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

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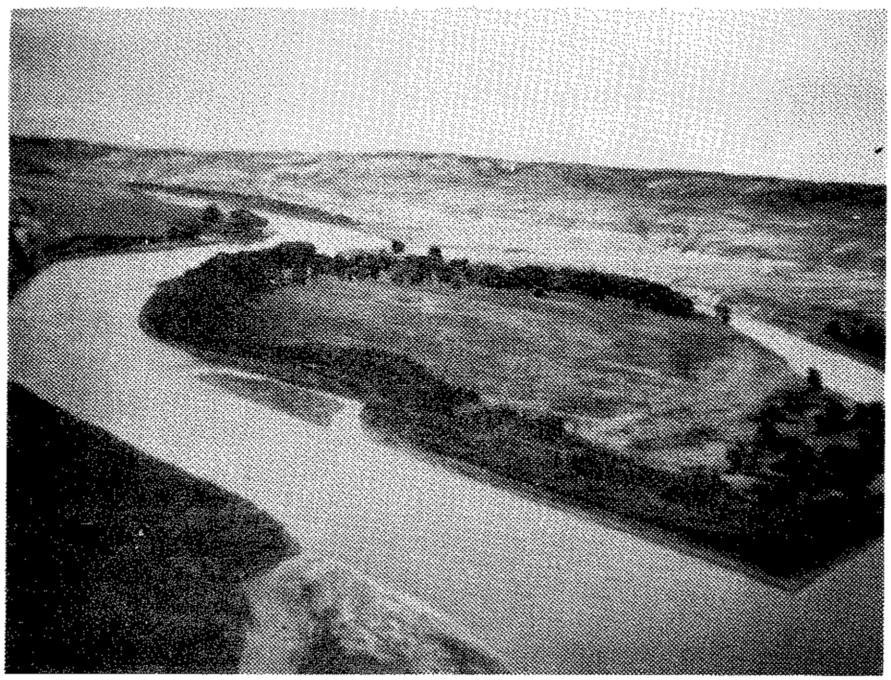

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ABSTRACT

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 applying for their federal reserve water right.

Rearing habitat preference studies conducted from July through September indicated that young-of-the-year sauger selected protected habitat in peripheral areas of the stream. Forty-three percent of the young-of-the-year sauger sampled in 1979 were found in side channel pools, and 70 percent of the fish collected were taken in a 70-km reach of stream below Cow Island. 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. In 1980, the WETP instream flow methodology will be utilized to determine the amount of instream flow required to maintain sauger rearing and forage fish habitat.

A food habits study of adult shovelnose sturgeon collected during the ice-free seasons revealed that they foraged almost exclusively on aquatic insects in riffle areas. In 1980, WETP will be utilized to determine the amount of instream flow required to maintain sufficient wetted perimeter in riffle areas for aquatic insect production.

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. A sturgeon chub was collected in the Teton River, which is a significant extension of its known range.

Several sickle fin chubs were collected in the Missouri River below Cow Island. Previously, this species had been reported in the Missouri River only as far upstream as the confluence with the Little Missouri River in North Dakota. A radiotelemetry system was developed to follow movements of paddlefish in the middle Missouri River.

INTRODUCTION

The middle Missouri River in northcentral Montana abounds with historical, scenic, recreational and natural values. The river is free-flowing in a 336-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 (U.S. 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 (U.S. 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 plans on the Missouri River are imminent. On October 1, 1979, the U.S. Water and Power Resources Service (WPRS) began an appraisal study for potential damsites on or adjacent to the Missouri River in the vicinity of Fort Benton. In addition, the Montana Power Company (MPC) is currently evaluating three sites in the middle Missouri River drainage for possible construction of coal-fired power generating plants. These plants would require substantial amounts of water from the Missouri River or one of its tributaries for cooling processes. The proposed WPRS and MPC projects have the potential to significantly alter the natural flow regime of the river, and consequently, detrimental effects on the native aquatic fauna can be expected. 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 336-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 (1980) 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.

Forty-nine species, representing 14 families of fish, are known to occur in the middle Missouri River drainage between Morony and Fort Peck dams (Berg 1980). Basically, two fishery zones occur on the mainstem Missouri. In the upper reach, from Morony Dam to the mouth 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 mouth 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 meters per kilometer. 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 meters per kilometer. 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 section of river characterized by a wide, meandering channel which contains numerous shifting sandbars and large developed islands. Many side channels and backwaters are found in these study sections.

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).

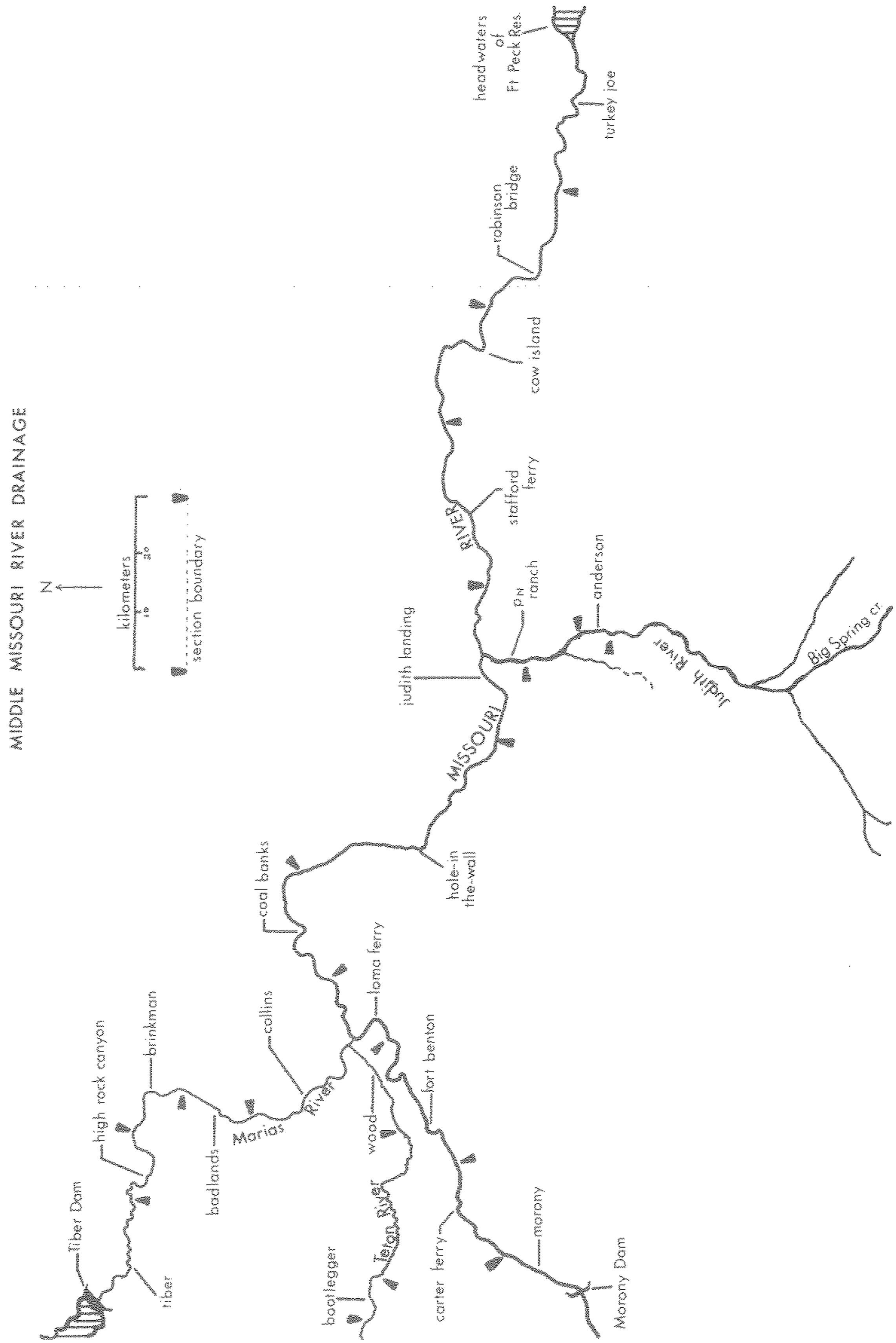

Figure 1. Map of middle Missouri River drainage and study area.

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

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 depth of 1 meter 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 meter. 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. Side channels had an influent and an effluent connection with the main river which allows for a flushing action. 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 and riffles. 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 pools and riffles. Depth ranged from 0.4 to 1.0 meters in this habitat.

The backwater habitat type exhibited no perceptible current velocity and had only a single connection to the main or side channel of the river. Some of the backwaters were formed when the upstream end of a side channel was closed by aggradation or declining water levels.

METHODS

Adult fish were collected by boom electrofishing in a 5.2-m (17 ft.) 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 (1980). The boom electrofishing unit was utilized on the mainstem of the Missouri River during all flows and on the lower Marias River during spring flows. During summer flows, the Teton and Judith Rivers were sampled with a mobile electrofishing unit as described by Berg (1980), and the Marias River was sampled with a boom electrofishing unit mounted on a 4.2-m (13 ft.) fiberglass boat.

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 meters. Gravel bars where known concentrations of sport fish were observed were sampled randomly at various depths up to 1 meter. 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.

