increased.

With these reported findings in mind, it is believed the summer diet is the most critical diet for the maintenance of the high quality shovelnose sturgeon fishery which exists in the middle Missouri River. Since the two mayflies *Rhithrogena* and *Traverella* together comprised 26 and 58 percent of the total RI and volume, respectively, in the summer diets, it is apparent that these two taxa are very important food sources for shovelnose sturgeon in this area. It should also be noted that these two taxa exhibit relatively little tolerance to alterations of physical and chemical characteristics of a river. It is essential that adequate flow be maintained in riffle areas so that *Rhithrogena* and *Traverella* can continue to provide the significant food base for shovelnose sturgeon as well as other species.

Sauger

Food habit analyses were completed for sauger sampled during the months of August to November 1980. The sauger ranged in length from 160-678 mm and were representative of the size structure normally found in the river (Appendix Table E). Of the 638 fish pumped for stomach contents, 185 yielded identifiable contents which consisted entirely of fish matter. A minimum of 12 fish species was found in the sauger diet, although 91 percent of the individual sauger stomachs contained single item contents (Table 17).

The principal food items for sauger were stonecats, "shoal" minnows (flathead chub, western silvery minnows, emerald shiner and fathead minnows), longnose dace and sculpins, having an overall average relative importance value of 26.8, 24.0, 23.2 and 11.0, respectively. When examined for each particular reach of river, differences in the diet were evident. For the relatively swift, cool water reach of river consisting of the Morony Dam and Carter Ferry sections, longnose dace, mottled sculpins and minnows comprised the major portion of the sauger's diet with RI values of 28.3, 26.0 and 22.3 percent, respectively. In the warmer, lower reach of the river from the Coal Banks Landing section downstream, the stonecat constituted the major portion of the diet with an RI value of 29.4 percent, followed by sicklefin/sturgeon chubs, channel catfish and longnose dace with RI values of 18.7, 13.0 and 11.7, respectively.

The diet of the piscivorous sauger was apparently influenced to a great degree by availability of food items. For example, in the upper reach, mottled sculpins were abundant, but rare in downstream areas. This distribution of sculpins was distinctly reflected in the diet of the sauger. Similarly, availability limited the importance of YOY channel catfish, sicklefin and sturgeon chubs and stonecats to the lower reach of river. Even though fishes associated with swift current areas

Table 17. Percentages of occurrences (O), average total numbers (N) and volumes (Vol) and relative importance values (RI) of the food items found in the diets of sauger in the middle Missouri River during late summer and autumn 1980.

	Morony Dam & Carter Ferry Sections				Ft. Benton & Loma Ferry Sections a/				Loma Ferry & Coal Banks Sections b/				Sections Below Coal Banks			
	%O	%N	%Vol	RI	%O	%N	%Vol	RI	%O	%N	%Vol	RI	%O	%N	%Vol	RI
Flathead chub	3	2	3	2.6	13	7	11	9.7	6	18	2	8.4	5	11	8	8.0
Sicklefin or Sturgeon chub		-	-	-	-	-	-	-	-	-	-	-	16	21	19	18.7
Emerald shiner	-	-	-	-	2	3	2	2.2	-	-	-	-	-	-	-	-
Western silvery minnow	5	3	3	3.6	15	21	30	20.7	13	9	6	9.1	5	4	3	4.0
Fathead minnow	-	-	-	-	-	-	-	-	3	2	1	1.9	-	-	-	-
Unidentified minnow	23	17	9	16.1	6	4	2	3.8	10	7	6	7.5	5	4	1	3.3
Longnose dace	30	46	10	28.3	47	50	6	35.4	23	27	3	17.2	21	11	3	11.7
Unidentified sucker	1	2	4	2.3	-	-	-	-	-	-	-	-	-	-	-	-
Channel catfish c/	2	3	1	2.0	-	-	-	-	3	5	tr e/	2.6	10	25	4	13.0
Stonecat	8	6	31	14.8	13	9	40	19.4	32	23	79	43.5	21	14	53	29.4
Sauger c/	- d/	-	-	-	2	1	2	1.6	-	-	-	-	5	4	6	5.0
Sculpin	25	16	38	26.0	11	5	7	7.2	13	4	1	5.8	10	7	3	6.7
Unidentified				4.3	-	-	-	-	6	5	1	3.9	-	-	-	-

a - Loma Ferry Section above the confluence of the Marias River.
b - Loma Ferry Section below the confluence of the Marias River.
c - YOY fish.
d - Denotes zero values.
e - Values less than 0.5 %.

comprised much of the sauger's diet, a substantial portion of the ration was comprised of minnows which prefer the slower, more protected areas (shoals) of the river.

When comparing the size of sauger to the type of food constituting their diet, it was noteworthy that sauger less than 250 mm selected the small-sized longnose dace, sicklefin and sturgeon chubs and YOY channel catfish which all prefer swift current. This was also the area where most of the juvenile sauger were sampled in the autumn. The other size groups did not appear to exhibit such selection. Flathead chub, longnose dace and YOY channel catfish comprised the major portion of the sauger's diet in the Yellowstone River (Elser et al. 1977). Also, the stonecat comprised a substantial portion of the diet in terms of volume, but they were not consumed as frequently as other food items. Basically, the sauger diet described by Elser et al. for the Yellowstone River resembles the middle Missouri River sauger's diet, with the exception of the stonecat being more prominent and young channel catfish being less important in the Missouri. It is evident that sauger feed extensively in the riffle areas where many forage fish are found. The importance of "shoal minnow" types in their diets also verifies the significance of side channels and other peripheral habitat areas as essential food producing areas for sauger.

Young-of-the-Year Fish

Limited studies were made during 1979 on the food habits of young-of-the-year (YOY) sauger, goldeye and freshwater drum. Results of diet analyses for these species are shown in Table 18.

Findings indicated that the diet of YOY sauger in the middle Missouri River was chiefly piscivorous. Priegel (1969) reported that YOY sauger less than 50 mm in size fed chiefly on cladocerans, and those larger than 50 mm preferred YOY troutperch, freshwater drum and white bass. However, when the YOY forage fish were not abundant or available, the YOY sauger larger than 50 mm continued with the plankton diet.

In the earlier discussion concerning larval fish, it was indicated that the peak of abundance of larval fish in the upper study sections occurred in late May and early June. A later peak in early July was observed in the lower river. It was also found that there was a selection by YOY sauger for rearing sites in the lower river. Growth rates for YOY sauger sampled during 1979 were highest during July. An adequate food supply is necessary during this period. This requirement is probably best fulfilled at the lower sites where larval fish are still available. Walburg (1976) reported the greatest growth increases occurred during July, and further comparisons between years indicated the greatest growth was realized in years when forage fish were available by mid-July and then utilized by YOY sauger.

The diets of YOY goldeye were the most diversified of the three fish species investigated. *Baetis*, corixids, and cladocerans comprised 69 percent of the diet during late July. In mid-October, Hymenoptera, corixids and cladocerans accounted for 71 percent of the diet. Food habits of the YOY goldeye appear to be correlated with the backwater and side channel pool habitats which they prefer as rearing areas. Since the rearing habitat preferences of YOY goldeye and sauger overlap to some extent, the invertebrate food items available to goldeye are also available to sauger. In spite of this abundant invertebrate food supply, the YOY sauger selected a diet comprised primarily of YOY forage fish.

Table 18. Diets, expressed as percent composition by numbers, of young-of-the-year fish seined in the middle Missouri River during the summer and autumn 1979.

Food Items	Sauger Jul 26	Sauger Oct 15	Goldeye Jul 26	Goldeye Oct 15	Freshwater Drum Aug 10
Ametropus			1		
Baetis			20	11	1
Hydropsychidae			1	14	
Culicidae			1		
Chironomidae			6	5	95
Corixidae			22	17	
Terrestrial			11		
Mayfly					
Antfly				40	
Midge				6	
Cladocera			17		4
Fish larvae	100		8		
Minnows		100			
Unidentified			12	5	
No. Sampled	N=17	N=6	N=25	N=14	N=10
length range (mm)	39-97	128-170	30-67	75-120	37-70

Analysis of the diets of a number of YOY freshwater drum sampled near the headwaters of Fort Peck Reservoir in mid-August 1979 revealed a strong preference for chironomids, which comprised 95 percent of the diet. A few cladocerans were also consumed.

Tributary Resident Fish Populations

The two major tributaries of the middle Missouri River, the Marias/Teton and Judith rivers, have an influence upon the physical, chemical and biological characteristics of the mainstem. The tributaries each augment the flow, increase channel depth and width and, during spring, add sediment to the Missouri. Berg (1981) reported significant changes in the fish communities below these major tributaries, especially below the Marias. Berg also documented substantial spawning migrations of several important fish species from the Missouri into these tributaries. The importance of major tributary streams to the mainstem of a larger river has also been reported by Penkal (1981), Elser et al. (1977) and Rehwinkel et al. (1976).

Little is known about the resident fish populations in these tributaries. This phase of the study was conducted to determine species composition, longitudinal distribution, relative abundance and size composition of the resident fish populations in the tributaries.

A total of 24, 21 and 15 fish species was observed in the Marias, Teton and Judith rivers, respectively, during electrofishing and seining surveys conducted in 1979 (Table 19). Most of these species are also found on the mainstem between Morony Dam and Fort Peck Reservoir (Berg 1981).

Table 19. A list of fish species sampled by electrofishing and seining in the three major tributaries of the middle Missouri River during August-October 1979.

	Marias	Teton	Judith
Goldeye	*	*	*
Mountain whitefish	*	*	*
Rainbow trout	*		
Brown trout	*		
Carp	*	*	*
Sturgeon chub		*	
Flathead chub	*	*	*
Lake chub	*	*	
Emerald shiner		*	
Brassy minnow	*	*	
Plains minnow	*	*	
Western silvery minnow	*	*	*
Fathead minnow	*		
Longnose dace	*	*	*
River carpsucker	*	*	
Blue sucker	*		
Smallmouth buffalo	*		
Shorthead redhorse sucker	*	*	*
Longnose sucker	*	*	*
White sucker	*	*	*
Mountain sucker	*	*	*
Channel catfish	*	*	*
Stonecat	*	*	*
Burbot	*	*	*
Sauger	*	*	*
Walleye	*		
Freshwater drum		*	
Mottled sculpin			*

Marias River

The Marias River is the largest tributary in the study area. Resident fish populations were surveyed in a 125-km reach between Tiber Dam and the confluence with the Teton River near Loma, Montana. The Marias River in this reach has a narrow floodplain confined by steep badlands, and very little off-channel development is evident. Stream gradient averages 0.6 m/km. Sand, gravel and small cobble are the predominant substrate materials.

At the head of the study reach is Tiber Dam, which impounds a reservoir with a storage capacity of 13,979 cubic hectometers (11,337,000 acre-ft). The reservoir was completed in 1956 to provide flood control, irrigation, recreational uses, municipal water supply and, possibly, hydroelectric power generation. Its actual uses, however, have been principally limited to flood control, recreation and municipal water supply.

The Marias River's flow and temperature regime are completely controlled by the operation of the dam. In general, spring runoff in the Marias River below Tiber Dam has been reduced since the dam was constructed, while flows during the fall and winter have been augmented (Missouri River Basin Commission 1978). Stober (1962) reported that the effect of cold water releases from Tiber Dam on the temperature regime of the Marias River were manifested as thermal constancy along with reduced summer water temperatures. He reported these effects were evident at least 38 kilometers below the dam.

Water quality of the Marias River in this reach is typical of large prairie rivers. Conductivity usually ranges from 500-600 micromhos/cm^2 and bicarbonate alkalinity ranges from 150-200 mg/l (Garvin and Botz 1975). Suspended sediments carried by the river are greatly reduced because of Tiber Reservoir (Stober 1962).

Five study sections were established between Tiber Dam and the mouth of the Teton River (Figure 1). The Tiber Dam study section, approximately 30 km in length, had a wide floodplain through which the river meandered. This section contained large mats of aquatic vegetation, primarily *Potamogeton* and *Chara*. The High Rock Canyon study section was 21 km long, and it had a narrower floodplain confined by precipitous cliffs. The Brinkman study section was also 21 km long. In this section the canyon opened, and the river was not as confined. The Badlands study section was 18 km long and began at the only major rapids of the entire reach. This section was surrounded by rugged badlands and breaks. Topography generally leveled off again through the Collins study section, which was 32 km in length and extended to the mouth of the Teton River.

Total catch, average size, size range and catch per unit effort for individual fish species sampled by electrofishing in each of the five study sections are shown in Tables 20 through 24. The Marias River, in a 30-km section immediately below Tiber Dam, supports a significant salmonid fishery. Mountain whitefish are the predominant game fish in this section, and a number of trophy-size specimens larger than 1.8 kg (4 lbs) were sampled. The average size of mountain whitefish sampled in this section was significantly larger than in most other Montana streams. Rainbow and brown trout also attained large sizes in the Marias River below Tiber Dam. A few mountain whitefish were found throughout the entire length of the Marias River between Tiber Dam and the mouth of the Teton River. However, catch-per-unit

Table 20. Catch statistics of fish sampled by electrofishing in the Tiber Dam section of the Marias River during August and October 1979.

Species	Number Sampled	Average Length (mm)	Length Range (mm)	Average Weight (gm)	Weight Range (gm)	Catch per unit effort
Goldeye	13	330	320-350	375	300- 430	3.7
Mountain whitefish	236	360	110-500	695	20-1840	26.7
Rainbow trout	13	338	80-530	899	10-2470	1.5
Brown trout	2	401	360-440	994	830-1160	0.2
Carp	36	485	420-650	1540	930-4130	10.3
Longnose dace	4	81	60-100	14	5- 20	2.9
River carpsucker	9	445	420- 510	1076	930-1570	2.6
Blue sucker	1	660	-	2860	-	0.1
Smallmouth buffalo	3	605	570-650	3314	2630-3860	0.3
Shorthead redhorse	6	448	380-490	1058	550-1520	5.7
Longnose sucker	34	371	130-490	785	30-1450	9.7
White sucker	5	395	310-470	763	280-1140	4.0
Burbot	12	427	170-770	654	40-2910	1.4
Sauger	36	377	280-510	427	150-1070	4.1

Table 21. Catch statistics of fish sampled by electrofishing in the High Rock Canyon section of the Marias River during October 1979.

Species	Number Sampled	Average Length (mm)	Length Range (mm)	Average Weight (gm)	Weight Range (gm)	Catch per unit effort
Mountain whitefish	27	266	100-420	268	20- 770	9.8
Carp	12	472	420-530	1466	960-1990	6.9
River carpsucker	1	390	-	670	-	0.6
Shorthead redhorse	16	452	390-480	1058	640-1400	9.1
Longnose sucker	13	417	140-480	876	30-1130	7.4
White sucker	2	318	250-380	418	190- 640	1.1
Sauger	17	384	310-560	440	230- 840	6.2

Table 22. Catch statistics of fish sampled by electrofishing in the Brinkman section of the Marias River during October 1979.

Species	Number Sampled	Average Length (mm)	Length Range (mm)	Average Weight (gm)	Weight Range (gm)	Catch per unit effort
Goldeye	*P					
Mountain whitefish	15	315	140-420	359	40- 830	7.5
Brown trout	2	335	280-390	499	310- 680	1.0
Carp	2	451	440-460	1235	1200-1260	4.0
River carpsucker	*P					
Shorthead redhorse	3	446	420-480	940	840-1060	6.0
Longnose sucker	5	447	410-500	990	710-1590	10.0
Burbot	*P					
Sauger	11	363	320-430	363	260- 600	5.5

*P - Denotes this species was observed but not sampled.

Table 23. Catch statistics of fish sampled by electrofishing in the Badlands section of the Marias River during October 1979.

Species	Number Sampled	Average Length (mm)	Length Range (mm)	Average Weight (gm)	Weight Range (gm)	Catch per unit effort
Goldeye	1	380	-	420	-	1.0
Mountain whitefish	19	276	160-330	232	20- 420	6.3
Carp	18	472	420-510	1326	910-1680	18.0
River carpsucker	2	425	420-430	1000	960-1040	2.0
Shorthead redhorse	13	434	250-490	908	130-1230	13.0
Longnose sucker	31	413	360-470	740	500-1080	31.0
White sucker	3	361	270-420	590	220- 880	3.0
Channel catfish	1	690	-	5270	-	0.3
Burbot	1	460	-	530	-	0.3
Sauger	63	370	140-530	368	20-1060	21.0

Table 24. Catch statistics of fish sampled by electrofishing in the Collins section of the Marias River during October 1979.

Species	Number Sampled	Average Length (mm)	Length Range (mm)	Average Weight (gm)	Weight Range (gm)	Catch per unit effort
Goldeye	6	325	310-350	291	240- 340	3.0
Mountain whitefish	24	279	150-360	250	20- 540	5.7
Brown trout	2	351	300-400	508	290- 720	0.5
Carp	3	471	460-480	1402	1210-1660	1.5
Shorthead redhorse	3	216	120-400	277	10-810	1.5
Longnose sucker	20	298	200-420	286	270-780	10.0
White sucker	2	304	240-360	341	160-520	1.0
Mountain sucker	1	140	-	30	-	0.5
Stonecat	1	180	-	20	-	0.5
Burbot	1	320	-	170	-	0.2
Sauger	137	326	150-530	286	20-1230	32.2
Walleye	1	430	-	700	-	0.2

effort for this species was substantially reduced downstream from the Tiber Dam study section. Rainbow trout were very ephemeral in their longitudinal distribution, being confined exclusively to the Tiber Dam section. A few YOY rainbow trout and many YOY mountain whitefish were found in the surveys, indicating that successful natural reproduction of these species occurs in the Marias River below Tiber Dam.

The abundance of sauger in the Marias River increased gradually from Tiber Dam to the mouth of the Teton River. Sauger catch increased from 4.1 fish per electrofishing hour in the Tiber Dam section to 32.2 fish per hour in the Collins section. A number of YOY sauger were collected in the Badlands and Collins study sections, indicating that spawning and rearing of this species occurs in the lower Marias. Sauger are the most common game fish below Tiber Dam, and comprise the bulk of the sport fishery.

Other common game fish found in the Marias River between Tiber Dam and the mouth of the Teton River include burbot, walleye, northern pike and channel catfish. These fish are known to permanently reside in this reach. The scarcity of northern pike, channel catfish and burbot in the electrofishing sample is partly due to the poor response of these species to electrofishing. Posewitz (1962), utilizing frame traps as a sampling technique, found substantial populations of sauger, burbot and channel catfish throughout the Marias River below Tiber Dam. Berg (1981) reported significant annual spawning migrations of several fish species from the Missouri River into the lower Marias. The most important migrant species included sauger, shovelnose sturgeon, blue suckers and smallmouth and bigmouth buffalo.

