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

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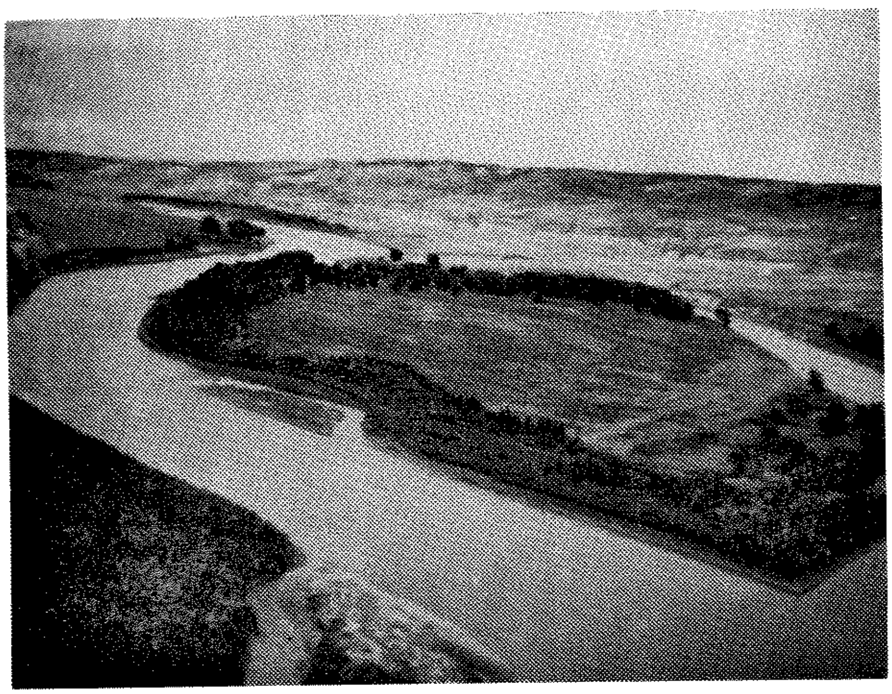

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ABSTRACT

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

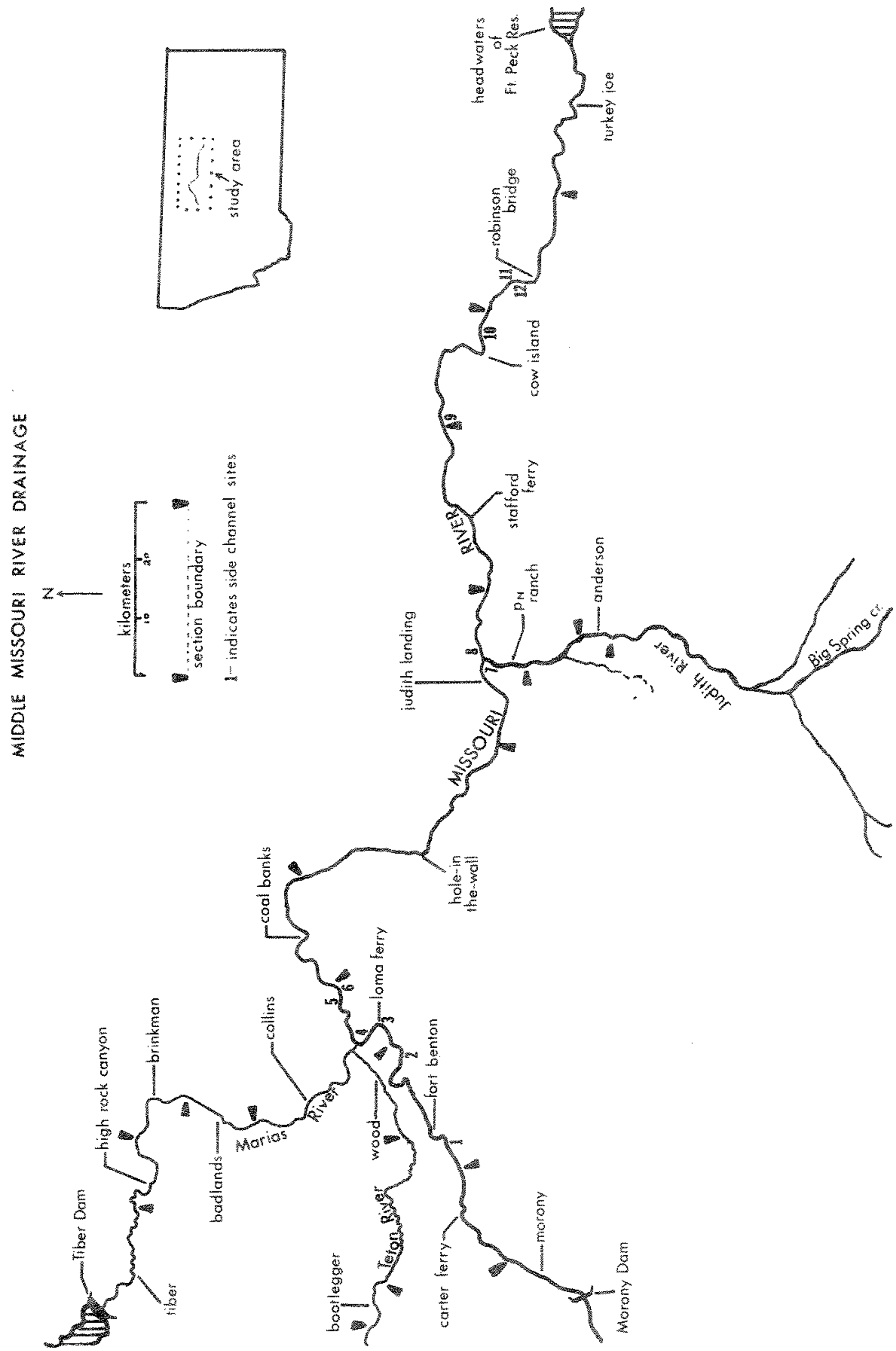

Figure 1. Map of middle Missouri River drainage and study area.

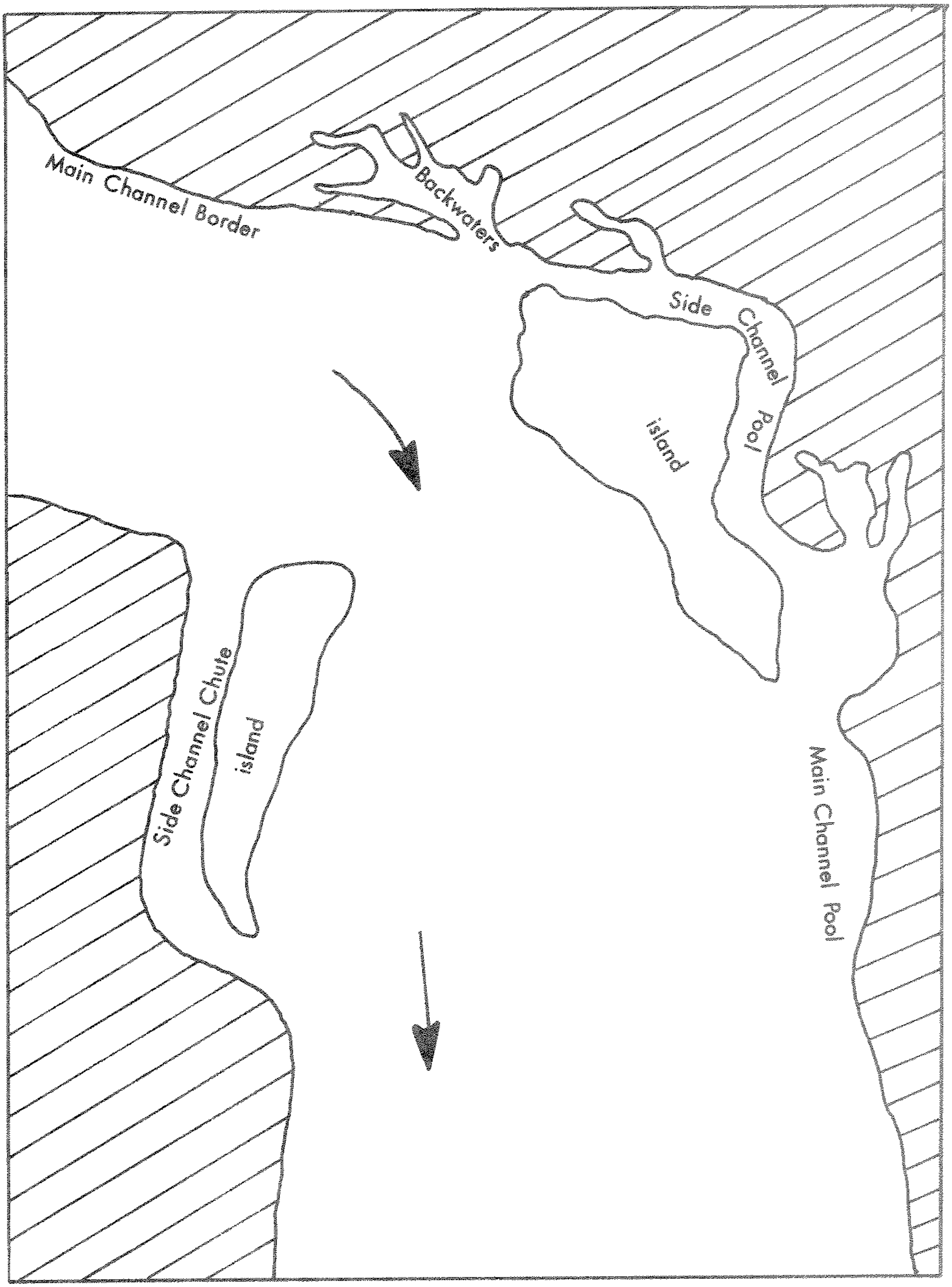

Figure 2. Diagrammatic representation of peripheral habitats in the middle Missouri River. (modified from Kallemeyn and Novotny 1977).

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.

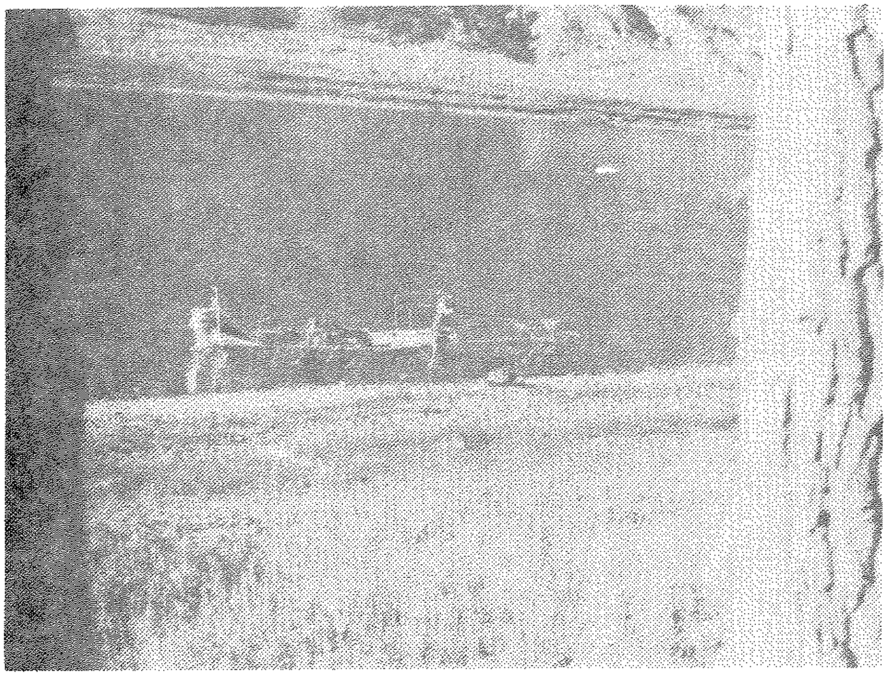

Figure 3. Electrofishing collections were made from a 5.2 m aluminum boat.

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.

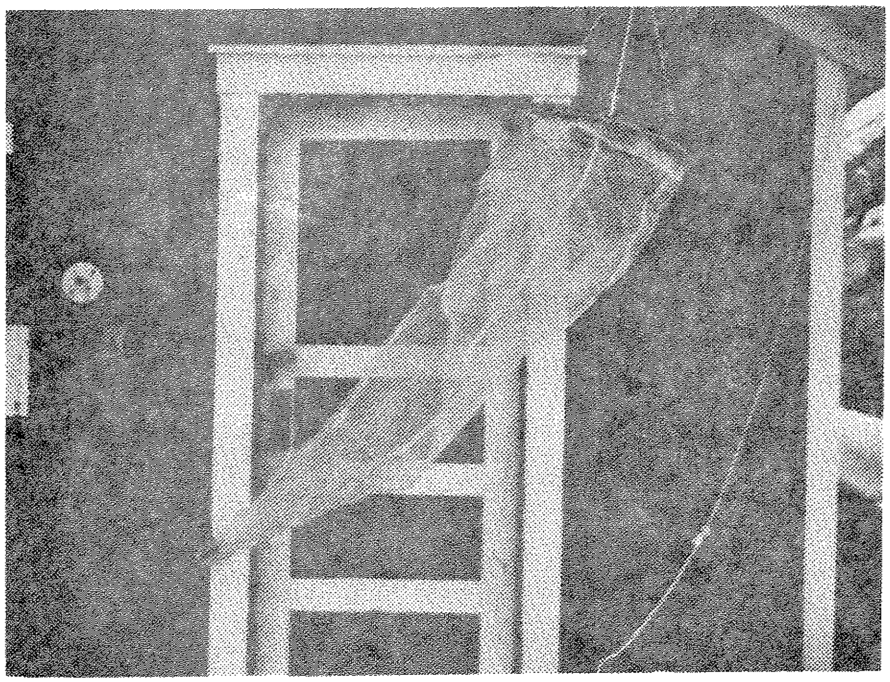

Figure 5. A 0.5 m diameter larval fish net was used to collect drifting fish larvae in the middle Missouri River and its major tributaries.

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.

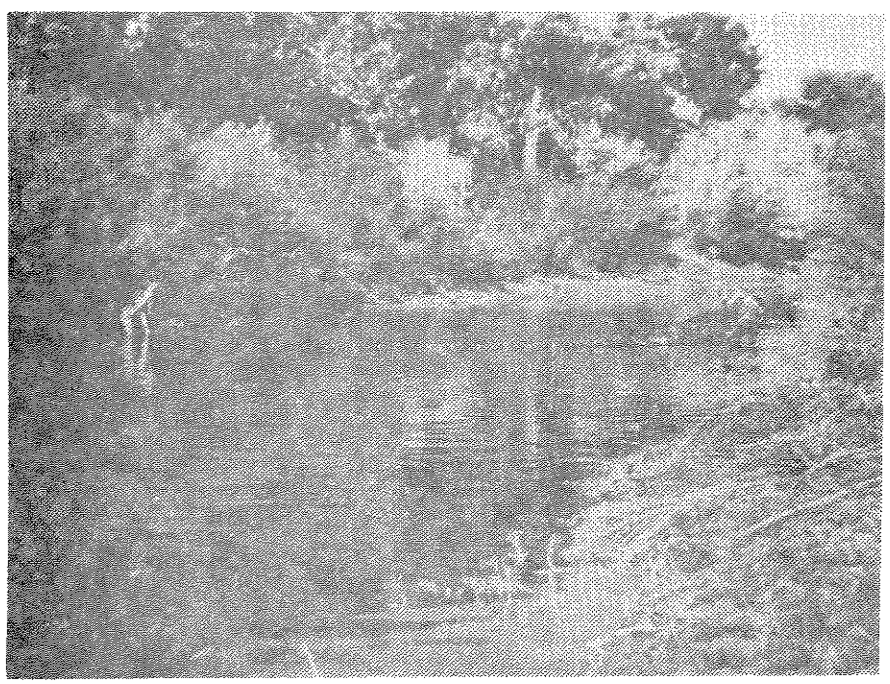

Figure 6. A beach seine was an effective device used to sample for young-of-the-year fish and minnows.

