Vital Statistics and Instream Flow Requirements of
Fish in the MONTCO Mine Area of the Tongue River, Montana

By

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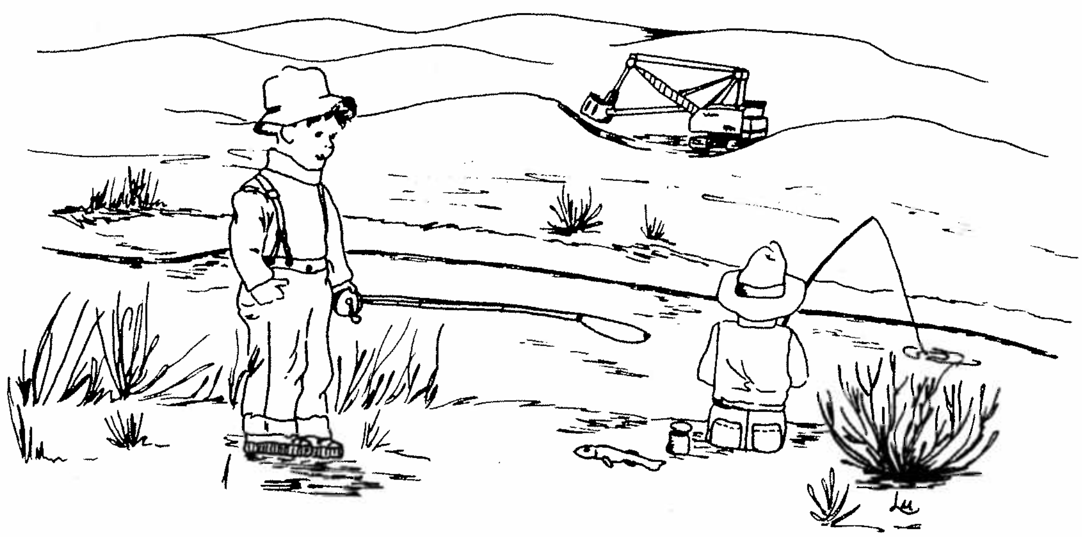

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ABSTRACT

A survey of the fish populations in the Ashland-Birney area of the Tongue River was undertaken during 1978 and 1979 in light of proposed surface coal mining adjacent to the river.

Four study sections were chosen on the river to assess vital statistics of the fish populations. Habitat in the four sections was similar with section three containing higher amounts of instream brush than the other sections. Shorthead redhorse were the most common species in the study area. Downstream drift of larval fish probably accounts for the fact that larger individuals of most species occur in the upstream sections. Smallmouth bass are the prevalent gamefish in the study area. Population estimates indicate a healthy population exists in the study area. Older bass (3+) exhibited an upstream migration during April and May followed by a downstream migration during September and October. Growth was comparable to smallmouth bass in the Tongue River Reservoir and was best in the farthest upstream section (1). Growth of rock bass was similar to other northern latitude waters. The 1975 year class of smallmouth bass was severely depressed by a flood coupled with cool spring and summer temperatures. Condition and survival are similar to the Tongue River Reservoir fish. Tag loss was higher for spring tagged fish than for fall tagged fish. Growth of young of the year was better than other northern latitude waters. Minimum instream flow requirements of the bass were measured for all times of year. Movement of fish into the two primary tributaries was assessed. A discussion of possible impacts of coal mining is included.

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ACKNOWLEDGEMENT

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OBJECTIVES

MONTCO has proposed a surface coal mine adjacent to the Tongue River in Rosebud County, Montana (Map I-1). This study was performed by the Montana Department of Fish, Wildlife and Parks, for MONTCO, as input to their mine permit application.

The Tongue River originates on the eastern slopes of the Bighorn Mountains of Wyoming, flowing in a northeasterly direction through Montana to it's confluence with the Yellowstone River at Miles City, Montana. In Montana, the flow is controlled by the Tongue River dam, which was completed in 1939 for irrigation purposes. The dam is situated 51 kilometers (32 miles) upstream of the study area. The deep water withdrawal system of the dam releases cool hypolimnetic waters to the Tongue River. Directly downstream of the dam the river supports a trout fishery, and as the water warms into a more typical prairie stream system, the transition area supports a smallmouth bass fishery. This is the area in which the mine is planned.

The Tongue drains approximately 13,932 km^2 (5,379 sq. mi.), with an average annual discharge of 11.5 cms (405 cfs) at the mouth where it joins the Yellowstone River at Miles City. Specific conductance ranges from 280 to 1310 umbos/cm in the study area and pH ranges from 7.7 to 8.7 (Olson-Elliott and Ass., 1979). The river is an important source of water for agricultural, domestic, recreational and industrial use.

The purpose of this study was to assess the present status of the fishery in the Tongue River between Hanging Woman and Otter Creeks (Map I-1).

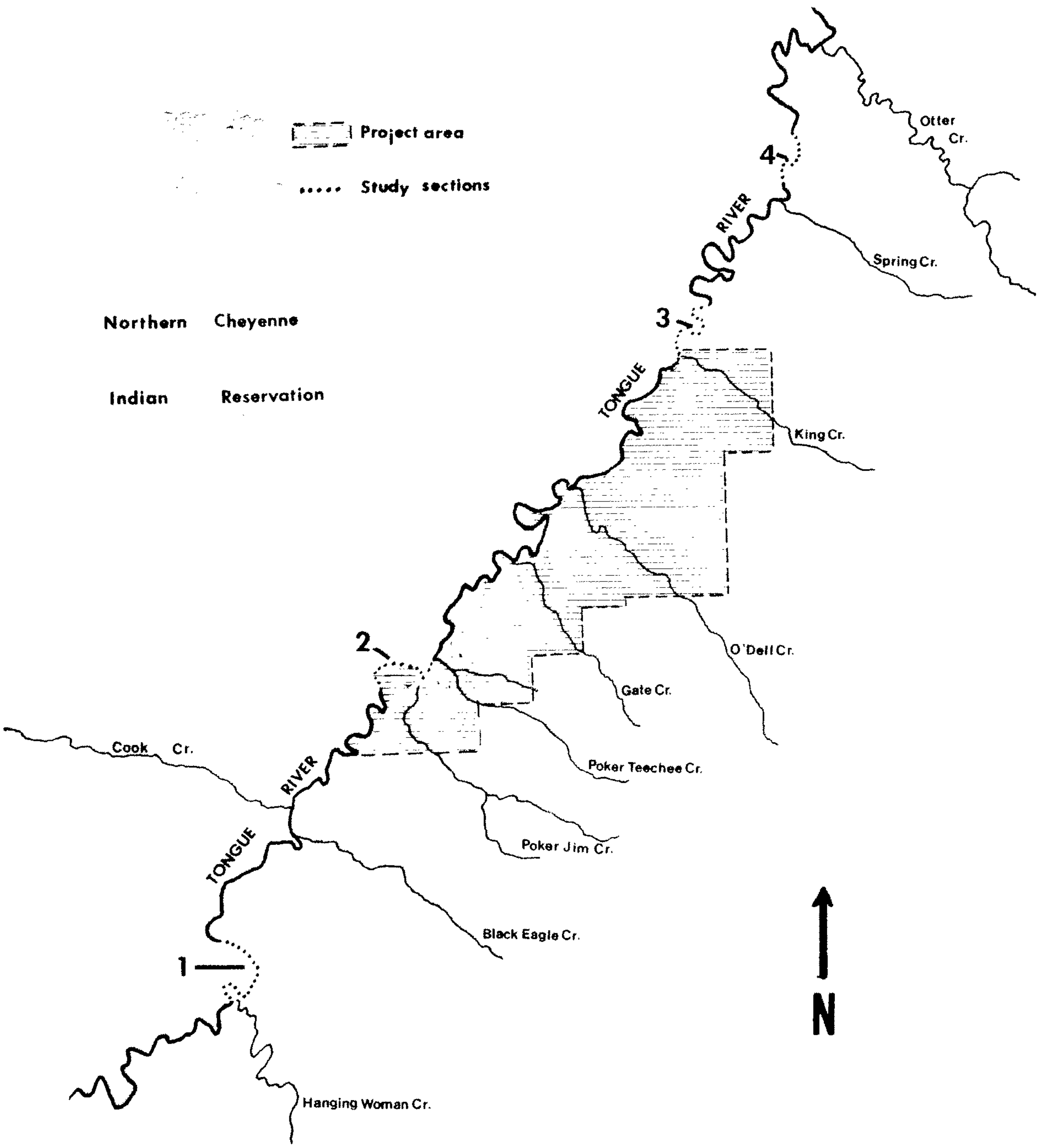
Information from this report will be used for reclamation planning, a fish and wildlife management plan and as a comparison for detecting potential impacts of stripmining.

MATERIALS AND METHODS:

The fisheries study was conducted along four sections of the Tongue River. These sections varied in length from 2 kilometers to 4 kilometers (1-3 miles) (Map I-1). Section 1 is upstream of the project area, Sections 2 and 3 are adjacent to the project area, and section 4 is downstream of the project area. Study sections were selected on the basis of: inclusion of representative aquatic habitat types (riffles, pools, runs), accessibility, and cooperation of the landowner.

Electrofishing was the primary method of fish collection. The system was designed by Coffelt Electronics of Englewood, Colorado and modified in accordance with Novotny and Priegel (1974) and Peterman (1978). During the fall of 1978, electrofishing was conducted by drifting downstream. During 1979 an outboard motor, fitted with a riffle runner, was used successfully.

A minimum of 5 mark and 5 recapture runs were completed on each section during the fall of 1978, and the spring and fall of 1979. Approximately one week was allowed to elapse between mark and recapture runs. Fish



Map I-1. Map of study area (1-inch = 3 1/8 miles) were shocked using pulsed direct current, captured in dipnets and placed inside a live box which maintained a continuous circulation of river water. Intermediate stops were made along the shocking sections to measure, weigh and mark fish. Gamefish were tagged with a numbered red floy tag which was inserted posterior to the soft dorsal fin. Scales were taken from underneath the left pectoral fin of all gamefish. During recapture runs, fish were measured and weighed, inspected for marks or tags, and all new game fish were tagged. During the fall of 1978 and spring of 1979, a selected fin was punched to avoid counting any fish more than once.

Gill nets and trap nets were also employed in fish sampling, however, both proved to be of marginal use. Hoop nets, which were baited with cheese, were fished for channel catfish during June and July of 1979 on the study sections.

Population estimates were calculated using Chapman's adjustment of the Petersen equation:

$$N = \frac{(M+1)(C+1)}{(R+1)} - 1$$

The standard deviations of these estimates were calculated according to the following equation:

$$SE(\hat{N}) = \sqrt{\frac{(\hat{N})^2(C-R)}{(C+1)(R+2)}}$$

Fish scales were mounted on acetate slides and all readable scales were measured for back calculations. Age and growth data were tabulated by the FIRE I computer program (Hesse 1977). Back calculations were computed according to the Lee corrected equation:

$$l_n - c = \frac{Sn}{s}(l - c)$$

where: c = intercept of length axis
l_n = length of fish when annulus 'n' was formed
l = length of fish at time scale samples was obtained
S_n = radius of annulus 'N' (at length 'l_n')
S = total scale radius

Sampling for young of the year fish was attempted by seining during September 1978 and August 1979 in the seinable areas of the four study sections. A 50-foot, 1/4 inch mesh seine was used to sample back water and slow moving areas in the river.