Teton River

The Teton River is the largest tributary of the Marias River. It enters the Marias just 1.5 km above its confluence with the Missouri near Loma, Montana. Resident fish populations were surveyed in a 123-km reach of the lower Teton River from the Shannon bridge to the confluence with the Marias River. The Teton River in this reach has a fairly well developed floodplain which is confined to some extent by steep hills. The predominant stream substrate is small cobble heavily laden with silt and sand.

Five irrigation reservoirs with a combined storage capacity of 134.684 cubic hectometers (106,800 acre ft) influence the natural flow regime of the Teton River. During the irrigation season, it is not uncommon for several sections of the lower Teton River to be dewatered to the extent that only larger pools remain.

Water quality data indicate that total dissolved solids in the Teton River are greater than in the Marias River (Garvin and Botz 1975). This is due primarily to increased amounts of magnesium, sodium and, especially, sulfate ions. Conductivity of the lower Teton River usually ranges from 700-800 micromhos/cm^2, and bicarbonate alkalinity ranges from 200-300 mg/l.

Two study sections were established on the Teton River (Figure 1). The Bootlegger study section was 10 km in length, and it had a well developed floodplain. Most of the river channel through this reach was deep and meandering, with few riffles. Vegetative bank cover was extensive. The Wood study section was 39 km long. This section exhibited more youthful stream features. Channel depth and meandering were reduced, and riffles were more common than in the Bootlegger section.

Total catch, average size, size range and catch per unit effort for individual fish species sampled in each of the two study sections on the Teton River are shown in Tables 25 and 26. Sauger was the most common game fish found in both study sections. The sauger were large, averaging 400 mm and 535 g (15.7 in and 1.17 lb) in length and weight, respectively. No YOY sauger were found in either study section, indicating that the large sauger are probably seasonal migrants. The desirability of the lower Teton River for sauger is undoubtedly related in part to the abundant forage fish food base found in the river. Minimum flows in the lower Teton River which would enable the sauger to reside as year-round residents would be desirable.

Other game fish sampled in the Teton River study sections included mountain whitefish, channel catfish and burbot. The low catches per unit effort for channel catfish and burbot are related in part to these species' poor response to electrofishing. A YOY channel catfish was collected in the Bootlegger study section, indicating that some reproduction and rearing of channel catfish occurs in the Teton River.

Common nongame fish sampled in the Teton River included carp, goldeye and several varieties of suckers. Flathead chubs, western silvery minnows, longnose dace and stonecats were the most common forage fish. Berg (1981) observed migrant use of the lower Teton River by sauger, channel catfish and blue suckers.

Table 25. Catch statistics of the fish sampled by electrofishing in the Bootlegger section of the Teton River during September and October 1979.

Species	Number Sampled	Average Length (mm)	Length Range (mm)	Average Weight (gm)	Weight Range (gm)	Catch per unit effort
Goldeye	35	327	300-370	272	190- 380	4.9
Carp	8	489	450-520	1430	1130-1870	1.1
Flathead chub	195	99	70-140	20	10- 20	-
Lake chub	1	80	-	10	-	-
Brassy minnow	2	-	-	-	-	-
Plains minnow	1	-	-	-	-	-
Western silvery minnow	75	136	130-150	20	20- 30	-
Longnose dace	19	-	-	-	-	-
River carpsucker	1	460	-	1050	-	0.1
Shorthead redhorse	31	266	60-360	200	10- 360	4.4
Longnose sucker	26	236	70-340	160	10- 380	3.7
White sucker	53	240	130-370	190	10- 540	7.5
Mountain sucker	39	113	70-220	20	10- 40	5.5
Channel catfish	1	50	-	10	-	0.1
Stonecat	4	119	70-150	20	10- 40	0.6
Burbot	1	530	-	800	-	0.1
Sauger	25	406	340-510	550	270-1080	3.5

Table 26. Catch statistics of fish sampled by electrofishing in the Wood section of the Teton River during September 1979.

Species	Number Sampled	Average Length (mm)	Length Range (mm)	Average Weight (gm)	Weight Range (gm)	Catch per unit effort
Goldeye	5	340	320-370	341	260- 480	0.5
Mountain whitefish	1	160	-	20	-	0.1
Carp	24	483	100-640	1390	20-2210	2.6
Flathead chub	276	96	40-250	20	10- 140	-
Western silvery minnow	5	106	90-130	20	10- 20	-
Longnose dace	55	57	40- 80	10	10- 20	-
River carpsucker	7	432	390-510	917	710-1250	0.8
Shorthead redhorse	13	350	50-470	540	10-1020	1.4
Longnose sucker	47	111	60-240	27	10- 160	5.0
White sucker	4	214	120-300	150	10- 300	0.4
Mountain sucker	18	96	50-140	14	10- 20	1.9
Channel catfish	3	686	640-710	3677	3000-4540	0.3
Stonecat	19	144	40-220	45	10- 130	2.0
Burbot	3	357	250-460	268	80- 480	0.3
Sauger	28	394	320-530	520	230-1210	2.5
Freshwater drum	1	380	-	610	-	0.1

A limited amount of seining was done on the Teton River in 1979 in conjunction with the electrofishing surveys. An uncommon species collected by seining, but not found in the electrofishing surveys, was the sturgeon chub. This species was also found in the Judith Landing and Robinson bridge sections of the Missouri River.

Judith River

The Judith River is the second largest tributary of the middle Missouri River. Resident fish populations were surveyed in a 32-km reach of the lower Judith between Anderson bridge near Winifred, Montana, and the confluence with the Missouri River. The Judith River in this reach has a fairly well developed floodplain, which is confined to some extent by steep hills. Small cobble and gravel are the predominant stream substrate materials. A significant feature of the flow regime of the Judith River drainage is the presence of several spring creeks which augment the flow at a constant rate throughout the year. Big Spring and Warm Springs creeks, the two largest spring creeks in the drainage, have constant flows of approximately 3.5 m^3/s (125 cfs).

The largest user of water in the Judith River drainage is irrigated agriculture. Stream dewatering and irrigation return flows undoubtedly have some influence on the water quality characteristics of the lower Judith. The only major water storage facility in the Judith River drainage is Ackley Reservoir with a storage capacity of 0.008 cubic hectometers (6,140 acre-ft).

Water quality of the lower Judith is described by Kaiser and Botz (1975) as basically a calcium bicarbonate water of good quality. The chemical characteristics of the Judith are similar to the Teton River. Conductivity of the lower Judith River usually ranges from 800-1000 micromhos/cm^2, and bicarbonate alkalinity ranges from 200-300 mg/l.

Two study sections were established on the lower Judith River between Anderson bridge and the confluence with the Missouri River (Figure 1). The Anderson study section was 5 km in length. The river channel in this section was shallow, with little pool development or meanders. Water velocity was relatively high, and the stream substrate was comprised primarily of large cobbles. The PN Ranch study section was 6.5 km in length. Pools and riffles were well developed in this section, and the river meandered through a wide floodplain. Loose gravel and sand were the most common stream substrate materials.

Total catch, average size, size range and catch per unit effort for individual fish species sampled in each of the two study sections are shown in Tables 27 and 28. The results of electrofishing in both study sections were unsatisfactory because conductivity of the water was too high. In addition, the PN Ranch study section contained very deep pools which were difficult to electrofish.

Sauger was the most common gamefish sampled by electrofishing in the Judith River. Catch rate of sauger averaged 3.4 fish per electrofishing hour for both study sections combined. In addition, a number of YOY sauger were collected in the PN Ranch section, indicating that reproduction and rearing of this species occurs in the lower Judith River. Other game fish sampled included mountain whitefish, channel catfish and burbot. Goldeye, carp and

Table 27. Catch statistics of fish sampled by electrofishing in the Anderson Bridge section of the Judith River during September 1979.

Species	Number Sampled	Average Length (mm)	Length Range (mm)	Average Weight (gm)	Weight Range (gm)	Catch per unit effort
Goldeye	3	338	320-360	436	380- 490	0.7
Carp	3	503	490-510	1748	1540-2010	0.7
Flathead chub	31	122	50-160	23	10- 60	-
Longnose dace	21	73	50- 90	10	10	-
Longnose sucker	24	310	160-420	350	40- 740	5.7
White sucker	1	300	-	300	-	0.2
Mountain sucker	18	154	120-220	36	20- 100	4.3
Stonecat	16	158	130-190	23	10- 90	3.8
Burbot	3	396	260-510	404	80- 780	0.7
Sauger	7	294	240-370	236	130- 420	1.7
Mottled sculpin	1	70	-	10	-	0.2

Table 28. Catch statistics of the fish sampled by electrofishing in the PN Ranch section of the Judith River during September 1979.

Species	Number Sampled	Average Length (mm)	Length Range (mm)	Average Weight (gm)	Weight Range (gm)	Catch per unit effort
Goldeye	1	320	-	230	-	0.3
Mountain whitefish	1	120	-	20	-	0.3
Carp	3	492	460-500	1575	1370-1850	0.8
Flathead chub	100	130	510-730	32	10- 120	-
Longnose dace	3	67	60- 80	10	10	-
Shorthead redhorse	3	214	60-380	245	10- 620	0.8
Longnose sucker	30	274	80-360	232	10- 410	8.1
White sucker	1	220	-	130	-	0.3
Mountain sucker	9	134	80-200	36	10- 110	2.4
Channel catfish	1	680	-	3810	-	0.3
Stonecat	4	139	120-160	23	10- 30	1.1
Burbot	3	415	390-430	300	300	0.8
Sauger	19	233	120-510	200	20-1090	5.1

a variety of suckers were the most common nongame fish. Flathead chubs were the most abundant forage fish. Other common forage fish included longnose dace, mountain suckers and stonecats. The variety of minnows in the lower Judith River was probably underestimated because of ineffective sampling.

Based on the surveys conducted in 1979, it appears that the lower Judith River contains a moderate population of resident sauger. Although no effort was made to investigate actual utilization of the lower Judith by spawning channel catfish, circumstantial evidence indicates that this river is an important tributary for this species. Numerous cottonwood logs and other instream cover features necessary for catfish nests are found in the lower Judith. Numerous channel catfish alevins were collected at the mouth of the Judith River in 1979. Channel catfish require very warm water temperatures for spawning, and summer water temperatures on the lower Judith River apparently meet their requirements. Based on these considerations, it appears that the lower Judith River is probably one of the most desirable spawning tributaries for channel catfish in the study area.

Paddlefish Radiotelemetry Study

Paddlefish are one of the most important fish species found in the middle Missouri River. Because of their limited distribution and habitat requirements, the Montana Department of Fish, Wildlife & Parks recently classified the paddlefish as a species of special concern - Class A. The paddlefish population in the middle Missouri River is considered to be one of the last known "stable" populations. Successful spawning of paddlefish in the study area has been documented by collecting several larvae and one incubating embryo.

The periodicity and peak of paddlefish spawning runs in the middle Missouri River and the extent of the upstream migration in normal water years have been determined by electrofishing surveys (Berg 1981). Berg monitored the spawning migration of paddlefish in 1977, 1978 and 1979. He found that no significant spawning run occurred in 1977, a year when streamflow levels in the Missouri River were considerably below normal. In 1978 and 1979, streamflow levels in the Missouri River were near normal, and considerable numbers of paddlefish migrated as far upstream as the mouth of the Marias River, 245 km above Fort Peck Reservoir.

Radiotelemetry studies were conducted during 1979 and 1980 to further define instream flow requirements of paddlefish in the middle Missouri River. Objectives of the radiotelemetry study were:

1. To monitor the movement patterns of individual paddlefish prior to and during the spring runoff period.
2. To determine the amount of flow required by paddlefish for passage through shallow water areas which may act as hindrances or barriers to movement during the spawning period.
3. To aid in determining locations of spawning areas, periodicity of the spawning run and extent of upstream migrations of paddlefish.

The middle Missouri River is a large river with deep pools, and contains water of a relatively high ionic conductivity. It is difficult to develop an aquatic radiotelemetry system which functions adequately in this situation. Only limited success has been attained by researchers attempting to utilize radiotelemetry in streams similar to the middle Missouri River. Therefore, all of our effort in 1979 was spent in developing a radio-telemetry system which would be suitable for our requirements. In 1980 the actual tracking of paddlefish took place.

Equipment

A Smith-Root SR-40, 10 channel search receiver with a frequency range between 40.000 and 41.000 MH_z was used to simultaneously monitor the radio-instrumented fish. An omnidirectional whip antenna was matched with the receiving unit and mounted to the wing strut of a Supercub airplane.

Radio transmitters from three different commercial suppliers were used to increase the probability of success. In 1979, the Smith-Root P-40-1000L, a radio transmitter powered by a lithium battery, was superior in performance to its mercury battery powered counterpart. Because of this, the Smith-Root P-40-1000L transmitters were used in 1980. In addition, transmitters manufactured by Dav Tron and Wyoming Biotelemetry were used in 1980. These transmitters were also powered by lithium batteries. The Dav Tron LF-815 transmitter was very similar in design to the Smith-Root, but the Wyoming Biotelemetry transmitter consisted of an enclosed antenna on a circuit board and its basic component was all micro-circuitry.

The Smith-Root transmitter was approximately 85 grams, cylindrical in shape, measuring 190x19 mm with a 150 mm external antenna. Dav Tron radio transmitters were approximately the weight and size of a "D"-cell battery, 100 gms and 70x35 mm dimensions with a 250 mm external antenna. Wyoming Biotelemetry transmitters were not entirely symmetrical; however, their overall length was 155 mm with a maximum diameter of 20 mm and weight of 50 grams (Figure 23). The three companies adjusted the current drain of the transmitters to meet the environmental conditions, yet transmit a strong signal for 90 days. Each radio transmitter was individually identified by the channel frequency and a specified pulse rate. During feasibility tests conducted in 1979, it was determined the Smith-Root P-40-1000L transmitter's signal could be relocated at an accuracy of $\pm$ 50 m and received at a maximum distance of approximately 1.5 km from the airplane.

Implantation and Attachment of Transmitters

Radio transmitters were attached to paddlefish using both internal and external plants. Internal plants were surgically implanted in the peritoneal cavity of paddlefish (Figure 24). Using standard surgical procedures, a 70 mm incision was made with a scalpel along the upper right ventrum immediately posterior to the pectoral fin (Figure 25). The incision was made at this site to avoid severing major vessels present along the ventral axis. After the incision was completed, a transmitter dipped in parafin was inserted into the peritoneal cavity with the external antenna (plastic coated copper wire 1 mm diameter) extending outside the body. The incision was then closed with

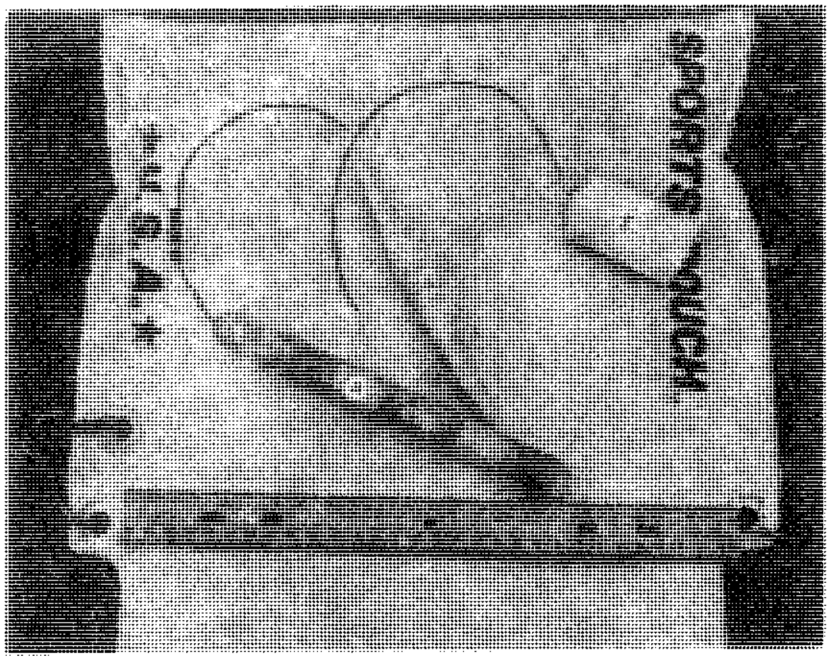

Figure 23. Radio transmitters from three different commercial suppliers were used to increase the chances of success. Radio-A - Smith-Root; B - Wyoming Biotelemetry; and Z - Dav Tron.

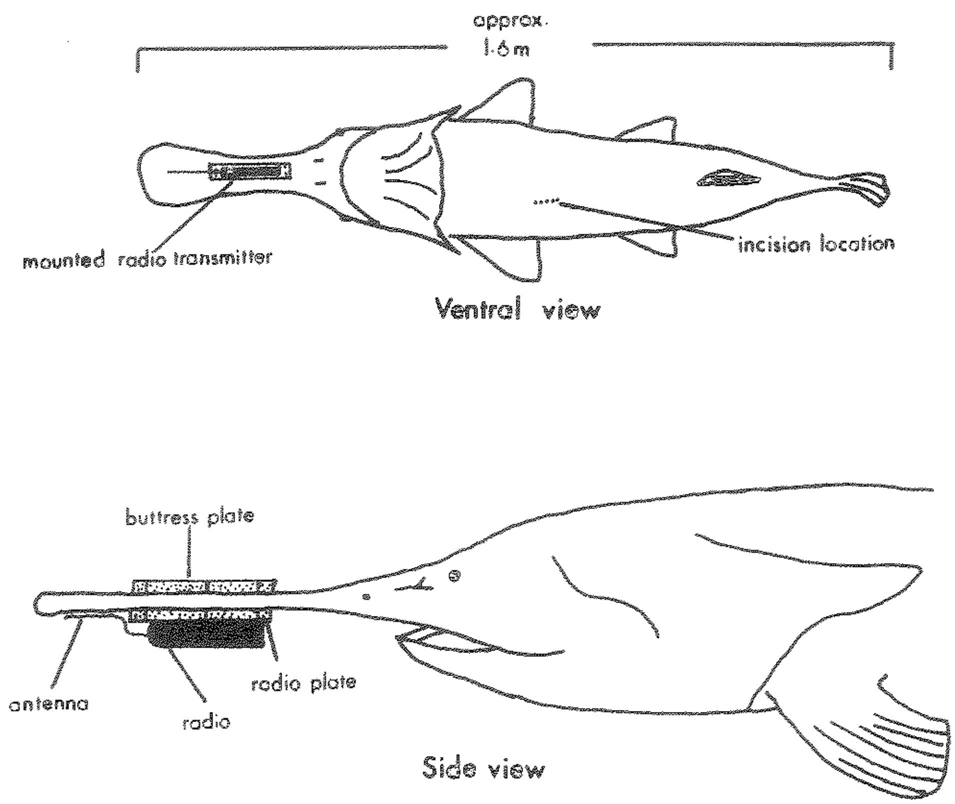

Figure 24. Attachment and implant sites for the paddlefish radio transmitters.