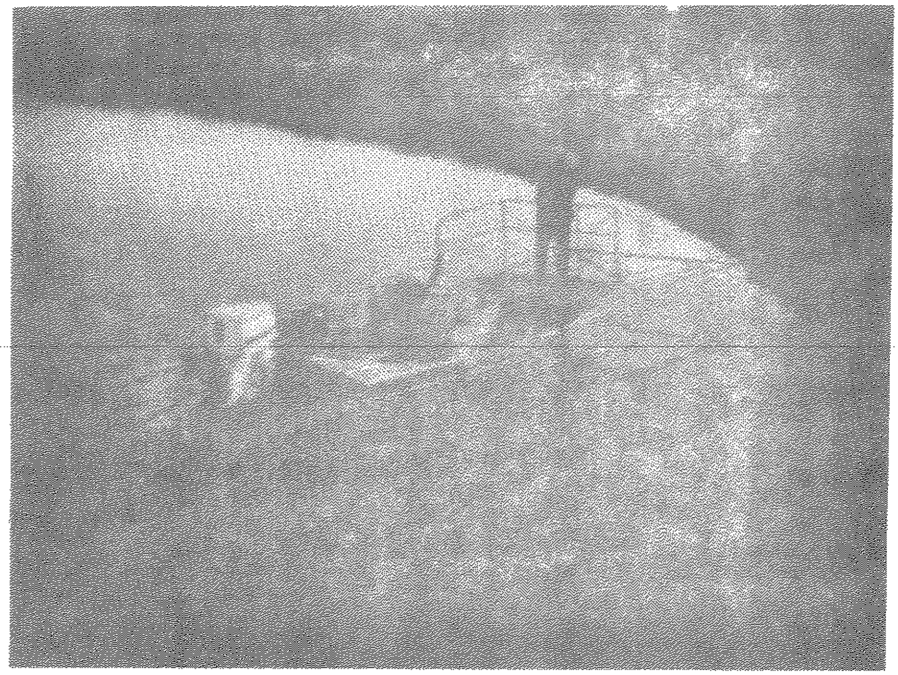

Figure 3. Electrofishing collections were made from a 5.2-meter aluminum boat.

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-meter diameter by 1.6-meter 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-meter net were employed, stationary sets and integrated width tows.

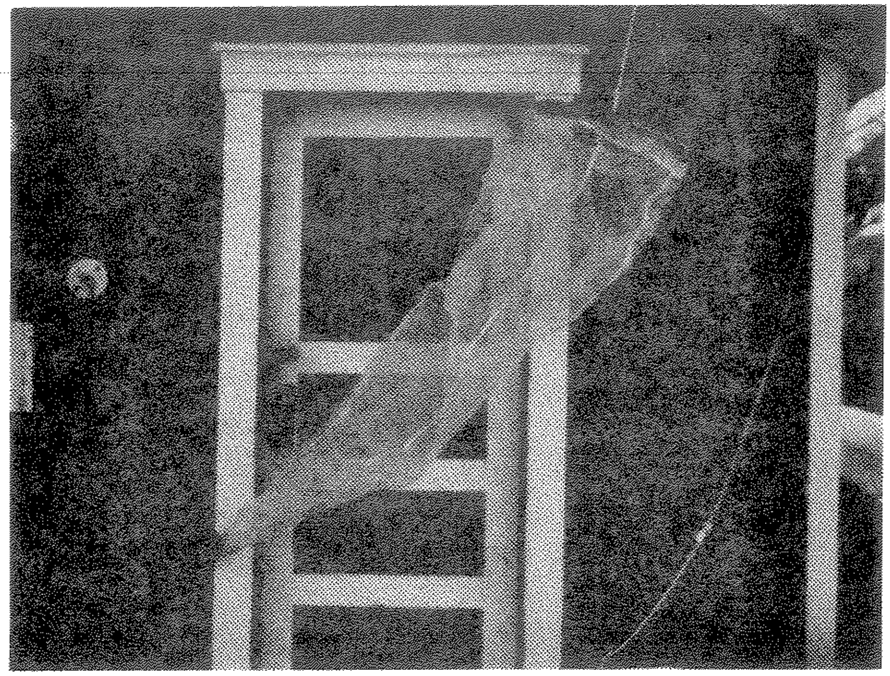

Figure 5. A 0.5-meter diameter larval fish net was used to collect drifting fish larvae in the middle Missouri River and its major tributaries.

The stationary sets involved fishing the 0.5-meter 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-meter 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-meter 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-sectioned 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-meter 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 Hague 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-meter (50 x 4-ft) beach seine with 3.2 mm (1/8-inch) 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.

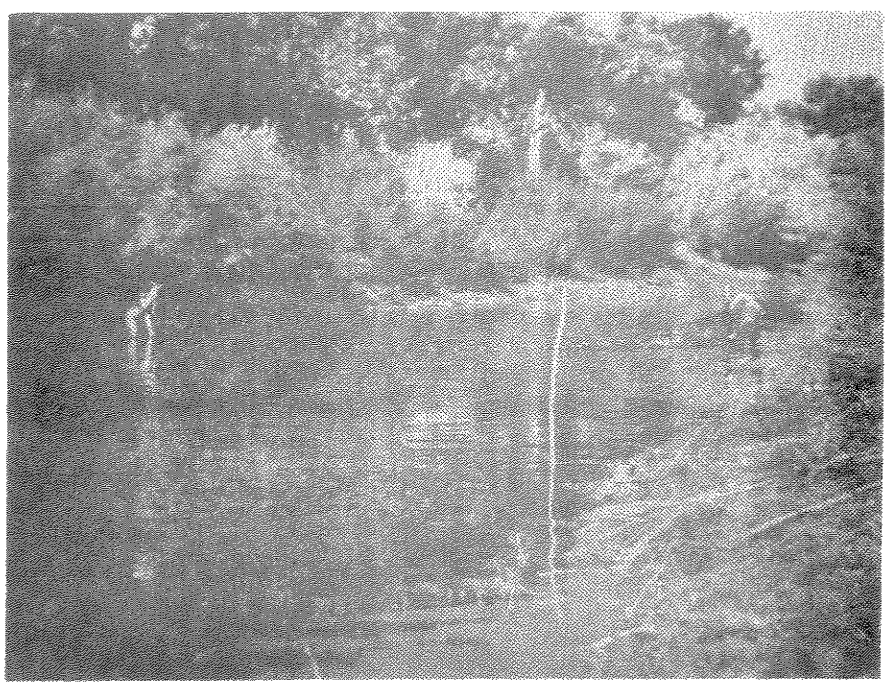

Figure 6. A beach seine was an effective device used to sample for young-of-the-year fish and minnows.

An attempt was also made to sample young-of-the-year fish and minnows with a 2.4-meter (8-ft) wide semi-balloon fry trawl fitted with 3.2-mm (1/8-inch) 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. Preliminary results of sampling with the trawl in 1979 were encouraging. Clams and small cobble substrate were collected, indicating that the trawl was being towed close to the river bottom. Further testing and modification of the trawl and its related rigging will be accomplished in 1980.

To facilitate interpretation of forage fish data, a grading scheme based on percent occurrence and percent composition was utilized. The grading scheme was as follows:

> For a grade of 3 (strong distribution) the species must average a percent composition in the seine hauls greater than 30 percent. This species must also occur in the hauls at least 50 percent of the time.
>
> For a grade of 2 (moderate distribution) the species must average a percent composition of 15-30 percent and occur in at least 50 percent of the hauls.
>
> For a grade of 1 (weak distribution) the species averages a percent composition of less than 15 percent or occurs in less than 50 percent of the hauls.

Food Habits

Food habits were determined for shovelnose sturgeon and young-of-the-year-fish of several species. Specimens were preserved in a 10 percent solution of formaldehyde. In the laboratory, stomach contents were sorted and identified in the lowest taxon practical using Edmondson's (1959) key.

To facilitate interpretation of the shovelnose sturgeon food habits, a relative importance index (RI) as described by George and Hadley (1979) was utilized. 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. The formula is:

$$RI\ item_a = 100\ A\ item_a \Big/ \sum_{item_a = 1}^{n} AI\ item_a$$

Where AI $item_a$ = % frequency of occurrence + % total numbers + % total volume for food item a, and n is the number of different food types.

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.

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 sauger and shovelnose sturgeon.

No unusually large concentrations of adult sauger or shovelnose sturgeon were observed in the study area during their reported spawning seasons in 1979. 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 isolated tributaries.

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

Table 1. Spawning conditions of sauger sampled in the Fort Benton through Judith Landing study sections of the middle Missouri River during spring and early summer 1979.

Date	Spawning Condition
May 14 - May 17	gravid females; partially spent females; spent females; many not ripe fish; few ripe males
May 19 - May 24	spent females; many not ripe fish; increased number of ripe males
Jun 4 - Jun 6	spent females; fewer not ripe fish; many ripe males
Jun 16 - Jun 19	many not ripe fish; fewer ripe males
Jul 9 - Jul 16	all fish sampled not ripe fish

Table 2. 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 gravid females and not ripe fish
Jun 4 - Jun 6	46 observed; 12 examined gravid females; not ripe fish; ripe males
Jun 5	unfertilized shovelnose eggs taken from a collected shovelnose stomach
Jun 16 - Jun 19	77 observed; 8 examined gravid females; 1 spent female; not ripe fish; ripe males
Jun 28	25 observed; 10 examined 2 spent females and ripe males
Jul 9 - July 16	65 observed; 22 examined gravid females; 3 spent females; not ripe fish; ripe males

For sauger, the entire spawning period could not be defined because several spent female sauger and a few gravid females were collected on the first sampling effort made on May 14, 1980 (Fig. 7). By May 19, no gravid females were found, and a larger number of spent females and ripe males were observed in the collections. Finally, during the first week of June, the last spent female was collected, and the number of ripe males in the samples decreased noticeably. These observations of the spawning conditions of sauger coincide with those reported by Elser et al. (1977) for the Tongue River during similar dates.