Discharge related habitat conditions were measured in the river using the Water Surface Profile technique (Spence 1975). Three areas were chosen for measurement including riffle, backwater, and pool areas.

Habitat information for smallmouth bass was collected during 1978 and 1979. Depth, velocity and substrate were measured for each bass observation. Electrofishing, seining, snorkeling and attachment of bobbers were used to identify the habitat of these fish. The mean value of these measurements was incorporated into the Water Surface Profile program to quantify the flows required for the fish during a particular season.

The physical characteristics of the four study sections was identified. Cross sections were established at 100 m intervals. On each cross section, 10 observations were made, recording depth, width, area of pool, riffle and run, and stream bottom materials. Aquatic habitat types and substrate were defined as shown in Table I-1. Brush piles were rated according to their size and the amount of fish habitat they provided.

Table I-1. Criteria followed in habitat classification of 4 study sections.

Aquatic Habitat Types:

	Depth	Velocity
Pool	>.8 ft.	<1 ft/s
Riffle	<.8 ft.	>1 ft/s
Run	>.8 ft.	>1 ft/s
Shallow, slack	<.8 ft.	<1 ft/s

Substrate (Spence 1975):

Bedrock	
Boulder	>12 in. diameter
Cobble	3.0-11.9 in. diameter
Gravel	0.1-2.9 in. diameter
Sand, silt, clay	<.1 in. diameter
Vegetation - plants other than algae	

During the spring of 1979, baited minnow traps were distributed throughout the four study sections of the Tongue River and Otter and Hanging Woman Creeks. These were discontinued after approximately two months. Trap nets were set in Hanging Woman, Black Eagle, Poker Jim, Poker Teechee, Cook and Otter Creeks to assess movement of fish from the river into these creeks. Hoop nets were used in all but Otter Creek where a chicken wire catfish trap was used. The stream channel was blocked off in all creeks with chicken wire.

Fisherman creel census log books were handed out during 1979 to assess the catch of local fishermen,and posters were distributed to all local businesses in an effort to educate the public about the study.

LITERATURE REVIEW

Several studies have been completed on fisheries in southeast Montana. Rehwinkel (1978) studied the fish and aquatic invertebrates in the Powder River and concluded that the system was a unique and important branch of the Yellowstone River fishery. Extensive work on the lower Yellowstone River have identified the fish present, their movement, growth and habitat requirements in the river (Peterman and Haddix, 1975; Haddix and Estes, 1976; and Graham and Penkal, 1978). Elser et al. (1978) studied the fish and aquatic invertebrates in the Beaver Creek drainage near Wibaux, Montana while the fishery in Rosebud Creek was described by Elser and Schreiber (1978). Clancey (1978) surveyed the fisheries of Sarpy Creek, an intermittent tributary of the Yellowstone River.

The Tongue River has drawn much interest in recent years and has been studied extensively in some areas. Elser and McFarland (1977) studied instream flows in the lower Tongue River and recommended passage and rearing flows for several species. Elser (1975) identified fish distribution within the Tongue River system. Instream flow requirements have been studied in the river for several different species (Bovee 1974, and Bovee et al. 1978). Gore (1977, 1978) studied the invertebrates in the river and identified instream flows which would maintain the aquatic invertebrate community.

The Tongue River Reservoir, which controls the flow of the Tongue River in Montana has also received a great deal of attention in recent years. Elser and McFarland (1977) surveyed fish populations and the effects of water withdrawals on the reservoir. Penkal (1977) worked on largemouth bass (*Micropterus salmoides*) and smallmouth bass (*Micropterus dolomieui*) populations in the reservoir, studying growth, populations and movement of these fish. Riggs (1978) studied age and growth of walleye (*Stizostedion vitreum*) and sauger (*Stizostedion canadense*) in the reservoir. He found that growth was excellent for a northern latitude reservoir. Standard chemical parameters and primary (algae) production in the reservoir were studied by Whalen (1979), with the conclusion that strip-mining adjacent to the reservoir was having no detectable impact on the water because the mine was contributing very little water to the reservoir. Leathe (1977) described the ecology of zooplankton in the reservoir.

The smallmouth bass is the most prevalent game fish in the study area, therefore, a literature review on this species is necessary. The subject material in most of these papers overlaps, however,they are grouped according to specific areas.

Several authors have described the general life history of the smallmouth bass. Doan (1940) described smallmouth bass life histories in several Ontario Lakes, but was mainly concerned with lake morphometrics and bass growth. Male smallmouth bass in Lake Michigan reach maturity at 3 years of age and females at 4 years (Latta 1943). Emig (1966) conducted a thorough literature review on the life history of this species with an excellent discussion. A more recent literature review including more precise information was presented by Coble (1975).

Spawning, early life history and survival of bass fry are discussed in nearly every paper written about smallmouth bass. Spawning is generally intitiated when water temperatures reach 60^{o}F (15.5^{o}C). The male constructs a nest by fanning out a gravelly area 2-4 feet in diameter. He then attempts to chase a female over the area where they simultaneously release milt and eggs. The female generally leaves and the male guards the nest and fans the eggs, remaining nearby until the young disperse. The young usually rise off the nest when they reach a length of 8-9 mm and disperse a week or two after rising. Survival of young depends upon many factors, including flows, water temperature, and predation. Renesting by adult bass has been observed in some populations. The following contain a great deal of information on the early life history of smallmouth bass: Beeman (1924), Breder (1936), Clady (1975), Cleary (1956), Deangelis and Coutant (1979), Doan (1939), Eipper (1975), Fry and Watt (1957), Horning and Pearson (1973), Larimore and Duever (1968), Neves (1975), Oliver (1977), Oliver et al. (1979), Pflieger (1966, 1975), Rawson (1937), Surber (1943), Tester (1930), Turner and MacCrimmon (1970), and Webster (1945).

Age and growth is also covered by many authors. Many variations exist between study areas and methods of assessing growth, but in general, warmer waters (southern latitudes) produce faster growing fish than the cold northern waters. A short list of age and growth studies includes Beckman (1947, 1948), Bennett (1938), Everhart (1950), Kilambi et al. (1977), Penkal (1977), Redmon and Krumholz (1978), and Reynolds (1965).

Food habits of the smallmouth bass seem to follow a universal trend. The smallmouth feeds on the most available item. Bass fry feed on zooplankton and small mayflies and later switch to larger invertebrates and after the first year of life the diet shifts toward fish and crustaceans. Adults feed heavily on fish and seem to prefer crayfish if they are available. Aggus (1972) and Keast (1968) worked on the food habits of smallmouth bass.

Temperature preferences of smallmouth bass vary considerably depending upon the acclimation temperature of the young fish (Cherry et al. 1975, Coutant 1975, and Ferguson 1958). Laboratory experiments predict higher preferred temperatures than field studies, however, the preferred temperature during warm season is generally between 70-80^{o}F (21-27^{o}C).

Population dynamics of smallmouth bass are the main concern of papers by Fajen (1975 a,b), Funk (1975), Pargamian (1979), Paragamian and Coble (1975), and Sanderson (1958). Populations vary considerably between streams and between areas within streams. Year class strengths vary depending upon the physical conditions throughout the spawning period and the subsequent year. Smallmouth are extremely fecund so the number of spawners is not as important to year class strength as the conditions in the stream during the spawning period.

Smallmouth prefer streams with moderately high gradients, firm, rocky bottoms; and clear, cool water. Backwaters and boulder substrates are used extensively for resting, and gravel is generally used for spawning. The preferred habitats are discussed by Funk and Pflieger (1975), Hallam (1959), Munther (1970) and Vogele and Rainwater (1975).

Fajen (1962), Henderson and Foster (1956), Munther (1970) and Robbins and MacCrimmon (1977) discuss movement by smallmouth bass. In general, they tend to be a sedentary species, while a few individuals move about randomly.

For the angler, the smallmouth bass is a highly sought after prize. Henshall (1889) was referring to the smallmouth when he stated, "inch for inch and pound for pound, the gamest fish that swims". The world record is over 11 pounds and the Montana record is 4 lbs., 11½ oz. Fleener (1975) found that anglers can harvest a large percentage of the adults resulting in imposed regulations in some streams to preserve the fishery.

Northern pike (*Esox lucius*) are occasionally captured in the study area. They provide a chance to "catch the big one" during their annual "run" into Hanging Woman Creek. Franklin and Smith (1963), Hokanson et al. (1973), Priegel and Krohn (1975), Snow (1974) and Wolfert and Milelr (1978) completed studies on different aspects of northern pike behavior and life history.

Several species of nongame fish are common throughout the study area. Shorthead redhorse (*Moxostoma macrolepidotum*) are the most common fish in the study area and other sucker species are also present. Literature pertaining to these species is not as widespread as the game species. However, some pertinent papers and books are available including: Baxter and Simon (1970), Brown (1971), Meyer (1963), Pflieger (1975), and Scott and Crossman (1973).

Instream flows have become an important issue in the past few years. Aquatic life is sensitive to changes in flows throughout the year, and without a proper flow the aquatic community cannot maintain itself. A great deal of literature has been published in recent years dealing with flows and aquatic life. Quantification of instream flows which are adequate for maintenance of biological communities has been the subject of an increasing volume of literature. Tennant (1975) recommends flows based on a percentage of the mean flow of record. The Water Surface Profile technique (WSP) uses the predictive capabilities of the Manning equation to extrapolate (over a wide range of flows) measurements taken at one flow (Spence 1975). Bovee and Cochnauer (1977) described the Instream Flow Group (IFG) method which uses measurements taken at different flows and interpolates measurements between these flows. The IFG predictions are generally more accurate than the WSP predictions, however, field measurements are also more time consuming and difficult to obtain. A literature review on instream flow methodologies is presented by Stalnaker and Arnett (1976).

RESULTS AND DISCUSSION

Habitat analysis

Substrate analysis for the four study sections is presented in Figure I-1. All sections are composed primarily of a mixture of sand, gravel and cobble. Gravel, generally the most common substrate type, increases with a progression downstream while sand decreases in a downstream direction. Silt is the only other substrate that is found in over 10% of the observations, and bedrock composes a significant amount of the substrate in Section 2.

A stable substrate composed of gravel and cobble is generally recognized as supportive of a diverse invertebrate fauna. Silty and sandy substrates generally support less diverse aquatic invertebrates than the cobble-gravel mixture (Hynes 1970). Smallmouth bass tend to nest over gravel (Breder 1936).