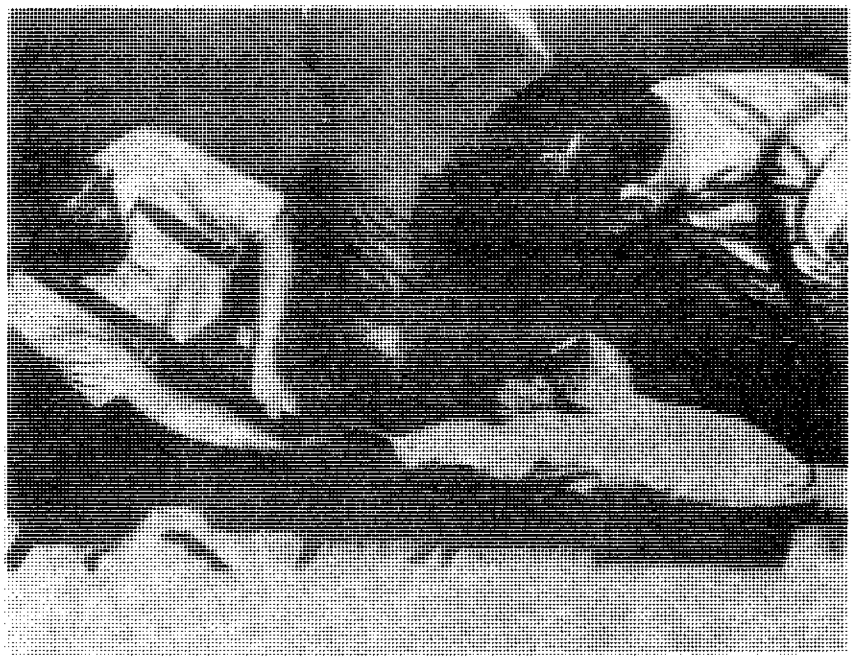

Figure 25. Surgical procedures were used to implant the radio transmitters in the peritoneal cavity of the paddlefish.

individual sutures spaced 5 mm apart. The antenna was protected by stitching it along the skin. Finally, the fish was injected with an antibiotic at a dosage of 1 cc antibiotic per 4.5 kg of paddlefish body weight.

The external plants were made by attaching the radio transmitters to the paddlefish rostrum (Figure 24). This was facilitated by cementing the transmitters to a length of plexiglass similar to that described by Haynes (1978). Holes were drilled in the plate through the rostrum to a buttress plate where the wires were secured. The transmitter antenna was stitched to the skin of the rostrum for protection. Dave Combs (Oklahoma Dept. of Wildlife Conservation pers. com.) first experimented with this method, and he reported good success because the technique did not circumscribe the rostrum and cause irritation as reported by Elser (1976).

Evaluation of Radio Transmitters' Placement

Of the 28 radio transmitters instrumented on paddlefish in 1980, only 7 worked successfully (Table 29). The Smith-Root transmitter, internal placement, was the only combination which worked reasonably well. Other combinations probably failed because of weak signal strength and antenna problems. Performance of surgically implanted radio transmitters was far superior to that of the external placements (Table 29). The failure of the rostrum attachments was probably related to the unit being torn off, since two of the externally planted radio transmitters were consistently relocated in the same area where the fish was tagged.

Table 29. Performances of radio tags used in the 1980 middle Missouri River paddlefish radiotelemetry study.

	Companies/Placement				
	Smith-Root		Dav Tron	Wyoming	
	Internal	Rostrum	Internal	Internal	Rostrum
Total number radios attached	9	3	9	2	5
Percent of radios which worked	78	67	22	0	0
Average number relocations for each working radio	7.0	2.0	1.5	-	-
Range: number relocations	2-11	1-3	1-2		
Average radio life (days)	56.3	41	29		
Radio life range (days)	14-87	7-76	29		

Some problems were also encountered with internally planted tags. Apparently, because of the large amount of tension on the sutures, the skin could not hold the strain; consequently, some of the sutures tore through. This problem was observed on two of the paddlefish with internal radio transmitter placements. The problem could be easily alleviated by placing wider sutures in addition to the primary, medium width ones. Another problem encountered with the surgically implanted radio transmitters was associated with the external antenna. The connection between the base of the antenna to the component was sound; however, a length of antenna was sheared off on two of the recovered radio transmitters. The shearing could have been related to abrasion caused by the fish rubbing the bottom, or corrosion caused by a chemical reaction with the fishes' mucous covering. Stainless steel antenna or other noncorrosive materials would probably remedy this problem.

There is little doubt that successful radio tracking of a large fish under these conditions can be achieved. Dennis Unkenholtz (South Dakota Dept. of Game, Fish & Parks pers. com.), using a similar radio telemetry system for studying movements of paddlefish in the Missouri River below Ft. Randall Dam, has achieved very encouraging results. During the present study, one paddlefish instrumented with an internally implanted radio transmitter in 1979 was recovered 1 year later and exhibited no apparent abnormalities. This fish gained 2.3 kg in weight during an 11-month period after the radio was implanted.

Individual Paddlefish Movements

Twenty-eight paddlefish were equipped with radio transmitters in 1980, of which 11 initially were relocated from fixed-wing aircraft. Of these 11, 4 were males and 7 were gravid female fish. Radio tracking of the fish commenced April 22 and terminated July 16, 1980. During this period, 15 flights of the river were made at an average of 6 day intervals; during the highwater period, these flights were taken at shorter intervals. A total of 48 relocations was made on the radio-tagged paddlefish.

Individual paddlefish movement patterns are presented in Appendix Figure B. Relocations of each radio-tagged fish for all flights are given in Table 30. From these data, it was evident that paddlefish movements were correlated with the high spring flows. Figure 26 relates the average radio-tagged paddlefish movement in response to 1980 spring runoff flows. From April 22 through May 26, the paddlefish exhibited minor movements in the staging area. Individual movements averaged 9.5 km per relocation extending from river km -17 to +17. Flow during this period averaged 250 m^3/sec (8850 cfs) at the Robinson Bridge gage station. Water temperatures during this time had surpassed 10 C (Appendix Table F). Purkett (1961) indicated water temperature reaching about 10 C was one of the factors initiating the paddlefish migratory run in the Osage River, Missouri.

On May 26, discharge of the Missouri River increased sharply to 455 m^3/sec (16,100 cfs) at the Robinson Bridge gage. However, most paddlefish still remained in the staging area; the average relocation of the radio-tagged fish being river km 4.

By May 29, the paddlefish movements increased substantially with the average fish relocated at river km 41, well above the staging area. Individual movements were extensive from May 29 through June 30, averaging 40 km/fix and extending from river km -30 to +78. Between May 26 and 29 the river discharge increased to 802 m^3/s (28,316 cfs). The initial run observed on May 29 was followed by a major retreat observed during the flight made on June 2. Four of the five paddlefish relocated on June 2 moved downstream a considerable distance and the average relocation was made at river km -5 (i.e., 5 km downstream in Fort Peck Reservoir). During this period, a large amount of suspended debris (logs, twigs, bark, etc.) was carried in the river, washed in from heavy rain storms. In 1978, during a similar occurrence, a substantial number of paddlefish also retreated downstream into Ft. Peck Reservoir (Berg 1981). A few of the paddlefish were captured and a considerable amount of debris was found in their mouths and gill cavities (Bob Watts, Mont. Dept. Fish, Wildlife & Parks pers. com.). Considering these past occurrences, it was likely that the major retreat of radio-tagged paddlefish in 1980 was related to the abnormally large amounts of instream debris. Between June 5 and 30, most of the paddlefish were relocated back upstream between river km 44 and 75 (Robinson Bridge to Cow Island). The lower end of this reach (Lower Two Calf Island area) is the lowest downstream site with suitable gravel bars for paddlefish spawning (Berg 1981). Paddlefish were also relocated in the Cow Island area where paddlefish spawning activity was observed during previous years. After the paddlefish initiated the major portion of their spawning run, only one of the radio-tagged fish could be consistently relocated. This paddlefish remained in the river well above the staging area for approximately the duration of the major runoff period. Three other radio-tagged paddlefish were relocated a considerable

Table 30. Paddlefish radiotelemetry relocations in the middle Missouri River during April 15-July 16, 1980.

	Individual Radio Transmitters[a]											Average Paddlefish Location (km)[b]	Discharge[c] (m^3/sec)
	1/1	2/1	3/1	5/1	8/1	9/1	10/1	1/2	2/2	3/2	4/2		
April 15			5R[d]		-14R								243.8
22			17		-14							2	265.3
May 1	-1R	-1R	17	-1R		-1R	-1R	-1R	-1R	-1R	-1R	17	285.3
7	7	7	5	4		-14	-13	4	-14	-14		-3	276.6
15			7		8	-12	7	4	-2			3	242.4
26	15				-14			10	8	-17	20	4	454.8
29	21[e]				57	28		30	67			41	802.3
June 2			-30		-13	27		-30	21			-5	638.4
5		20	-13		49			45				25	655.4
8			45		75	73						64	731.7
10					78							78	768.4
16					44							44	802.3
30					75							75	743.0
July 7					9							9	435.0
16		18				22		13				18	324.9

a/ Radio transmitters were coded $\frac{\text{channel (MH}_z\text{)}}{\text{pulse rate}}$

b/ River kilometer 0 was located where the river ends and reservoir resumes. (Negative km value indicates location in reservoir.)

c/ River discharge as gaged at the Fred Robinson Bridge near Landusky, MT.

d/ R denotes release site and date after being instrumented with a radio transmitter.

e/ This fish was harvested at river km 43 on May 30, 1980.

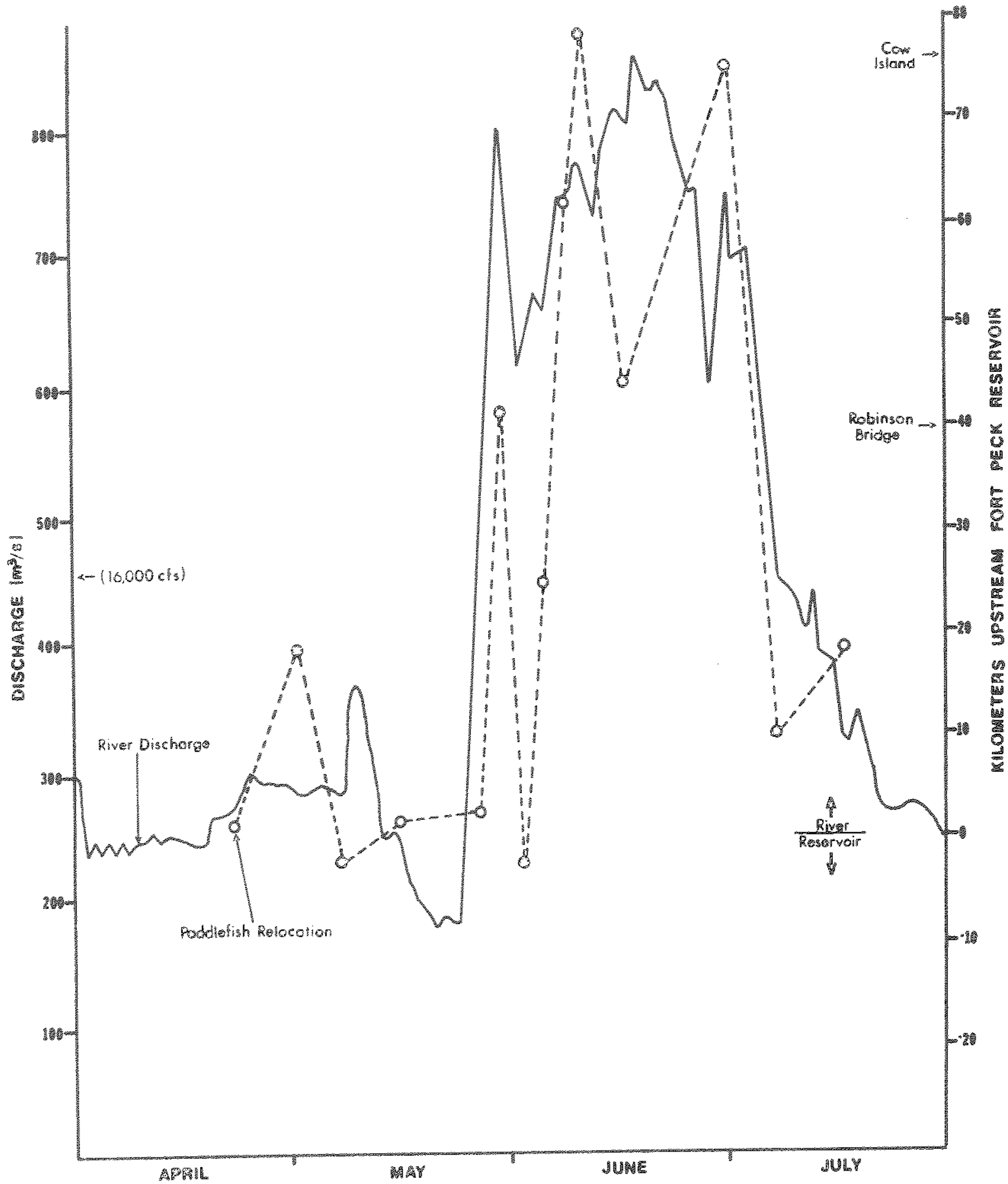

Figure 26. Average location sites of the 11 radio-tagged paddlefish and the spring runoff hydrograph of the middle Missouri River during 1980.

*Each point is an average location of all the paddlefish located, and it may represent 1-9 fish located for that date.

distance upstream from the paddlefish staging area in the vicinity of known spawning sites. The presence of paddlefish in spawning areas through the runoff period has been extensively documented by other researchers (Elser 1976, Purkett 1961, Berg 1981). Purkett (1961) indicated paddlefish prefer spawning areas on shallow gravel bars which are inundated to the proper depth and velocity during the runoff period.

Because of the rapid increase in flow late in May, no evaluation could be made concerning possible migratory barriers. It is possible that the inception of the paddlefish migration to upstream spawning sites is related more to behavioral motivation than the presence of physical barriers. In other words, when the flow which motivates paddlefish to migrate upstream is attained there may be no physical barriers to navigate.

Radiotelemetry provided little information on possible paddlefish spawning sites because only one paddlefish could be monitored during the entire spawning period. Paddlefish spawning sites on the middle Missouri River have been previously identified by Berg (1981).

Along with the tracking of radio-equipped fish, electrofishing was used as a method to monitor and census the paddlefish migratory run in 1980. Electrofishing provided a significantly better appraisal of the relative abundance and distribution of migratory paddlefish than radiotelemetry. An electrofishing census run was made from June 3 through 8, 1980, to monitor paddlefish distribution after the high flows were attained. The result of this electrofishing run is presented in Table 31. The observed distribution and relative abundance of paddlefish were similar to previous years (Berg 1981). Results of censusing the upper river from Fort Benton to Coal Banks Landing on four occasions from June 3 to July 1 (Table 32) indicate substantial numbers of paddlefish were distributed up to 251 km above Fort Peck Reservoir, peaking in numbers slightly after the crest of the runoff, but persisting until at least July 1.

Instream Flow Assessment for Paddlefish

Berg (1981) found that paddlefish require a flow of 396.5 m^3/sec (14,000 cfs) in the Virgelle gaged reach of the Missouri River to complete their annual spring migration to spawning sites. To maintain the paddlefish migration, flow should remain at or above 396.5 m^3/sec for 48 consecutive days from May 19 through July 5 in the Virgelle gaged reach. This time period was selected because it satisfies the biological requirements of paddlefish. It also conforms to the time period when median flow historically reaches or exceeds 396.5 m^3/sec at the Virgelle gage.

Results of paddlefish radiotelemetry studies conducted in 1980 firmly support these conclusions. Movement of radio-tagged paddlefish to spawning sites occurred during the high flow period from late May through early June (Figure 26).

Table 31. The longitudinal distribution of paddlefish in the middle Missouri River as determined by one electrofishing census run taken during the peak runoff period of June 3-8, 1980.

Study Section	Area	River km*	No. Fish Observed	Total No. Fish Observed in Sec.
Fort Benton	-		-	0
Loma Ferry	Three Ids	234	5) -)	5
Coal Banks	Virgelle Ferry Little Sandy	218 205	3) 11)	14
Hole-in-Wall	-		-	9
Judith Landing	Deadmans Rpds Holmes Rpds	140 131	3) 9)	12
Stafford Ferry	Dauphine Rpds Bird Rpds	114 92	14) 25)	39
Cow Island Landing	Bullwacker Power Plant Ferry	79 65	36) 28)	64
Robinson Bridge	Grand Id Two Calf Ids	51 45	Not sampled) 25)	25

*Upstream from Ft. Peck

Table 32. Seasonal distribution of paddlefish in the upper section of the middle Missouri River as determined by four electrofishing "census" runs taken during the peak runoff period June 3-July 1, 1980.

Location of Reach Electrofished	River km	No. of Paddlefish Observed			
		6/3 & 4	6/10 & 11	6/25	7/1
Ft Benton Community-Evans Bend	281-272	0	0	0	0
Evans Bend-Brule Bottoms	272-251	0	0	0	0
Brule Bottoms-Marias R confluence	251-246	0	0	7	0
Marias R confluence-Crow Id	246-228	2	7	19	21 1/
Crow Id-Boggs Id	228-220	3	10	11	9
Boggs Id-Coal Banks Landing	220-212	3	6	3	2
Total		8	23	40	32

1/ Six of these 21 paddlefish were censused in the mouth of the Marias River.

Based on these considerations, a flow of 396.5 m^3/sec is recommended for the Virgelle gaged reach of the Missouri River. This reach extends from the confluence of the Marias to the confluence of the Judith River. The Missouri River upstream from the confluence of the Marias River is the source of most of the water downstream from the Marias. The reach of the Missouri River from the confluence of Belt Creek to the confluence of the Marias River is gaged by the Fort Benton USGS station. Based on calculations made from USGS data gathered at the Virgelle and Fort Benton gage stations, it was determined that the Missouri River at Fort Benton contributes 80.6 percent of the median flow of the Missouri River at Virgelle during the paddlefish spawning period from May 19 through July 5. Therefore, to maintain the annual spring paddlefish migration in the Missouri River, a flow of 319.6 m^3/sec (11,284 cfs) is recommended for the reach of the Missouri River from the confluence of Belt Creek to the confluence of the Marias River. This flow must be maintained from May 19 through July 5.