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 sexually mature 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 classified as not ripe, and, if milt could be stripped the sturgeon was considered a ripe male. No ripe females, as evident by stripping eggs, were observed during the spawning period in this study area. The scarcity of ripe females with strippable eggs has also been reported by Moos (1978) and Elser et al. (1977).

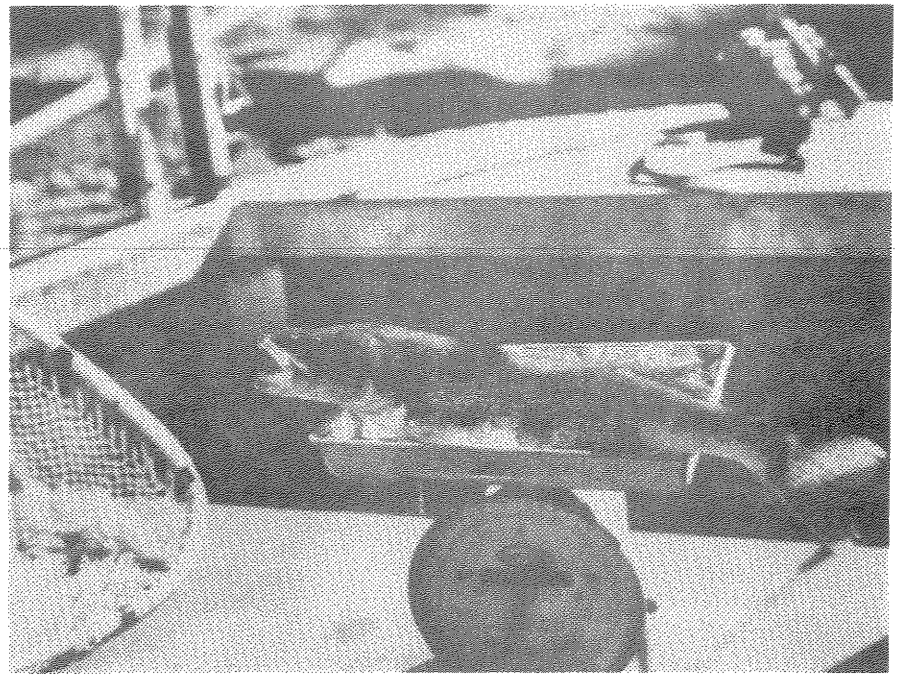

Figure 7. The sauger's spawning peak probably occurred in early May.

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 5-centimeter 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. These stages probably represent the first, second and third years of development following a successful spawning season.

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. 8). 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 preliminary observations indicate that spawning of shovelnose sturgeon in the Missouri River in 1979 occurred primarily during a period from early June through early July.

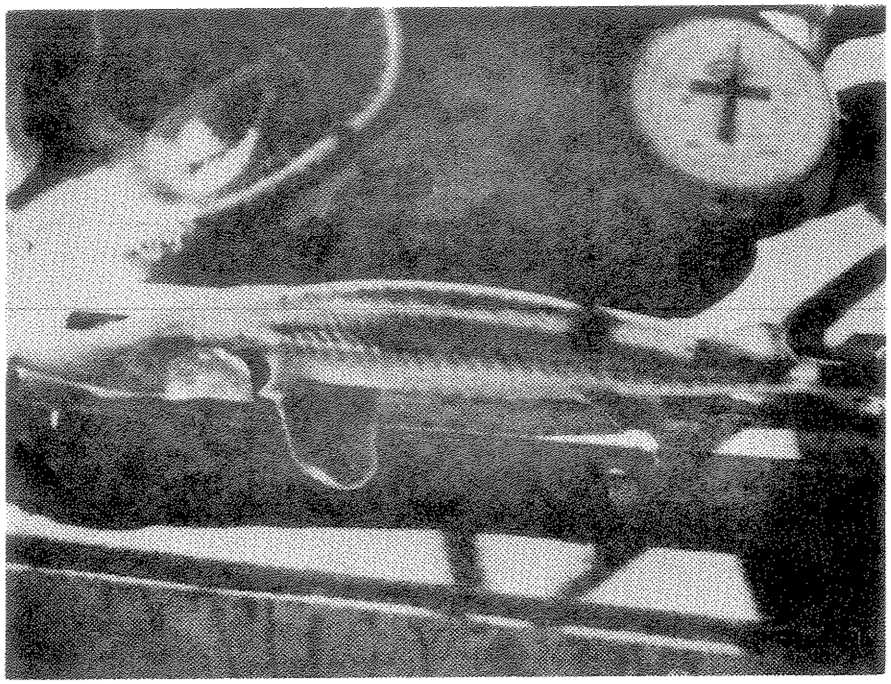

Figure 8. Shovelnose sturgeon were in spawning condition from early June to early July.

Internal examinations were made on a number of shovelnose sturgeon sampled during late August 1979. Several 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 reabsorbing 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.

Incubation

An attempt was made to locate fertilized eggs of sauger, paddlefish and shovelnose sturgeon at anticipated or known spawning sites for these speciesin the study area. Types of areas sampled were similar to those described by Nelson (1968) and Graham and Penkal (1978) for sauger, and Purkett (1961) for paddlefish. 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, an early life history taxonomy specialist. Berg (1980) previously reported that the Stafford Ferry area, with its numerous gravel bars, was the most important spawning site utilized by migrating paddlefish in the Missouri River upstream from Cow Island.

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 were sampled in eight study sections in the middle Missouri River 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 in the middle Missouri River. This information will eventually be examined to determine possible correlations of hatching success with stream discharge and water temperature. An example of larval fish sampled in the river is shown in Fig. 9.

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 sections. Berg (1980) 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.

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

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

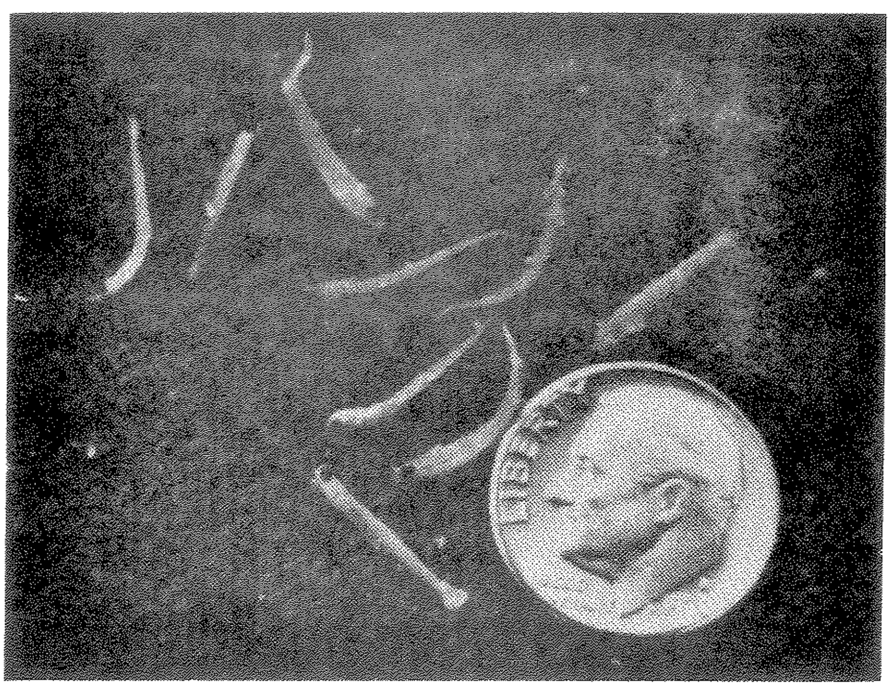

Figure 9. Fish larvae of eight subordinal taxa were collected in the middle Missouri River and its major tributaries.