The Tongue River Reservoir has an effect on the substrate for a great distance downstream. Clear water released below a dam in place of the sediment-laden flows that existed prior to construction lead to erosion of the channel and lowering of the bed of the channel below the dam (Leopold, et al. 1964). Therefore, the river adjacent to the project area probably contains a lower amount of silt than more typical prairie streams.

Pools and runs are the most common habitat types in the study area (Figure I-2). All sites appear to be similar in this respect. Over 50% of each section is composed of runs (velocity >1 ft/s, depth >.8 ft.).

Mean depth and instream brush were also measured in the four study sections. These parameters are presented in Figure I-3. Depth is similar among the sections, however, section 3 contains nearly twice as much instream brush as the other sections. This could relate to higher populations of smallmouth bass in this section.

FISH POPULATIONS

A list of the fish collected in the study area, their scientific names, and abbreviations used in the text is presented in Table I-2.

Table I-2. Fish species, scientific names and abbreviations use in the text.

Common Name	Scientific Name	Abbreviation
Yellow perch	*Perca flavescens*	YP
Northern pike	*Esox lucius*	NP
Carp	*Cyprinus carpio*	Carp
Longnose dace	*Rhinichthys cataractae*	Lnd
Flathead chub	*Hybopsis gracilis*	FHC
Lake chub	*Couesius plumbeus*	LC
Fathead minnow	*Pimephales promelas*	FHM
Golden shinner	*Notemigonus crysoleucas*	GSh
River carpsucker	*Carpoides carpio*	RCS
Longnose sucker	*Catostomus catostomus*	LNS
White sucker	*Catostomus commersoni*	WS
Shorthead redhorse	*Moxostoma macrolepidotum*	SHR
Mountain sucker	*Catostomus platyrhynchus*	MS
Stonecat	*Noturus flavus*	SC
Black bullhead	*Ictalurus melas*	BB
Channel catfish	*Ictalurus punctatus*	CC
Smallmouth bass	*Micropterus dolomieui*	SmB
Pumpkinseed	*Lepomis gibbosus*	PS
Green sunfish	*Lepomis cyanellus*	GS
Black crappie	*Pomoxis nigromaculatus*	BC
White crappie	*Pomoxis annularis*	WCr
Rock bass	*Ambloplites rupestris*	RB
Walleye	*Stizostedion vitreum*	We
Sauger	*Stizostedion canadense*	Saug

Population statistics:

Population estimates per kilometer, kilograms per kilometer and kilograms per hectare for all species in which adequate recaptures were collected are presented in Tables I-3, I-4 and I-5 for fall 1978, spring 1979 and fall 1979, respectively.

Upstream sections generally supported larger numbers of large fish. For nearly every species, larger individuals were found in the upstream sections and small individuals in the two downstream sections. This is probably a result of downstream drift of larval fish during the spring, following spawning. Thus smaller fish are concentrated downstream, moving upstream as they grow and mature.

Shorthead redhorse contribute the highest numbers and biomass in all sections. Carp (*Cyprinus carpio*) appear in small numbers, however, as a result of their size, they compose a significant portion of the biomass. White cuskers, (*Catostomus commersoni*), longnose suckers (*Catostomus catostomus*) and river carpsuckers (*Carpoides carpio*) are present in significant numbers and biomass also.

Since higher level carnivores (i.e., smallmouth bass and northern pike) are not as abundant as their prey, population estimates were difficult to obtain. Smallmouth bass were observed to feed on small shorthead redhorse, flathead chubs and stonecats. Smallmouth bass collected for the spring 1979 population estimates were taken during the spring upstream migration in April and May (Figure I-4). Therefore, these estimates are biased overestimates. Movement violates an important assumption necessary for population estimates. When marked fish move out of the sampling area, there is no longer a random mixture of marked and unmarked fish, resulting in an overestimation of the population (Ricker 1968). The fish that were moving were larger individuals (>300 mm).

During the fall of 1979, population estimates for fish <300 mm were obtained in all sections. These estimates were 1.5, 1.4, 5.0 and 3.4 kg/ha. Funk (1975) cited 11 consecutive years of population studies in Courtois Creek, Missouri in which population estimates varied by as much as 350%. Fluctuation in year class strength are common with smallmouth bass. This coupled with seasonal movements results in variation in populations from year to year.

MOVEMENT

Most studies have found that smallmouth bass tend to be a sedentary species (Fajen 1962), (Munther 1970). Tongue River smallmouth exhibit a marked tendency to move long distances at two specific times of year. During the spring (April and May), individuals larger than 300 mm moved upstream (Figure I-4), some as far as 80 kilometers (50 miles). This movement is probably related to the nesting season. Dispersal to relieve crowding and search for adequate nesting habitat at this time of year may be important to successful nesting. Adequate flows must be maintained at this time to allow fish to pass over riffles.

By September and October, smallmouth larger than 300 mm have moved downstream (Figure I-5). A high proportion of these fish move into a short reach of river with boulder substrate, resulting in a concentration of fish in the fall. This area appears to be an important rearing area during the fall and winter.

Hanging Woman Creek and Otter Creek are used by fish which migrate long distances in the spring (Figures I-4 and I-5). These creeks are probably used by smallmouth bass for nesting.

Northern pike moved into Hanging Woman Creek during April and May 1979. Recapture of fish in the creek, indicates that some of these fish move long distances upstream through the project area. Maintenance of adequate flows, in the Tongue River, during this time of year is important to this migration.

AGE AND GROWTH

Scales were collected from smallmouth bass and rock bass (*Ambloplites rupestris*) for growth determination. Back calculated lengths and weights are presented in Table I-6 for smallmouth bass.

Table I-6. Back calculated lengths (mm) and estimated weights (gms) of smallmouth bass in the entire study area.

Age	Fish	ANNULUS 1	2	3	4	5
1	109	90				
2	307	100	167			
3	125	95	166	214		
4	207	97	167	241	296	
5	87	97	175	231	276	327
6	46	98	168	232	285	330
7	6	91	158	223	282	320
8	1	96	149	231	282	328
9	2	86	145	182	241	308
Weighted Grand mean (lengths)		97	168	230	290	328
Calculated Weights		11	61	128	334	492

Numerous studies have been completed on growth of smallmouth bass, however, several different back calculation techniques have been used, therefore many of the results are not comparable. Penkal (1977) studied growth of smallmouth bass in the Tongue River Reservoir, using the same back calculation equation as this study. Growth for smallmouth bass in the Tongue River and Tongue River Reservoir is compared in Figure I-6. Growth is similar, however bass in the river grow better during ages 1-3 and reservoir fish are larger in the older age classes. This may be due to a different forage base. In the river, invertebrates are the main diet of the smaller fish and the older fish rely mainly on fish forage (personal observation). In the reservoir young smallmouth fed almost entirely on zooplankton during the first year and then invertebrates (Penkal, personal communication). The older fish fed on young perch, crappie and others. The river probably supports a more diverse aquatic insect community for small fish but does not maintain as varied a fish forage base as the reservoir for older fish.

A comparison of length at annulus for smallmouth bass in the 4 study sections shows bass in the upper section (1) grew better than in the other sections (Figure I-7). Age composition information for the four sections is presented in Table I-7. The smallmouth population in section one had a higher percentage of young fish. Figure I-7 shows that growth of older age fish (3-4) is much better in section 1 than the other sections. This may be due to lack of competition for the food source in section 1. While this difference in growth could be attributed to Lee's phenomenon (a tendancy for back calculated growth from young fish to be greater than old fish) it is not evident in scales from Tongue River smallmouth bass.

Table I-7. Age composition of smallmouth bass in the 4 study sections.

	SECTIONS			
Age	1	2	3	4
1-2	71%	38%	32%	59%
1-3	85%	47%	50%	72%

Rock bass do not commonly exceed 1/2 pound in northern waters (Scott and Crossman, 1973), however, in southern waters 1 pound fish are common and they are a popular sport fish (Pflieger 1975).

Back calculated lengths and weights for Tongue River rock bass are presented in Table 8. The length-weight relationship of rock bass in the Tongue River is described by the equation $\log W = -4.87 + (3.09) \log L$. This is good growth for a northern latitude, however, rock bass are not highly sought after by fishermen in the Tongue. Incremental growth is best during the first year of life for rock bass and smallmouth bass (Figure I-8). This is common among many fish populations.

Year Class Strength

Numerous studies have found that smallmouth bass year class strengths fluctuate considerably from year to year (Fry and Watt, 1957). This occurrence is generally a result of environmental influences upon young of the year fish. Figures I-9, I-10 and I-11 illustrate year class strengths of smallmouth bass in the study area during fall 1978, spring 1979 and fall 1979, respectively. Electrofishing bias against small fish, probably masks actual numbers of 1977 year class fish in figures I-10 and I-11. Actual numbers are probably higher.

Table I-8. Back calculated lengths (mm) and estimated weights (gms) of rock bass in the entire study area.

		ANNULUS				
Age	Fish	1	2	3	4	5
2	11	66	90			
3	43	65	93	119		
4	55	67	93	127	155	
5	71	67	97	126	157	169
6	27	67	95	128	153	175
7	3	68	101	135	151	172
Weighted Grand Mean (Lengths)		67	95	125	156	178
Calculated Weight		6	18	41	81	122

The 1975 year class is suppressed in all collections. McFarland (1977) found the 1975 year class to be suppressed in his collections during 1975-1976. The 1974 and 1976 year classes are well represented in all collections. Penkal (1977) found the 1975 year class was also weak in the Tongue River Reservoir.

Several studies have identified causes of poor survival by first year bass. Temperature is most often cited as the main factor in controlling survival of young of the year smallmouth bass (Clady 1975, Cleary 1956, Eipper 1975, Oliver and Holeton, 1979). Low temperatures during nesting and post nesting periods is detrimental to that years survival. Other factors that have been cited as affecting survival of first year smallmouth bass is silt, fungus, predation, diseases, starvation, wind and floods. Postnesting water level rises have been found to be deleterious to survival (Cleary 1956, Pflieger 1975).

In the Tongue River, the two most recent flood years have been 1975 and 1978. Although the 1978 flood was of greater magnitude than the 1975 flood (Figure I-12), the 1978 year class of smallmouth bass is strong while the 1975 year class is weak. A highly significant positive correlation exists between mean air and water temperatures in the study area. Figure I-13 compares spring air temperatures during 1975 and 1978. During 1975, spring air temperatures average 15-20^{o} cooler than the 1978 spring air temperatures. Delayed and protracted spawning during 1975 was probably caused by this cool weather. Penkal (1977) found that Tongue River Reservoir smallmouth bass nested 3 weeks later in 1975 than in 1976. In an average year, smallmouth bass spawn in late May in the Tongue River (Figure I-18). During 1979, spring air temperatures were close to average and smallmouth nested in late May. Black fry were first collected in the Tongue River on June 8 (Figure I-16). By estimating 2 weeks between the time of nesting and rise off the nest, May 24 is assumed to be the average nesting time in the Tongue River. During 1975 cold spring temperatures probably delayed nesting, a documented occurrence in other bass populations (Pflieger 1975).