The reach of the Missouri River from the confluence of the Judith River to Fort Peck Reservoir is gaged by the Robinson Bridge (Landusky) USGS station. Flow accretion in this reach of the river during the paddlefish spawning period is mostly attributable to the contribution of the Judith River. Based on calculations made from USGS data gathered at the Virgelle and Robinson Bridge gage stations, it was determined that median flow of the Missouri River at Robinson Bridge amounts to 109.3 percent of the median flow of the Missouri River at Virgelle during the paddlefish spawning period from May 19 through July 5. Therefore, to maintain the annual spring paddlefish migration in the Missouri River, a flow of 433.4 m^3/sec

(15,302 cfs) is recommended for the reach of the Missouri River from the confluence of the Judith River to Fort Peck Reservoir. This flow must be maintained from May 19 through July 5.

The paddlefish is officially listed as a "Species of Special Concern - Class A" in Montana (Holton 1980), and only six major self-sustaining populations remain in the United States. Adequate flows are essential to maintain the Fort Peck Reservoir/Missouri River paddlefish population.

Instream Flow Assessment for Channel Morphology

Dominant Discharge/Channel Morphology Concept

It is generally accepted that the major force in the establishment and maintenance of a particular channel form in view of its bed and bank material is the annual high flow characteristics of the river. It is the high spring flows that determine the shape of the channel rather than the average or low flows.

The major functions of the high spring flows in the maintenance of channel form are bedload movement and sediment transport. It is the movement of the bed and bank material and subsequent deposition which form the mid-channel bars and, subsequently, the islands. High flows are capable of covering already established bars with finer material which leads successively to vegetated islands. Increased discharge associated with spring runoff also results in a flushing action which removes deposited sediments and maintains suitable gravel conditions for aquatic insect production, fish spawning and egg incubation.

Reducing the high spring flows beyond the point where the major amount of bedload and sediment are transported would interrupt the ongoing channel processes and change the existing channel form and bottom substrates. A significantly altered channel would affect both the abundance and species composition of the present aquatic populations by altering the existing habitat types.

Several workers adhere to the concept that the form and configuration of river channels are shaped by and designed to accommodate a dominant discharge (Leopold et al. 1964, US Bureau of Reclamation 1973, Emmett 1975). The discharge which is most commonly referred to as a dominant discharge is the bankful discharge (Leopold et al. 1964, Emmett 1975). Bankful discharge is defined as that flow when water just begins to overflow onto the active floodplain.

Bankful discharge tends to have a constant frequency of occurrence among rivers (Emmett 1975). The recurrence interval for bankful discharge was determined by Emmett (1975) to be 1.5 years and is in close agreement with the frequency of bankful discharge reported by other studies (Leopold et al. 1964, Emmett 1972).

Dominant Discharge Flow Recommendations

The bankful discharges for the Missouri River were estimated by using 1½ year frequency peak flows derived for USGS gage stations located at Fort Benton, Virgelle and Robinson Bridge. Dominant discharges were:

USGS Gage Station	Dominant Discharge	
Fort Benton	614.6 m^3/sec	(21,700 cfs)
Virgelle	606.1 m^3/sec	(21,400 cfs)
Robinson Bridge	664.6 m^3/sec	(23,466 cfs)

Therefore, dominant discharge flow recommendations are:

Missouri River Reach	Flow Recommendation	
Confluence of Belt Creek to confluence of Marias R	614.6 m^3/sec	(21,700 cfs)
Confluence of Marias River to confluence of Judith R	606.1 m^3/sec	(21,400 cfs)
Confluence of Judith River to Fort Peck Reservoir	664.6 m^3/sec	(23,466 cfs)

It is not presently known how long the bankful flow must be maintained to accomplish the necessary channel formation processes. Until further studies clarify the necessary duration of the bankful discharge, a duration period of 24 hours was chosen.

Instream Flow Assessment for Riffles

Wetted Perimeter/Inflection Point Method

Flow recommendations from September 1 through March 23 were based on the wetted perimeter/inflection point method. Wetted perimeter is the distance along the bottom and sides of a channel cross-section in contact with water. As the flow in the stream channel decreases, the wetted perimeter also decreases, but the rate of loss of wetted perimeter is not constant throughout the entire range of flows. There is a point, called an inflection point, on the curve of wetted perimeter versus flow at which the rate of loss of wetted perimeter is significantly changed. Above the inflection point, large changes in flow cause only very small changes in wetted perimeter. Below the inflection point, the river begins to pull away from the riffle bottom, exposing the bottom at an accelerated rate. The flow recommendation is selected at or beyond this inflection point.

The maintenance of suitable flows in riffles is essential for the Missouri River fish populations. Four apparent reasons are:

1. Riffles contain substantial standing crops of aquatic invertebrates and forage fish, the principal food organisms of important fish species in the Missouri River.
2. Production of aquatic invertebrates occurs primarily in riffle areas (Hynes 1970).
3. Adequate flow must be maintained in riffle areas to allow for passage of migratory fish species.
4. Riffle areas provide critical habitat for the rare sicklefin and sturgeon chub populations of the Missouri River.

If flows in the Missouri River were reduced below the inflection point, the riffle bottom would be exposed at an accelerated rate, causing a decrease in riffle area and channel depth.

Riffles are also the area of a stream most affected by flow reductions (Bovee 1974, Nelson 1977). Consequently, the maintenance of suitable riffle conditions in pools and runs, areas normally inhabited by adult fish.

The wetted perimeter/inflection point method was applied to six riffle transects located in four typical riffles of the Missouri River in the Fort Benton gaged reach during 1980.

In addition, three riffle transects were located in the shallow Cow Island riffle of the Robinson Bridge gaged reach. Many times this riffle marked the uppermost point which steamboats of the 1800 era could ascend the Missouri River. Because of its shallow depth, it also was the most preferred ford crossing within hundreds of miles for buffalo, Indian tribes and voyagers of the upper Missouri River country. The Cow Island riffle area has been identified as a potential barrier to up or downstream fish migration during low flows (Berg 1981). Because of the extensive riffles in the Cow Island area, a great diversity of riffle fish is found here. The sicklefin chub, a "Species of Special Concern" (Holton 1980), depends largely upon riffles located in the Cow Island area. The loss of this species due to inadequate flows would be significant, as the sicklefin chub is sparsely distributed throughout the entire length of the Missouri River (Pflieger 1975).

Also, the sturgeon chub, another "Species of Special Concern" (Holton 1980), is substantially more abundant in the Cow Island riffle area than in any other part of the Missouri River from Morony Dam to Fort Peck Reservoir. For these reasons, the Cow Island riffle area was identified as a critical riffle area. Adequate flow over this riffle must be maintained so that it can continue to provide its unique values.

Wetted Perimeter Flow Recommendations

For the Fort Benton riffle transects, the WETP program was calculated to field data collected at flows of 308.7 (10,900), 212.4 (7500), 181.2 (6400) and 127.4 m^3/sec (4500 cfs). The inflection point on the wetted perimeter-discharge relationship occurs at 104.8 m^3/s (3700 cfs) for the composite of seven riffle transects located in the Fort Benton study area (Figure 27). Therefore, 104.8 m^3/s (3700 cfs) is the flow recommended to maintain wetted perimeter of the riffles at the inflection point. This flow is recommended for the Fort Benton gaged reach of the Missouri River from the confluence of Highwood Creek to the confluence of the Marias River.

For the Cow Island riffle transects, the WETP program was calibrated to field data collected at flows of 382.3 (13,500), 250.1 (8830), 232.2 (8200) and 160.3 m^3/sec (5660 cfs). The inflection point on the wetted perimeter discharge relationship occurs at 133.1 cms (4700 cfs) for the composite of three transects located in the Cow Island riffle (Figure 28). Therefore, 133.1 cms (4700 cfs) is the flow recommended to maintain wetted perimeter at the inflection point.

This flow is recommended for the Robinson Bridge gaged reach of the Missouri River from the confluence of the Judith River to Fort Peck Reservoir.

The Missouri River upstream from the confluence of the Judith River is the source of most of the water downstream from the Judith. Adequate flows in this reach are necessary to maintain riffles in the Robinson Bridge gaged reach. The reach of the Missouri from the confluence of the Marias River to the confluence of the Judith River is gaged by the Virgelle USGS station. Based on calculations made from USGS data gathered at the Virgelle and Robinson Bridge gage stations, it was determined that the Missouri River at Virgelle contributes 91.6 percent of

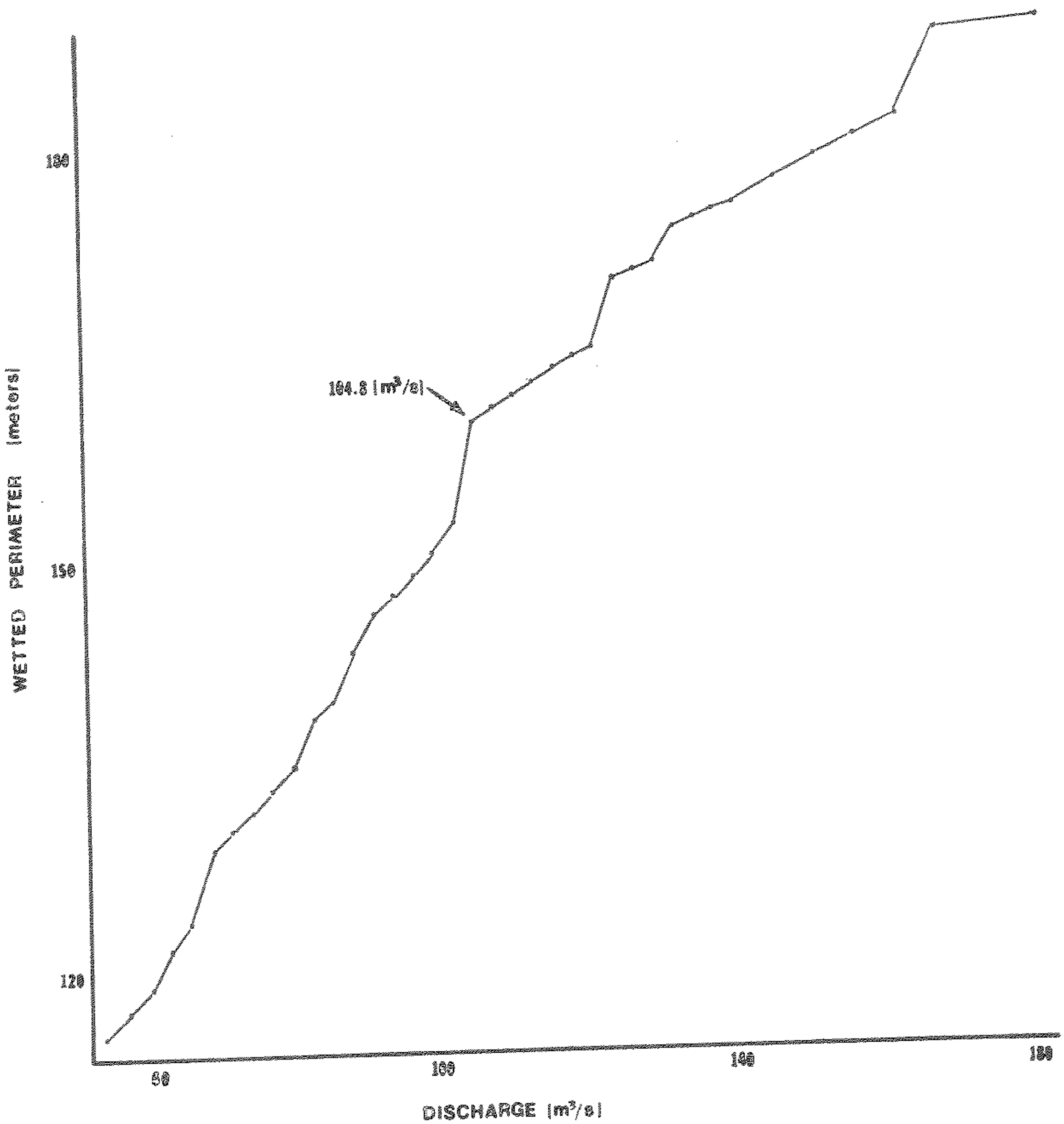

Figure 27. Wetted perimeter-discharge relationship for a composite of seven riffle transects located on the Missouri River in the Fort Benton gaged reach, 1980.

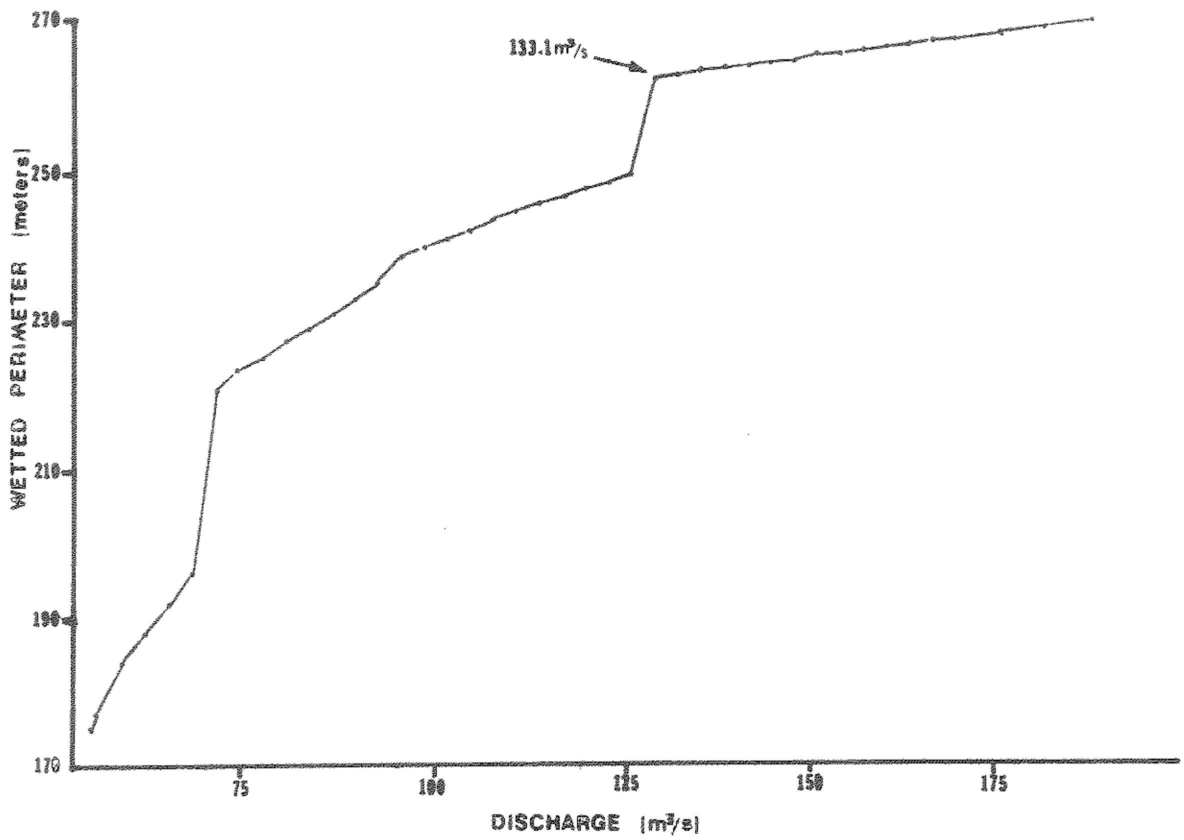

Figure 28. Wetted perimeter-discharge relationship for a composite of three riffle transects located on the Missouri River at the Cow Island riffle, 1980.

the median flow of the Missouri River at Robinson Bridge during the base flow period from September 1 through late March. Therefore, a flow of 121.9 m^3/sec (4305 cfs) is recommended for this reach.

Flow recommendations for riffle maintenance are:

Missouri River Reach	Flow Recommendation	
Confluence of Belt Creek to confluence of Marias River	104.8 m^3/sec	(3700 cfs)
Confluence of Marias River to confluence of Judith R	121.9 m^3/sec	(4305 cfs)
Confluence of Judith River to Fort Peck Reservoir	133.1 m^3/sec	(4700 cfs)

The wetted perimeter riffle maintenance flows may not be adequate during the early portion of the runoff period from late March through May 18. Sauger, walleye, northern pike and other early spring spawners probably require a higher flow for spawning, but their flow requirement was not assessed during this study. Since this assessment was not made, the riffle maintenance flow is recommended until the paddlefish migration flow recommendation commences on May 19.

Summary of Minimum Instream Flow Requirements

Assessed minimum instream flows for the middle Missouri River are given according to the seasonal schedule in Table 33. These are the flows necessary for the species with the highest requirements for that particular season. Using the Robinson Bridge gaging station as an example, it is evident the instream flows requested are less than the median flows (Figure 29). The median flow provides a measure of water availability during a normal or typical water year. The median is the flow that is exceeded in 5 of 10 years or, in other terms, in 5 years out of 10 there is more water than the median flowing in the river.

Table 33. The schedule of the assessed minimum instream flows for the middle Missouri River.