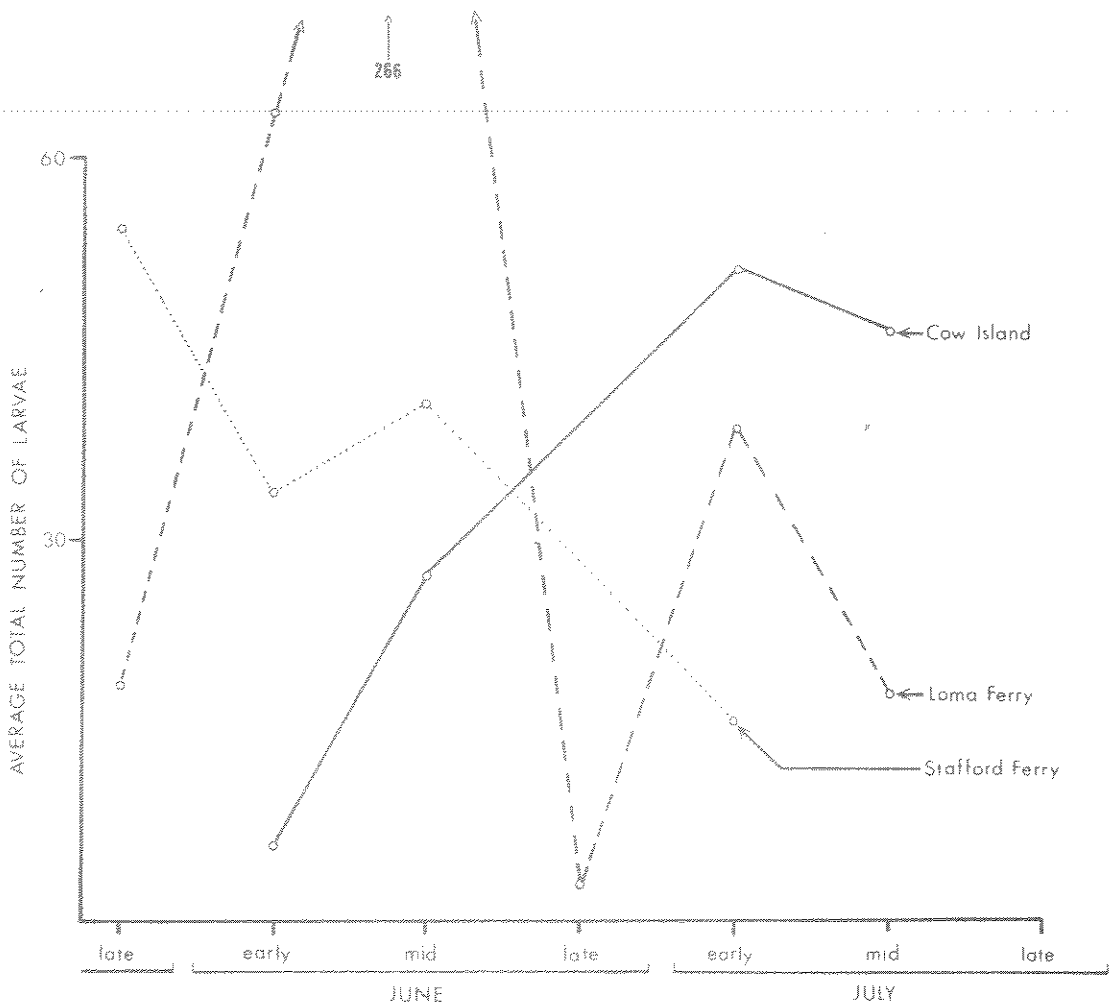

Figure 10. Average total number of fish larvae collected from 20-minute integrated width tows taken in three sections of the middle Missouri River during late May - mid-July, 1979.

In a study of the larval fish distribution and abundance for the Missouri River below Gavins Point Dam, Kallemeyn and Novotny (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.

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.

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

	Goldeye	Catostominae	Ictiobinae/ Cyprinidae	Channel Catfish	Stonecat	Sauger	total
Marias		938	87			1	1026
Teton	1	446	218		1		666
Judith	1	5	18	33			57

Density of larvae sampled (No./100 m^3)

	late May	early June	mid-June	late June	early July	mid-July	late July	early August
Marias	114	38		68	92		285	14
Teton	169	11		137	189		57	3
Judith	1		3	1		3		18

Ninety-one percent of the 1,026 fish larvae collected from the Marias River in 1979 were Catostomiae. 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 1980), but only one sauger 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 (1980) collected a large variety of fish larvae near the mouth of the Marias River in 1978. In addition to the species listed on 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 1980), 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 25 C was 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 on the middle Missouri were sampled during 1979 in an effort to determine rearing habitat preferences of important fish species. Sampling was directed primarily toward peripheral habitat areas such as side channels and backwaters. 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 in the middle Missouri River, 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 rearing habitat preference studies conducted on the middle Missouri River in 1979 indicate that young-of-the-year sauger (Fig. 11) select protected habitat in peripheral areas of the stream. During July, August and September, 43 percent of the 122 young-of-the-year sauger sampled in the Missouri River were found in the side channel pool habitat type (Fig. 12). The catch rate in side channel pool averaged 1.86 young-of-the-year sauger per seine haul (Fig. 13). Main channel pools, backwaters, main channel borders and side channel borders accounted for 30, 18, 7 and 2 percent of the young-of-the-year sauger, respectively. Catch rates also followed a similar pattern averaging 0.54, 0.46, 0.12 and 0.17 young-of-the-year sauger per haul for the previously mentioned habitat types.

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.

Figure 12. This typical side channel pool, 2 kilometers in length, was intensively utilized by rearing young-of-the-year sauger in 1979.

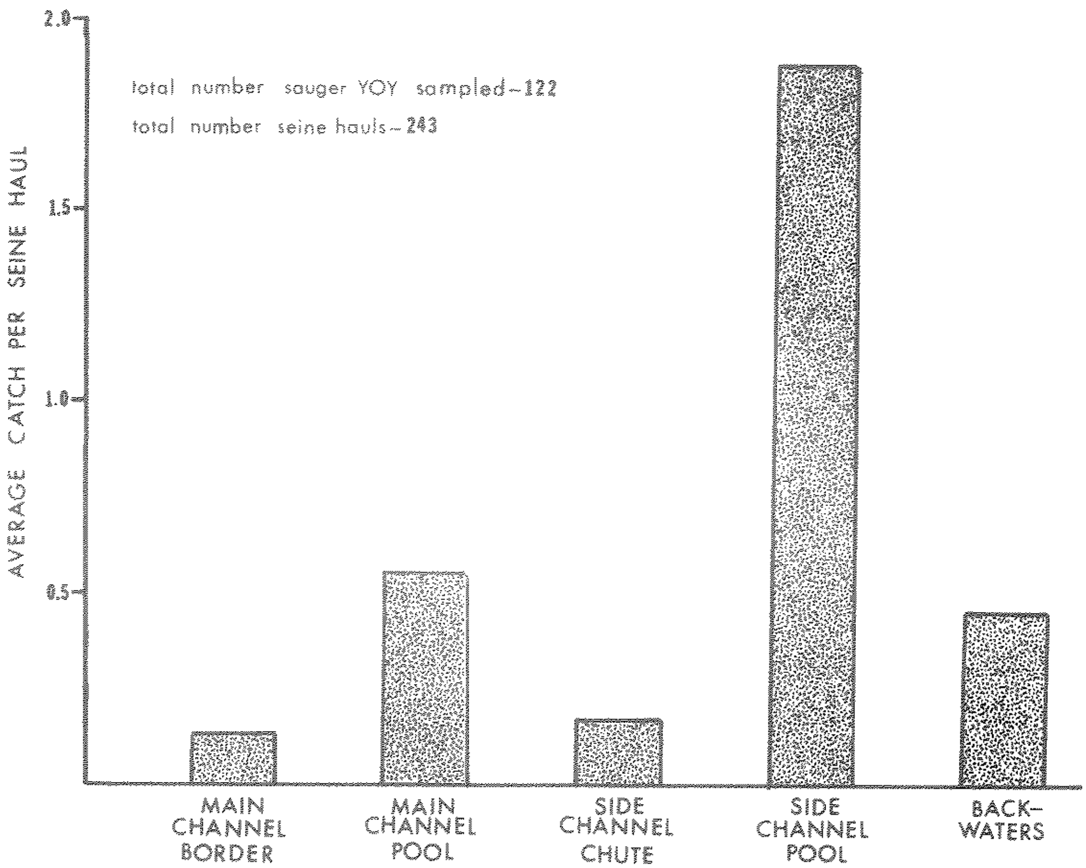

Figure 13. Young of the year (YOY) sauger habitat preferences as described by the average catch rates of YOY sauger seined in five habitat types of the middle Missouri River during Summer, 1979.

Seventy percent of the young-of-the-year 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 1.57 young-of-the-year sauger per seine haul (Fig. 14). This indicates that the Cow Island and Robinson Bridge study sections contain a substantial amount of sauger rearing habitat. This area is probably vital for the maintenance of sauger populations throughout the middle Missouri River.

The Hole-in-the-Wall study section also contained a significant amount of sauger rearing habitat. Eighteen percent of the young-of-the-year sauger sampled during July, August and September were found in this study section, and catch rates averaged 0.71 young-of-the-year sauger per seine haul.

Habitat preferences probably had a large influence on the longitudinal distribution of young-of-the-year sauger in the middle Missouri River during 1979. The Robinson Bridge study section contained an extensive amount of the most preferred sauger rearing habitat type, the side channel pools. The Hole-in-the-Wall study section contained a 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 "pocket pools" are located immediately downstream from and behind the peninsula (Fig. 15).

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 young-of-the-year sauger collected, most were found off shallow sandbars or in the backwaters habitats. Walburg (1976) reported that most of the young-of-the-year sauger which he collected were found in the shallow floodplain (shoals) of Lewis and Clark Reservoir.

In the fall of 1979, there appeared to be 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 deeper water during October, and most of these areas could not be effectively seined. An attempt was made to sample this deeper water with a 2.4-meter (8-ft.) wide semi-balloon fry trawl. However, this trawl was lost in the river shortly after initial testing. Sampling with a trawl will be resumed in 1980 in an attempt to document the shift of sauger rearing habitat preference.