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

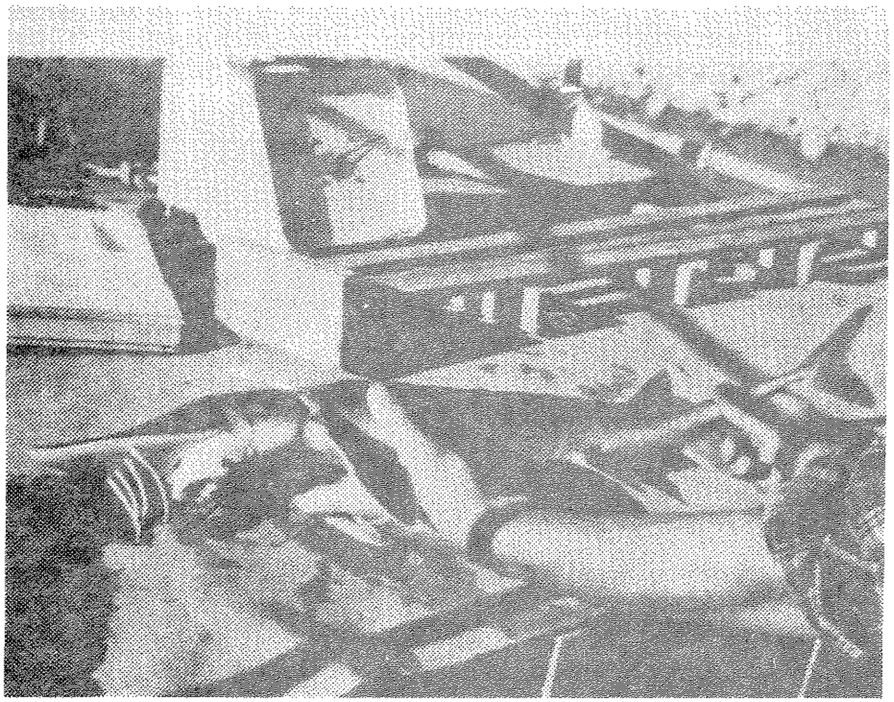

Figure 7. Shovelnose sturgeon were in spawning condition from early June to early July.

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.

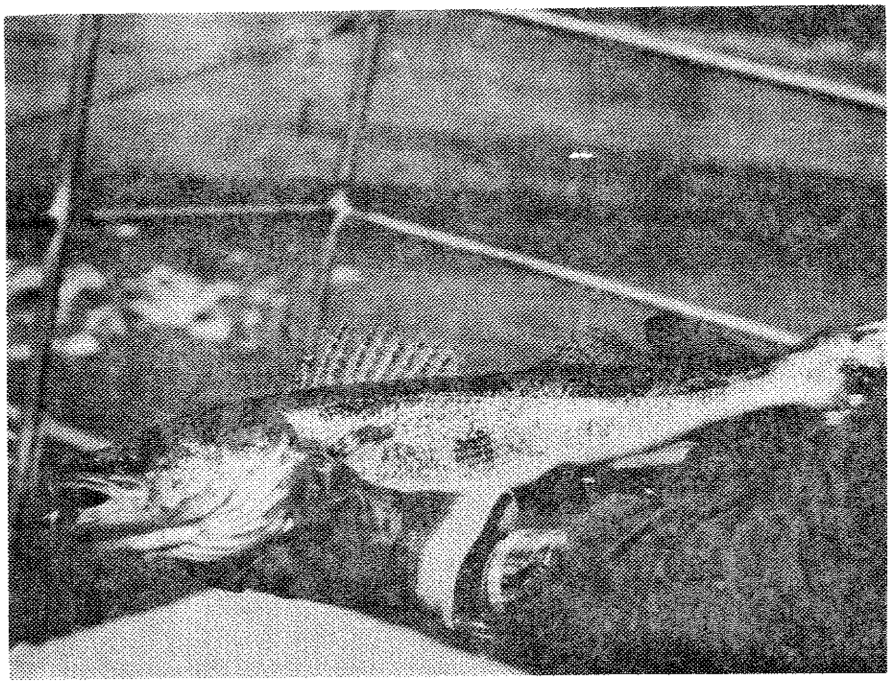

Figure 8. The sauger's spawning peak occurred in early May.

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	Total number of larvae sampled: 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	

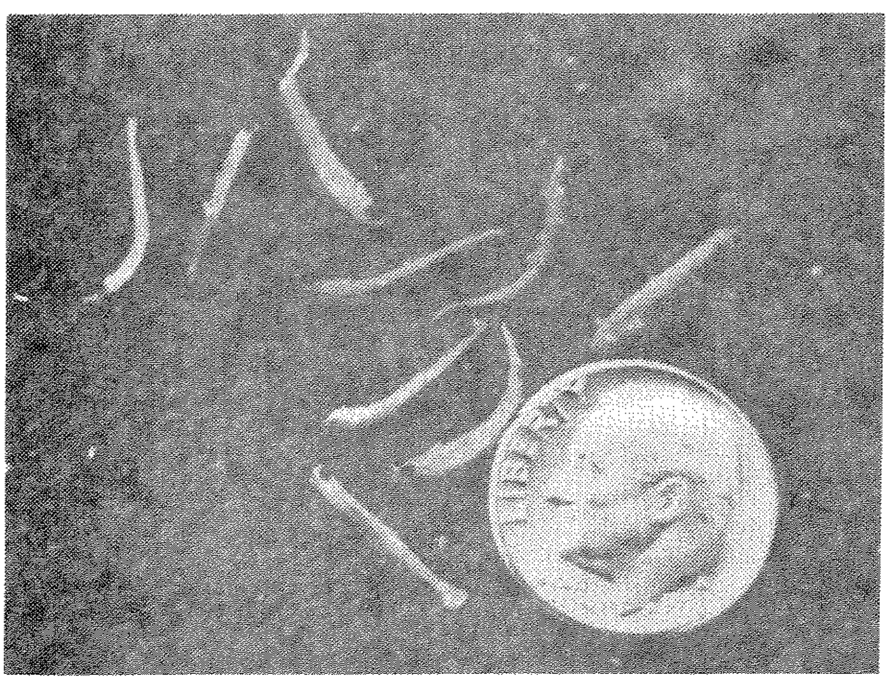

Figure 9. Fish larvae of eight subordinal taxa were collected in the middle Missouri River and its major tributaries.

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

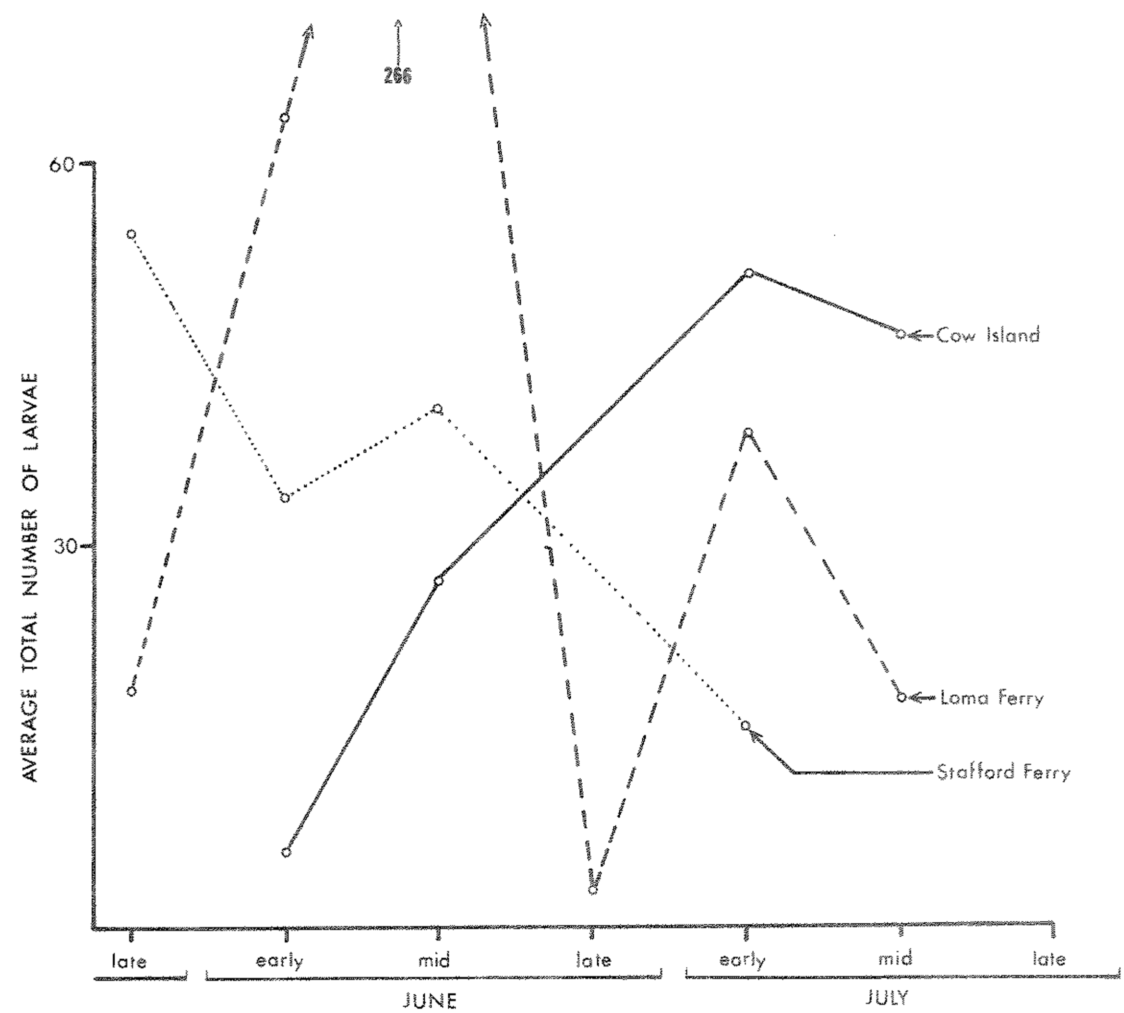

Figure 10. Average total number of fish larvae collected from 20-minute integrated width tows taken in three sections of the middle Missouri River during late May - mid-July, 1979.

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.

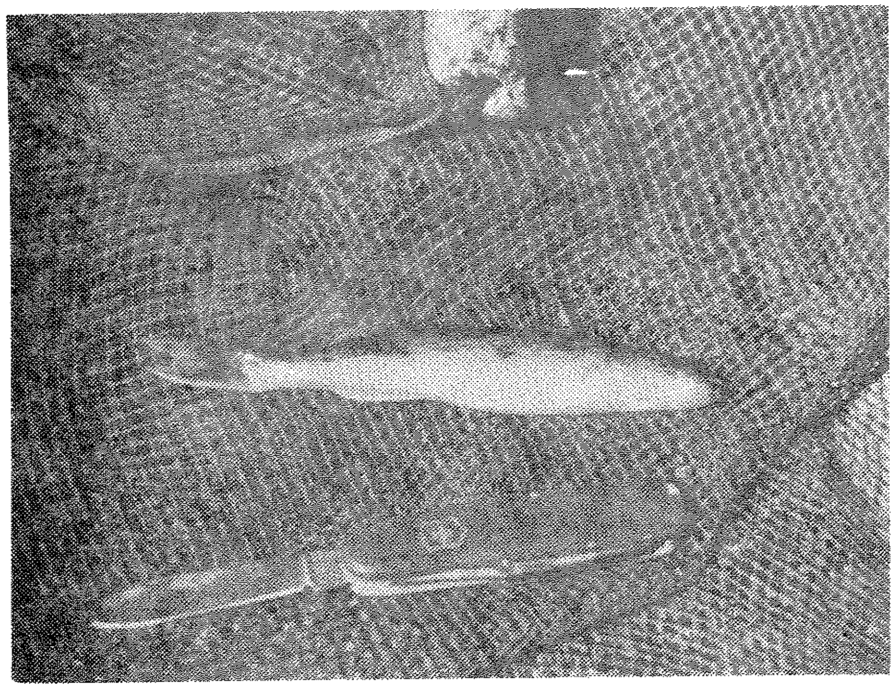

Figure 11. Young-of-the-year sauger ranging in length from 40 to 188 millimeters were collected in various peripheral habitat types on the middle Missouri River.

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

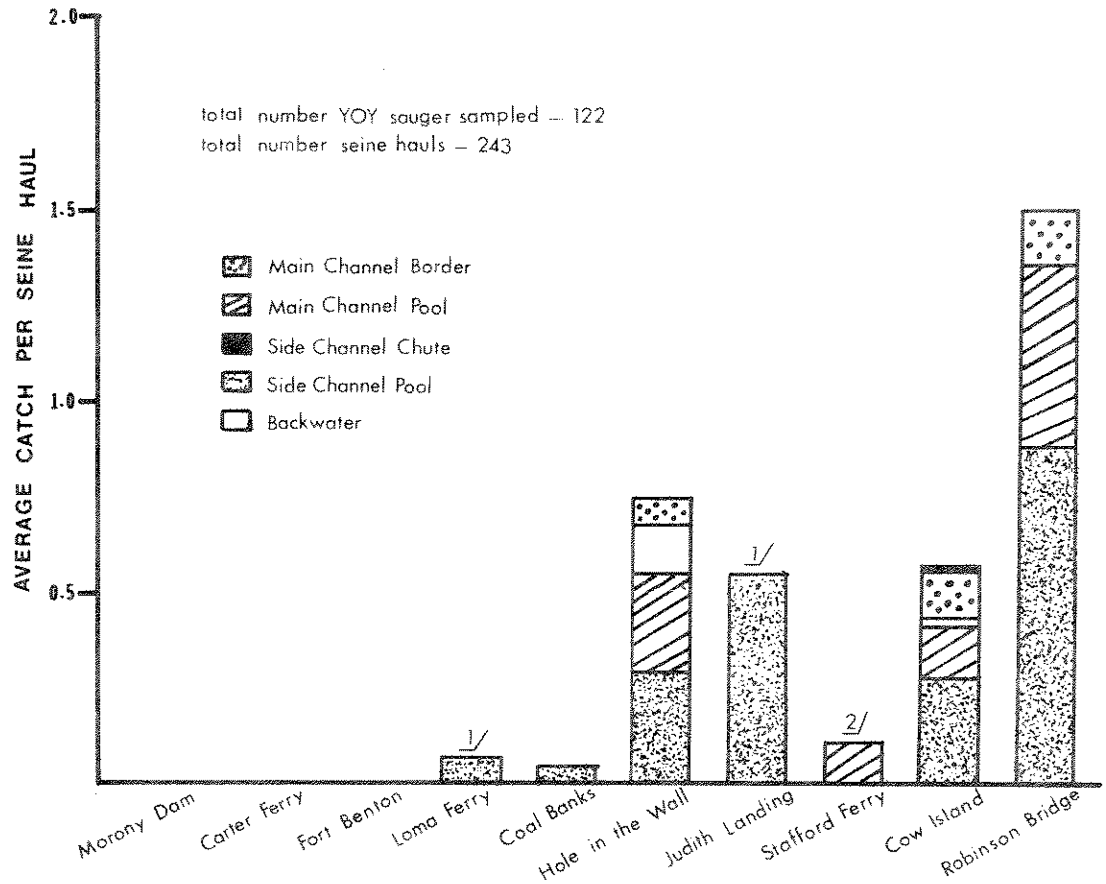

Figure 12. Longitudinal distribution, relative abundance and habitat preference of young-of-the-year (YOY) sauger seined in the middle Missouri River during 1979.

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).