Nesting in 1975 preceded the flood by about one week, thus the flood scoured the stream bottom resulting in lost nests and/or very young fish. During 1978, the peak of the nesting season probably occurred in late May. This time period followed the peak flood and was during stable and declining water levels. The 1978 year class is strong and was thus not affected by the high magnitude flood.

Post nesting temperatures are also important to survival of young of the year smallmouth bass. Fry and Watt (1957) and Clady (1975) found that summer air temperatures correlated directly with year class strengths of smallmouth bass. Oliver and Holeton (1979), found that larger young of the year smallmouth bass survived over winter better than small fish. The hypothesis that warm summer temperatures cause increased growth for young of the year smallmouth and, therefore, better over-winter survival, appears to hold true in the Tongue River. Table I-9 illustrates deviations from normal June-October temperature from 1973-1978 and shows that 1975 was much cooler than average. In 1978 temperatures were close to average while 1976 and 1977 were very warm years. The 1976 and 1977 year classes appear to be strong. Cool summer temperatures coupled with cool spring temperatures and a June flood nearly eliminated the 1975 year class.

Table I-9. Deviations from daily normal temperatures during June through October 1973-1978.

Year	1973	1974	1975	1976	1977	1978
°F	+1.2	+1.4	-4.2	+4.8	+4.8	-0.8

Condition, Mortality and Tag Loss:

<u>Condition:</u> Condition factors are one way of quantifying the relationship between length and weight of a fish. Figure I-14 shows condition factors of smallmouth bass of different ages during the three collection periods. Condition is poorest during the spring and better in the fall of 1978 than during the fall 1979. Penkal (1977) found similar condition factors in the Tongue River Reservoir. However, the reservoir fish were in slightly better condition than river fish. Mean condition factors of smallmouth bass are presented in Table I-10. Smallmouth bass in southern waters display higher condition factors than Montana fish (Emig 1966).

The length-weight relationship for smallmouth bass in the Tongue River and Tongue River Reservoir is illustrated in Figure I-15. Reservoir fish are heavier at all lengths than the river fish. The length-weight relationship of smallmouth bass in the river is described by the equation $\log W = -5.14 + (3.11) \log L$.

Table I-10. Mean condition factors (standard deviation in parenthesis), of smallmouth bass of different ages in the four study sections.

Section	AGE 1	2	3	4	5
1	1.35 (.43)	1.39 (.35)	1.30 (.23)	1.33 (.18)	1.41 (.24)
2	1.38 (.28)	1.33 (.24)	1.31 (.13)	1.46 (.23)	1.49 (.21)
3	1.33 (.21)	1.35 (.27)	1.36 (.28)	1.38 (.17)	1.49).17)
4	1.41 (.23)	1.34 (.21)	1.30 (.15)	1.41 (.18)	1.47).13)

Mortality

Mortality is difficult to determine for smallmouth bass in the Tongue River. The use of a catch curve does not adequately define mortality since year class strength and survival rates are not constant (Robson and Chapman 1961). Accurate population estimates of each age class from year to year are not available. Gulland (1955) estimated mortality rates of plaice (*Pleuronectes platessa*) by comparing catch per unit effort between successive years.

For smallmouth bass, survival was calculated for ages 2-5 between fall 1978 and fall 1979 based on 10 electrofishing runs (Tables I-11). Calculation of survival by this method appears to give the best estimation, however, problems do exist. For example, the 1975 year class showed a survival rate of 1.31. Year classes composed of a small number of individuals do not appear to be of adequate size to estimate mortality. Penkal (1977) reported a mortality rate of 39.7% in the Tongue River Reservoir.

Table I-11. Smallmouth bass survival calculated from catch per unit effort during fall 1978 and 1979.

Age	c/f[1] 78	s	c/f[1] 79
2	143		
3	13	.55	79
4	65	1.31	17
5	31	.42	27
6		.52	16

Tag Loss

Table I-12 illustrates tag loss for smallmouth bass during 1978 and 1979 in the Tongue River. Bass that were tagged during the fall 1978 and recaptured the following spring had a tag loss of 9%. This same group of fish, which was recaptured one year later during fall 1979 had a tag loss of 20%. There is no significant tag loss difference between these time periods. However, bass that were tagged during the spring of 1979 and recaptured during the fall of 1979 had a 70% tag loss. This rate of tag loss is highly significantly different from the fall tagged fish.

Spring tagged fish are more active, preparing for nesting and are more closely associated with each other. Tag loss during this time could be the result of closer contact or individuals pulling tags out of each other. Tags in bass that have overwintered may be slightly discolored from accumulated algae and silt and therefore less noticeable. The use of a more subtle colored tag could be tried in future work.

Table I-12. Tag loss by smallmouth bass during 1978 and 1979.

	Recaptures	Tags Lost	% Tag Loss
Fall 1978-Spring 1979	43	4	9*
Fall 1978-Fall 1979	15	3	20*
Spring 1979-Fall 1979	27	19	70

*Denotes highly significant difference from 70% tag loss.

Young of the Year:

Smallmouth bass young of the year were collected and measured throughout 1979. Black fry were first collected on June 8 and fingerlings were measured through October. Figure I-16 illustrates maximum, mean and minimum sizes collected throughout the 1979 field season.

Information pertaining to growth of young of the year smallmouth bass is scant, however, comparing Tongue River growth to published work shows that growth is excellent in the Tongue River (Figure I-17). Comparisons with scattered information from Missouri streams suggests that growth in the Tongue River is similar (Pflieger, personal communication).

Variation in growth between individuals is considerable in the Tongue River. Mean length at the end of September, which is essentially the end of the growing season, was approximately 100 mm. This compares to average back calculated growth for this population of 97.3 mm.

There was no obvious correlation between 1979 water temperature fluctuations and growth of young of the year for the corresponding time interval. However, growth of young of the year smallmouth bass has been correlated with summer temperatures in other studies (Oliver 1977 and Oliver and Holeton 1979).

Results of seining during early August 1979 for young of the year fish is presented in Table I-13. Suckers (shorthead redhorse, white suckers and longnose suckers) were dominant in all sections. The number of suckers per haul decreases in a downstream direction. This does not support the larval drift hypothesis, however, habitat variation in the backwaters may be more important to numbers of young of the year fish than location on the river. The average number of individuals per seine haul may reflect preferred nesting areas of smallmouth bass.

Table I-13. Mean number of individuals per seine haul (number of seine hauls in parenthesis) during mid-August 1979.

	SECTION				
	1 (7)	2 (11)	3 (9)	4 (7)	x per haul
SmB	0.9	1.5	0.8	0.4	1.0
Sucker	19.8	15.3	10.3	5.5	12.6
BB	1.4	0.4	0.6		0.6
Carp	0.1	0.3	0.1		0.1
YP	0.6	0.3	0.1		0.2
CS		0.1	0.1		0.8
WCr	0.3	0.2	0.1	3.4	0.2
RB	0.1	0.1		0.4	0.1
Total	23.2	18.2	12.1	9.7	14.7

Spawning Season

Figure I-18 illustrates when mature fish were collected and at what temperatures they were collected during 1979. White suckers and longnose suckers were the first species to mature. White suckers were more prolonged, spawning throughout April and May. Shorthead redhorse initiated spawning when temperatures reached 50°F. Smallmouth bass began maturing when temperatures were greater than 60°F. Spawning trends closely agreed to the time which these species migrated into Otter Creek (Figure I-24). Water temperature appears to be an important parameter for maturing fish in the Tongue River.

River carpsucker, white sucker and longnose sucker males matured during the fall of 1979.

INSTREAM FLOWS

The water surface profile technique was used to assess instream flow requirements of fish in the study area (Figure I-19). Photographs of the habitat areas are presented in Figures I-20, I-21, I-22. The three habitat zones were chosen for instream flow work as a result of the following observations.

Riffles: These areas must maintain adequate flows for passage of smallmouth bass and northern pike during April and May. The actual depths required by these fish to pass over a riffle is unknown. Passage depths for salmonids were measured by Thompson (1972). He found that the species he worked on required less than one foot of depth to pass over riffles. White (1975) proposed 1.5 m (5 ft.) be maintained over 25% of the shallowest bank to bank course over riffles for passage of the white sturgeon. For smallmouth bass and northern pike, one foot is recommended as the minimum depth for passage over riffles. This measurement was applied to the mean depth of riffle cross sections and a flow of 300 cfs obtained. Upstream migration is most common in April and May (Figure I-4) and 300 cfs is recommended for that time period.

Riffles are also important for invertebrate production. Gore (1977) recommended a minimum discharge of 130 cfs for maintaining the aquatic invertebrate community. Bovee et al. (1978) measured habitat preferences of stonecats, a riffle dwelling species, in the Tongue River and recommended a minimum of 8.3 to 12.7 m^3/sec. (293-448 cfs) for instream flows.

Backwaters: Smallmouth bass used backwater areas throughout most of the open water period of the year in the Tongue River, but mature individuals were concentrated in backwaters during the nesting season (May through June)(Figure I-18). Measurements indicated that 2.2 feet was the mean depth bass preferred during this time period. A flow of 700 cfs corresponds to this depth and is recommended from May 15 through June 15.

After nesting is completed, young of the year smallmouth bass utilize the backwaters as rearing areas. Seining during 1979 indicated that 1.0 foot was the mean depth used by these fish. This corresponds to a flow of 265 cfs which should be maintained through September 15. After this time, the young of the year appear to move into the main stream of the river.

Pools: During September and October, a large number of smallmouth bass migrate downstream to a major wintering area (Figure I-5). Measurements of preferred habitat in this area indicates that 3.4 feet is the preferred depth at this time of year. This corresponds to 185 cfs and is recommended as the minimum flow during this time period.

Throughout the winter, when the river is frozen over, instream flows are important. Flows must be adequate to prevent anchor ice formation. Bovee et al. (1978) worked on anchor ice in the Tongue River and his results suggest that the fall recommendations for smallmouth bass habitat is adequate to prevent severe anchor ice formation. Thus, this flow (185 cfs) is recommended throughout the winter months.

Channel Maintenance Flow: Bankfull flow during the spring flood is the most important determining factor in channel formation processes (Leopold et al. 1964). Peterman (1979) estimated that this flow should be maintained for a period of at least 24 hours to maintain channel configuration and to scour the sediment from the riverbed. In the Tongue River, this flow is approximately equal to the 1½ year frequency flood. This value is probably between 1650 cfs and 1800 cfs and therefore is adequate for this purpose. This peak should occur in early to mid-June, allowing smallmouth bass nesting to be completed during an average year. Nelson (1980) compared four different methods for recommending instream flows for trout. He found that a single cross section at a riffle produced consistently good information for recommending minimum instream flows. Calculating minimum instream flows by plotting flow versus wetted perimeter, produces a value of 165 cfs for the Tongue River in this area. Nelson (1980) did not attempt to apply habitat information from his streams to his morphological data, however, 165 cfs compares closely with the 180 cfs figure recommended for the low water period in the Tongue River. Prewitt and Carlson (1977) also compared several methods for quantifying instream flows. They found that applying habitat information to the incremental flow information provided the best information for instream flow recommendations. For the Tongue River, this was the method followed except the WSP program was used instead of the IFG.