Period	Assessed Minimum Instream Flow			Concept Based on
	Gage St.	m^3/s	cfs	
Sept. 1-May 18	Ft Benton	104.8	3700	Wetted perimeter/inflection point of riffles
	Virgelle	121.9	4305	
	Robinson Br	133.1	4700	
May 19-July 5	Ft Benton	319.6	11,284	Paddlefish migration flows
	Virgelle	396.5	14,000	
	Robinson Br	433.4	15,302	
24 hours between May 19-July 5	Ft Benton	614.6	21,700	Maintenance of channel morphology
	Virgelle	606.1	21,400	
	Robinson Br	664.6	23,466	
July 6-August 31	Ft Benton	127.5	4500	Maintenance of side channel water levels above threshold value.
	Virgelle	152.9	5400	
	Robinson Br	164.3	5800	

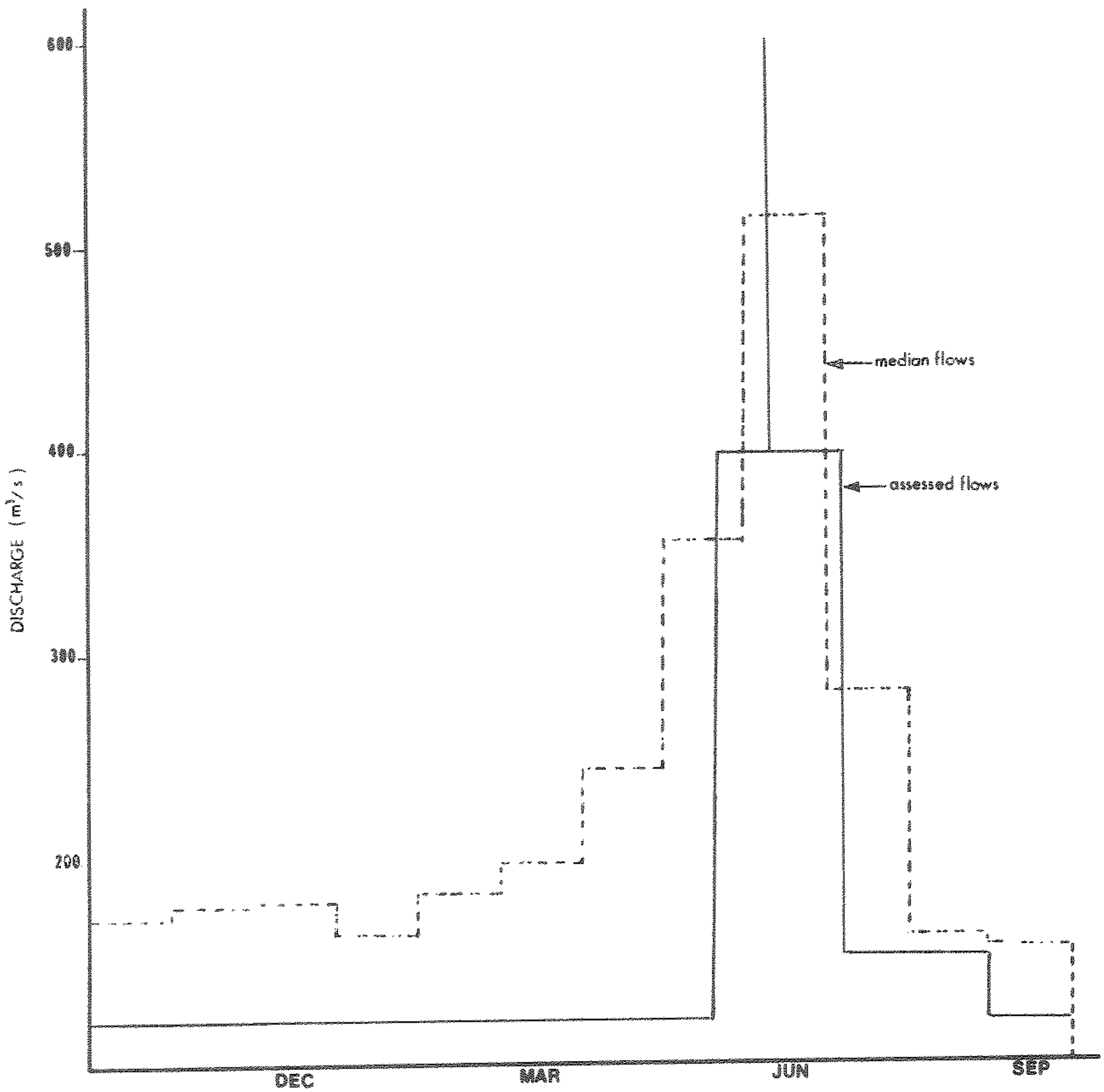

Figure 29. Comparison of assessed minimum instream flow hydrograph to the median monthly flow hydrograph of record for the Virgelle Ferry gage.

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APPENDIX

Appendix Table A. An example of relative importance (RI) calculation for food habits analyses.

Example:

To calculate the relative importance (RI) for a food item in a diet, first find the absolute importance (AI).

1. AI = % occurrence + % numbers + % volume
   (found in diet)

The percent of occurrence of each food item is simply the percentage of fish which consumed that particular food item. The average percent composition by number and volume is the average number or volume of that food item in the sample divided by the average total number or volume of all the food items in that sample, expressed as a percentage.

If,

AI item a = 2
AI item b = 6
AI item c = 1

The RI for a particular food item is obtained by summing the numerical percentage, volumetric percentage and percentage of occurrence of the food item in the diet, then dividing by the summation of all the food items in the diet.

Then,

$$RI_a = 100\ AIa / \sum_{a=1}^{n} AI_a$$

(Where a = food item a)
(n = number of different food types)

$= 100(2) \div (2+6+1)$
$= 200 \div 9$
$RI_a = 22.2$

Appendix Table B. Total catches of young-of-the-year sauger seined in the habitat types of each study section in the middle Missouri River during late July-early September 1979.

	Habitat Type					Total number of sauger sampled in each section	Total number of seine hauls made in each section
	Main Channel Border	Main Channel Pool	Side Channel Chute	Side Channel Pool	Back-waters		
Morony Dam	-[1] (2)[2]	- (6)	- (0)	- (0)	- (6)	0	14
Carter Ferry	- (4)	- (6)	- (0)	- (0)	- (4)	0	14
Fort Benton	- (4)	- (5)	- (0)	- (4)	- (9)	0	22
Loma Ferry	- (9)	0 (7)	- (0)	2 (7)	- (3)	2	26
Coal Banks	-(10)	- (7)	- (2)	- (2)	1 (1)	1	22
Hole-in-the-wall	2(11)	8 (8)	- (4)	9 (5)	4 (3)	23	31
Judith Landing	- (5)	- (2)	- (0)	6 (2)	- (2)	6	11
Stafford Ferry	- (7)	2 (9)	- (0)	- (0)	- (2)	2	18
Cow Island	5(14)	6 (8)	1 (9)	12 (8)	1 (4)	25	43
Robinson Bridge	6(18)	20 (9)	- (3)	37 (9)	- (3)	63	42
Total number sauger	13	36	1	66	6	122	
Total number seine hauls	84	67	18	37	37	243	

1/ Denotes zero sauger
2/ number of seine hauls in parentheses

Appendix Table C-1. Catch rates (number of fish per seine haul) of forage fish species in side channel 1 (Fort Benton section) of the middle Missouri River, 1980.

	Early August
Carp	0.3
Flathead chub	13.7
Lake chub	10.7
Emerald shiner	1.7
Western silvery minnow	3.0
Fathead minnow	5.7
Longnose dace	14.3
Suckers[a/]	17.7
Number seine hauls	3
Range of catch	22-148

a/ This group was not separated into shorthead redhorse, white and longnose suckers.

Appendix Table C-2. Catch rates (number of fish per seine haul) of forage fish species in side channel 2 (Fort Benton section) of the middle Missouri River, 1980.

	Late July	Early August	Late August	Late Sept.	Late October
Carp	0.75				
Lake chub	0.2	1.0			
Flathead chub		4.0	0.3	0.3	
Emerald shiner	1.0	1.5	0.7		
Fathead minnow	49.3		0.7	2.3	2.5
Longnose dace	0.2	17.0	10.3	4.3	4.0
Smallmouth buffalo		5.8			
Suckers[a/]	34.2	25.3	5.3	2.0	1.0
Yellow perch				0.3	
Larvae	0.8				
Number seine hauls	4	4	3	3	4
Range of catch	51-210	22-108	2-33	1-12	1-20

a/ This group was not separated into shorthead redhorse, white and longnose suckers.

Appendix Table C-3. Catch rates (number of fish per seine haul) of forage fish species in side channel 3 (Loma Ferry section) of the middle Missouri River, 1980.

	Late July	Early Aug.	Late Aug.	Late Sept.	Late Oct.
Carp		0.7	0.7		
Flathead chub		8.7	51.0		
Emerald shiner	1.2	6.0	3.0	2.5	
Western silvery minnow			32.7	11.5	2.0
Fathead minnow	53.0	12.0	31.0	0.5	0.5
Longnose dace		5.7	4.0	3.5	0.5
River carpsucker	1.0				
Smallmouth buffalo	10.8	7.0	2.7	0.5	
Bigmouth buffalo	1.0		0.7		
Suckers[a/]	16.8	13.3	9.7	5.0	
Pumpkinseed			0.4		
Yellow perch	4.2	0.7	4.7	1.0	
Larvae	22.5				
Number seine hauls	4	3	3	2	2
Range of catch	37-252	30-71	105-197	23-26	1-5

a/ This group was not separated into shorthead redhorse, white and longnose suckers.

Appendix Table C-4. Catch rate (number of fish per seine haul) of forage fish species in side channel 4 (Loma Ferry section) of the middle Missouri River, 1980.

	Late July	Early Aug.	Late Aug.	Late Sept.	Late Oct.
Goldeye		0.3			
Flathead chub	1.4	7.7			
Emerald shiner	4.8	16.0	3	0.3	
Western silvery minnow	1.0	2.3	58	5.7	
Fathead minnow	12.8	19.7			0.3
Longnose dace	0.4	11.0	5	15.0	
Suckers[a/]	11.0	28.0	7	0.7	
Yellow perch		16.0	2		0.2
Walleye		1.3	1		
Larvae	3.6				
Number seine hauls	5	3	1	3	4
Range of catch	8-94	62-154	-	11-33	0-1

a/ This group was not separated into shorthead redhorse, white and longnose suckers.

Appendix Table C-5. Catch rate (number of fish per seine haul) of forage fish species in side channel 5 (Loma Ferry section) of the middle Missouri River, 1980.

	Late July	Early Aug.	Late Aug.	Late Sept.
Flathead chub	4.9	38.7	14.4	
Emerald shiner	14.9	5.0	0.4	0.8
Western silvery minnow	0.3		8.2	20.5
Fathead minnow	1.1	0.3		
Longnose dace	0.1	20.0	6.8	0.8
Smallmouth buffalo			0.4	
Suckers[a/]	6.7	12.0	15.4	1.2
Yellow perch			0.8	
Larvae		2.3		
Number seine hauls	7	3	5	4
Range of catch	3-64	66-101	16-104	2-80

a/ This group was not separated into shorthead redhorse, white and longnose suckers.

Appendix Table C-6. Catch rate (number of fish per seine haul) of forage fish species in side channel 6 (Loma Ferry section) of the middle Missouri River, 1980.

	Late July	Early Aug.	Late Aug.	Late Sept.
Carp		0.4		
Flathead chub	1.7	35.2	38.5	7.8
Emerald shiner	14.7	1.0	0.5	2.5
Western silvery minnow	0.3	84.4	19.0	21.2
Fathead minnow	0.3	6.4	1.2	
Longnose dace		17.2	30.7	14.2
Smallmouth Buffalo		0.8	1.2	
Suckers[a/]	12.3	20.2	97.5	6.2
Number seine hauls	3	5	6	4
Range of catch	18-35	16-354	24-396	4-190

a/ This group was not separated into shorthead redhorse, white and longnose suckers.

Appendix Table C-7. Catch rate (number of fish per seine haul) of forage fish species in side channel 7 (Judith Landing section) of the middle Missouri River, 1980.

	Early July	Late July
Goldeye		0.3
Flathead chub	21.3	9.8
Lake chub		0.7
Emerald shiner	9.3	0.8
Western silvery minnow	11.5	0.7
Fathead minnow	1.0	
Longnose dace		0.8
Suckers[a/]	2.8	2.5
Yellow perch	0.2	0.2
Larvae	9.2	
Number seine hauls	6	6
Range of catch	11-107	8-27

a/ This group was not separated into shorthead redhorse, white and longnose suckers.

Appendix Table C-8. Catch rate (number of fish per seine haul) of forage fish species in side channel 8 (Judith Landing section) of the middle Missouri River, 1980.

	Early July	Late July	Early September
Goldeye		2.5	
Carp		30.0	15
Flathead chub	3.0	27.5	42
Emerald shiner	3.5	0.5	44
Western silvery minnow	0.5	0.5	25
Fathead minnow	45.5		
Longnose dace		7.5	14
Smallmouth buffalo			1
Bigmouth buffalo		1.5	1
Suckers[a/]	56.5	1.5	30
Number seine hauls	2	2	1
Range of catch	12-210	33-110	-

Appendix Table C-9. Catch rate (number of fish per seine haul) of forage fish species in side channel 9 (Cow Island Section) of the middle Missouri River, 1980.

	Early July	Late July	Early September
Goldeye	0.2	18.0	
Flathead chub	2.8	61.8	2.0
Emerald shiner	1.8	3.8	
Western silvery minnow	1.8	0.6	2.5
Longnose dace	0.2	7.5	
Suckers[a/]	0.8	6.0	0.5
Yellow perch	0.2	0.5	
Larvae	1.2		
Number seine hauls	5	4	2
Range of catch	2-15	29-200	1-9

a/ This group was not separated into shorthead redhorse, white and longnose suckers.

Appendix Table C-10. Catch rate (number of fish per seine haul) of forage fish species in side channel 11 (Robinson Bridge section) of the middle Missouri River, 1980.

	Early July	Late July	Early September
Goldeye	0.2		0.5
Carp	0.2		
Flathead chub	6.0	4.5	24.8
Emerald shiner	5.2		1.8
Western silvery minnow	61.8	0.5	10.5
Fathead minnow	1.0		
Longnose dace	0.4	0.5	0.2
Suckers[a/]		0.5	12.0
Larvae	5.2		
Number seine hauls	5	2	4
Range of catch	8-316	1-11	14-89

a/ This group was not separated into shorthead redhorse, white and longnose suckers.

Appendix Table C-11. Catch rate (number of fish per seine haul) of forage fish species in side channel 12 (Robinson Bridge section) of the middle Missouri River, 1980.

	Early July	Late July	Early September
Goldeye	0.5	0.8	
Flathead chub	0.8	15.6	2.7
Emerald shiner	2.5	0.6	1.0
Western silvery minnow	28.8	7.8	
Fathead minnow	0.5		
Longnose dace	0.5	0.6	2.0
Suckers[a/]		0.6	3.0
Yellow perch	0.2		
Larvae	9.5		
Number seine hauls	6	5	3
Range of catch	7-137	5-49	1-13

a/ This group was not separated into shorthead redhorse, white and longnose suckers.

Appendix Table D-1. Catch rates (number of fish per seine haul) of forage fish species in the Morony Dam section, middle Missouri River during late July-early September 1979.

	Main Channel Border	Main Channel Pool	Backwater
Carp			1.0
Flathead chub		1.5	
Lake chub		1.3	
Emerald shiner	1.5	34.2	11.0
Plains minnow		0.5	
Western silvery minnow		76.7	4.5
Fathead minnow			1.2
Longnose dace	40.5	19.0	44.0
Shorthead redhorse	9.5	34.5	5.7
Longnose sucker	1.0	4.7	3.8
White sucker	4.5	14.7	57.8
Ave. CPUE1/	57.0	187.1	129.0
Range	51-63	23-300	18-300
Number of seine hauls	2	6	6

1/ Catch rate - catch per unit effort

Appendix Table D-2. Catch rates (number of fish per seine haul) of forage fish species in the Carter Ferry section, middle Missouri River during late July-early September 1979.

	Main Channel Border	Main Channel Pool	Backwater
Mountain whitefish		0.2	
Carp			2.2
Flathead chub	0.2	0.5	
Lake chub			0.2
Emerald shiner	3.8		3.8
Plains minnow		0.2	
Western silvery minnow		9.2	2.0
Fathead minnow	21.5		95.5
Longnose dace	17.5	32.2	3.8
Shorthead redhorse	8.0	35.7	26.8
Longnose sucker	4.2	6.2	6.2
White sucker	4.8	2.1	8.5
Yellow perch			0.2
Iowa darter			0.2
Ave. CPUE1/	60.0	86.3	149.4
Range	11-110	9-302	24-300
Number of seine hauls	4	6	4

1/ Catch rate, catch per unit effort

Appendix Table D-3. Catch rates (number of fish per seine haul) of forage fish species in the Fort Benton section, middle Missouri River during late July-early September 1979.

	Main Channel Border	Main Channel Pool	Side Channel Pool	Backwater
Carp			3.8	1.4
Flathead chub		3.4	2.0	5.3
Lake chub				1.1
Emerald shiner	3.2	5.6	4.2	15.8
Western silvery minnow		9.6	2.8	34.0
Fathead minnow		3.2	15.0	19.6
Longnose dace	1.8	89.8	13.8	7.1
Shorthead redhorse	1.8	50.2	32.8	42.2
Longnose sucker	5.0	26.8	14.5	17.0
White sucker	0.5	5.0	0.2	5.0
Yellow perch		0.4		1.8
Ave. CPUE[1/]	12.3	194.0	89.1	150.3
Range	5-25	47-428	13-300	19-300
Number of seine hauls	4	5	4	9

1/ Catch rate, catch per unit effort

Appendix Table D-4. Catch rates (number of fish per seine haul) of forage fish species in the Loma Ferry section, middle Missouri River during late July-early September 1979.

	Main Channel Border	Main Channel Pool	Side Channel Pool	Backwater
Carp		0.3	2.0	5.2
Flathead chub	21.9	43.4	6.6	1.0
Lake chub			0.2	
Emerald shiner	19.0	29.4	13.8	6.4
Plains minnow			0.2	
Western silvery minnow		19.9	3.6	9.2
Fathead minnow	0.8	0.6	0.6	1.6
Longnose dace	25.3	11.7	9.6	46.8
River carpsucker		0.1		1.2
Shorthead redhorse	6.4	36.9	31.0	24.0
Longnose sucker	7.5	53.0	0.6	1.2
White sucker		0.4	0.2	0.2
Stonecat		0.1		
Sauger			0.4	
Ave. CPUE[1/]	80.9	195.7	68.8	96.8
Range	9-300	12-300	27-134	34-200
Number of seine hauls	9	7	5	5

1/ Catch rate, catch per unit effort.

Appendix Table D-5. Catch rates (number of fish per seine haul) of forage fish species in the Coal Banks section, middle Missouri River during late July-early September 1979.

	Main Channel Border	Main Channel Pool	Side Channel Chute	Side Channel Pool	Backwaters
Mountain whitefish		0.2			
Carp		0.1			5
Flathead chub	56.5	20.3	5.0	8.5	45
Lake chub	0.4			0.5	
Emerald shiner	9.7	7.4	7.0		45
Western silvery minnow	1.0	4.6		1.0	135
Fathead minnow					15
Longnose dace	11.0	23.7		10.0	5
River carpsucker	0.3	0.4			3
Shorthead redhorse	5.4	22.0	8.0	1.5	28
Longnose sucker	35.6	40.7		6.0	2
Sauger					1
Mottled sculpin	0.1				
Ave. CPUE1/	120.0	119.4	20.0	27.5	284.0
Range	9-300	6-300	7-33	8-47	
Number of seine hauls	10	7	2	2	1

1/ Catch rate, catch per unit effort.

Appendix Table D-6. Catch rates (number of fish per seine haul) of forage fish species in the Hole-in-the-Wall section, middle Missouri River during late July-early September 1979.