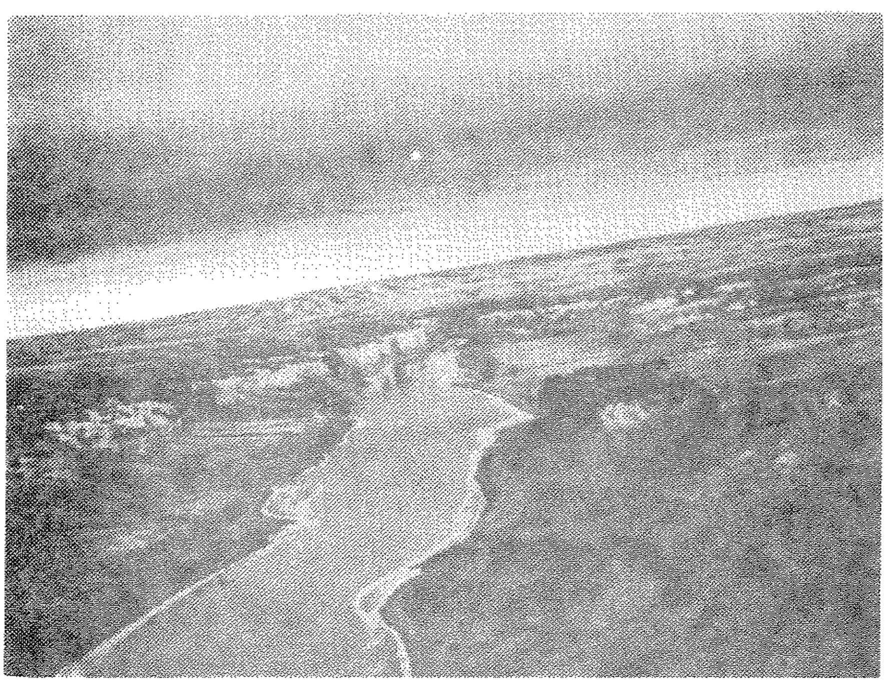

Figure 14. The Hole-in-the-Wall section exhibited extensive channel margin development; several peninsulas perpendicular to the margin formed important sauger rearing "pocket pools."

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,

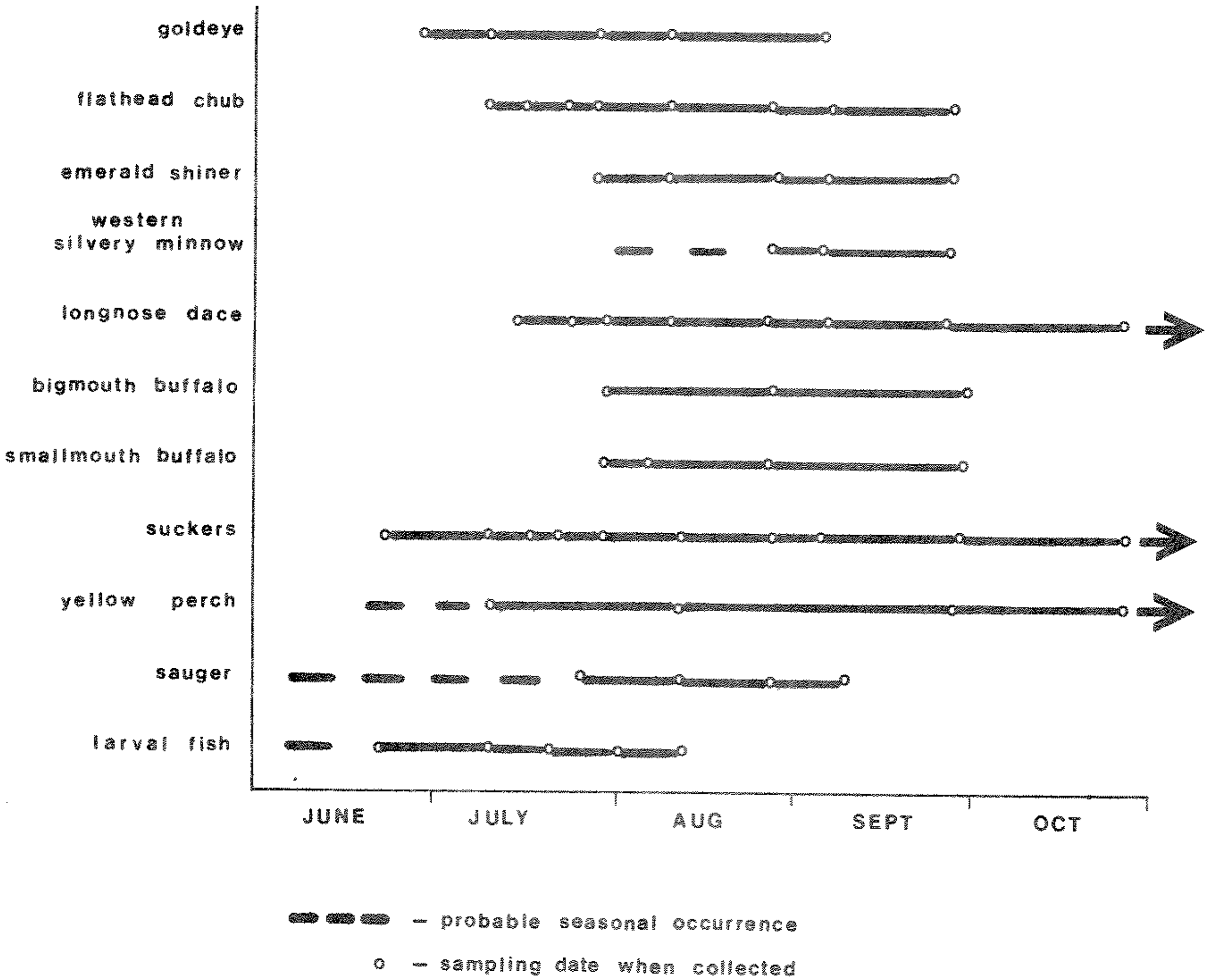

Figure 15. Seasonal occurrence of YOY fishes in the side channels of the middle Missouri River 1979-80.

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.

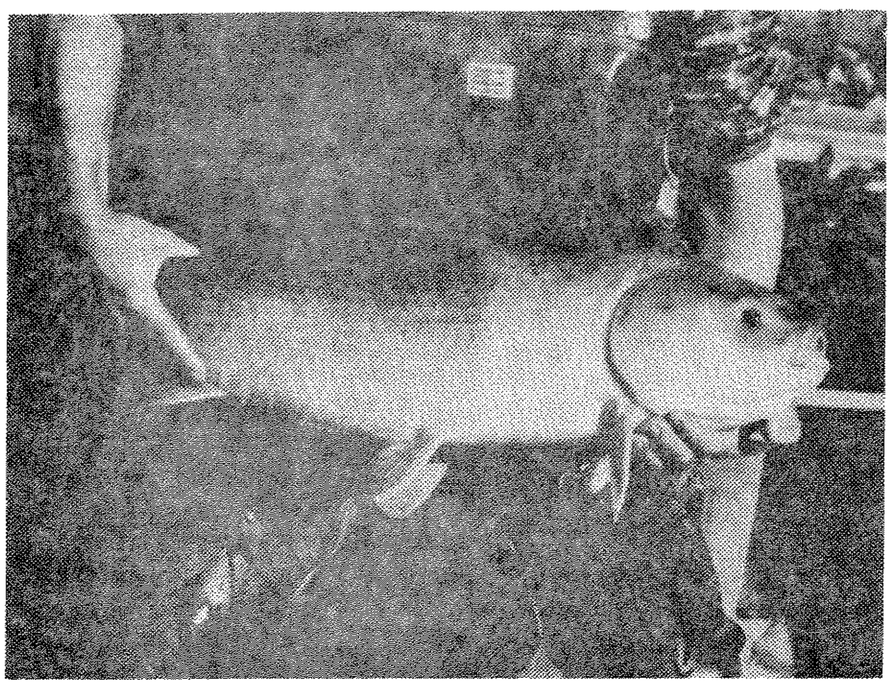

Figure 16. Bigmouth buffalo spawned in side channels and backwaters of the Missouri River.

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).

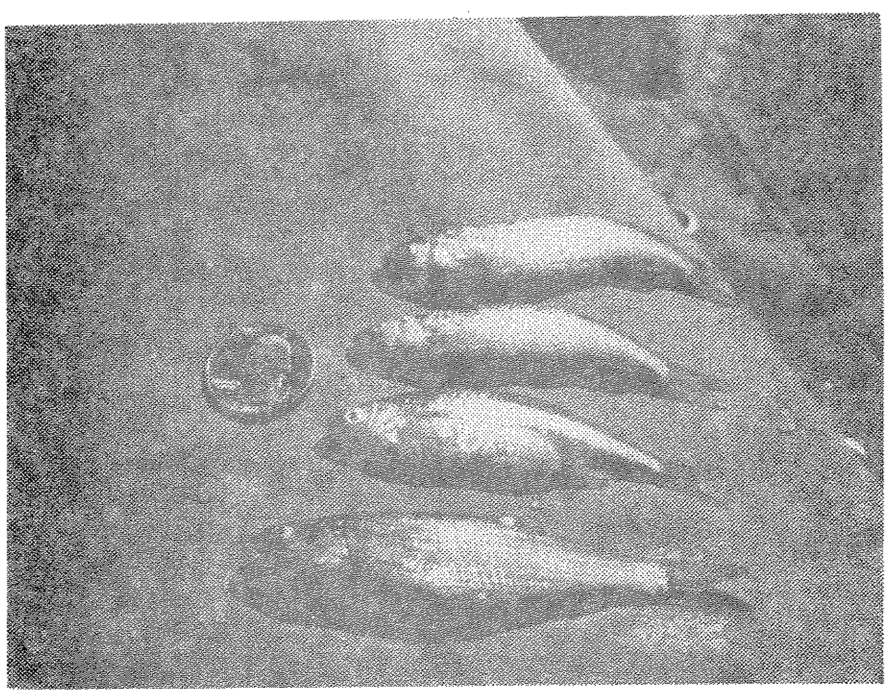

Figure 17. Forage fish distribution and abundance and their significance as a food source of sport fish were investigated during 1979-81.

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

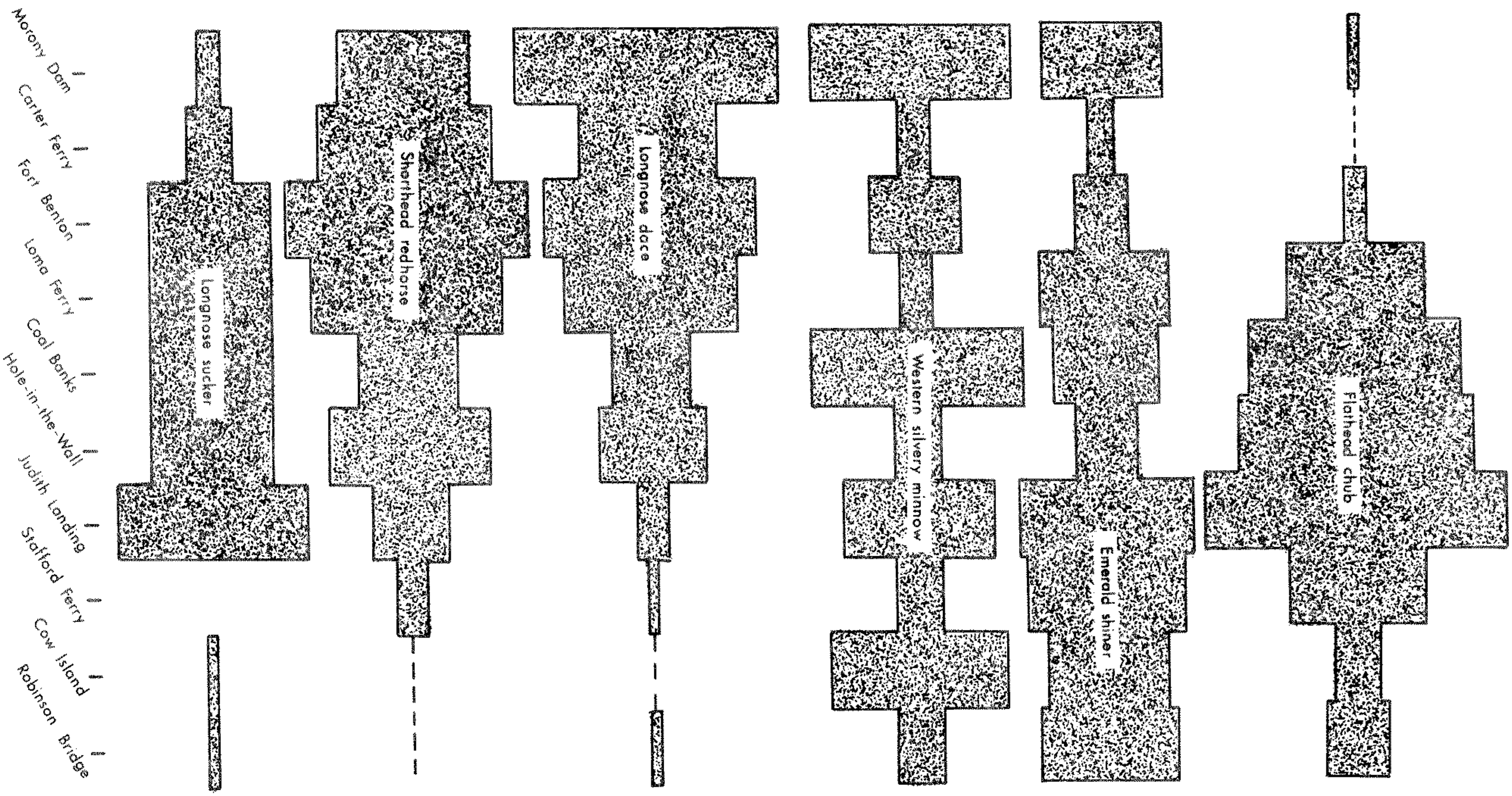

Figure 18. Longitudinal distribution and relative abundance (ave. catch rate) of six common forage fish species seined in the middle Missouri River during 1979. (10 mm on the vertical equals an average catch rate of eight fish per seine haul.)

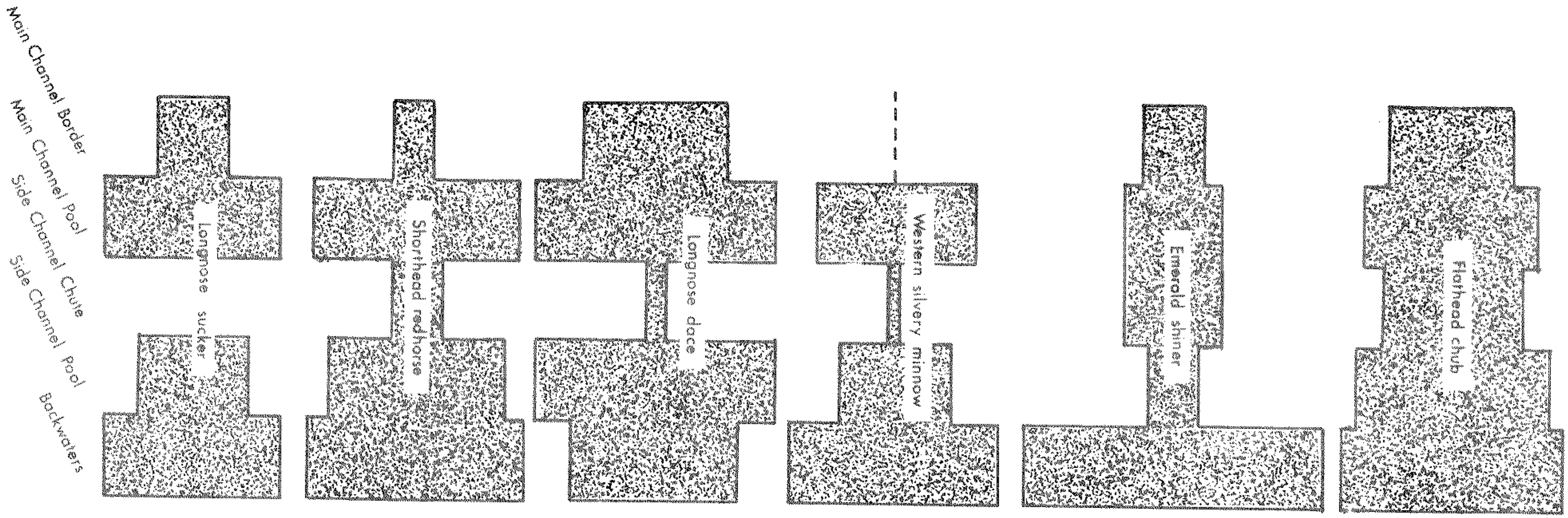

Figure 19. Forage fish habitat type preferences as described by the relative abundance (average catch rate) of six common forage species seined in five habitat types of the middle Missouri River during 1979. (10mm on the vertical equals an average catch rate of eight fish per haul.)