The Montana Fish and Game Commission (1976) applied to the Board of Natural Resources for instream flows in a section of the Tongue River, including this study area. The recommendations in this report equals or exceeds those requests at all times of year. Minimum instream flow recommendations for smallmouth bass are shown in Figure I-23.

Tributaries

During 1979, tributaries were sampled to assess fish migration and resident populations in these streams. Most of the creeks in the study area did not flow, even during snowmelt. Cook Creek, Hanging Woman Creek and Otter Creek were the only creeks which supported fish. Table I-14 is a list of fish species collected in these creeks. Cook Creek was sampled at the mouth and approximately 300 yards upstream from the mouth. Otter Creek and Hanging Woman Creek were sampled at various sites which are listed in Supplement I-2. Species with an asterik are known to spawn in that area. Others were found in spawning condition, however, young of the year fish were not collected.

Otter Creek is used extensively by fish migrating from the Tongue River (Figure I-24). White suckers, shorthead redhorse, white crappie, (*Pomoxis annularis*) and river carpsuckers move into Otter Creek in succession. Smallmouth bass and rock bass also migrate into Otter Creek during the spring.

Hanging Woman Creek is used by smallmouth bass, northern pike and suckers. Trap failure during 1979 resulted in poor monitoring of the migrations.

Smallmouth bass nest in lower Hanging Woman and large northern pike also use lower Hanging Woman during the spawning season. Electrofishing and angling recaptures estimate the northern pike population at 45 (26-64; 80% confidence intervals) on April 25, 1979. These fish averaged 2.3 kilograms including one specimen weighing 11.4 kg, which was caught by an angler. Several mature males and females were captured indicating that spawning occurs in Hanging Woman Creek, however, no fish were found upstream in the vegetated areas of the creek because flows were low during this time. Northern pike may spawn successfully when adequate flows allow passage into the vegetated areas. The lower creek, where they were found during 1979, does not appear to contain suitable spawning habitat for northern pike.

Table I-14. Species occurrence in three tributaries of the study area (*denotes larval fish collected).

Species	Cook Creek	Otter Creek				Hanging Woman Creek			
		1	2	3	4	1	2	3	4
Northern pike		X				X			
Carp	X	X*				X*	X	X	
Longnose dace	X						X		
Flathead chub		X							
Lake chub	X			X			X		
Fathead minnow	X						X	X	X
Golden shiner	X	X		X			X	X	X
River carpsucker		X				X			
Longnose sucker						X			
White sucker	X	X*	X	X	X	X*	X	X	X
Shorthead redhorse		X*				X*	X		
Stonecat		X					X		
Black bullhead	X	X				X*	X	X	
Smallmouth bass		X				X*			
Pumpkinseed			X	X	X				
Green sunfish		X*				X	X	X	X
White crappie		X*				X			
Black crappie						X			
Rock bass		X				X			
Sauger		X							
Walleye		X				X			
Yellow perch		X				X*			

Impacts of Coal Mining:

Stripmining the proposed area adjacent to the Tongue River could result in several direct and indirect impacts to the fishery. Moore and Mills (1977) identified the impacts of stripmining and suggest mitigating measures.

Potential direct impacts include: 1) sedimentation as a result of erosion from the mined area, 2) destruction of the aquifer resulting in disturbance of the water table and degredation of ground water quality, 3) high dissolved solids and heavy metal concentration in mine effluent, and 4) destruction of tributary streams in the mined area.

Indirect impacts include: 1) reduced instream flows in the Tongue River and tributaries as a result of related development such as synthetic fuel plants, electrical generation facilities and irrigation withdrawals for reclaimed land. Coal slurry pipelines are presently not a beneficial use of water as defined in the Montana Water Use Act of 1973, 2) increased populations will present related problems such as sewage disposal and increased recreation including fishing pressure.

Ongoing studies in the mine area will determine whether sedimentation, aquifer disturbance and chemical contamination in the water from the mine area will occur. The importance of the ephemeral tributary streams in the mine area to fish populations in the river is unknown.

Stripmining, in itself, is not a consumer of large amounts of water, however, related development may be. Coal generation, synthetic fuel plants and irrigation of reclaimed lands would require withdrawal of water from the Tongue River system. If minimum instream flow are not maintained, a reduction in the quantity and quality of the fishery will occur.

Increased fishing pressure as a result of a population growth will increase fisherman harvest. In this case, stricter fishing regulations may be imposed. At the present time, the limit on northern pike is five fish. Increased pressure in the Hanging Woman Creek area could have severe impacts on the population. There is no limit on the number of smallmouth bass taken by fishermen. In California, exploitation rates as high as 66% have been documented (Pelzman et al., 1980). Fishing pressure on smallmouth on their wintering area could severely deplete the mature popualtions. In this case, a daily limit will probably be instituted.

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Table I-3. Fish populations per kilometer (80% confidence intervals in parenthesis), kilograms per kilometer, and kilograms per hectare during August and September 1978.

Section	Species	N/km	Kg/km	Kg/ha
1	Rh>300 mm	613 (510-716)	328 (272-383)	103 (86-120)
2		636 (566-706)	297 (264-330)	79 (70- 88)
3		322 (281-363)	125 (109-141)	44 (38- 50)
4		314 (278-350)	116 (103-129)	37 (33- 41)
2	Rh<300 mm	267 (195-349)	60 (44- 78)	16 (12- 21)
3		844 (441-1247)	226 (118-334)	79 (41-117)
4		783 (581-985)	109 (81-137)	34 (25- 43)
1	Cs>250 mm	62 (30- 94)	26 (13- 39)	8 (4- 12)
3		33 (16- 50)	15 (7- 23)	5 (2- 8)
4		114 (77-151)	43 (29- 57)	14 (9- 18)
3	SmB>300 mm	10 (6- 14)	7 (4- 10)	2 (1- 3)
1	WS>300 mm	47 (28- 66)	26 (15- 37)	8 (5- 11)
3		147 (78-216)	68 (36-100)	24 (13- 35)
4		61 (44- 78)	25 (18- 32)	8 (6- 10)
3	LNS>300 mm	69 (31-107)	35 (16- 54)	12 (5- 19)
4		113 (55-171)	52 (25- 79)	17 (8- 26)
3	Carp>400 mm	78 (35-121)	161 (72-250)	56 (25- 87)
4		68 (50- 86)	210 (154-296)	66 (49- 93)

Table I-4. Fish populations per kilometer (80% confidence intervals in parenthesis) kilograms per kilometer, and kilograms per hectare during April and May 1979.

Section	Species	N/km	Kg/km	Kg/ha
1	RH>300 mm	792 (726-858)	443 (406-480)	139 (127-151)
2		804 (714-894)	386 (342-430)	103 (91-115)
3		317 (275-359)	129 (112-146)	45 (39- 51)
4		263 (223-303)	100 (85-115)	32 (27- 37)
2	RH<300 mm	288 (180-396)	47 (29- 63)	12 (8- 16)
3		637 (512-762)	113 (91-135)	40 (32- 48)
4		580 (374-786)	100 (64-136)	32 (20- 44)
1	RGS> 250 mm	46 (25- 67)	23 (12- 34)	7 (4- 10)
2		143 (133-153)	59 (55- 63)	16 (15- 17)
3		161 (118-204)	65 (48- 82)	23 (17- 29)
4		104 (58-150)	44 (25- 63)	14 (8- 20)
1	WS>300 mm	185 (152-218)	103 (85-121)	32 (26- 38)
2		277 (190-364)	138 (95-181)	37 (25- 49)
3		47 (37- 57)	21 (17- 25)	7 (6- 8)
4		120 (75-165)	48 (30- 66)	15 (9- 21)
3	WS<300 mm	149 (100-198)	22 (15- 29)	8 (5- 11)
3	LNS>300 mm	246 (146-346)	113 (67-159)	39 (23- 55)
2	SmB>300 mm	46 (19- 73)	33 (14- 52)	9 (4- 14)
3		76 (48-104)	51 (32- 70)	18 (11- 25)
2	Carp>400 mm	50 (31- 69)	103 (64-142)	28 (17- 39)
3		187 (88-290)	339 (160-526)	119 (56-182)

Table I-5. Fish populations per kilometer (80% confidence intervals in parenthesis), kilograms per kilometer, and kilograms per hectare during August and September 1979.

Section	Species	N/km	Kg/km	Kg/ha
1	Rh>300	713 (603-803)	409 (346-472)	128 (108-148)
2		699 (595-703)	340 (289-391)	91 (77-105)
3		267 (235-299)	115 (101-129)	40 (35- 45)
4		441 (362-520)	158 (130-186)	50 (41- 59)
2	RH<300	430 (190-670)	68 (39- 77)	18 (13- 23)
3		404 (271-537)	58 (30-106)	20 (10- 27)
4		407 (289-585)	58 (41- 85)	18 (13- 23)
1	WS>300	127 (63-191)	59 (29- 89)	18 (9- 27)
2		180 (122-238)	79 (54-104)	21 (14- 28)
3		77 (57- 97)	32 (24- 40)	11 (8- 14)
4		83 (44-122)	32 (17- 47)	10 (5- 15)
1	WS<300	51 (27- 75)	12 (6- 18)	4 (2- 6)
2		120 (66-174)	25 (14- 36)	7 (4- 10)
3		300 (185-415)	55 (34- 76)	19 (12- 26)
4		117 (74-160)	19 (12- 26)	6 (4- 8)
1	LNS >300	85 (46-124)	51 (27- 75)	16 (9- 23)
3		91 (60-122)	40 (26- 54)	14 (9- 19)
4		99 (54-144)	42 (23- 61)	13 (7- 19)
1	RCS>250	84 (46-122)	42 (23- 61)	13 (7- 19)
2		333 (290-376)	141 (123-159)	38 (33- 43)
3		80 (56-104)	32 (22- 42)	11 (8- 14)
4		51 (35- 67)	20 (14- 26)	6 (4- 8)
3	SmB >300	9 (5- 13)	5.5 (3.0-8.0)	1.9 (1.0-2.8)
1	SmB <300	36 (21- 51)	4.8 (2.8-6.8)	1.5 (0.9-2.1)
2		39 (24- 54)	5.1 (3.1-7.1)	1.4 (0.9-1.9)
3		89 (41-137)	15 (7- 23)	5 (2- 8)
4		65 (38- 92)	11 (6- 16)	3.4 (2.0-4.8)

Supplement I-1. Locations of upper and lower ends of electrofishing sections in the Tongue River (Universal Transverse Mercator Grid System).