	Main Channel Border	Main Channel Pool	Side Channel Chute	Side Channel Pool	Backwaters
Goldeye				0.2	
Carp	0.2	0.1		0.4	72.0
Flathead chub	6.2	38.6	54.5	38.4	17.0
Lake chub		2.0			0.3
Emerald shiner	3.5	2.5	1.3	4.6	27.0
Western silvery minnow	0.2	8.0	0.8	20.2	2.3
Fathead minnow					6.0
Longnose dace	14.1	29.6	4.5	5.0	17.7
River carpsucker		1.4	0.8	2.0	3.3
Shorthead redhorse	4.0	16.1	4.0	25.2	55.7
Longnose sucker	1.0	4.9		3.4	61.7
White sucker		0.4			
Stonecat	0.1		0.2	0.2	
Sauger	0.2	1.0		1.8	1.3
Ave. CPUE1/	29.5	104.6	66.1	101.4	264.3
Range	3-95	15-231	6-193	11-293	36-504
Number of seine hauls	11	8	4	5	3

1/ Catch rate, catch per unit effort.

Appendix Table D-7. Catch rates (number of fish per seine haul) of forage fish species in the Judith Landing section, middle Missouri River during late July-early September 1979.

	Main Channel Border	Main Channel Pool	Side Channel Pool	Backwaters
Goldeye				0.5
Carp			1.0	40.5
Flathead chub	5.8	9.5	85.0	79.5
Lake chub			1.0	1.0
Emerald shiner	2.6	2.5	18.0	70.5
Western silvery minnow	0.2	5.0	50.5	23.5
Longnose dace	4.8	0.5	5.0	4.5
River carpsucker			6.5	22.5
Shorthead redhorse	0.2	3.5	20.0	16.0
Longnose sucker	2.2		43.5	52.5
Stonecat	0.2			
Sauger			3.0	
Ave. CPUE[1/]	16.0	21.0	233.5	311.0
Range	6-38	10-32	201-266	302-313
Number of seine hauls	5	2	2	2

1/ Catch rate; catch per unit effort.

Appendix Table D-8. Catch rates (number of fish per seine haul) of forage fish species in the Stafford Ferry section, middle Missouri River during late July-early September 1979.

	Main Channel Border	Main Channel Pool	Backwaters
Carp		0.1	0.5
Flathead chub	2.4	21.0	32.0
Emerald shiner	2.3	5.9	54.5
Western silvery minnow		7.2	10.0
Longnose dace	0.6	1.4	
River carpsucker		0.1	4.5
Shorthead redhorse	2.7	3.9	6.5
Stonecat	0.3		
Sauger		0.2	
Ave. CPUE[1/]	8.3	39.8	108.0
Range	2-17	4-73	80-136
Number of seine hauls	7	9	2

1/ Catch rate, catch per unit effort.

Appendix Table D-9. Catch rates (number of fish per seine haul) of forage fish species in the Cow Island section, middle Missouri River during late July-early September 1979.

	Main Channel Border	Main Channel Pool	Side Channel Chute	Side Channel Pool	Backwaters
Goldeye					9.6
Carp					0.2
Flathead chub	3.9	10.6	3.3	2.5	10.5
Sicklefin chub	0.4	0.9	0.3		
Emerald shiner	22.2	32.0	2.3	0.7	24.2
Western silvery minnow	2.9	58.9	3.2	7.3	42.4
Longnose dace		0.1	0.1	0.2	
River carpsucker		0.1		0.2	0.6
Shorthead redhorse	0.4	0.2		1.0	
Longnose sucker	0.7	2.3	0.2	0.4	2.6
Channel catfish		0.1			
Stonecat			0.1		
Yellow perch					0.8
Sauger	0.4	0.8	0.1	1.3	0.1
Ave. CPUE1/	30.9	106.0	9.6	13.2	91.0
Range	2-202	14-300	1-24	2-32	23-237
Number of seine hauls	14	8	9	8	4

1/ Catch rate; catch per unit effort.

Appendix Table D-10. Catch rates (number of fish per seine haul) of forage fish species in the Robinson Bridge section, middle Missouri River during late July-early September 1979.

	Main Channel Border	Main Channel Pool	Side Channel Chute	Side Channel Pool	Backwaters
Goldeye	0.2	0.8		40.5	1.4
Carp				1.0	
Flathead chub	11.3	12.2	8.7	7.5	1.4
Sicklefin chub	1.6	0.7			
Emerald shiner	4.2	10.8	33.7	5.0	36.9
Plains minnow		0.2		0.5	
Western silvery minnow	0.9	5.4	0.7	12.8	11.5
Longnose dace	0.2	0.1	2.7	0.2	
River carpsucker					0.2
Shorthead redhorse	0.1	1.4			
Longnose sucker	0.3	0.4	0.7	5.5	0.5
Channel catfish	0.1				
Sauger	0.3	2.2		9.2	
Mottled sculpin	0.1				
Ave. CPUE1/	19.3	34.2	46.5	82.2	51.9
Range	1-109	2-85	7-107	12-178	3-103
Number of seine hauls	18	9	3	4	8

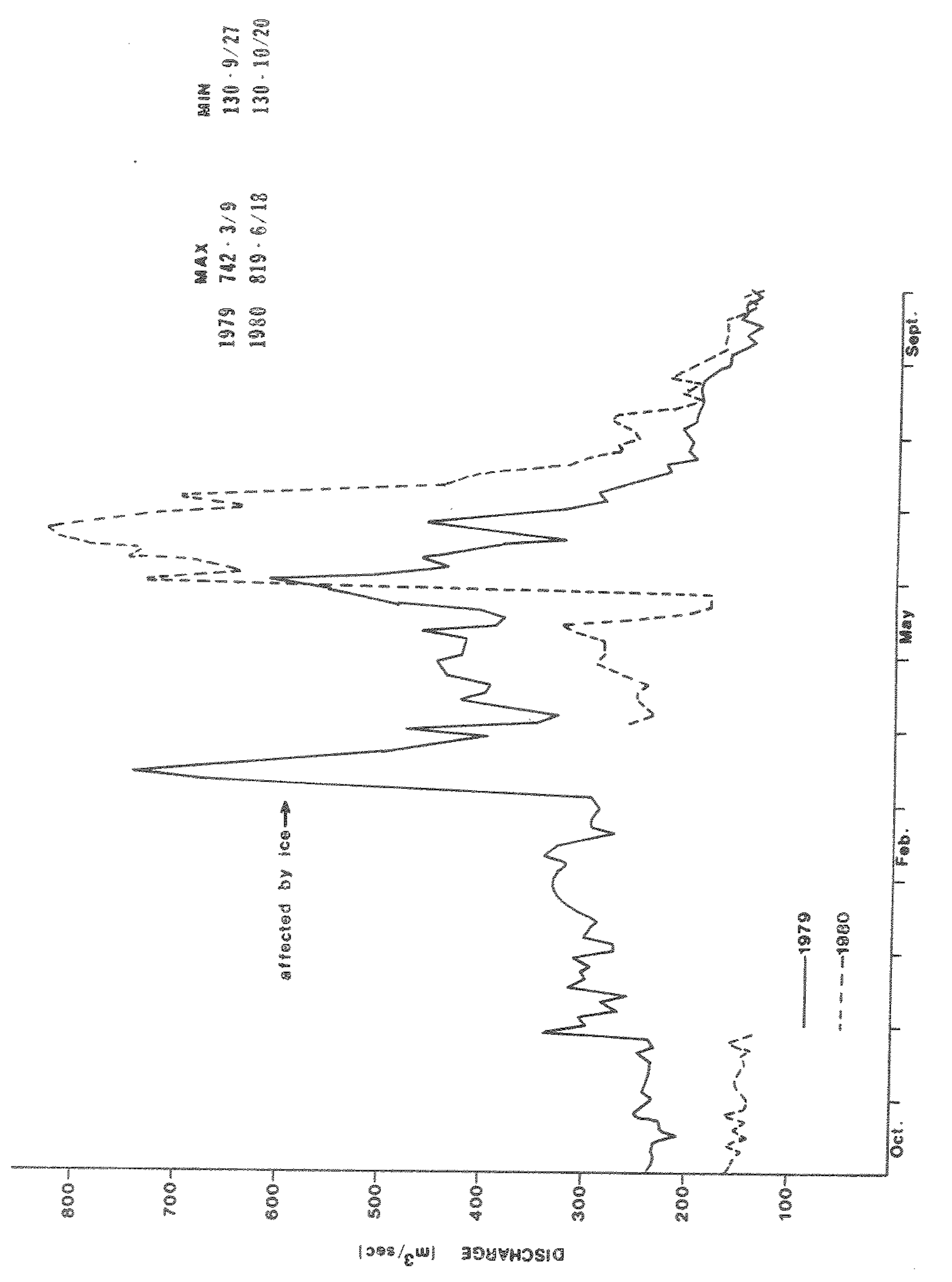
1/ Catch rate; catch per unit effort.

Appendix Table E. Distribution of sauger stomach samples collected for different length groups and study reaches in the middle Missouri River from August 19 through November 7, 1980.

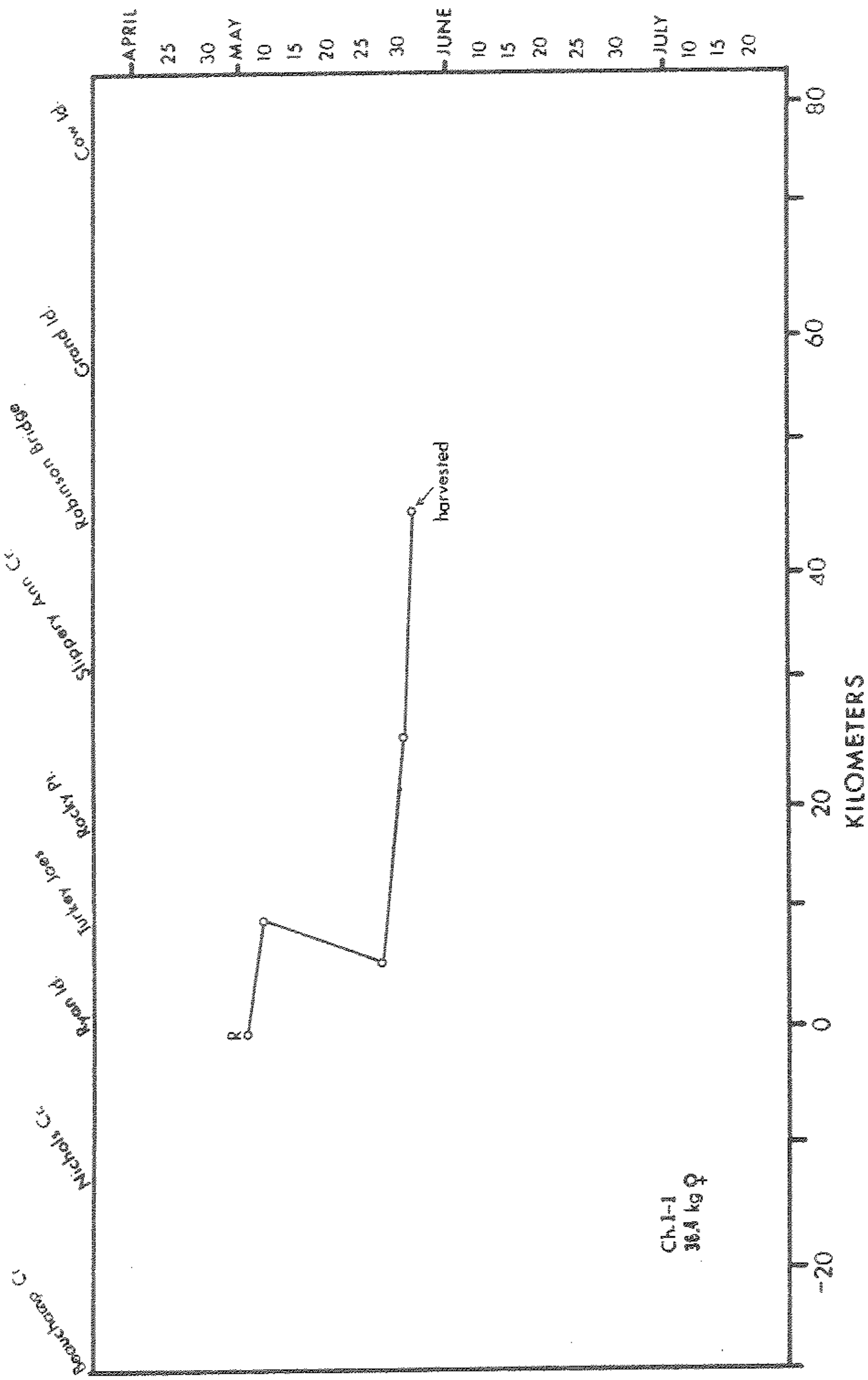
Fish Length	Morony Dam & Carter Ferry Sections	Fort Benton & Loma Ferry Sections	Loma Ferry & Coal Banks Sections	Sections below Coal Banks
≤ 249	𝍸	𝍸	|	||||
250-299	𝍸 𝍸 𝍸 𝍸	|||	𝍸 |||	|||
300-329	𝍸|	𝍸	|||	|||
330-359	𝍸 ||||	𝍸 𝍸 |	𝍸	||||
360-399	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸	𝍸 𝍸 𝍸 𝍸	𝍸 |	|||
≥ 400	𝍸 𝍸 𝍸 |||	|||	𝍸 |||	|
Number of Sauger sampled	88	47	31	19

Appendix Table F. Daily minimum and maximum water temperatures (degrees C) for the Missouri River at Virgelle (Coal Banks Landing section) during 1980.

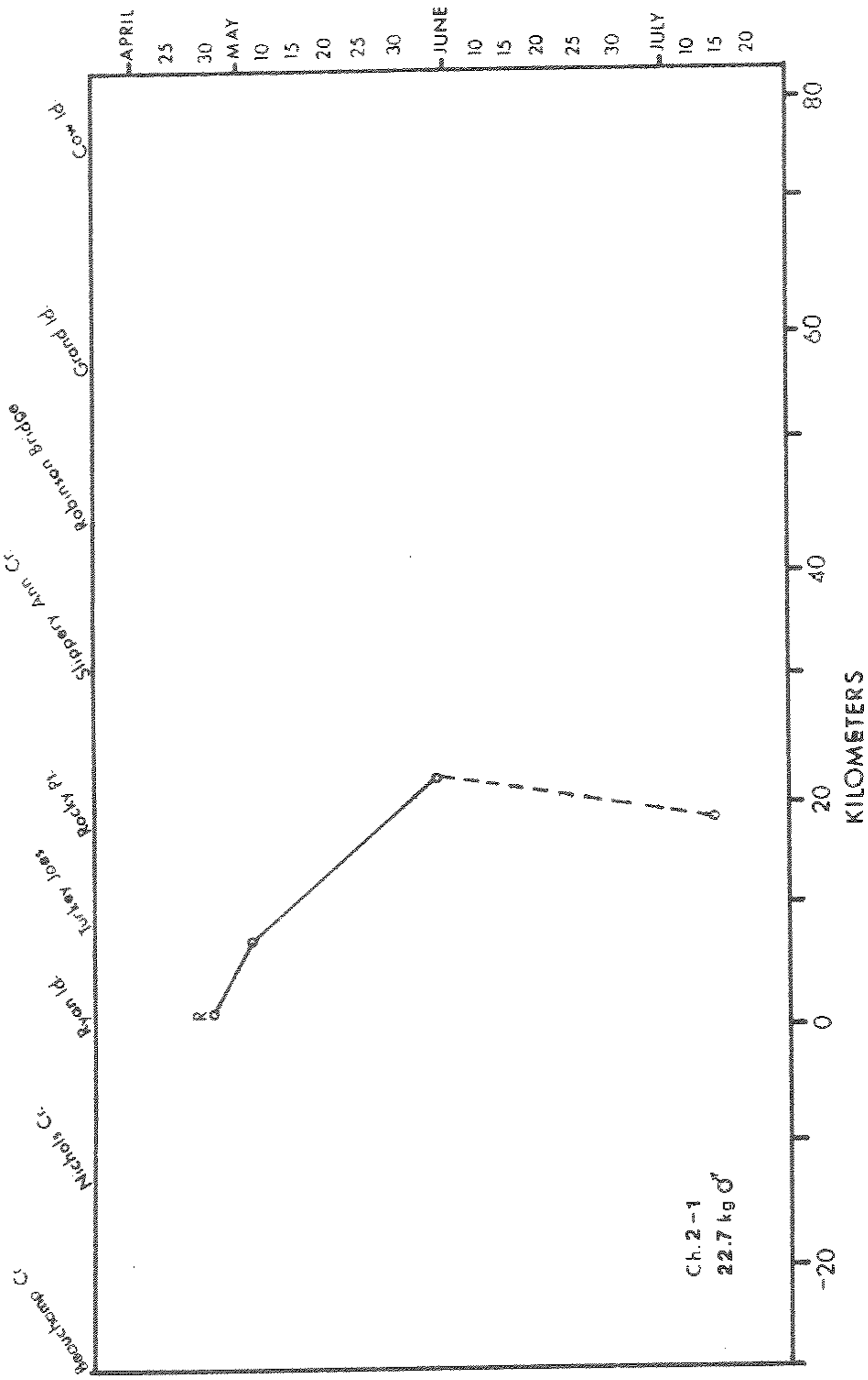
	April		May		June		July		Aug.		Sept.		Oct.	
Day	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1	4.0	5.0	14.0	16.5	14.1	15.4	17.9	19.6	21.3	22.7	15.4	18.0	12.2	14.0
2	4.5	5.5	15.0	17.5	14.2	15.4	18.8	20.3	20.0	21.7	16.6	18.5	11.4	14.0
3	4.0	6.0	14.0	15.5	13.7	14.4	19.2	20.2	18.2	21.0	15.5	17.2	12.1	14.7
4	5.0	8.0	12.5	15.5	13.8	15.0	18.7	20.2	16.8	19.0	14.2	16.5	12.9	15.0
5	6.0	8.5	14.0	17.0	13.4	14.7	19.8	20.9	17.9	20.2	14.9	18.0	13.1	15.1
6	7.0	9.5	13.5	16.0	12.9	14.6	19.7	21.0	18.0	19.8	15.7	19.1	12.7	15.1
7	7.0	8.0	12.5	14.5	12.9	14.2	19.2	20.9	18.3	19.8	17.2	18.7	13.2	15.4
8	6.0	9.0	12.5	14.5	12.9	14.5	20.4	21.9	17.8	20.1	15.6	17.9	13.7	15.6
9	7.0	9.0	14.0	15.5	13.4	15.9	20.7	22.2	18.8	20.4	15.4	18.1	12.6	14.7
10	7.0	8.0	13.0	14.5	15.4	17.2	20.4	22.1	18.3	20.9	16.4	18.9	10.9	12.7
11	6.5	9.0	12.0	15.0	16.6	17.6	19.9	21.1	19.2	21.3	17.6	19.2	10.0	11.6
12	7.5	10.5	12.5	15.0			20.1	21.5	19.2	20.2	16.3	18.5	10.6	12.7
13	8.0	11.0	12.5	15.5			19.4	20.7	18.3	20.7	15.8	17.0	11.8	13.1
14	9.0	12.0	13.0	16.0			18.6	19.7	17.9	20.9	15.1	17.8	10.4	11.8
15	10.0	11.5	13.0	16.5			18.0	19.4	19.7	21.4	14.6	17.1	8.2	10.2
16	9.0	12.0	14.0	17.0			17.5	20.1	19.5	21.5	12.6	14.9	8.1	8.6
17	10.0	13.5	15.0	18.0			18.4	20.2			14.0	14.8	8.3	9.1
18	11.5	14.0	16.0	19.5			18.5	20.2			13.5	14.2	7.9	9.6
19	12.0	14.0	17.0	18.0			18.7	20.4			13.3	15.1	8.4	9.9
20	12.0	15.0	16.0	19.0			17.6	20.3	17.5	19.8	13.2	15.1	8.4	9.7
21	13.0	15.5	18.2	19.8			18.9	22.0	17.6	19.7	12.8	14.3	9.0	10.0
22	11.0	13.0	19.2	22.1			20.0	22.0	17.1	18.3	11.8	13.3	6.9	9.2
23	10.0	12.5	16.9	20.0			21.2	23.5	16.3	18.4	11.8	13.0	6.4	7.8
24	12.0	14.5	15.5	17.4			20.7	21.8	16.6	19.4	11.1	12.6	6.7	8.0
25	13.0	15.5	14.4	16.6			19.5	22.2	15.7	18.7	10.2	12.7	6.0	6.8
26	13.0	14.5	12.4	14.3	17.0	18.3	21.2	23.2	15.4	18.8	11.3	13.7	5.7	6.2
27	12.5	15.5	11.4	12.9	16.5	18.2	20.9	22.9	16.7	18.7	12.2	14.7	5.4	6.1
28	14.0	16.5	11.7	13.0	15.9	17.2	20.9	23.5	16.2	17.7	12.5	13.6	5.0	6.5
29	14.5	17.0	12.0	14.2	15.9	18.1	21.2	22.8	15.6	17.3	12.0	14.2	5.9	6.8
30	15.0	16.5	13.6	14.6	17.2	18.5	20.3	22.8	15.2	18.0	12.9	13.9	6.0	7.3
31			13.7	14.9			20.6	23.4	15.7	17.2			6.8	7.8