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 km1/	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	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	12,000	Virgelle Rkm 217
6.	Three Islands	25N	11E	31	233	2.3	Approximately 107.6	3,800	Virgelle Rkm 217
7.	Judith Island	23N	16E	26	139	1.1	Between (141.6-254.0)	(5,000-8970)	Virgelle, Rkm 217
8.	Norris Island	23N	16E	25	138	2.0	Approximately 452.0	16,000	Fred Robinson Br. Rkm 40
9.	Lower Sturgeon Is.	23N	21E	6	89	1.0	Approximately 271.2	9,600	Fred Robinson Br. Rkm 40
10.	Snake Point Island	23N	21E	1	81	1.1	Approximately 107.6	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

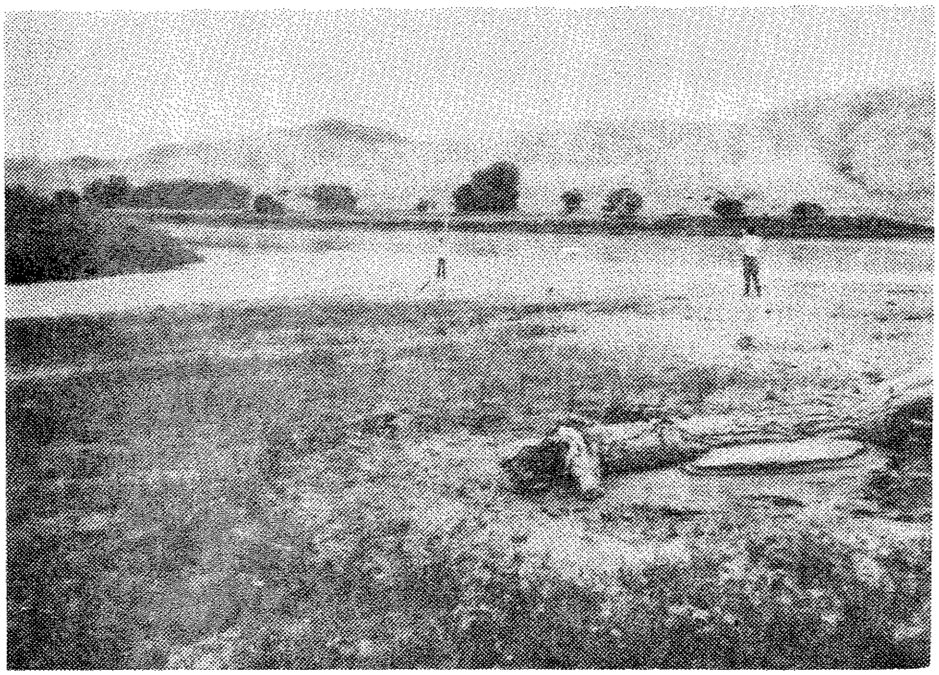

Figure 20. The influent flow of side channels (left) was an important factor maintaining both physical channel features and the fish communities utilizing this habitat.

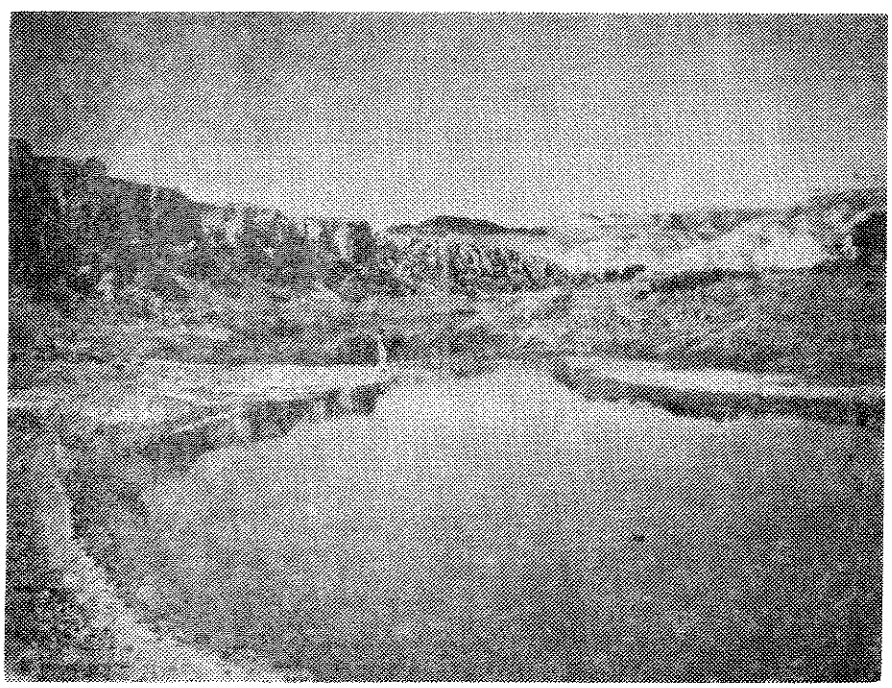

Figure 21. Example of a side channel with a nearly dewatered mid-section.

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.

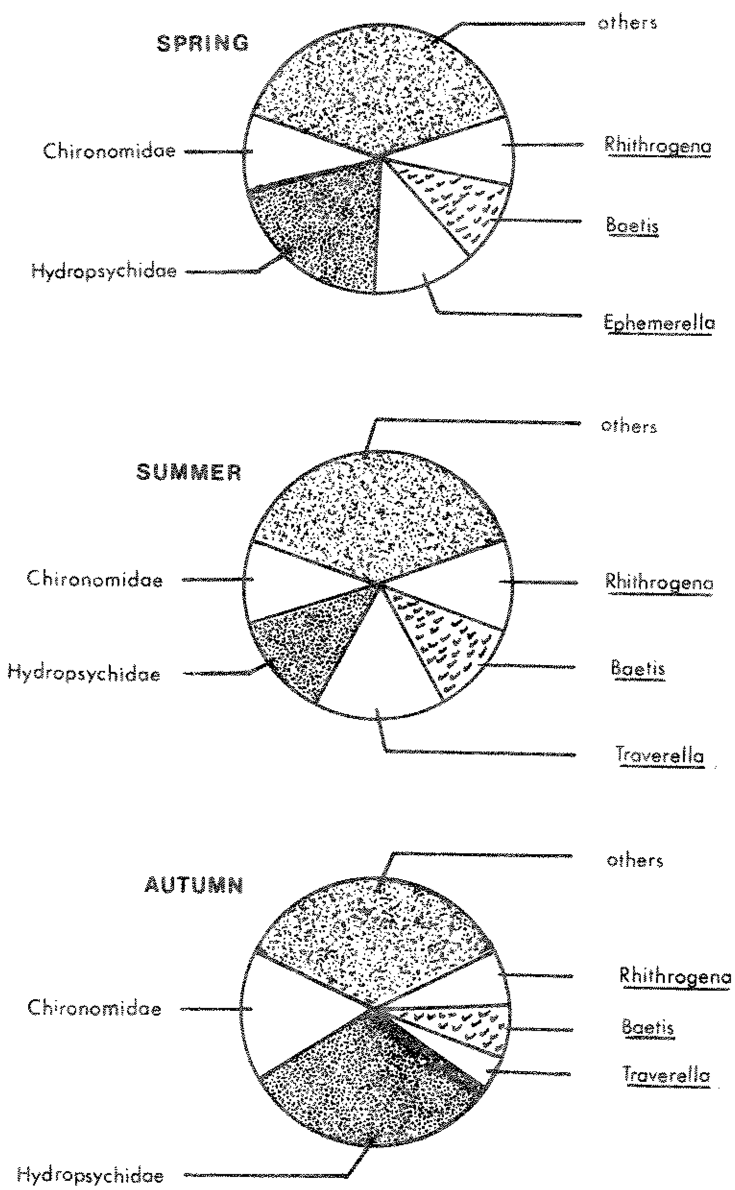

Figure 22. Seasonal comparisons of relative importance values (RI) of the six major food groups utilized by adult shovelnose sturgeon in the Loma Ferry and Coal Banks Landing sections of the middle Missouri River, 1978-79.

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

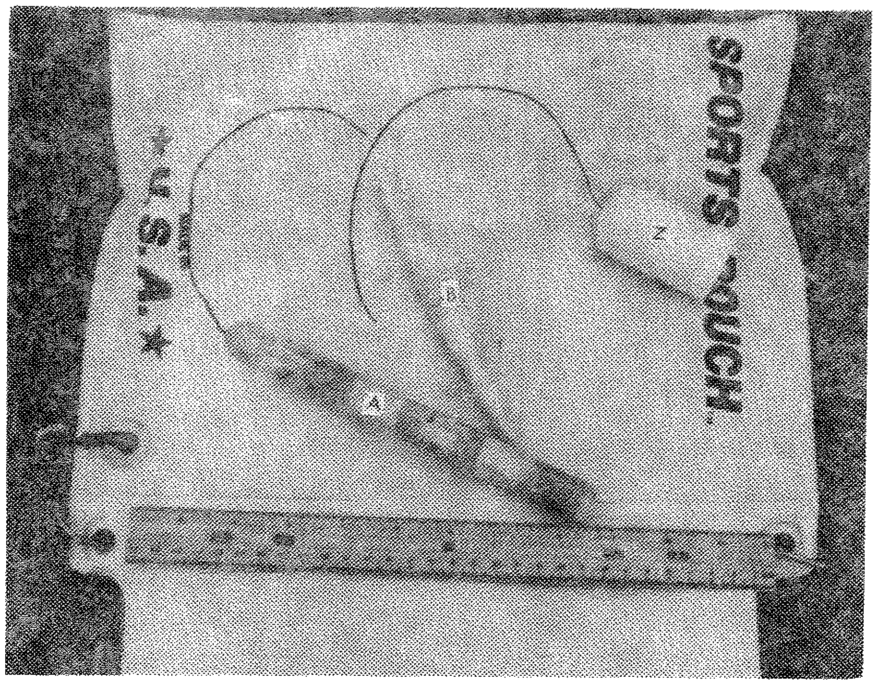

Figure 23. Radio transmitters from three different commercial suppliers were used to increase the chances of success. Radio-A - Smith-Root; B - Wyoming Biotelemetry; and Z - Dav Tron.

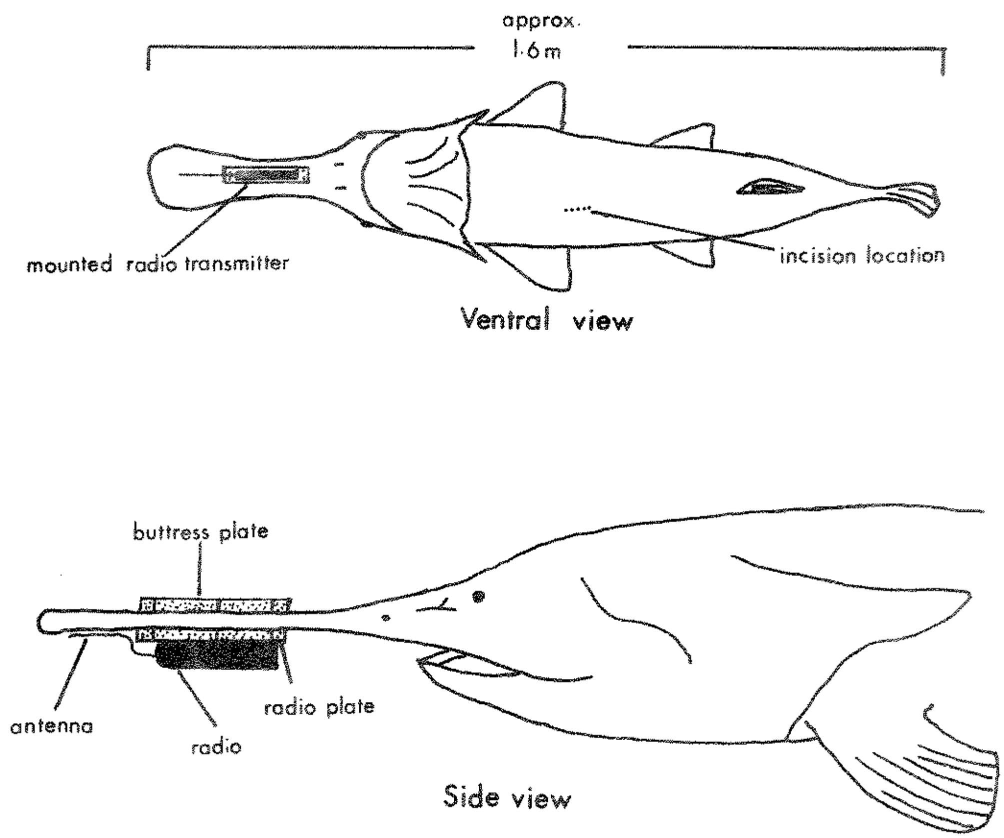

Figure 24. Attachment and implant sites for the paddlefish radio transmitters.

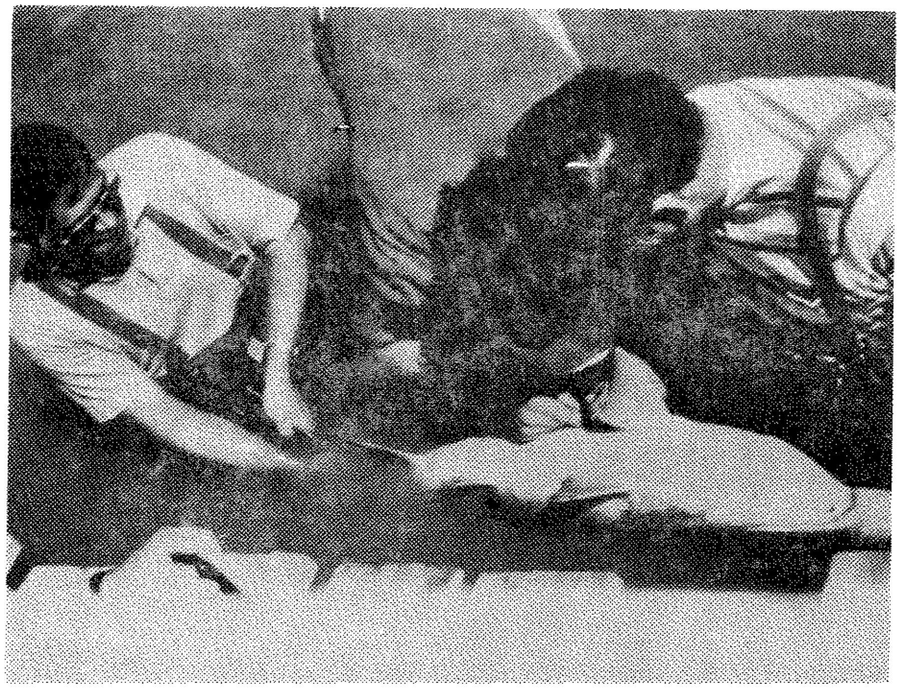

Figure 25. Surgical procedures were used to implant the radio transmitters in the peritoneal cavity of the paddlefish.