The WETP instream flow methodology will be utilized in 1980 in an effort to determine the amount of instream flow required to maintain sauger rearing habitat. Our knowledge of the habitat preference of young-of-the-year sauger will aid in selecting sites for measuring physical characteristics of the river. Available habitat will then be determined at various flows by examining the hydraulic simulation model generated by the WETP computer program. WETP is a simplified version of the IFG instream flow methodology developed by Nelson (1980).

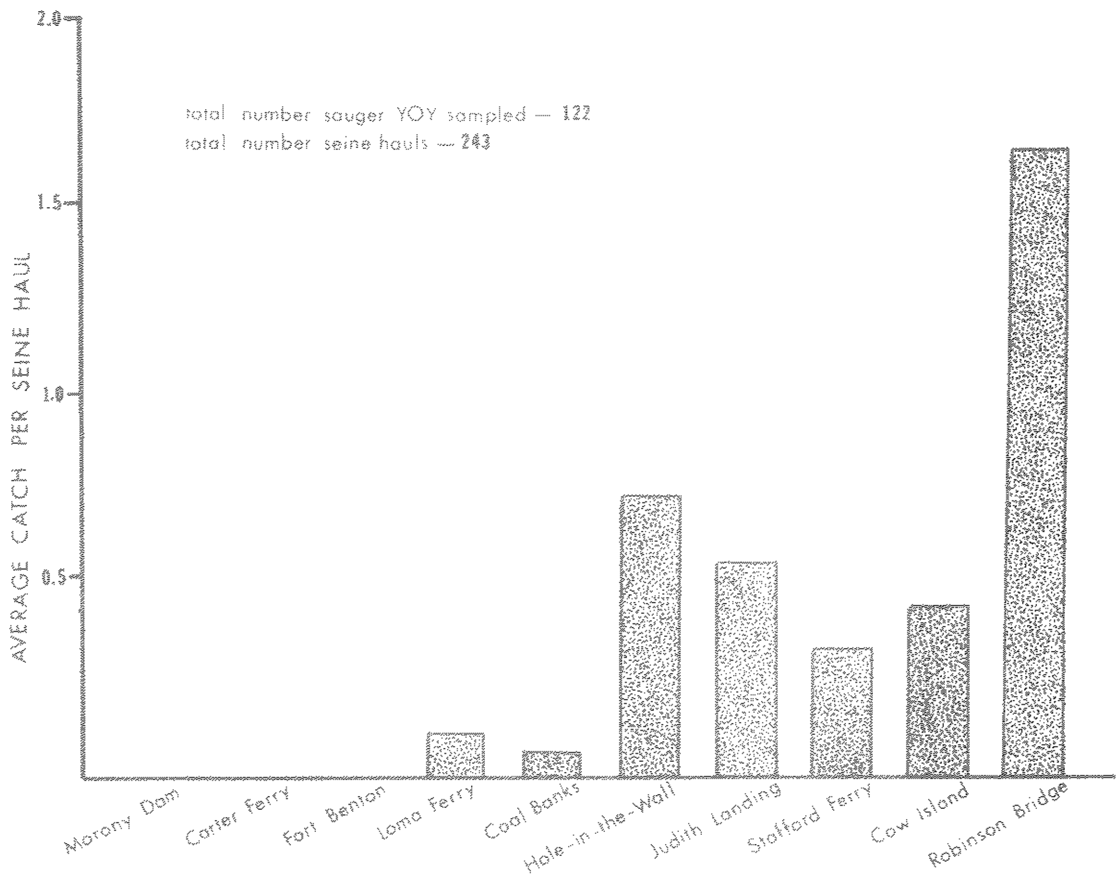

Figure 14. Longitudinal distribution and abundance (average catch rates) of young-of-the-year (YOY) sauger seined in the middle Missouri River during Summer, 1979.

Figure 15. The Hole-in-the-Wall section exhibited extensive channel margin development; several peninsulas perpendicular to the margin formed important sauger rearing "pocket pools."

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 these forage fish for the welfare of the sport fishery as well as for the welfare of the forage fish species themselves. This phase of the investigation was conducted to determine longitudinal distribution of forage fish species in the middle Missouri River and to identify their preferred habitat types. For the 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.

The longitudinal distribution of forage fish sampled in the middle Missouri River during 1979 is shown in Table 6. Twenty-four species were collected within the 336-kilometer reach of river. Considering the minnow family only, all of the species reported by Brown (1971) to occur in the middle Missouri River mainstem were collected. A notable addition was the collection of several sicklefin chubs (*Hybopsis meeki*) which had been previously reported to be in the Missouri River only as far upstream as the confluence of the Little Missouri River in North Dakota. This minnow is described by Pflieger (1975) "as strictly confined to the main channels of large turbid, rivers where it lives in a strong current over a bottom of sand or fine gravel." In the 70-kilometer reach of the Missouri River from Cow Island to the headwaters of Fort Peck Reservoir where the sicklefin chubs were found, the river generally exhibits the features described by Pflieger. Because of its strict requirements for a limited habitat and its paucity in Montana rivers, the Department of Fish, Wildlife and Parks recently designated this fish as a species of special concern.

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

	Morony Dam	Carter Ferry	Ft. Benton	Loma Ferry	Coal Banks	Hole-in-the-Wall	Judith Landing	Stafford Ferry	Cow Island	Robinson Br.	Turkey Joe
Goldeye						*	*		*	*	*
Mountain whitefish		*			*						
Carp	*	*	*	*	*	*	*	*	*	*	
Flathead chub	*	*	*	*	*	*	*	*	*	*	*
Sickle fin chub									*	*	*
Lake chub	*	*	*	*	*	*	*				
Emerald shiner	*	*	*	*	*	*	*	*	*	*	*
Brassy minnow											*
Plains minnow	*	*		*						*	
Western silvery minnow	*	*	*	*	*	*	*	*	*	*	
Fathead minnow	*	*	*	*	*	*					
Longnose dace	*	*	*	*	*	*	*	*	*	*	*
River carpsucker				*	*	*	*	*	*	*	*
Smallmouth buffalo											*
Shorthead red-horse sucker	*	*	*	*	*	*	*	*	*	*	*
Longnose sucker	*	*	*	*	*	*	*		*	*	
White sucker	*	*	*	*		*					
Channel catfish									*	*	
Stonecat		*		*		*	*	*	*		
Yellow perch		*	*						*		*
Sauger				*	*	*	*	*	*	*	*
Iowa darter		*									
Freshwater drum											*
Mottled sculpin	*	*		*		*				*	

Another notable extension of a forage fish distribution was the collection of the Iowa darter in the Carter Ferry study section. Previous to this discovery the known range of Iowa darters in Montana was limited to tributaries of the Little Missouri River and to the Missouri River and its tributaries below Fort Peck Dam (Brown 1971). The habitat where Iowa darters were collected in the Carter Ferry study section is similar to Brown's description of their habitat. He described the habitat as being "clear slow-flowing streams with solid bottoms."

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 is apparent that forage fish in the middle Missouri River prefer protected slow water habitat types.

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

Longitudinal distribution and relative abundance of seven of the most widely distributed forage fish in the study area are presented in Fig. 16. Flathead chubs, emerald shiners and western silvery minnows were relatively more abundant in the lower gradient downstream study sections. In contrast, longnose dace and suckers were more prevalent in the swift habitat areas found in the upstream study sections.

Specific habitat preferences of the seven common forage fish species are shown in Fig. 17. With the exception of the longnose sucker, all of these species exhibited preferences for certain habitat types. Western silvery minnows and young-of-the-year carp and shorthead redhorse showed a preference for the protected habitat types, which include main channel pools,