	SECTIONS 1	2	3	4
Upper	50 19 480 N	50 29 500 N	50 39 440 N	50 45 920 N
	3 80 855 E	3 86 626 E	3 95 900 N	3 99 350 E
Lower	50 21 445 N	50 30 190 N	50 41 833 N	50 47 090 N
	3 80 755 E	3 87 660 E	3 96 880 E	3 99 910 E

Supplement I-2. Locations of study sites in Otter and Hanging Woman Creeks.

	Otter Creek			Hanging Woman Creek		
Site	Section	Township	Range	Section	Township	Range
1	2	3S	44E	18	6S	43E
2	4	4S	45E	18	6S	43E
3	2	5S	45E	5	7S	43E
4	30	6S	46E	17	7S	43E

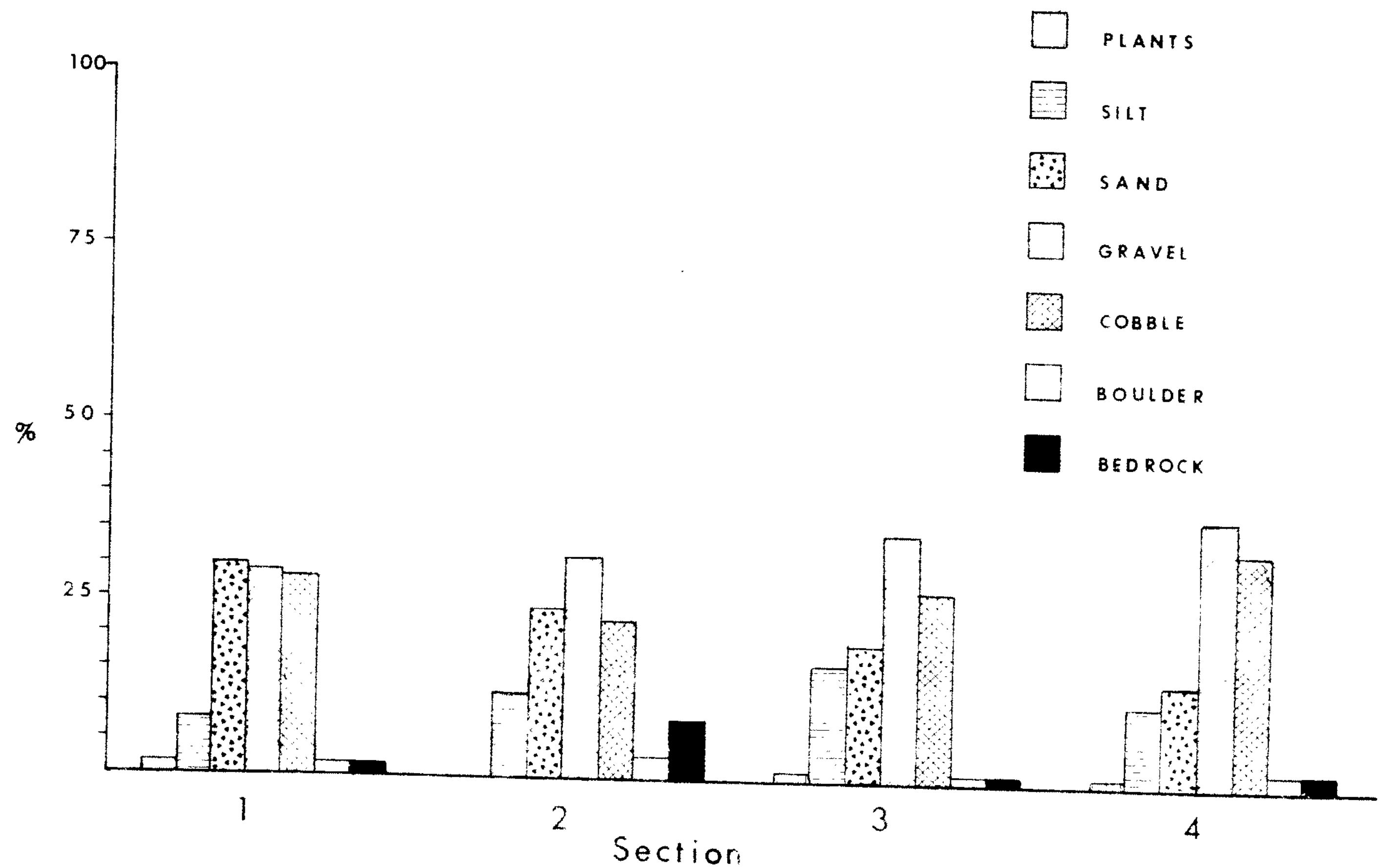

Figure I-1. Percent composition of various stream bottom substrates in the 4 study sections during October 1979.

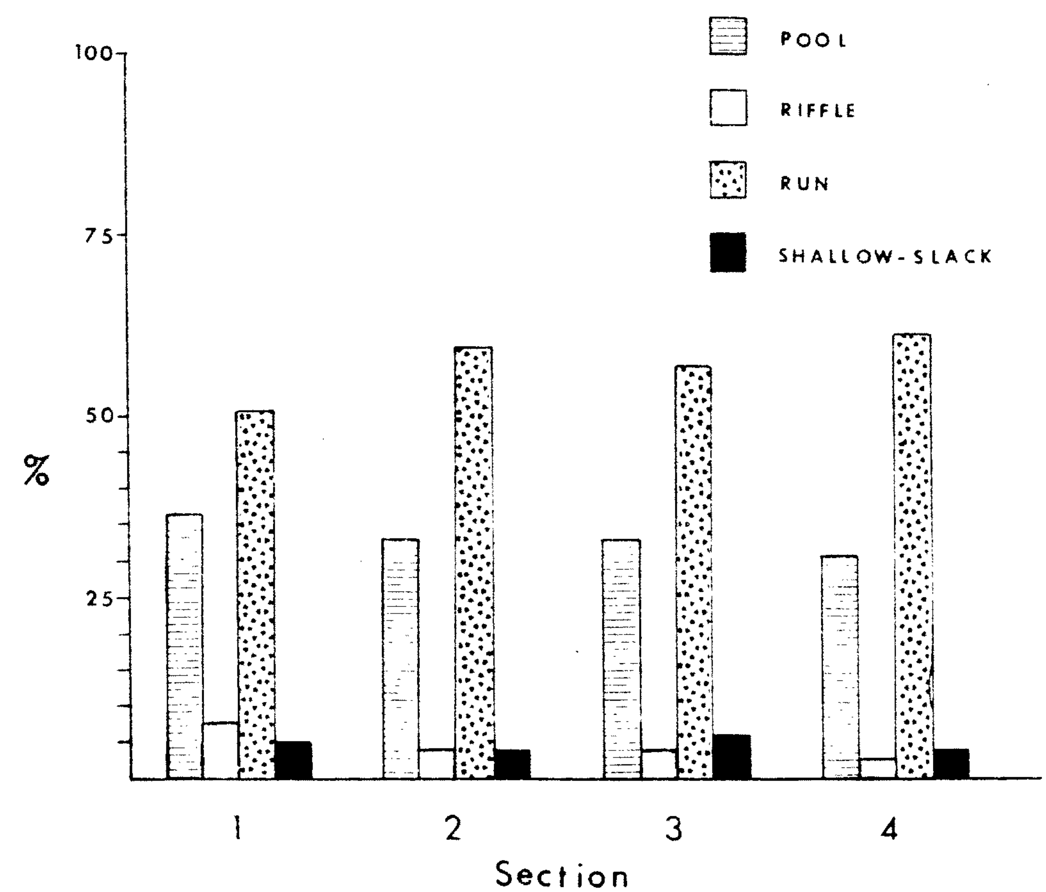

Figure I-2. Percent composition of aquatic habitat types in the 4 study sections during October 1979.

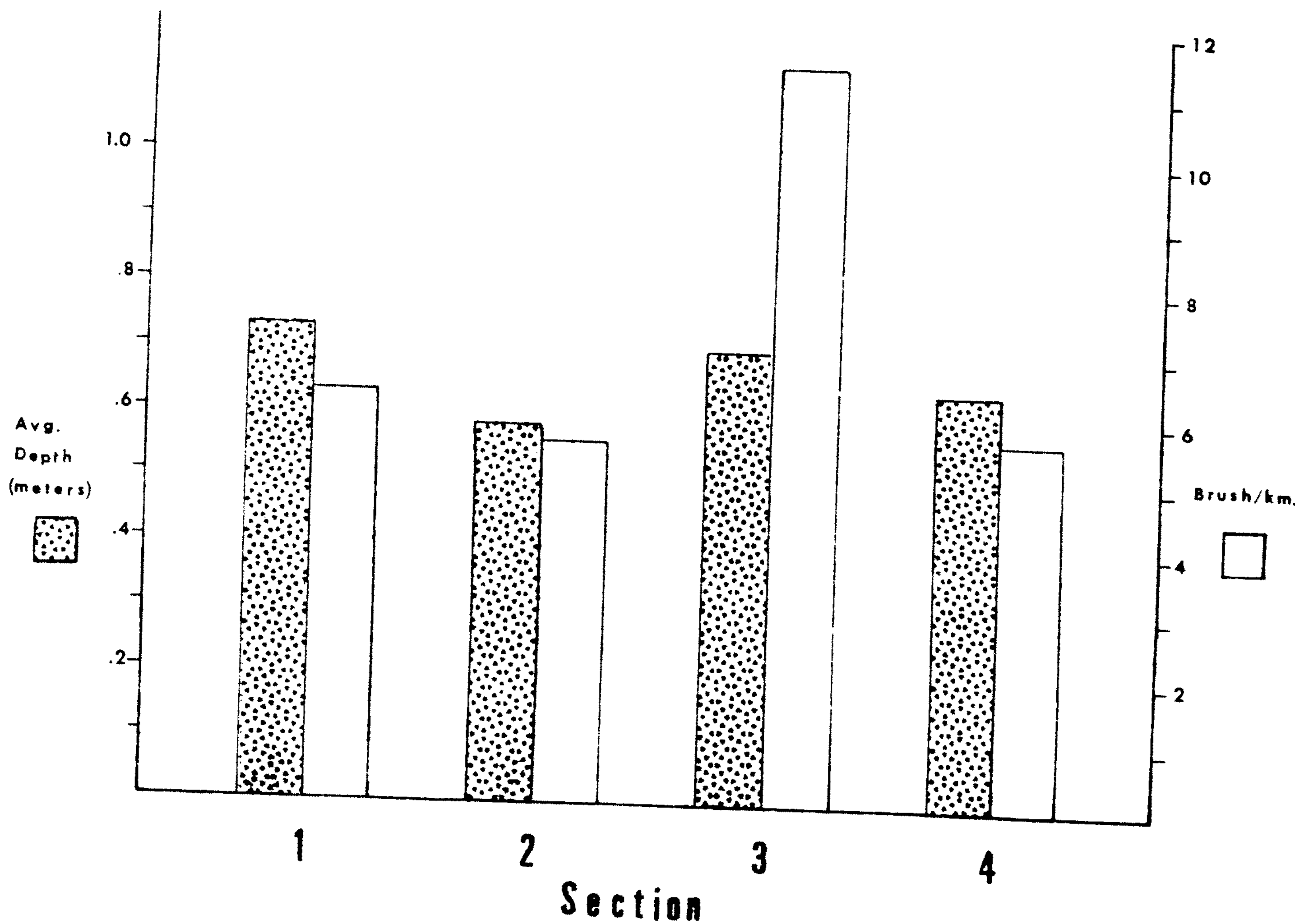

Figure I-3. Mean depth and instream brush in the 4 study sections during October 1979.