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	Discharge c/
	1/1	2/1	3/1	5/1	8/1	9/1	10/1	1/2	2/2	3/2	4/2	(km) b/	(m^3/sec)
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.

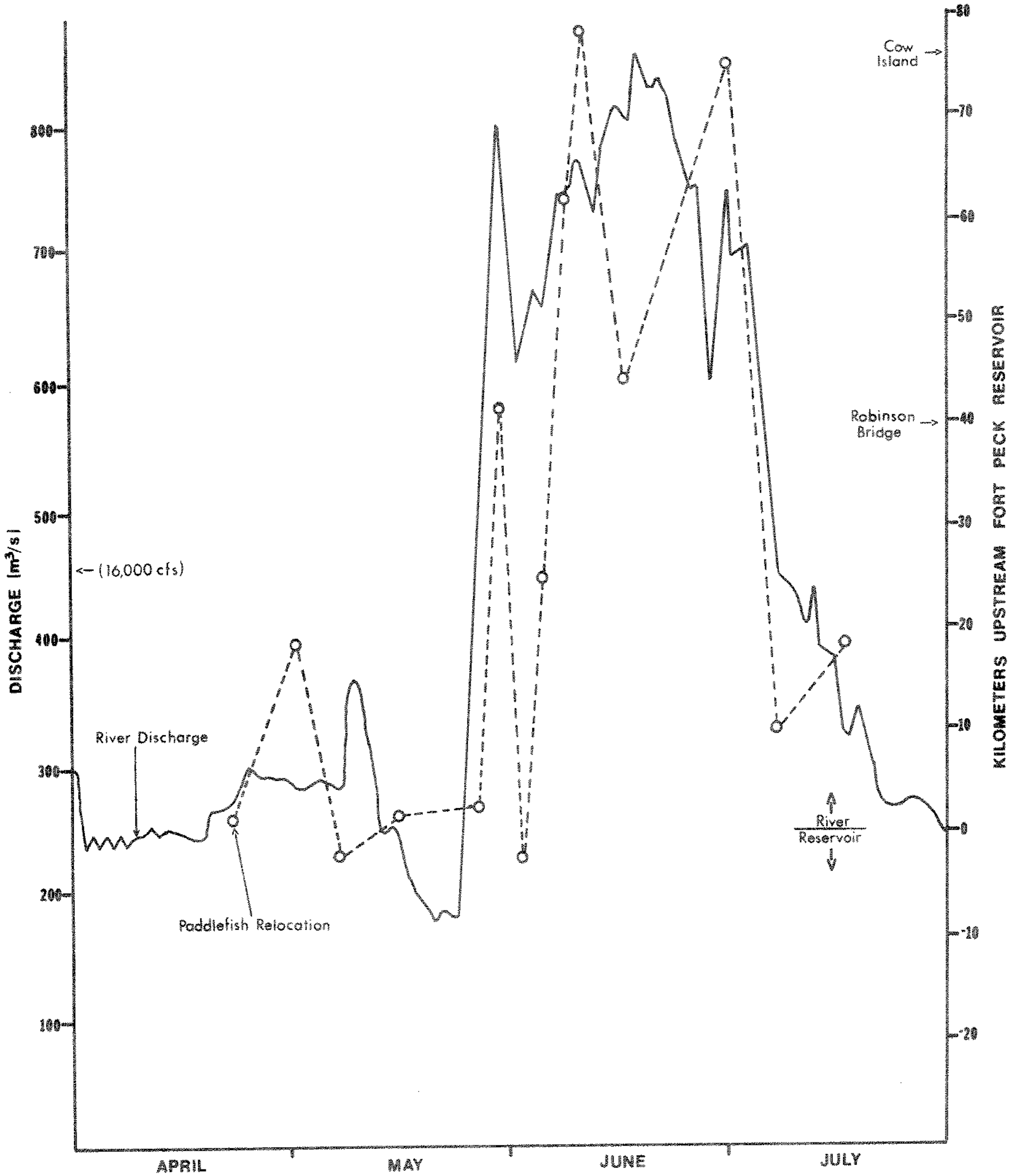

Figure 26. Average location sites of the 11 radio-tagged paddlefish and the spring runoff hydrograph of the middle Missouri River during 1980.

*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

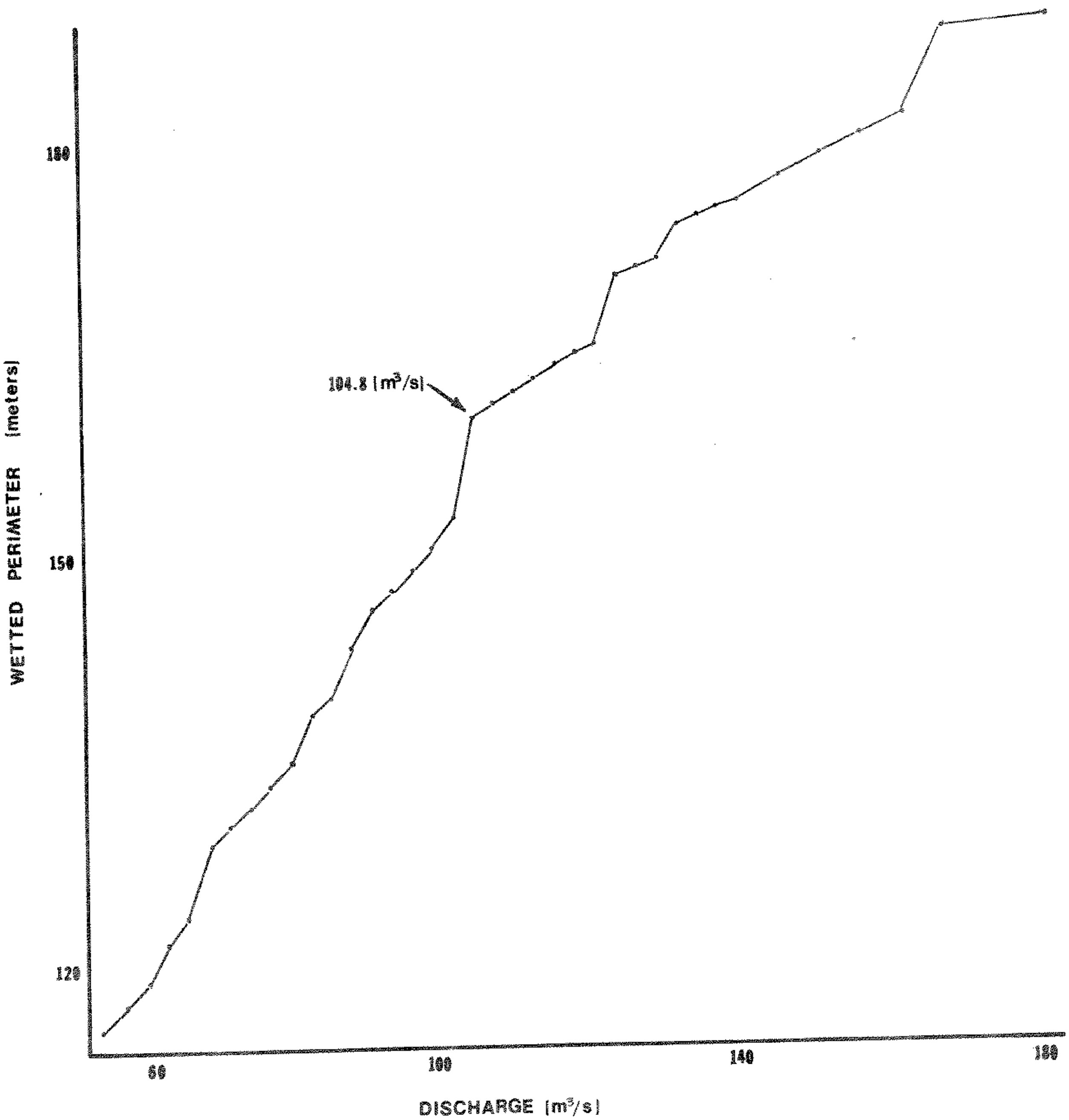

Figure 27. Wetted perimeter-discharge relationship for a composite of seven riffle transects located on the Missouri River in the Fort Benton gaged reach, 1980.

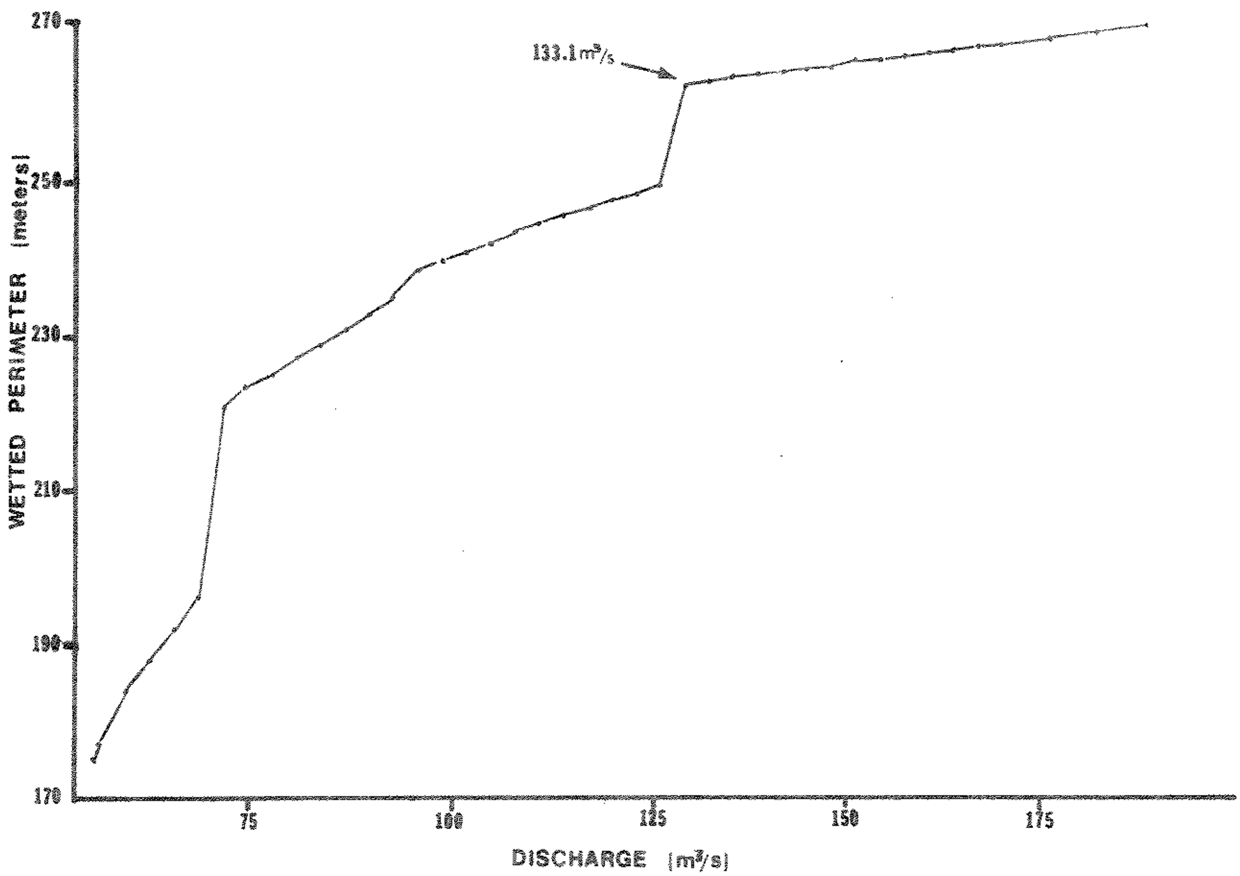

Figure 28. Wetted perimeter-discharge relationship for a composite of three riffle transects located on the Missouri River at the Cow Island riffle, 1980.

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	

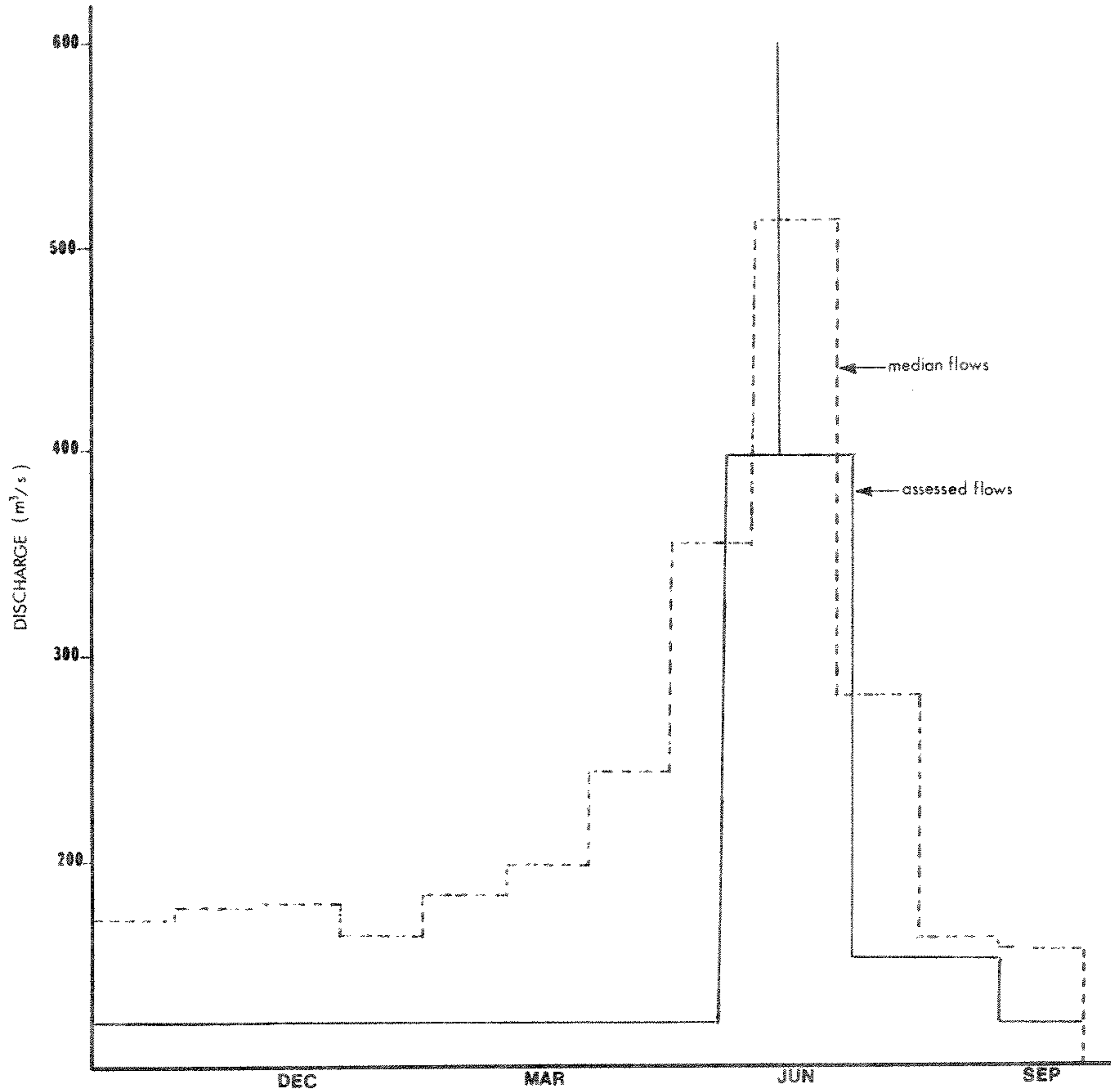

Figure 29. Comparison of assessed minimum instream flow hydrograph to the median monthly flow hydrograph of record for the Virgelle Ferry gage.