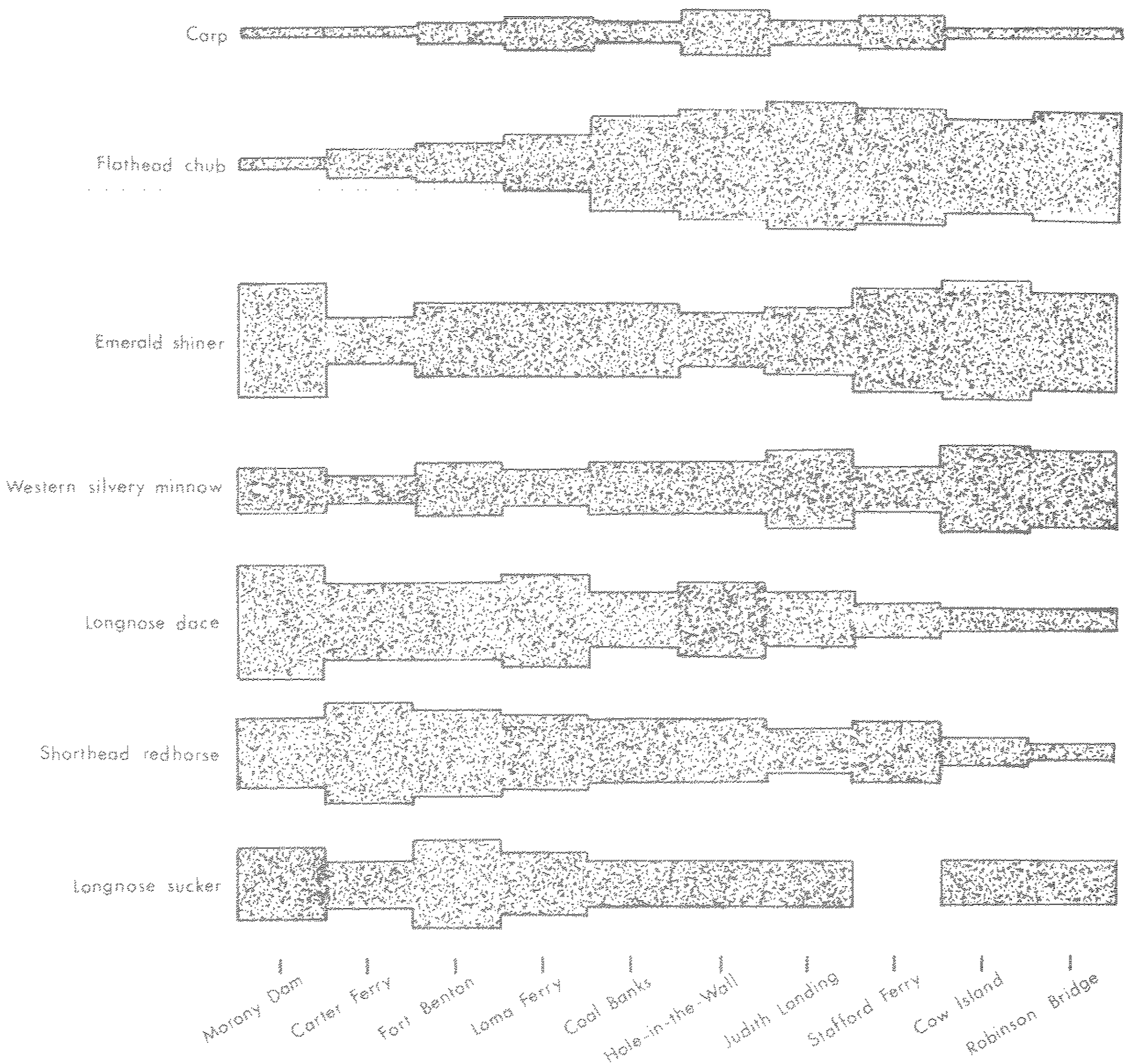

Figure 16. Longitudinal distribution and relative abundance (grade of occurrence) of seven common forage fish species seined in the middle Missouri River during 1979.

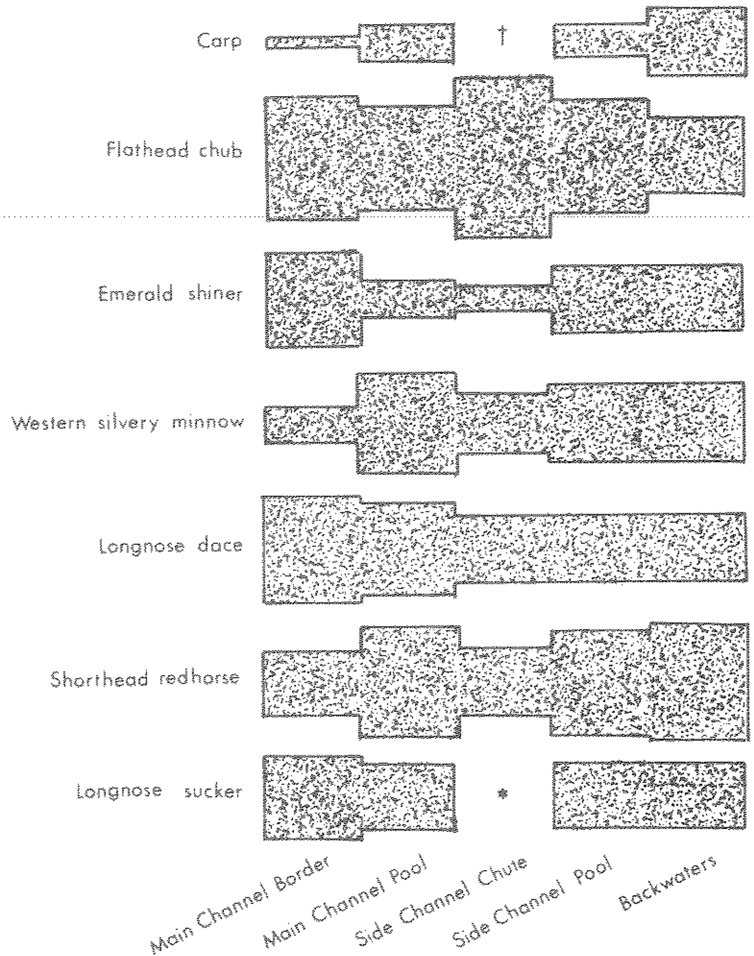

Figure 17. Forage fish habitat type preferences as described by the relative abundance (grade of occurrence) of seven common forage fish species seined in five habitat types of the middle Missouri River during 1979.
+ zero fish collected in this habitat type
* This habitat type not sampled in its preferred longitudinal range.

side channel pools and backwaters. Emerald shiners and longnose dace preferred the main channel border habitat type. Flathead chubs were most prevalent in side channel chutes and main channel borders.

The WETP instream flow methodology will be utilized in 1980 in an effort to determine the amount of instream flow required to maintain forage fish habitat. Our knowledge of the habitat preference of forage fish will aid in selecting sites for measuring physical characteristics of the river. Available habitat will then be determined at various flows by examining the hydraulic simulation data generated by the WETP computer program.

Food Habits

An essential part of a fish species habitat is the area where it fulfills its food requirements. A thorough understanding of a fish species' food habits throughout the year is necessary in order to determine the importance of specific food organisms. After a fish species' food habits have been determined, a reasonable evaluation can be made of the amount of instream flow required to maintain the habitat of important food organisms.

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 of the middle Missouri River. The sturgeon were collected during the autumn of 1978 and during the spring, summer and autumn of 1979. The fish ranged in weight from 1200 to 4680 grams.

Results of the shovelnose sturgeon food habits analyses are presented in Table 8. The diet was basically comprised of a wide variety of aquatic insects. Twenty-three subordinal taxa of aquatic insects were observed in the diet.

The relative importance (RI) of mayflies in the diet of shovelnose sturgeon 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 in the sturgeon diet.

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 4 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.

Table 8. Percentages of occurrences, average total numbers and volumes of the food items found in the diets of adult shovelnose sturgeon in the middle Missouri River during 1978-1979.

	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
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
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	-	-	-
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	-	-	-

Table 8 (continued). Percentages of occurrences, average total numbers and volumes of the food items found in the diets of adult shovelnose sturgeon in the middle Missouri River during 1978-1979.

	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 (unknown)	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

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

Seasonal comparisons of the relative importance (RI) of six major food groups utilized by adult shovelnose sturgeon in the middle Missouri River are shown in Figure 18. 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 relative importance (RI) of mayflies in the summer diet was 54 percent. Two mayfly taxa, *Rhithrogena* and *Traverella*, alone had a 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 a relative importance of 32 percent.

The seasonal diets of shovelnose sturgeon have been report by other investigators. Wallburg et al. (1971) and Modde (1973) found the shovelnose in the Missouri River below Gavins Point Dam to be mostly indiscriminate 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. Although no selectivity analysis was conducted for this investigation, based on the distribution and composition of the aquatic insect fauna as described by Berg (1980), it is believed that 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 Fig. 18 frequent a wide array of habitats, also including the swift current areas. Berg (1980) indicated that *Heptagenia* was a common insect in the middle Missouri River. However, this insect is not considered to be an important food item in the diet of shovelnose sturgeon in the study area. Newell (1976) reported that the velocity requirement for *Heptagenia* is substantially less than that of *Rhithrogenia* and *Traverella*. This observation provides further evidence to support the idea that shovelnose sturgeon feed nonselectively in swift current areas in the middle Missouri River.

Fish growth rates follow a seasonal pattern in response to temperature changes. 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