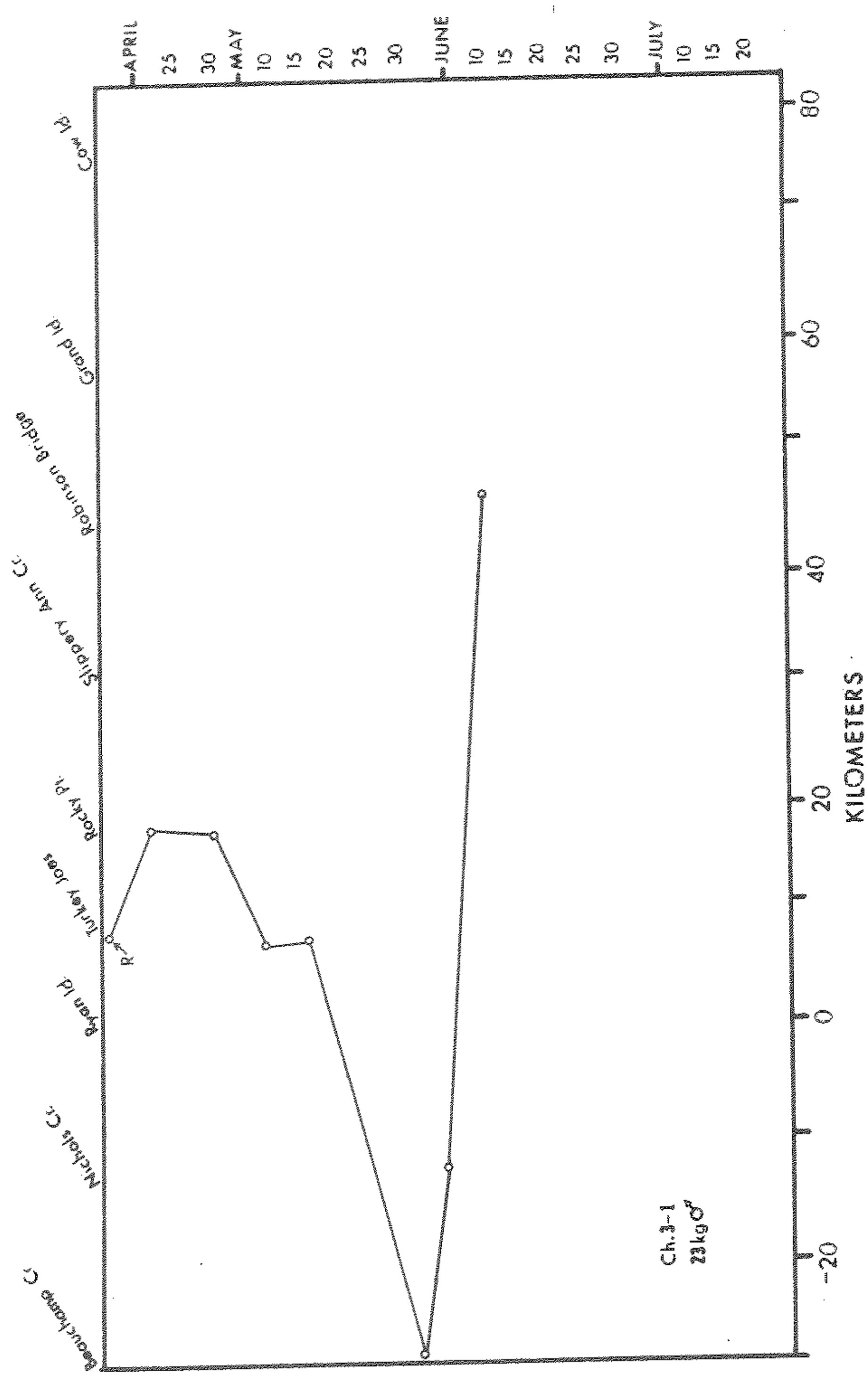
Appendix Figure A. Hydrographs of the Missouri River for 1979 and 1980 at the USGS gaging station located at the Fred Robinson Bridge (Robinson Bridge section). (USGS 1979 and 1980).



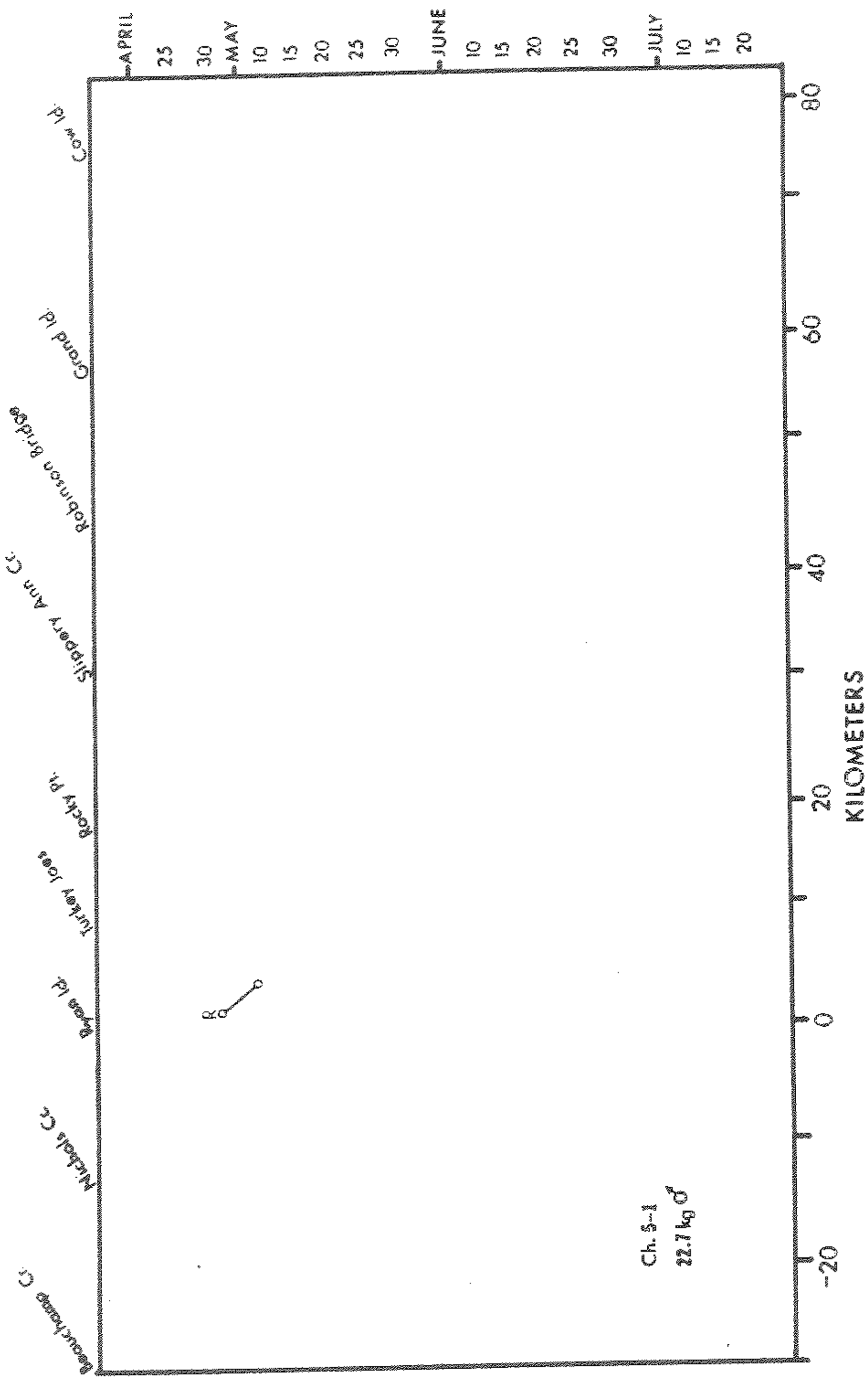
Appendix Figure B-1 . Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



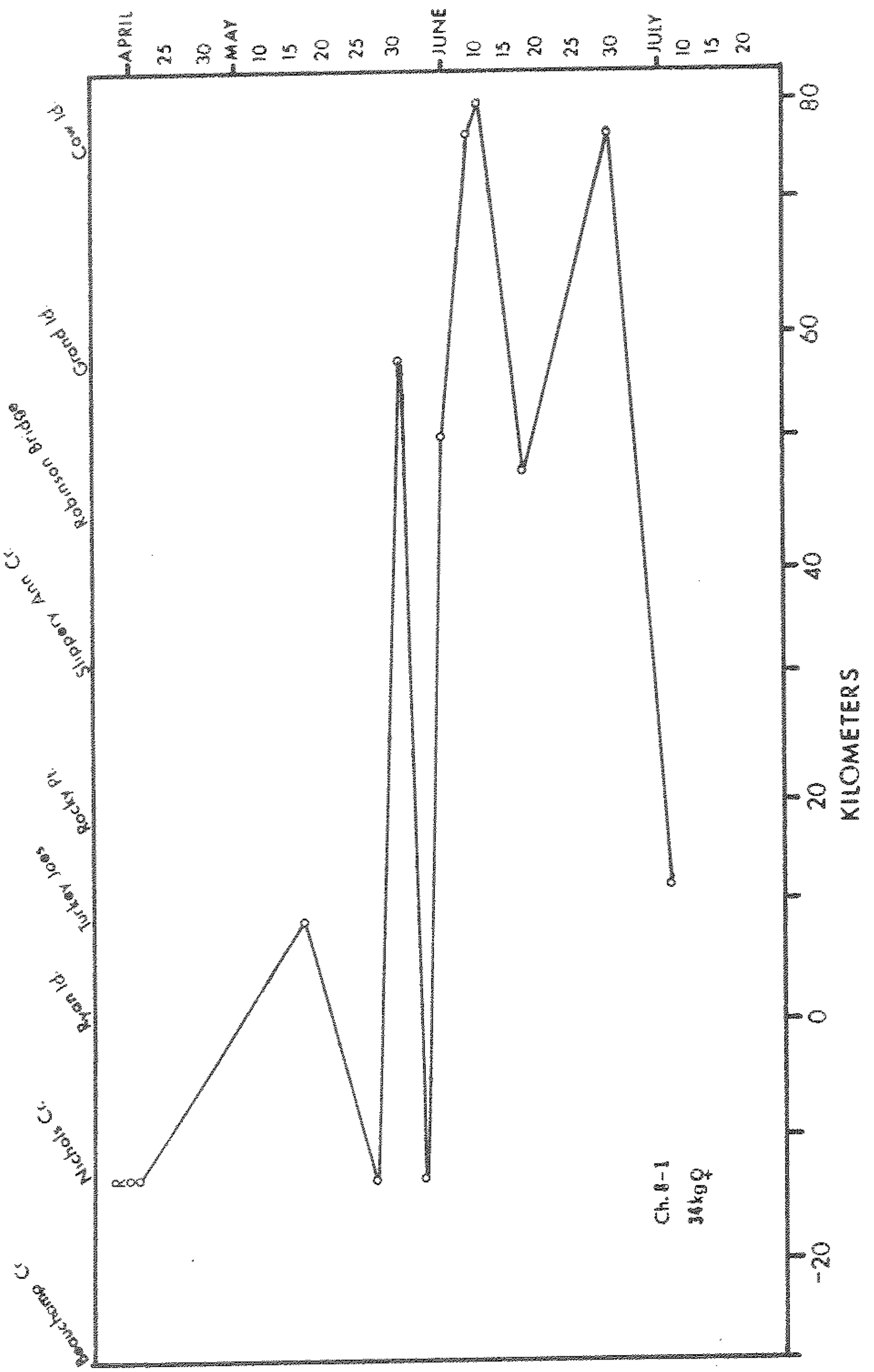
Appendix Figure B-2. Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



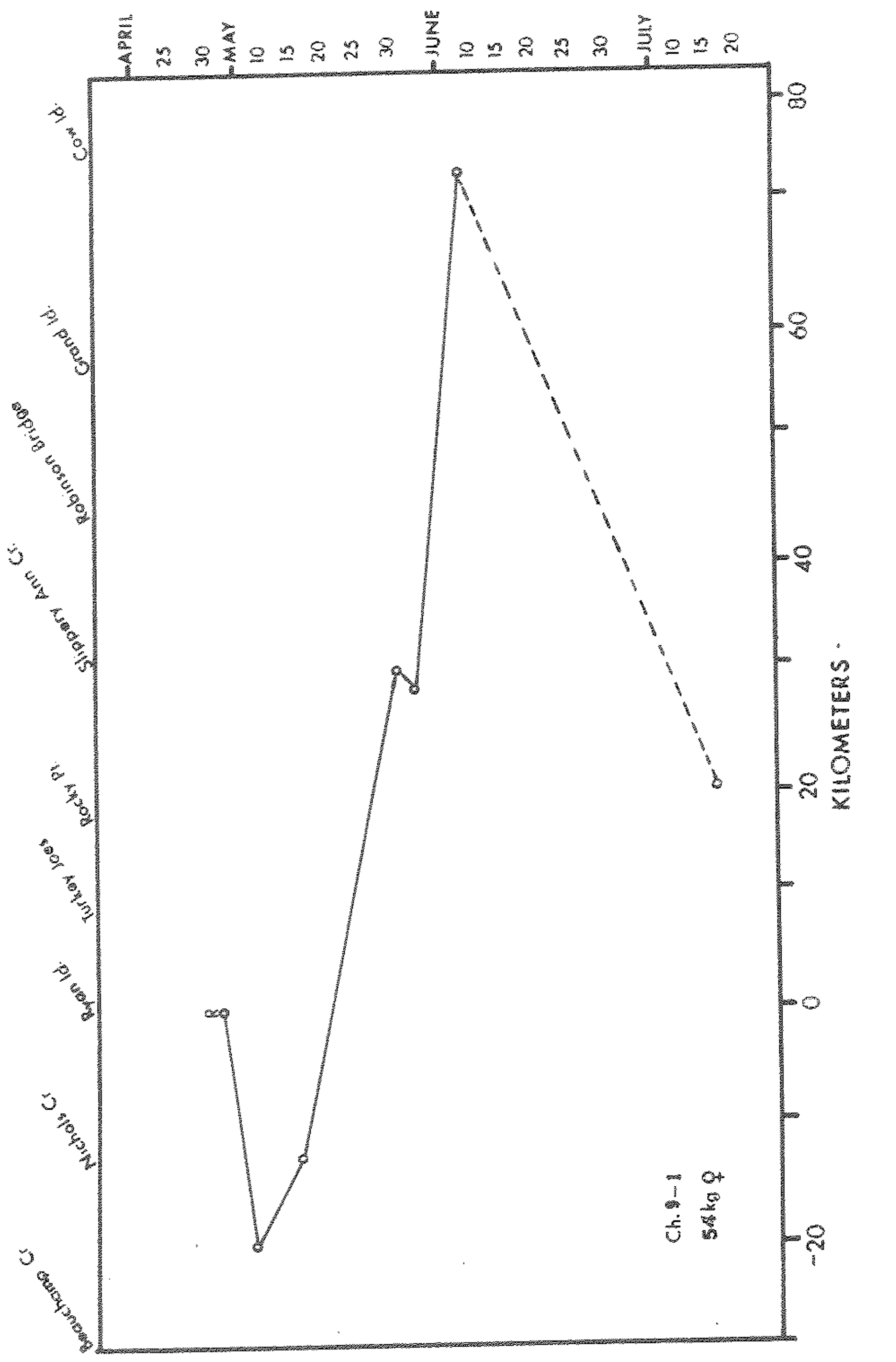
Appendix Figure B-3 . Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