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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. 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-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. 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-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. 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

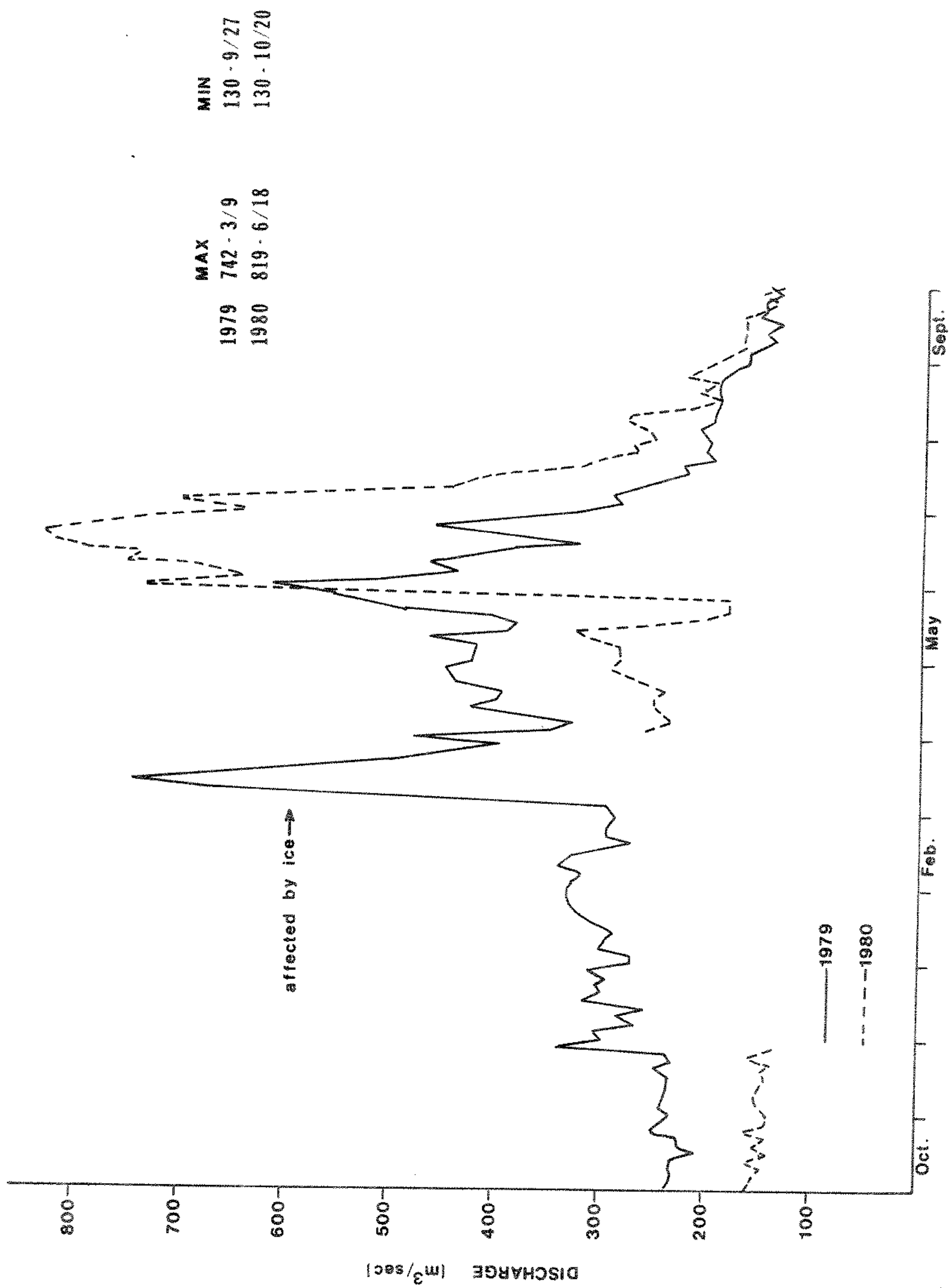
1/ Catch rate; catch per unit effort.

Appendix Table 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.

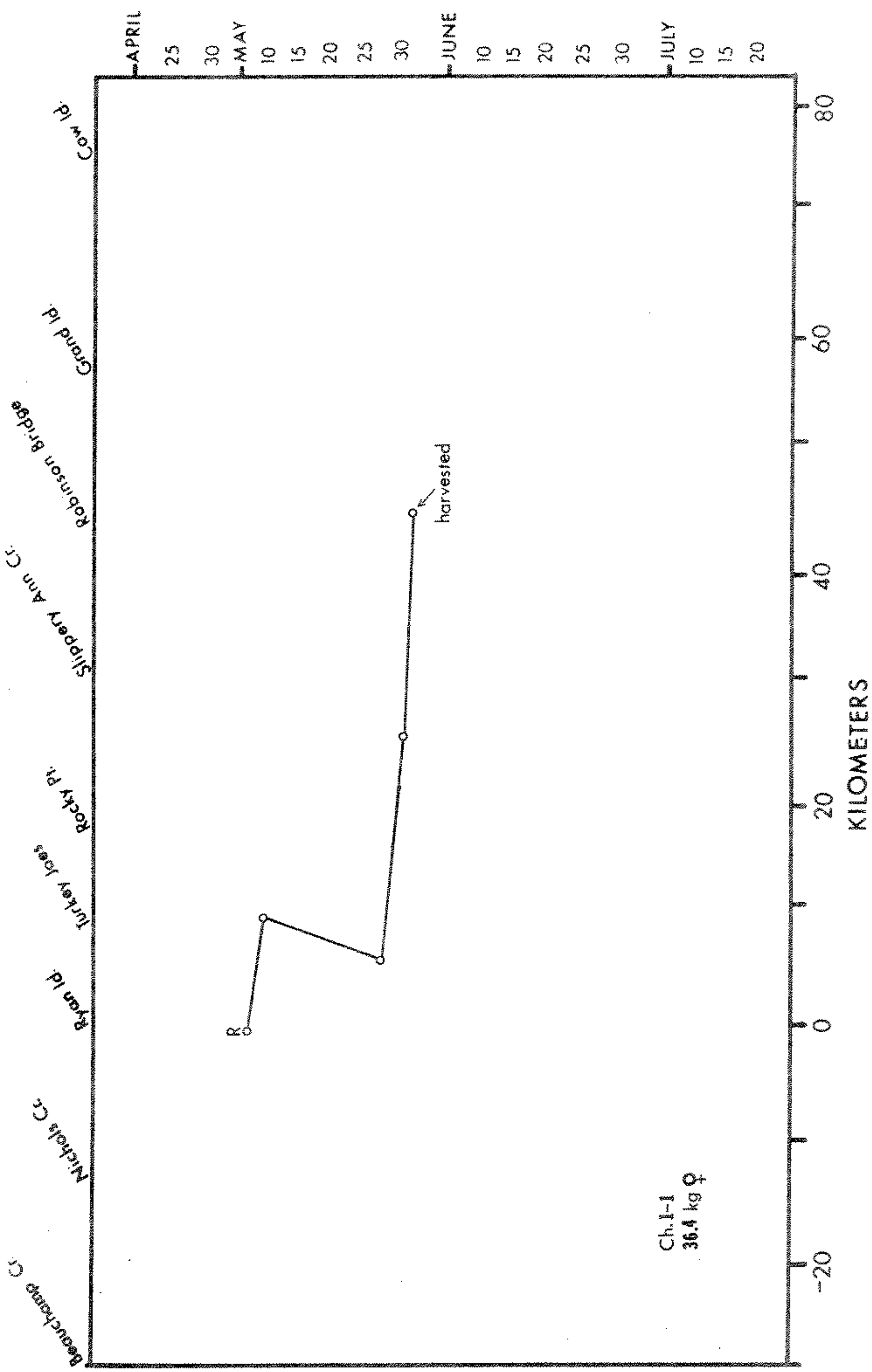
Fish Length	Morony Dam & Carter Ferry Sections	Fort Benton & Loma Ferry Sections	Loma Ferry & Coal Banks Sections	Sections below Coal Banks
≤ 249	~~||||~~	~~||||~~	|	||||
250-299	~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~	|||	~~||||~~ |||	|||
300-329	~~||||~~ |	~~||||~~	|||	|||
330-359	~~||||~~ ||||	~~||||~~ ~~||||~~ |	~~||||~~	||||
360-399	~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~	~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~	~~||||~~ |	|||
≥ 400	~~||||~~ ~~||||~~ ~~||||~~ |||	|||	~~||||~~ |||	|
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.

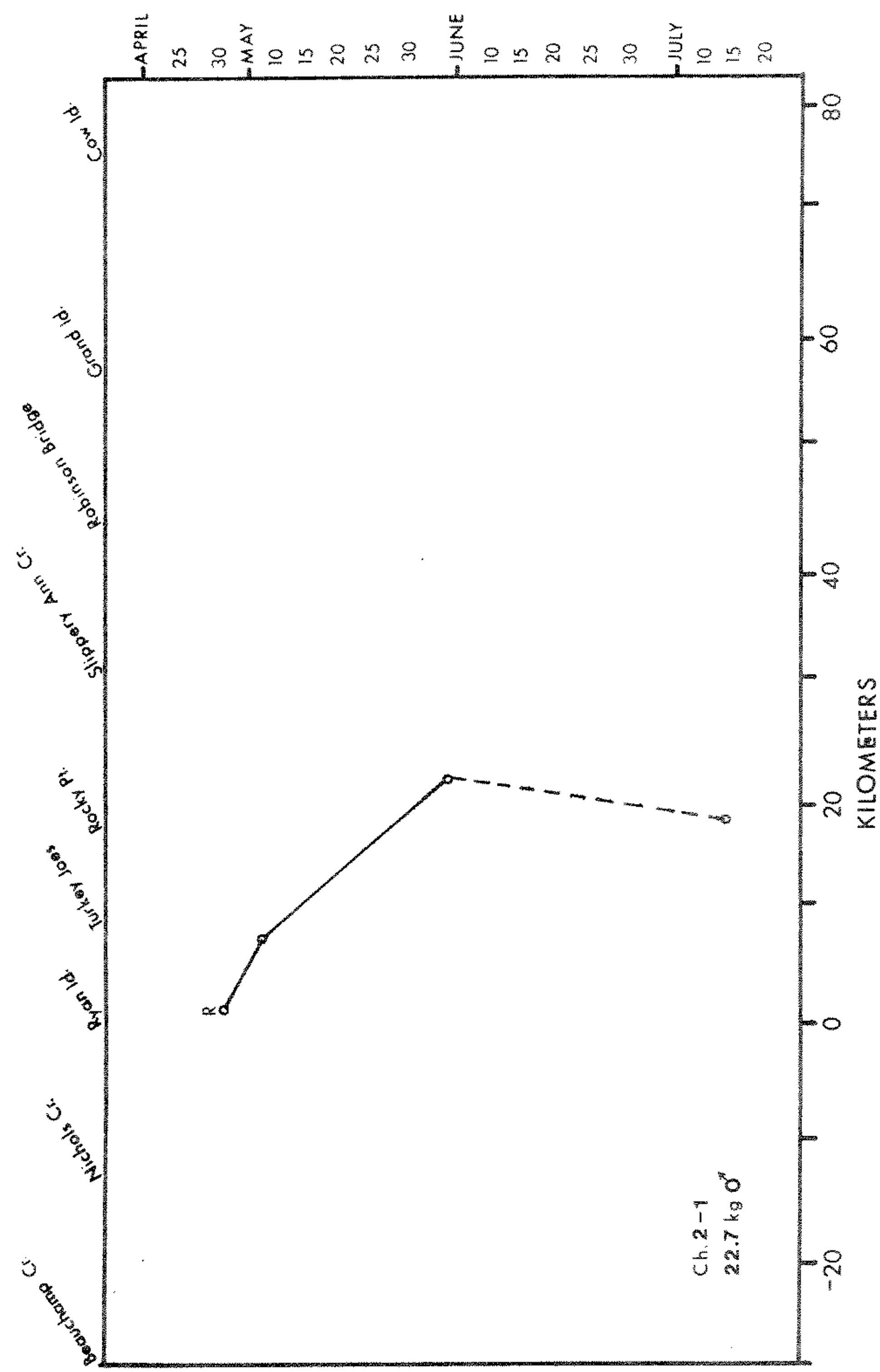
	April		May		June		July		Aug.		Sept.		Oct.	
Day	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1	4.0	5.0	14.0	16.5	14.1	15.4	17.9	19.6	21.3	22.7	15.4	18.0	12.2	14.0
2	4.5	5.5	15.0	17.5	14.2	15.4	18.8	20.3	20.0	21.7	16.6	18.5	11.4	14.0
3	4.0	6.0	14.0	15.5	13.7	14.4	19.2	20.2	18.2	21.0	15.5	17.2	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



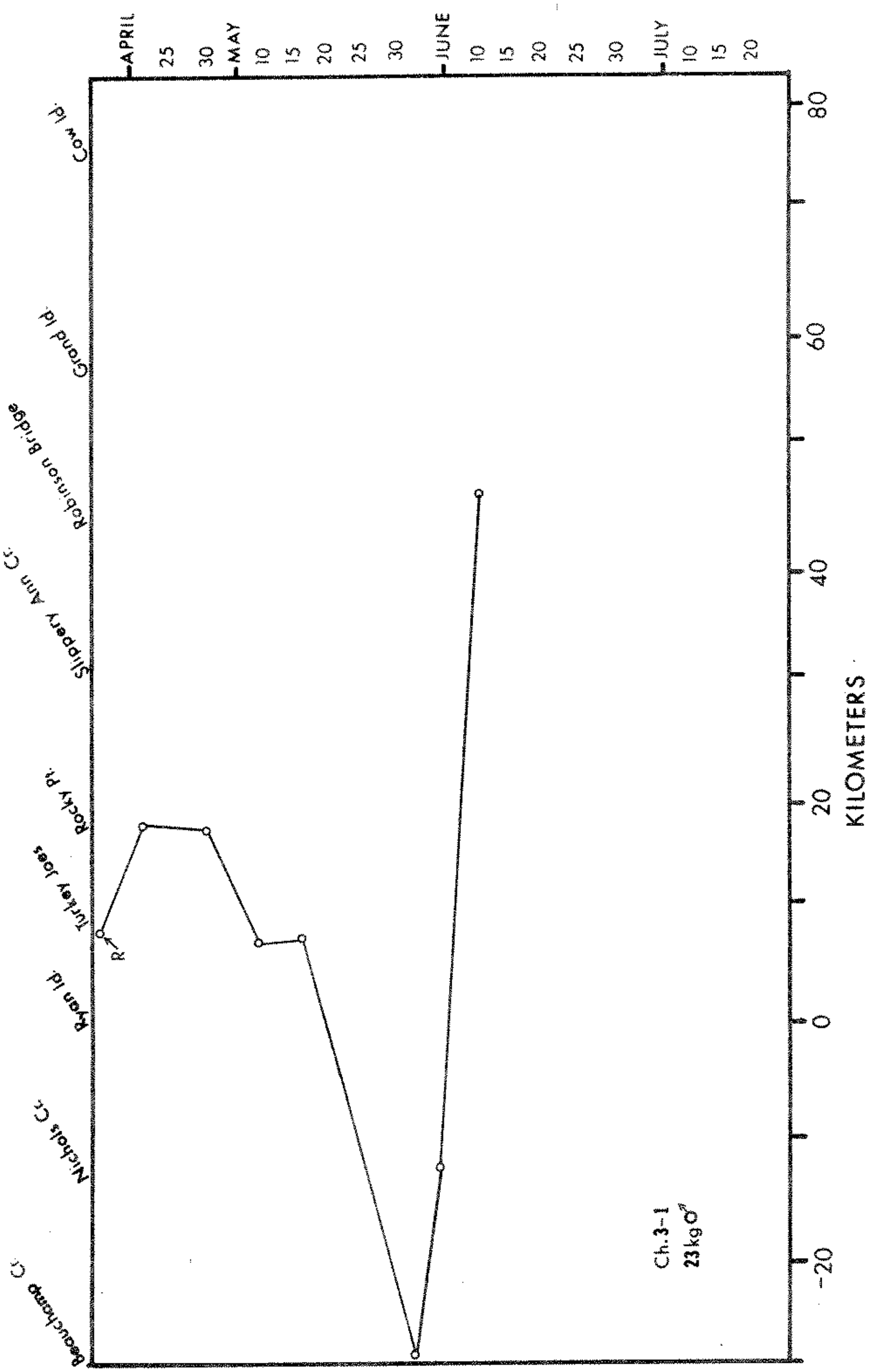
Appendix Figure A. Hydrographs of the Missouri River for 1979 and 1980 at the USGS gaging station located at the Fred Robinson Bridge (Robinson Bridge section). (USGS 1979 and 1980).