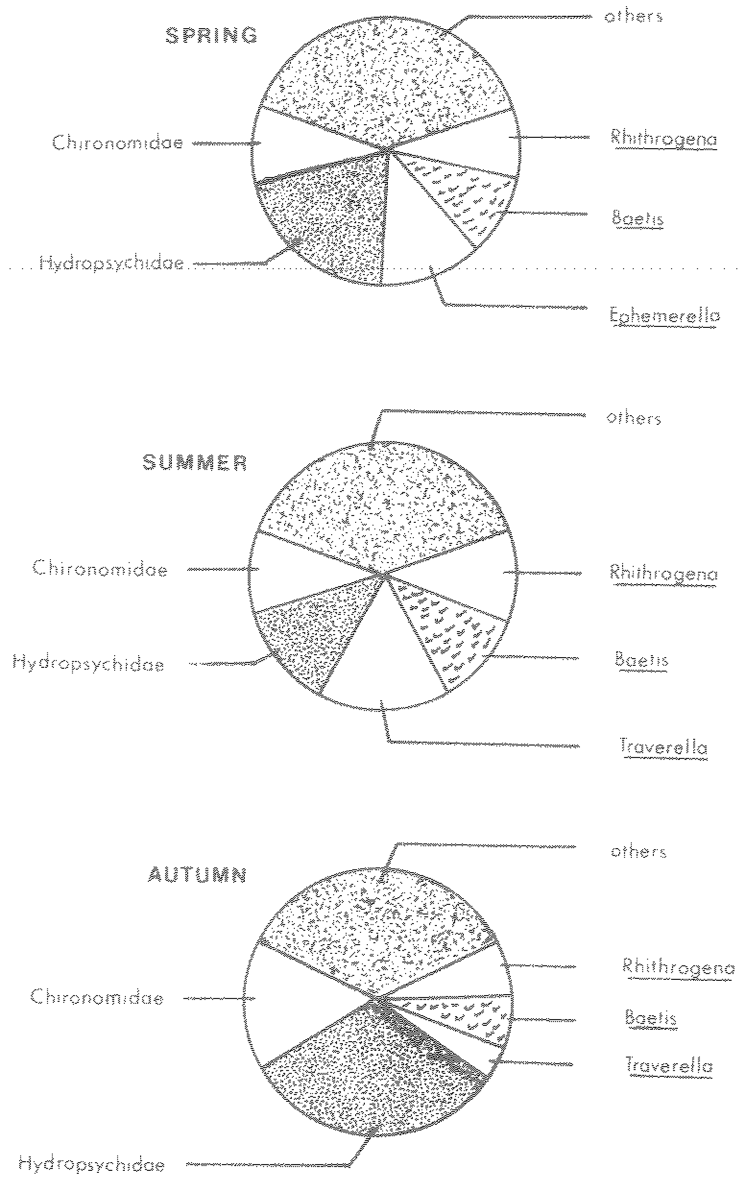

Figure 18. Seasonal comparisons of relative importance (RI) of the six major food groups utilized by adult shovelnose sturgeon in the Loma Ferry and Coal Banks Landing sections of the middle Missouri River, 1978-1979.

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 the middle Missouri River. It should also be noted that these two taxa exhibit relatively little tolerance to alterations of physical and chemical characteristics of a river. Therefore, it is recommended that particular attention be given to the requirements of *Rhithrogena* and *Traverella* when instream flow determinations are made and future water development plans are proposed.

The WETP instream flow methodology will be utilized in 1980 in an effort to determine the amount of instream flow required to maintain sufficient wetted perimeter in riffle areas for aquatic insect production. Instream flow recommendations for the Missouri River, particularly during the critical low flow period through the winter, will be based largely on maintenance of the riffle areas.

Young-of-the-Year Fish

Limited studies were made during 1979 of 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 9.

Table 9. 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.

	Sauger		Goldeye		Freshwater Drum
Food Items	Jul 26	Oct 15	Jul 26	Oct 15	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

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 trout, perch, freshwater drum and white bass. However, if 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 of findings about larval fish in the middle Missouri River 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 in the study area during 1979 were highest during July. Therefore, an adequate food supply is required during July to insure maximum growth during this critical period. This requirement is probably best fulfilled at the lower sites where larval fish are still available. Walburg (1976) reported the greatest growth of young sauger was in July and early August. Priegel (1969) also 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 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.

Analysis of the diets of a number of YOY freshwater drum sampled near the headwaters of Fort Peck Reservoir in mid-August of 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 of the middle Missouri River. The tributaries each augment the flow, increase channel depth and width and, during spring, add sediment to the Missouri. In an intensive inventory of the fish populations of the middle Missouri River, Berg (1980) reported significant changes in the fish communities below these major tributaries, especially below the Marias River. Berg also documented substantial spawning migrations of several important fish species from the Missouri River into these tributaries. The importance of major tributary streams to the mainstem of a larger river has also been reported by Elser et al. (1977) and Rehwinkel et al. (1976).

Little information is known about the resident fish populations in tributaries of the middle Missouri River. Therefore, 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 on the tributaries in 1979 (Table 10). Most of these species are also found on the mainstem of the middle Missouri River between Morony Dam and Fort Peck Reservoir (Berg 1980).

Table 10. 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 of the middle Missouri River in the study area. Resident fish populations were surveyed in a 125-kilometer reach of the Marias River 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 step badlands, and very little off-channel development is evident. Stream gradient averages 0.6 meters per kilometer. Sand, gravel and small cobble are the predominant stream substrate materials.

At the head of the study reach is Tiber Dam, 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. However, its actual uses 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 to 600 micromhos/cm^2, and bicarbonate alkalinity ranges from 150 to 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 on the Marias River between Tiber Dam and the mouth of the Teton River (Figure 1). The Tiber Dam study section was approximately 30 km in length, and it 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 levelled 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 on the lower Marias River are shown in Tables 11 through 15. The Marias River in a 30-kilometer section immediately below Tiber Dam supports a significant salmonid fishery. Mountain whitefish are the predominant gamefish in this section, and a number of trophy size specimens larger than 1.8 kilograms (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 effort for this species was substantially reduced downstream from the Tiber Dam study section. Rainbow trout were very ephemeral in their longitudinal distributution 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 River. Sauger are the most common gamefish in the Marias River below Tiber Dam, and they comprise the bulk of the sport fishery.

Other common gamefish 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 of the Marias. 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 (1980) reported substantial annual spawning migrations of several fish species from the Missouri River into the lower Marias River. The most important migrant species included sauger, shovelnose sturgeon, blue suckers and smallmouth and bigmouth buffalo.

Table 11. 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 12. 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 13. 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 14. 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	20-1000	21.0

Table 15. 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

Teton River

The Teton River is the largest tributary of the Marias River. It enters the Marias River just 1.5 kilometers above its confluence with the Missouri River near Loma, Montana. Resident fish populations were surveyed in a 123-kilometer 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 by 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 to 800 micromhos/cm^2, and bicarbonate alkalinity ranges from 200 to 300 mg/l.

Two study sections were established on the Teton River between the Shannon bridge and the confluence with the Marias 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 16 and 17. Sauger was the most common gamefish found in both study sections. The sauger were large, averaging 400 mm and 535 grams (15.7 inches and 1.17 pounds) in length and weight, respectively, for both study sections combined. 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 which would enable the sauger to reside as year round residents would be desirable for the lower Teton River.

Table 16. 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

Other gamefish 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 (1980) observed migrant use of the lower Teton River by sauger, channel catfish and blue suckers.

Table 17. 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 important species collected by seining, but not found in the electrofishing surveys, was the sturgeon chub. Brown (1971) reported that this species was found in Montana only in the lower Yellowstone River and its tributaries, making this collection a significant extension of its known range. The sturgeon chub in Montana is considered uncommon, and it is listed by the Montana Department of Fish, Wildlife and Parks as a species of special concern - class B.

Judith River

The Judith River is the second largest tributary of the middle Missouri River in this study area. Resident fish populations were surveyed in a 32 kilometer reach of the lower Judith River 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 at approximately 200 cubic meters per minute (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 River. The only major water storage facility in the Judith River drainage is Ackley Reservoir which has a storage capacity of 0.008 cubic hectometers (6,140 acre-ft).

Water quality of the lower Judith River is described by Kaiser and Botz (1975) as basically a calcium bicarbonate water of good quality. The chemical characteristics of the Judith River are similar to the Teton River. Conductivity of the lower Judith River usually ranges from 800 to 1000 micromhos/cm^2, and bicarbonate alkalinity ranges from 200 to 300 mg/l.

Two study sections were established on the lower Judith River between Anderson bridge and the confluence with the Missouri River (Fig. 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 study 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 on the lower Judith River are shown in Tables 18 and 19. 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.

Table 18. 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 19. 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

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 gamefish sampled included mountain whitefish, channel catfish and burbot. Goldeye, carp and a variety of suckers were the most common nongame fish. Flathead chubs were by far 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 efffort was made to investigate actual utilization of the lower Judith River 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 River. As described in a previous section of this report, 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 and 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 (Carlson 1980). Successful spawning of paddlefish in the study area has been documented by collecting numerous 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 1980). Berg monitored the spawning migration of paddlefish in the middle Missouri River in 1977, 1978 and 1979. He found that no significant spawning run occurred in 1977, a year when stream flow levels in the Missouri River were considerably below normal. In 1978 and 1979, stream flow 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 kilometers above Fort Peck Reservoir.

Radiotelemetry studies were initiated in 1979 to aid in better determining instream flow requirements of paddlefish in the middle Missouri River. Objectives of the radiotelemetry study are:

1) 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,

2) to evaluate responses of individual paddlefish to increases, decreases or sharp fluctuations of flow,

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 it contains water of a relatively high ionic conductivity. It is very 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 radiotelemetry system which would be suitable for our requirements.

Equipment

A Smith-Root RF40 tracking receiver with a frequency range between 40.000 and 41.000 MHz was used to monitor the radio transmitters. An omnidirectional whip antenna was matched with the receiving unit and mounted to the wing strut of a Super Cub airplane.

Two different types of radio transmitters were tested in 1979. The first type, Smith-Root P-40-250M, contained mercury power cells, and the second type, Smith-Root P-40-1000L, had lithium power cells (Fig. 19). The cylindrical transmitters were 1.9 cm in diameter, and lengths of the 250 m and 1000L were 12 and 18 cm, respectively. Their weights in water were 16 and 25 grams, respectively.