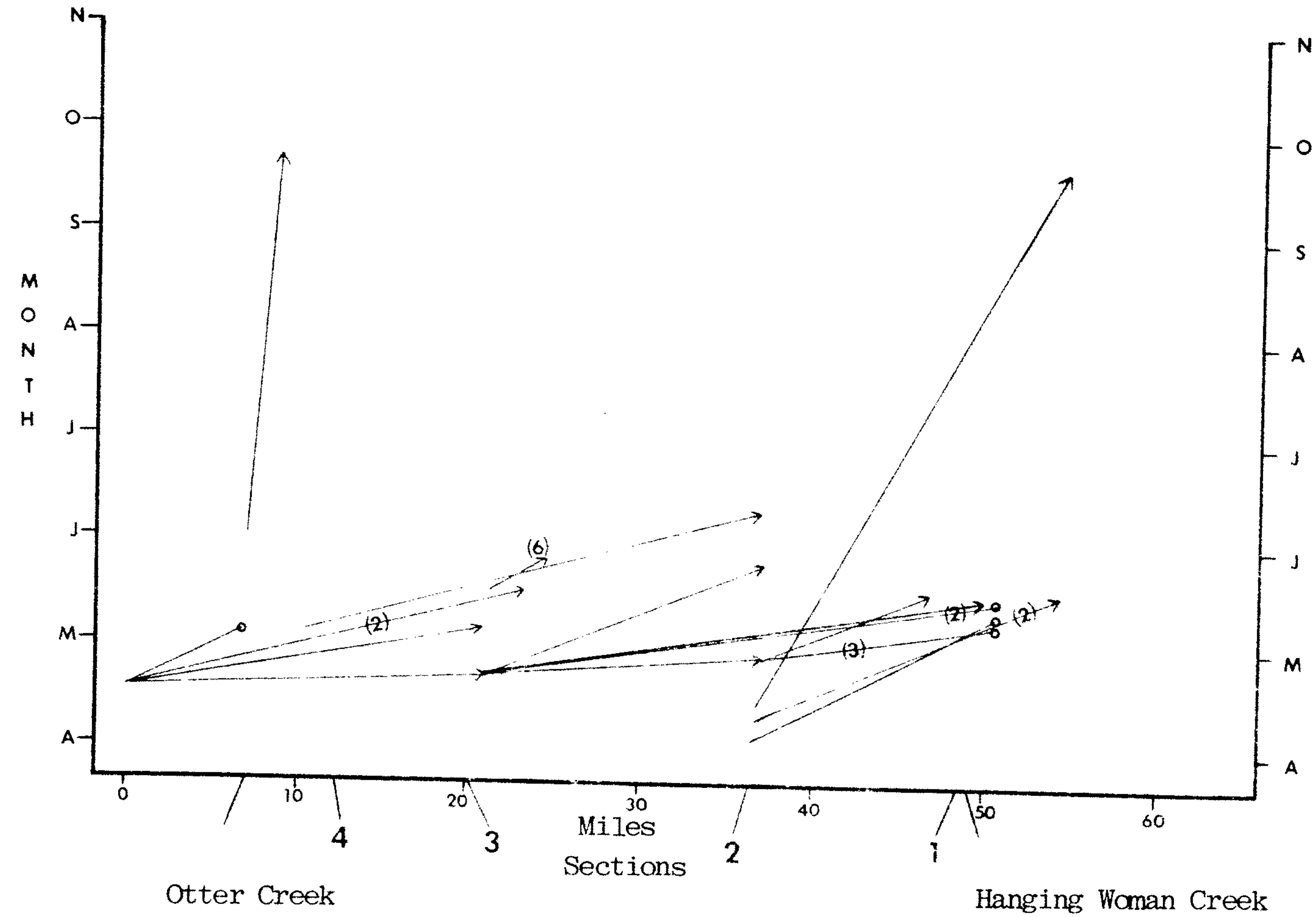

Figure I-4. Upstream movement by smallmouth bass in the study area during 1979.

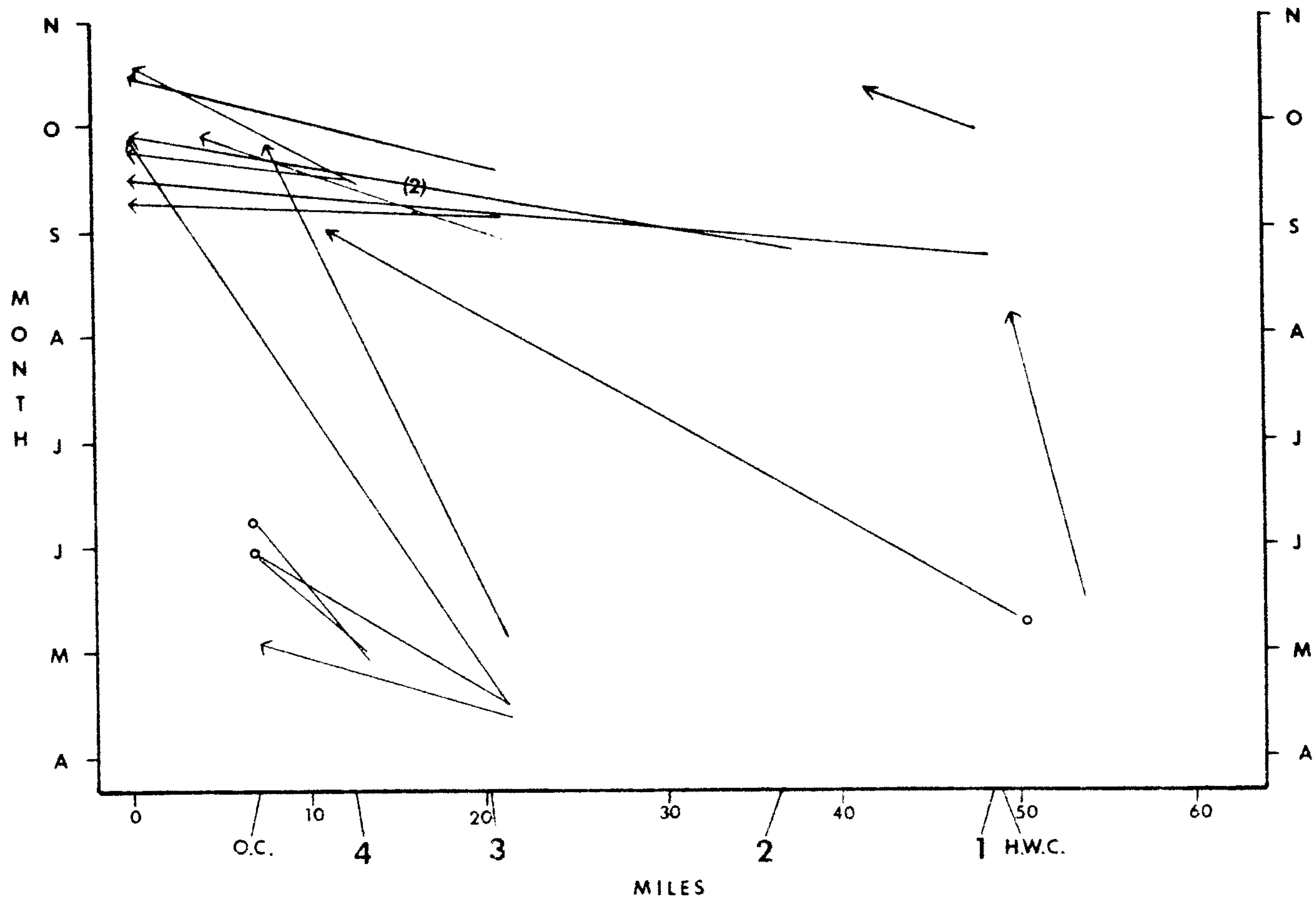

Figure I-5. Downstream movement by smallmouth bass in the study area during 1978 and 1979.

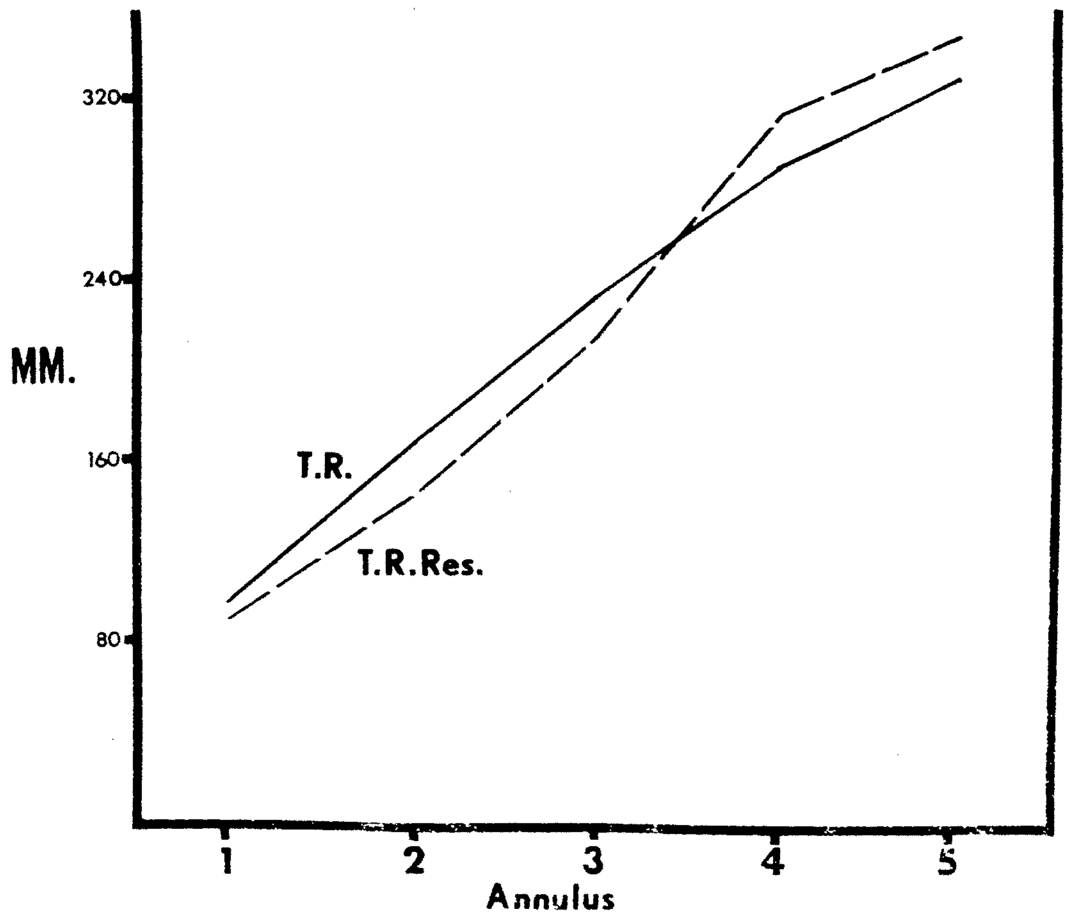

Figure I-6. Length at annulus of smallmouth bass in the Tongue River and Tongue River Reservoir.