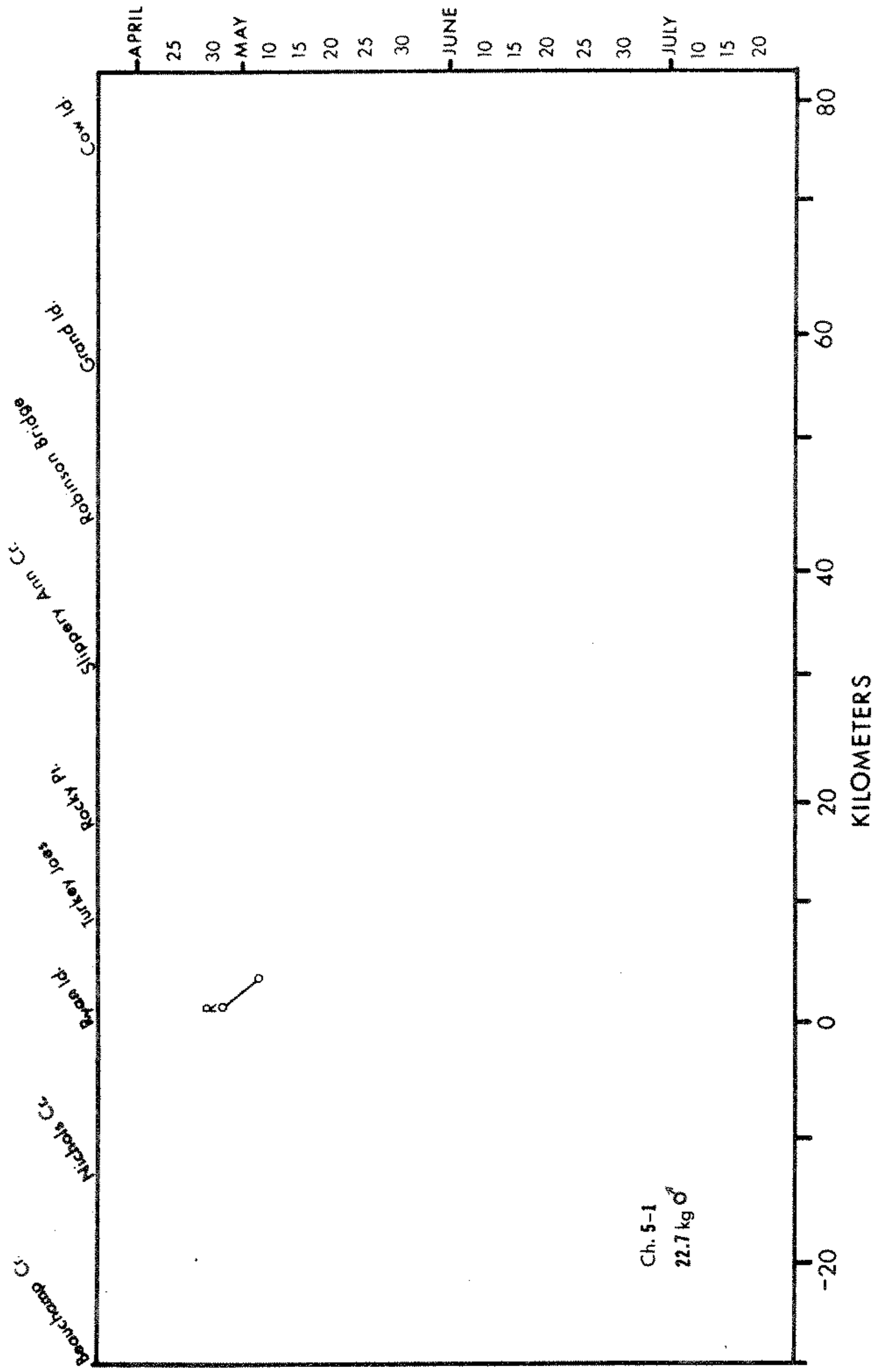
Appendix Figure B-1 . Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



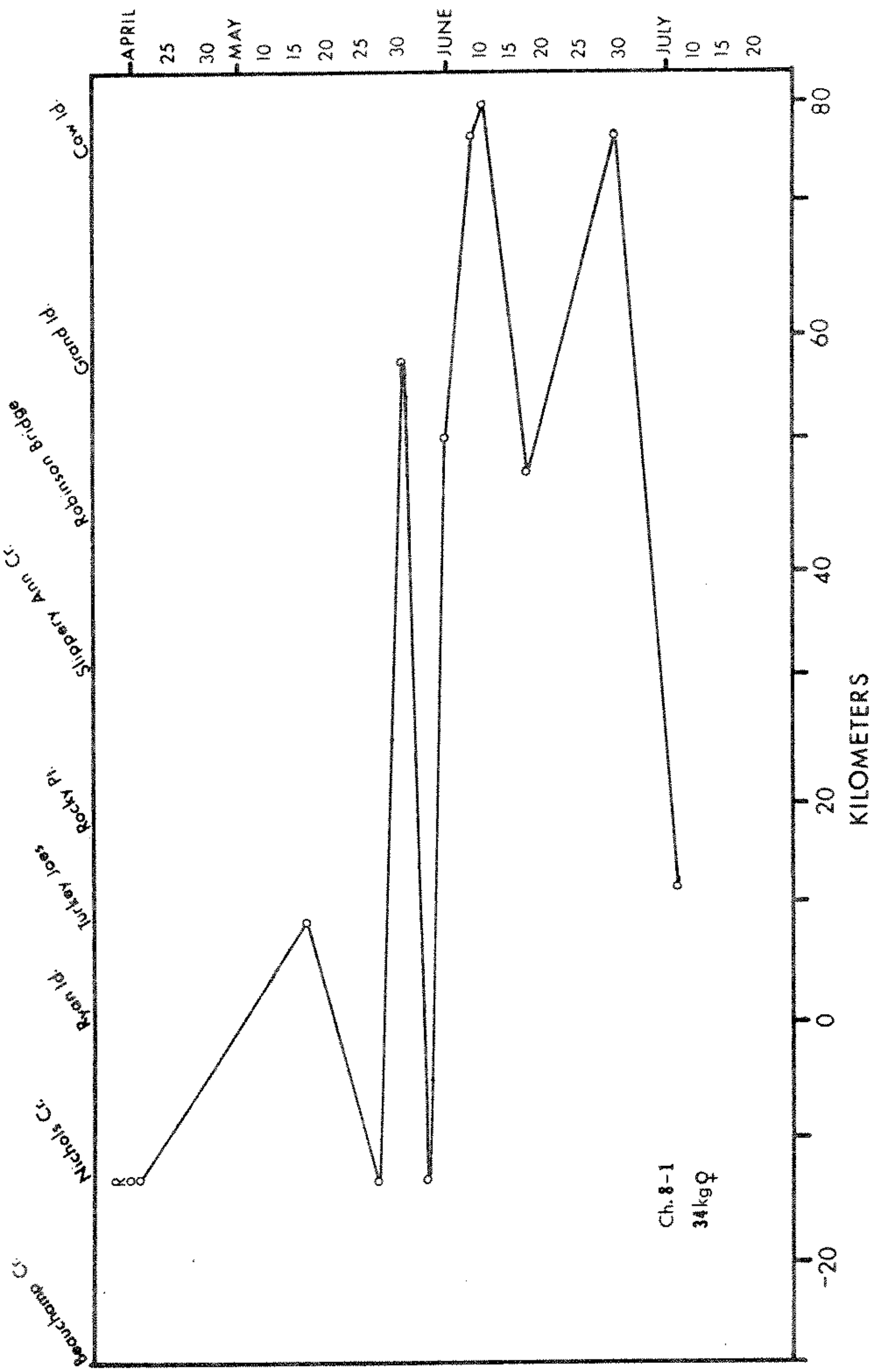
Appendix Figure B-2. Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



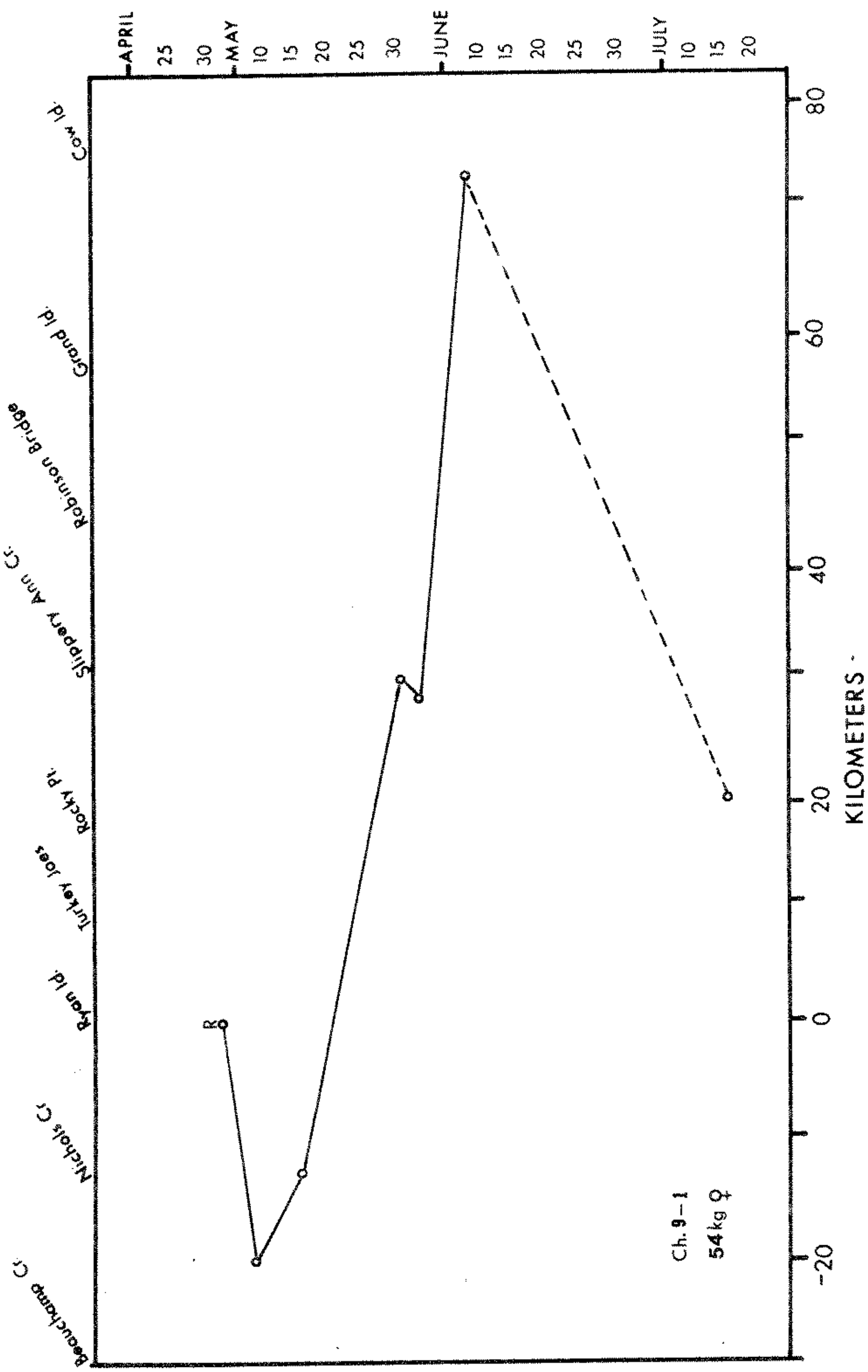
Appendix Figure B-3. Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



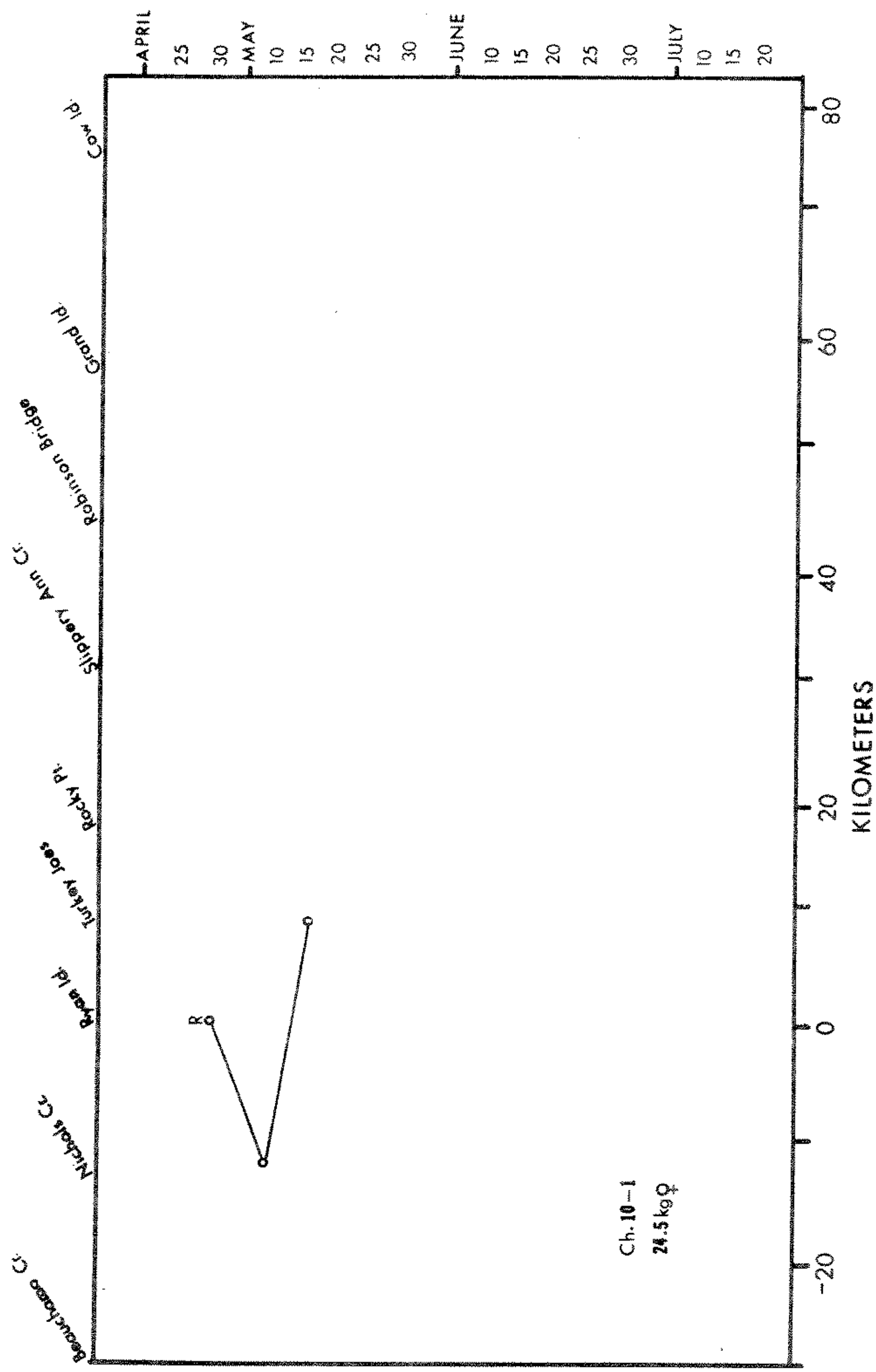
Appendix Figure B-4 . Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