Several of the radio transmitters were placed in the Missouri River at various locations and depths to evaluate each tag's signal strength. Relocations

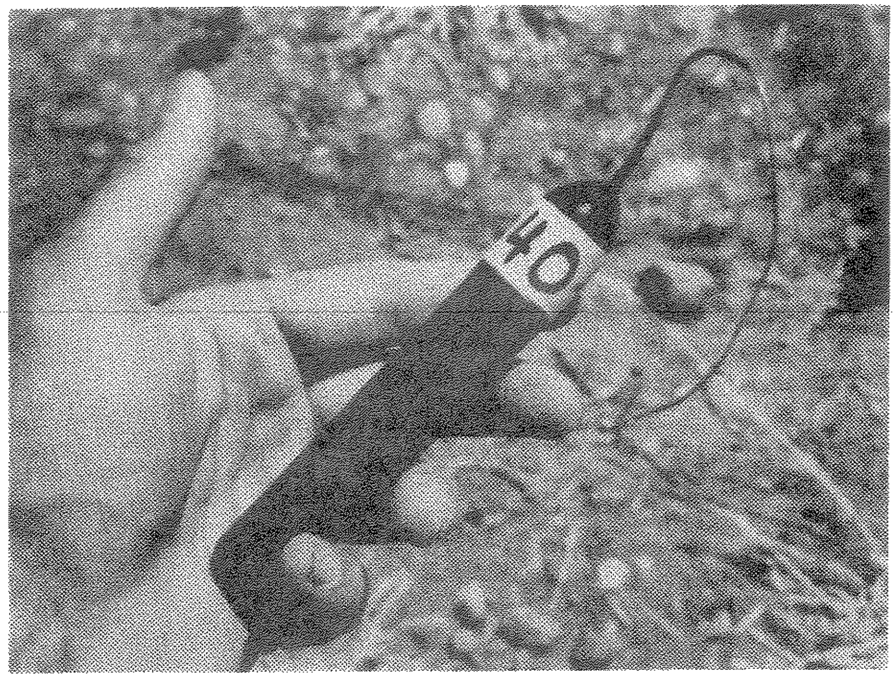

Figure 19. Radio transmitters were surgically implanted or attached to the rostrum of paddlefish to monitor their movements.

of the tags were made from the Super Cub flying the river's course. The 1000 L transmitters emitted a strong signal which could be received at a distance of 1.5 kilometers flying approximately 300 meters above the river. Life expectancy of the 1000 L transmitters is 90 days, which meets our requirements. The 250 M transmitter did not produce an adequate signal, and further testing of this unit was abandoned.

Implantation and Attachment of Transmitters

To test the response of paddlefish to implantations and attachments of the 1000 L transmitters, five paddlefish, ranging in weight from 15 to 30 kilograms, were instrumented with transmitters and released in a small 4 hectare pond. Three of the five radio tags were implanted in the peritoneal cavity of the paddlefish. Using standard surgical procedures, a 7 cm incision was made with a scalpel, along the upper right ventrum immediately posterior to the pectoral fin (Fig. 20) and sterilized in a solution of Nolvasan. The incision was made at this site to avoid severing major vessels present along the ventral axis. After the incision was completed, a sterilized transmitter dipped in paraffin was inserted into the peritoneal cavity with the 10 cm antenna either extending from the incision or internally extending in the cavity. The incision was then closed with individual sutures spaced 5 mm apart. Finally, the fish was injected with an antibiotic at a dosage of 1 cc antibiotic per 4.5 kg of paddlefish body weight.

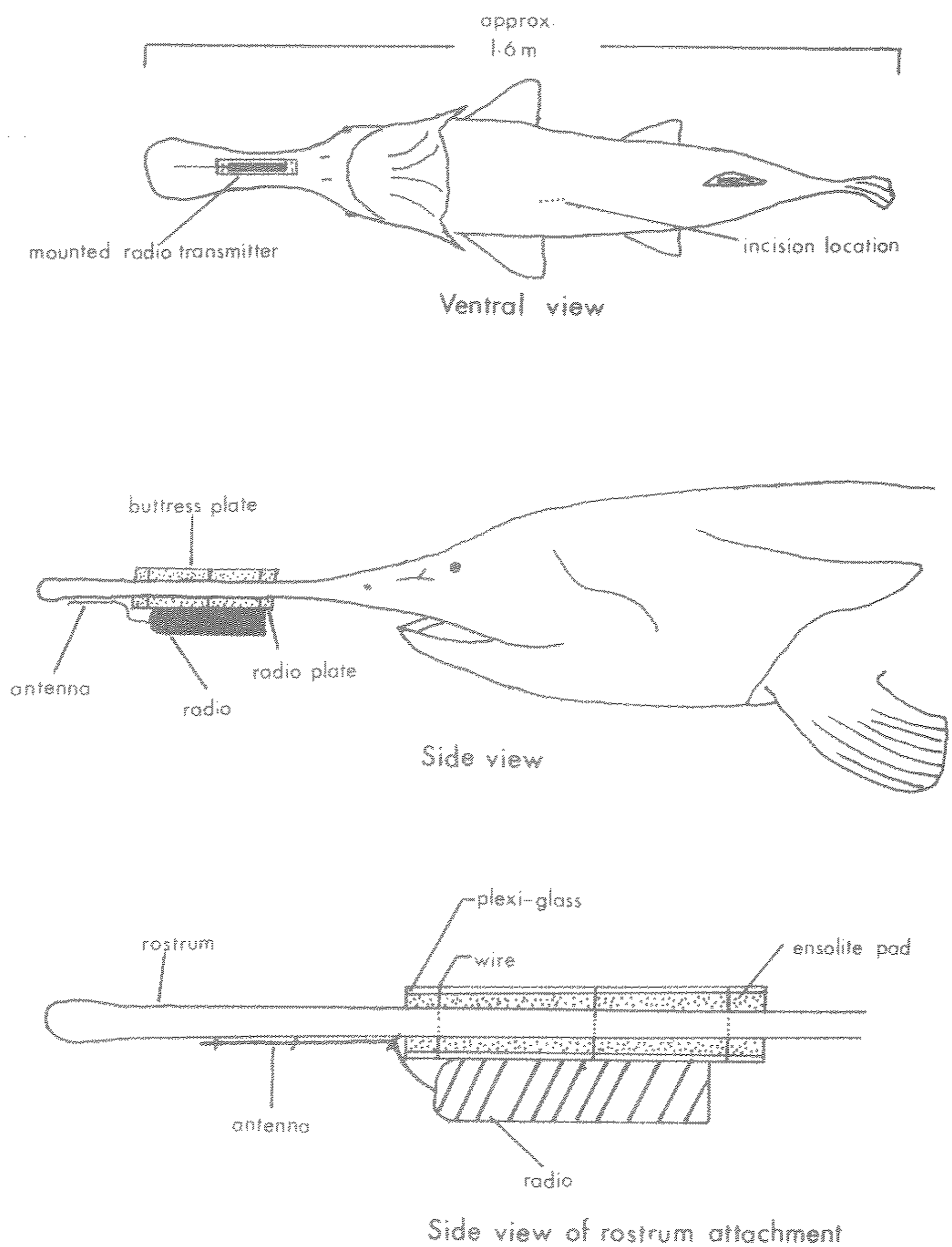

Figure 20. Attachment and implant sites for the radio transmitters for paddlefish.

Two of the five radio transmitters were attached to the rostrum of the paddlefish (Fig. 20). The transmitters were cemented to a 16 x 4 cm plexiglass plate similar to that described by Haynes (1978). Holes were drilled in the plate to facilitate threading of a stainless steel wire from the mounting plate through the rostrum to a buttress plate where the wire was anchored. The transmitter antenna was anchored to the rostrum by stitching it to the skin. Dave Combs (personal communication) first experimented with this method, and he reported good success because the technique does not circumscribe the rostrum and cause irritation as reported by Elser (1976).

Feasibility Testing

All five paddlefish appeared to be minimally affected by implantation or attachment of the radio transmitters. When released into the testing pond they immediately swam away. Radios were monitored for proper signal transmission immediately before being released and at 4 hour intervals thereafter. Approximately 18 hours after instrumentation, locations of all five paddlefish were determined and movement was apparent.

Twenty days later an attempt was made to relocate the radio instrumented paddlefish from a fixed wing aircraft, however, no signals were received. Sixty days after the initial instrumentation an attempt was made to relocate the tagged fish from a boat. One tagged fish with a rostrum attachment was located and movements of the fish were apparent. An attempt was made to recover the five radio instrumented paddlefish by use of gill nets, a large seine and electrofishing to determine the cause of the assumed transmitter failures and examine the fish for possible rejection of the tag. None of the paddlefish could be collected by these methods. The poor results in relocating the radio instrumented paddlefish can probably be attributed to high conductivity of the water in the pond (exceeding 2000 micromhos/cm^2). The high conductivity of the pond apparently caused severe attenuation of the radio transmitter signals. Conductivity of the middle Missouri River during the paddlefish migration and spawning period ranges from about 400 to 600 micromhos/cm^2, and should present no problems for transmitting the radio signals.

Based on the above considerations, paddlefish radiotelemetry studies should be continued. An attempt will be made in the spring of 1980 to instrument thirty paddlefish with radio transmitters. The tagging will be done at the onset of the migration, and movements of the fish will be followed. Since the research program is still at an experimental stage, transmitters produced by three different commercial suppliers will be utilized. With diversification among several suppliers, the opportunity for success in the radio telemetry study should be greatly improved.

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