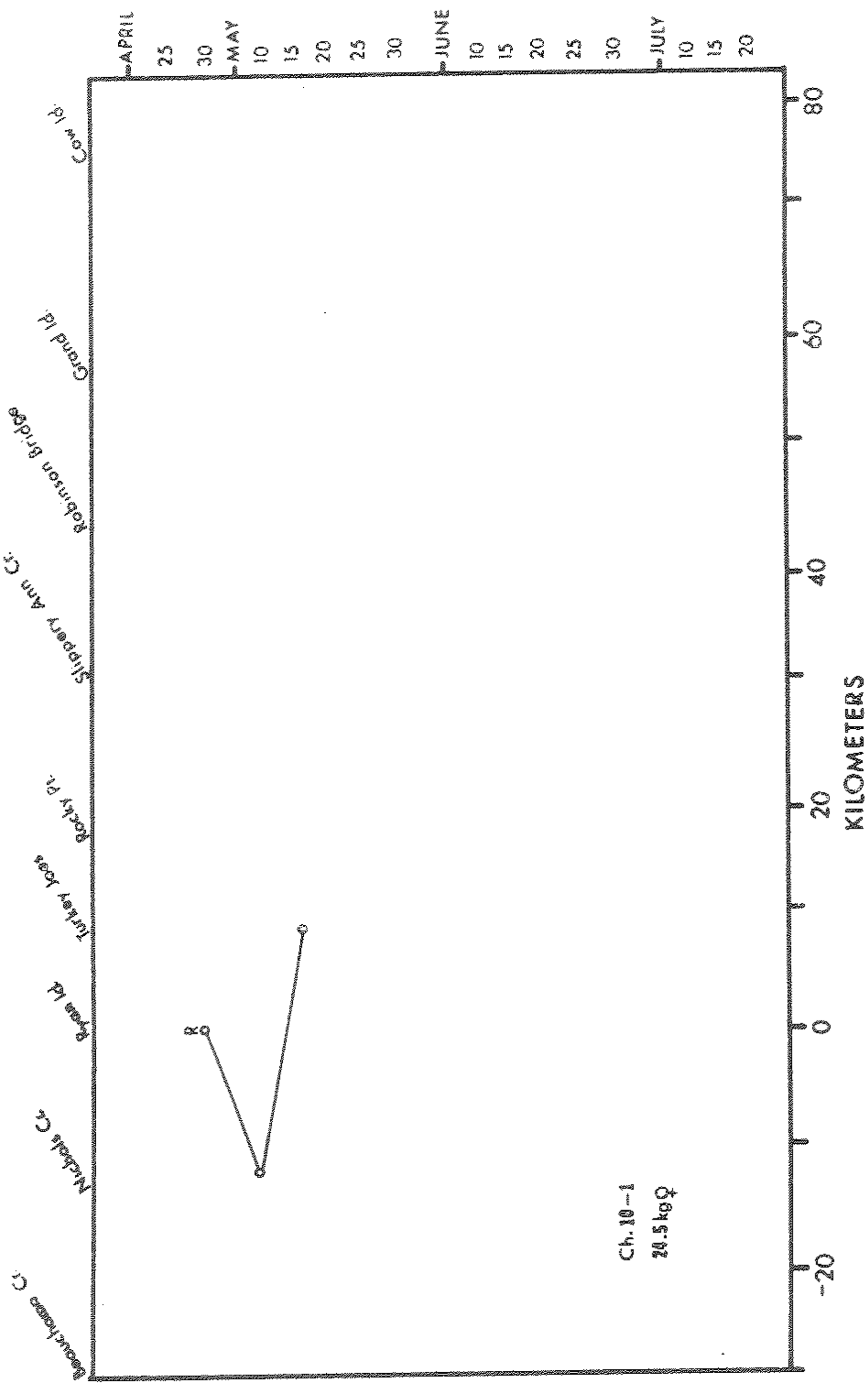
Appendix Figure B-4 . Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



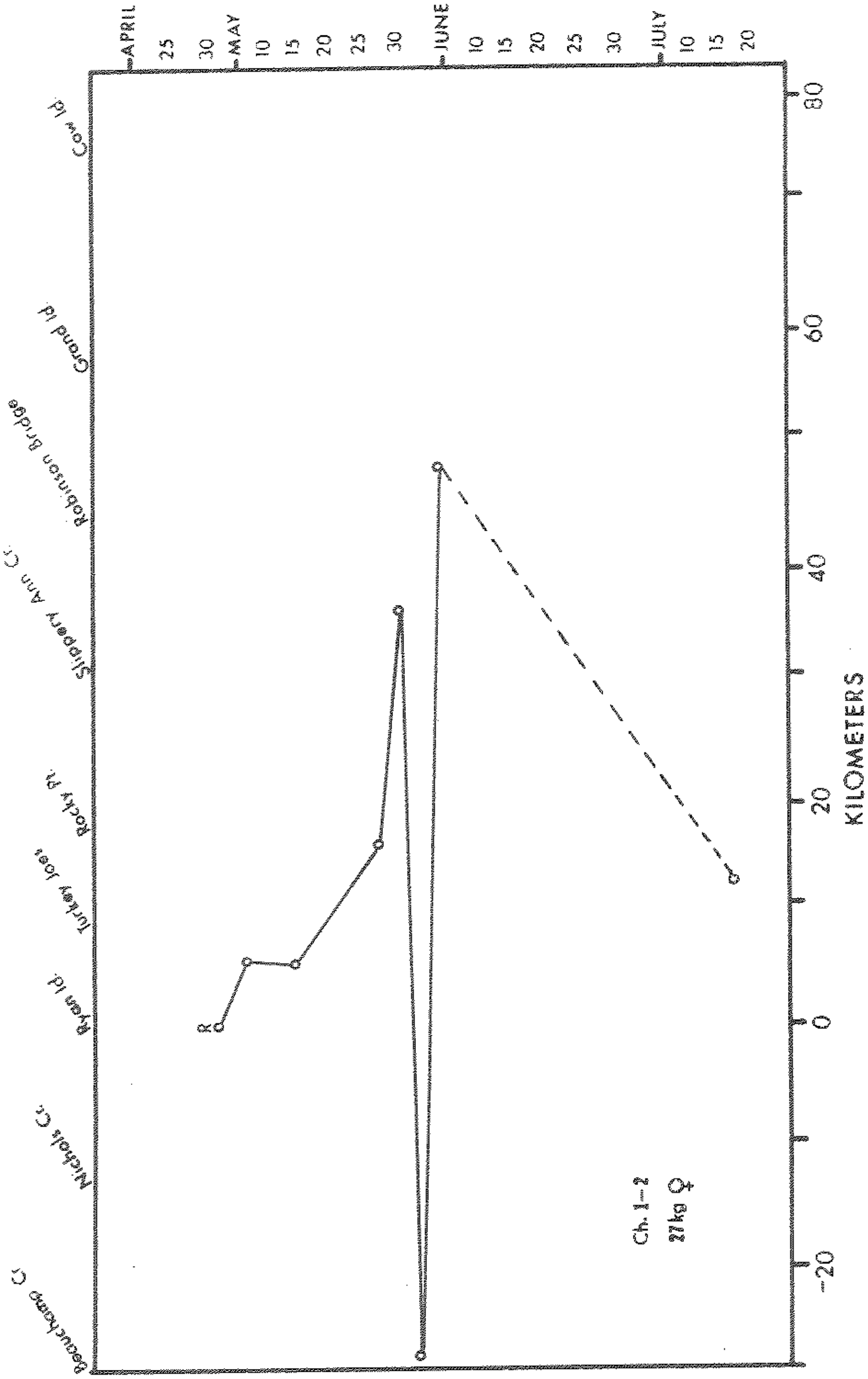
Appendix Figure B-5 . Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



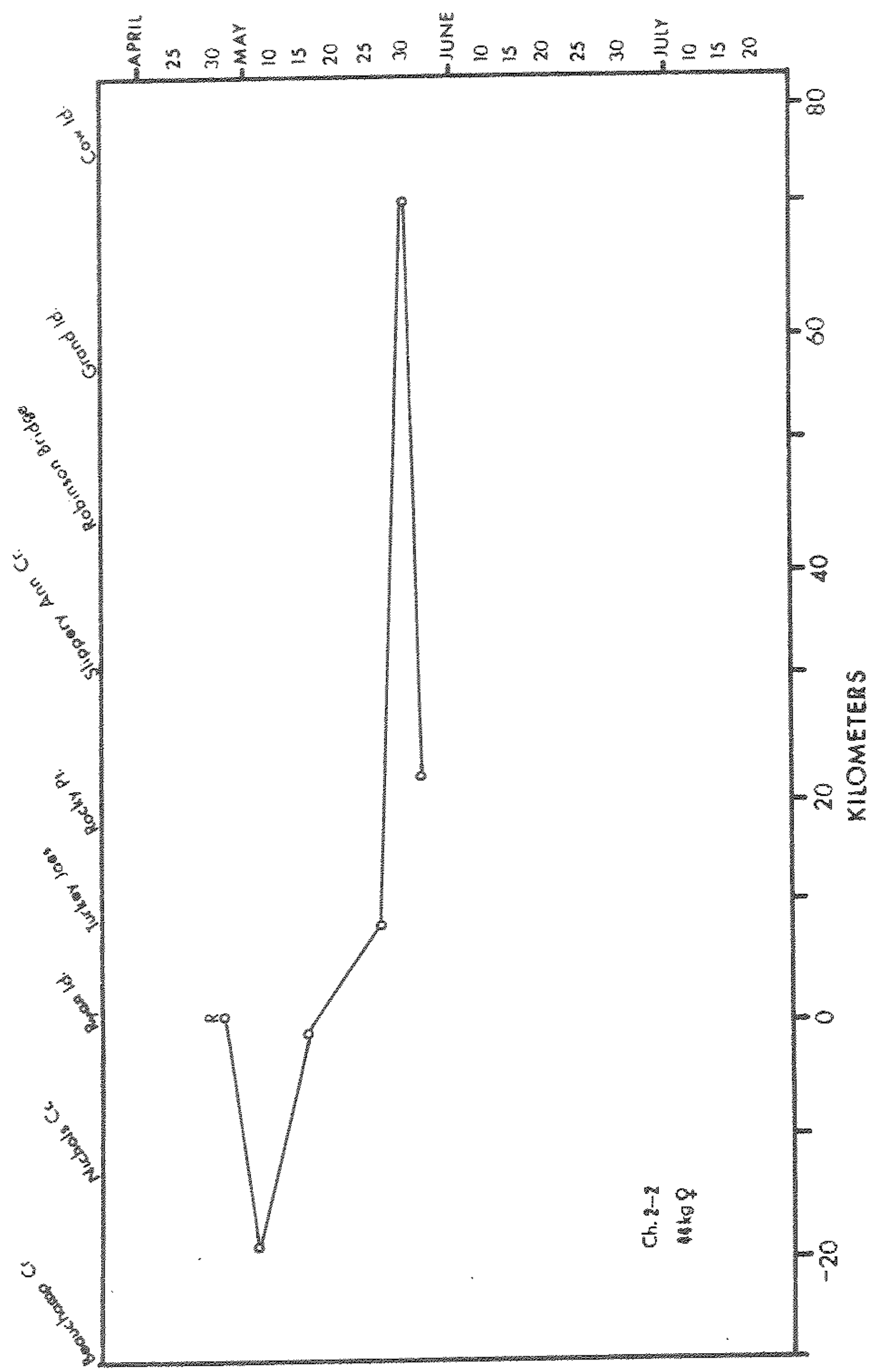
Appendix Figure B-6. Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



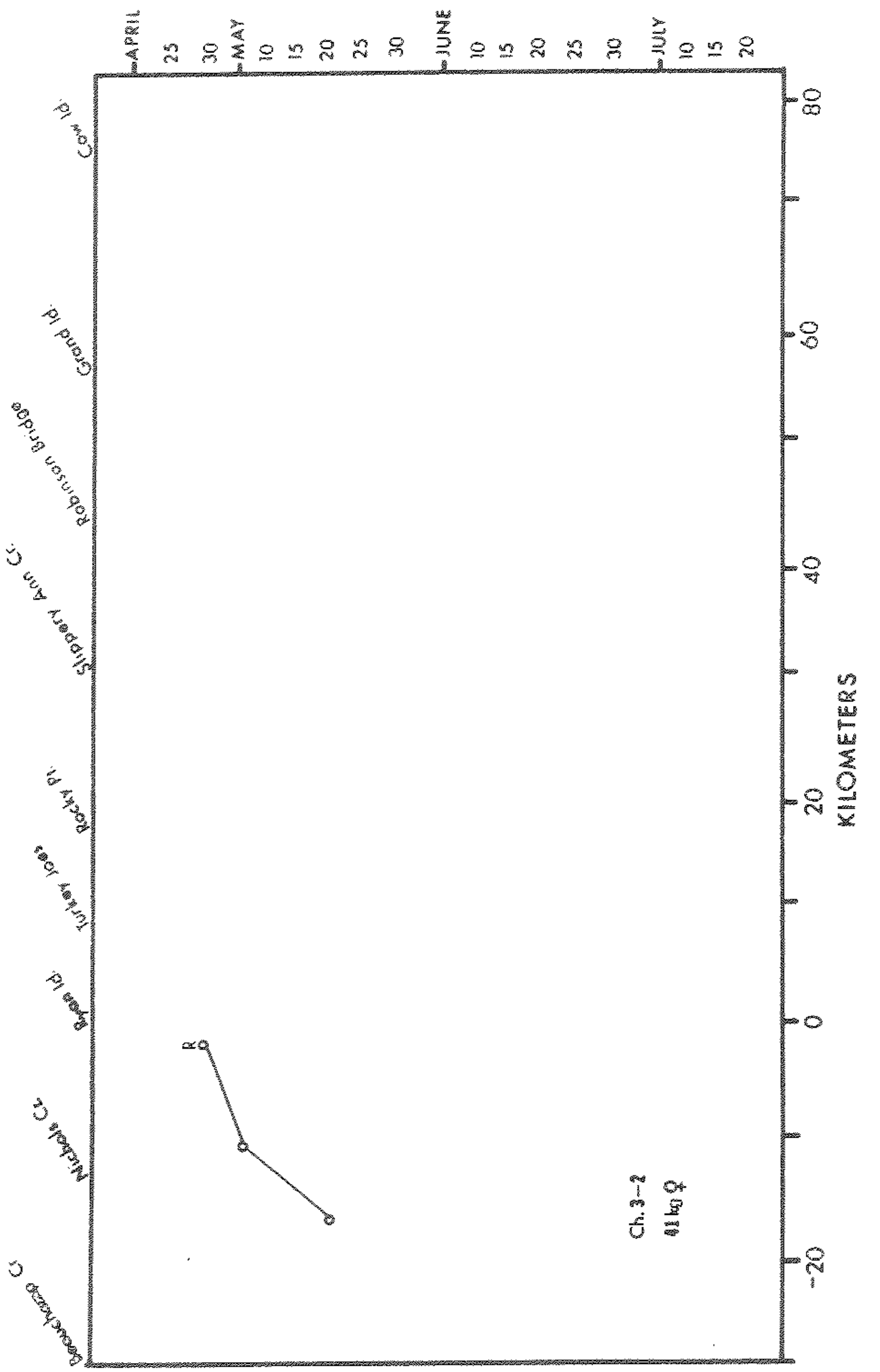
Appendix Figure B-7. Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



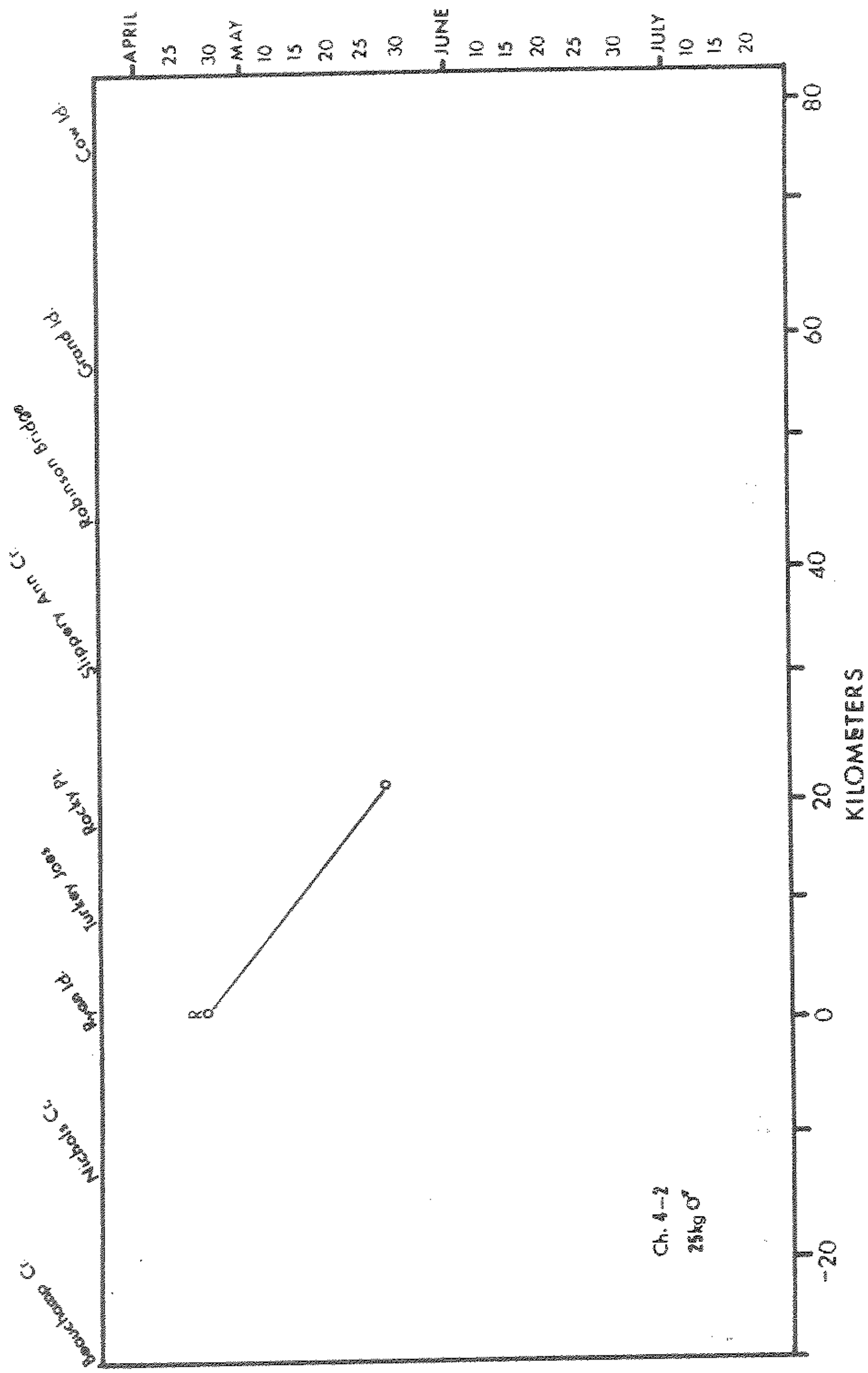
Appendix Figure B-8. Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



Appendix Figure B-9. Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



Appendix Figure B-10 . Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



Appendix Figure B-11. Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.