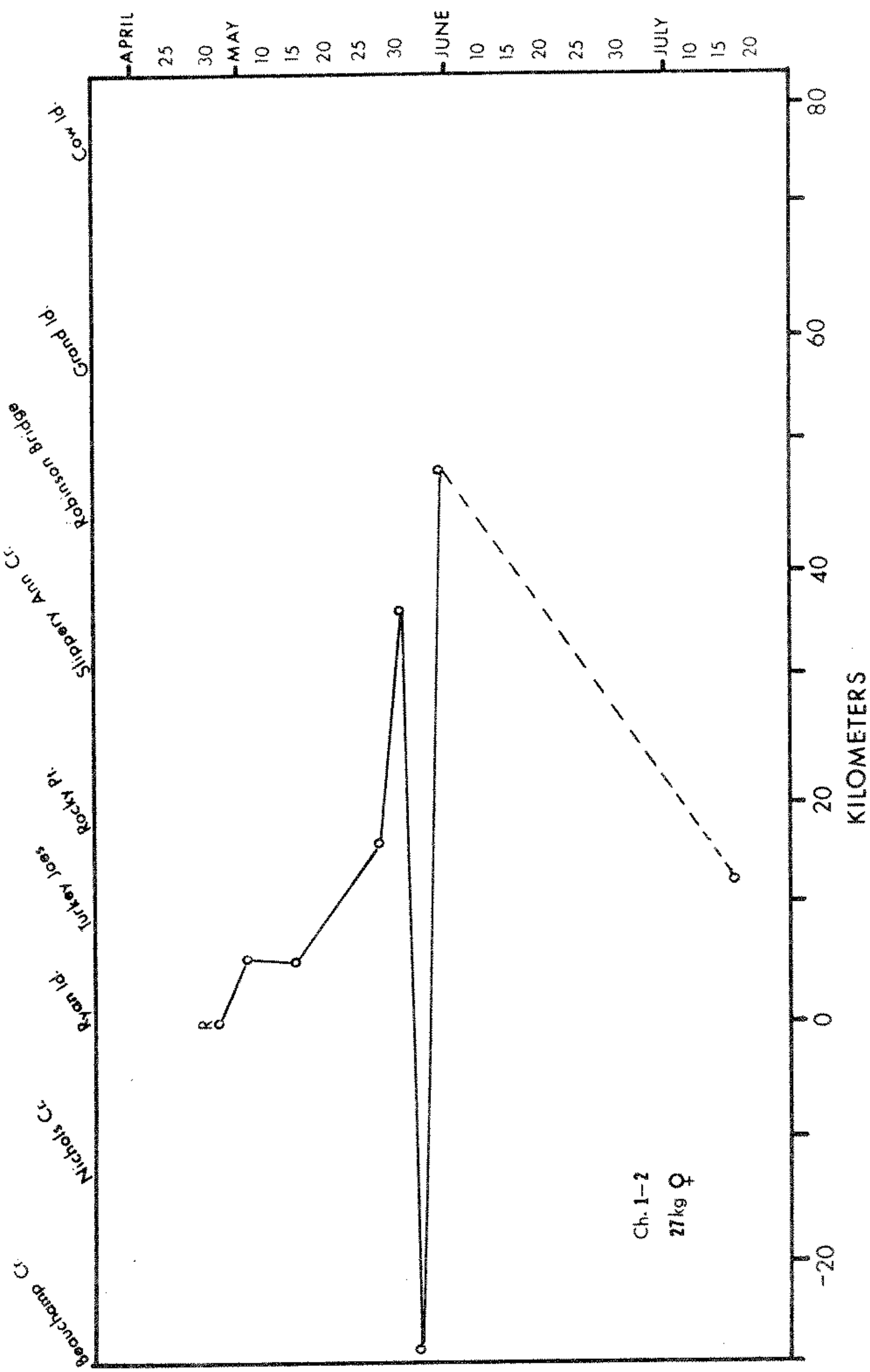
Appendix Figure B-5 . Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



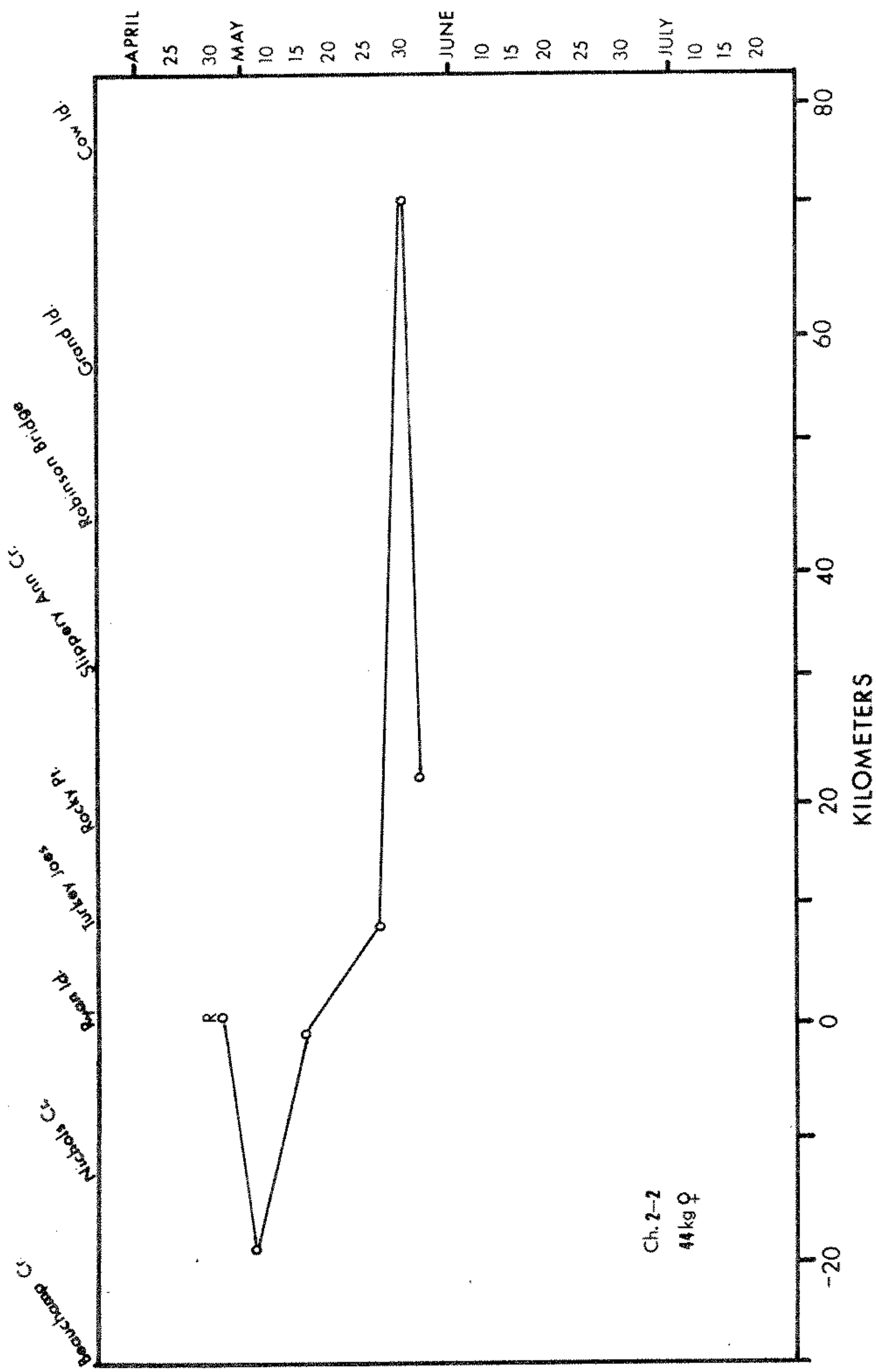
Appendix Figure B-6 . Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



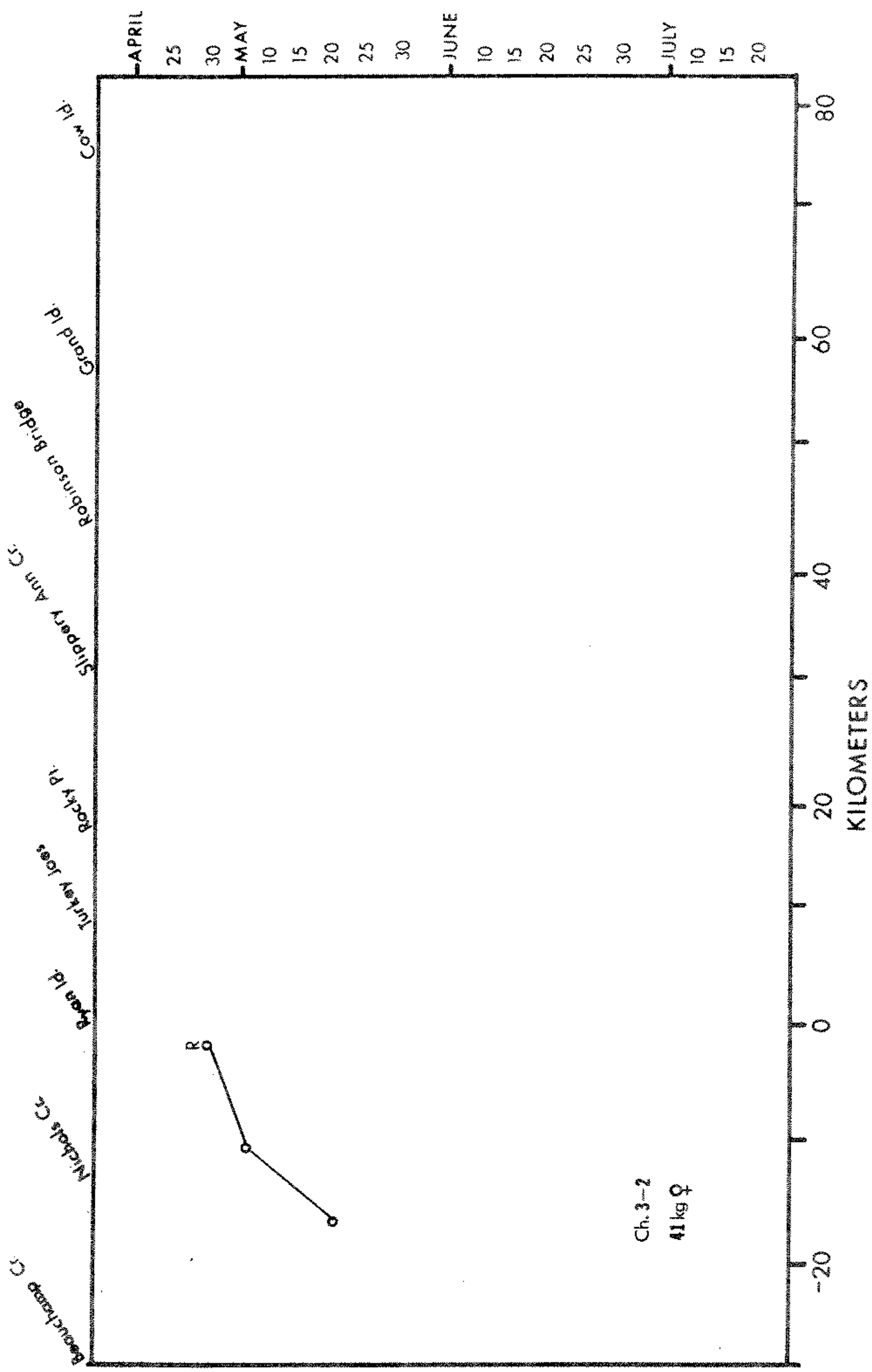
Appendix Figure B-7. Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



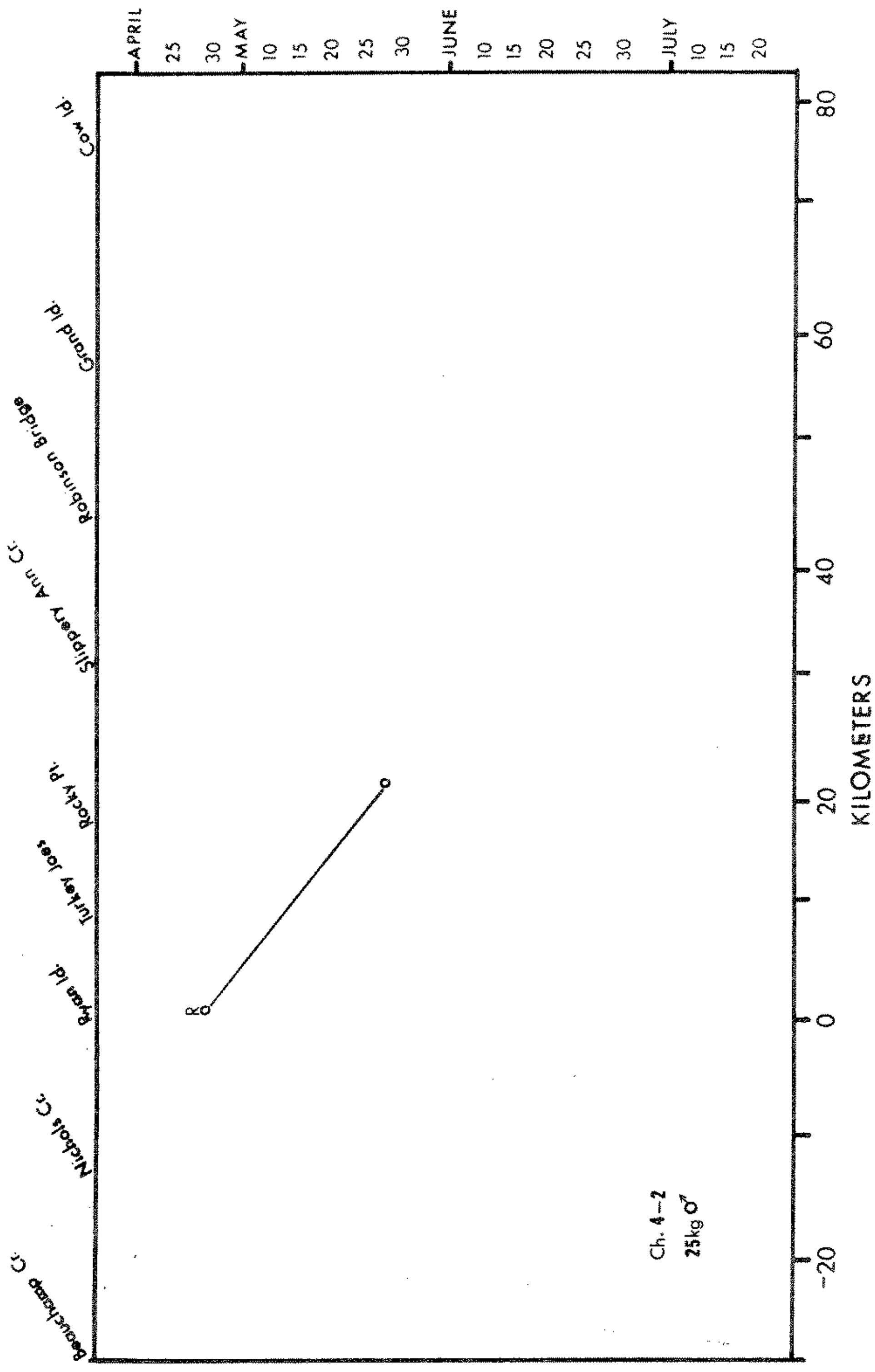
Appendix Figure B-8. Movement pattern of individual radio-tagged paddlefish in the lower reach of the middle Missouri River during 1980; included are dates of movements, size and sex of fish.



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.