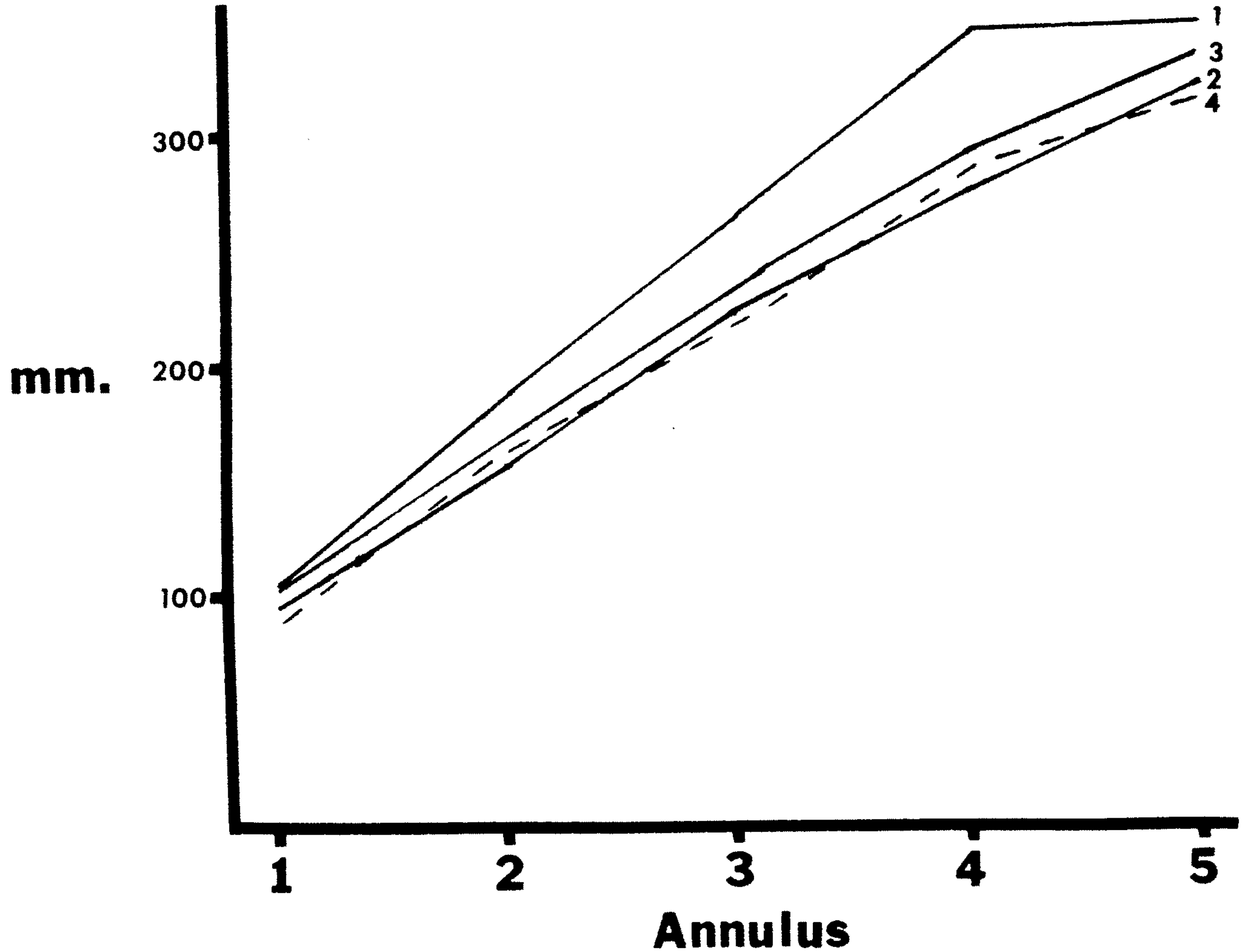

Figure I-7. Length at annulus of smallmouth bass in the 4 study sections during 1978 and 1979.

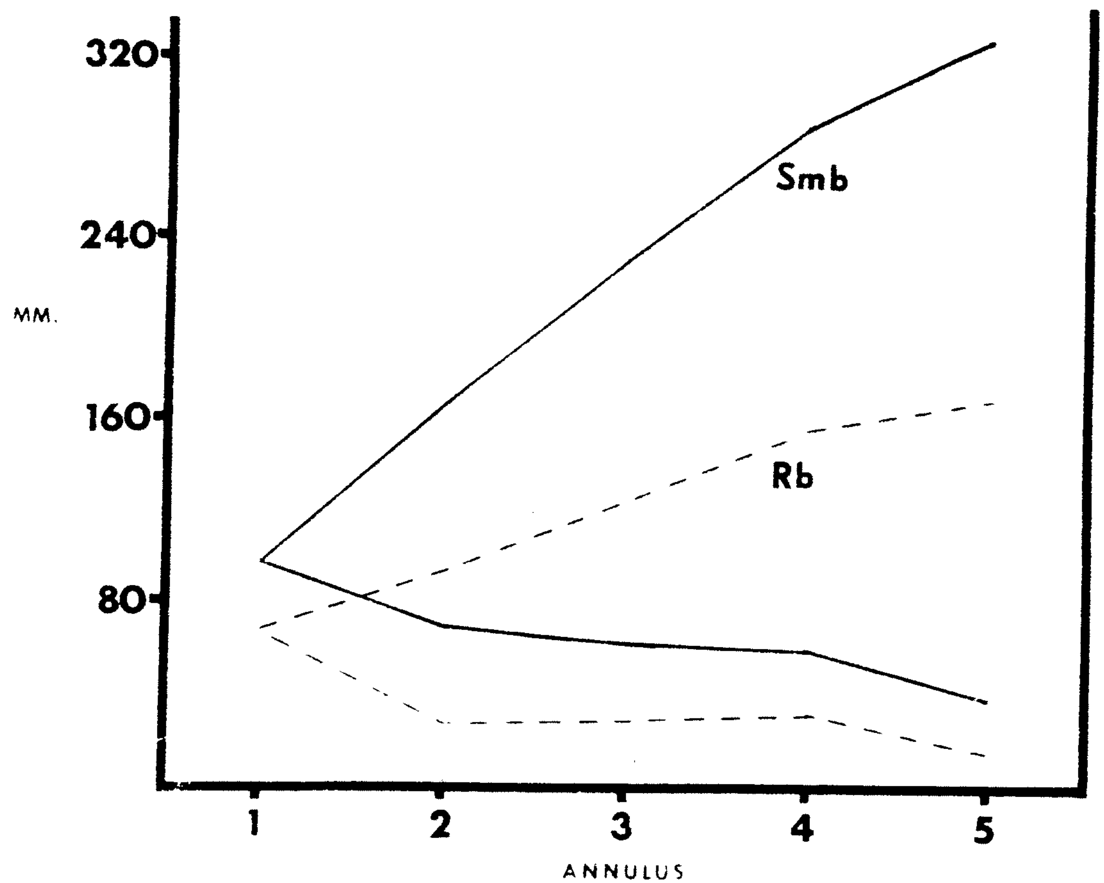

Figure I-8. Length at annulus and incremental growth of smallmouth bass and rock bass in the study area.

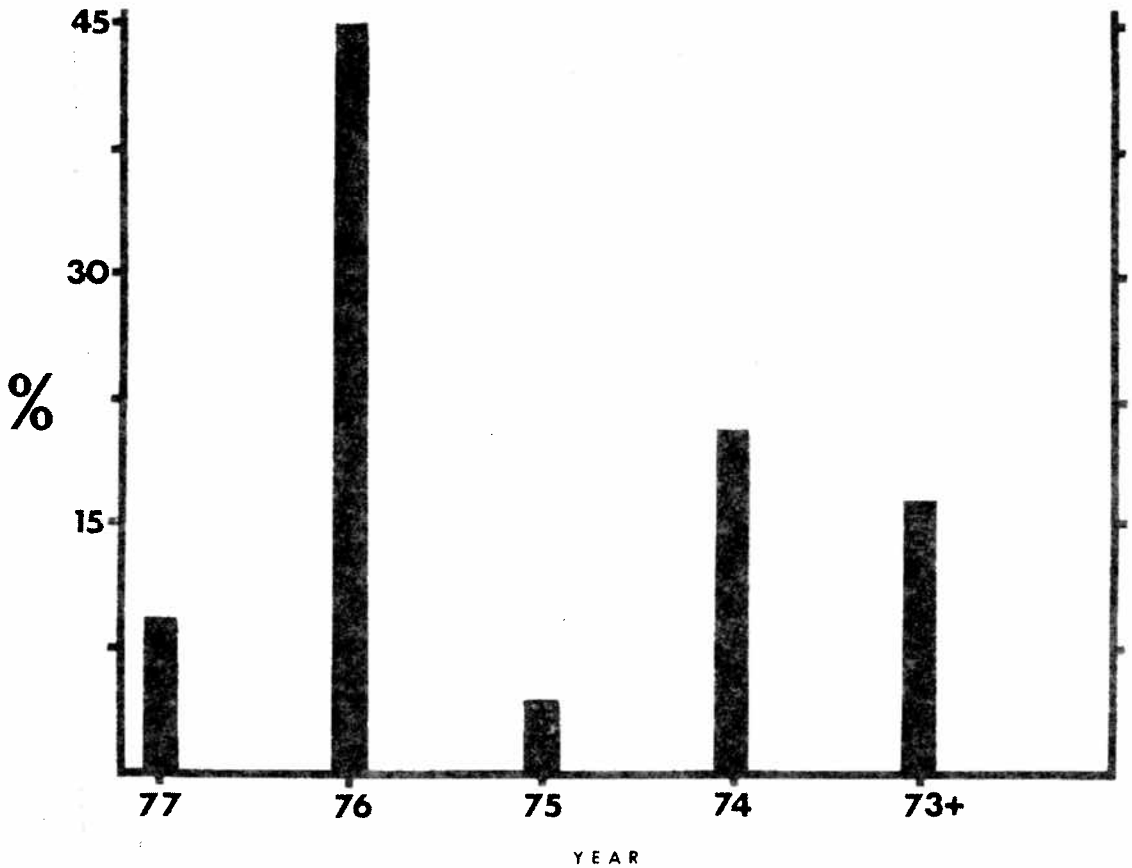

Figure I-9. Year class strength of smallmouth bass collected in the study area during August-October, 1978.

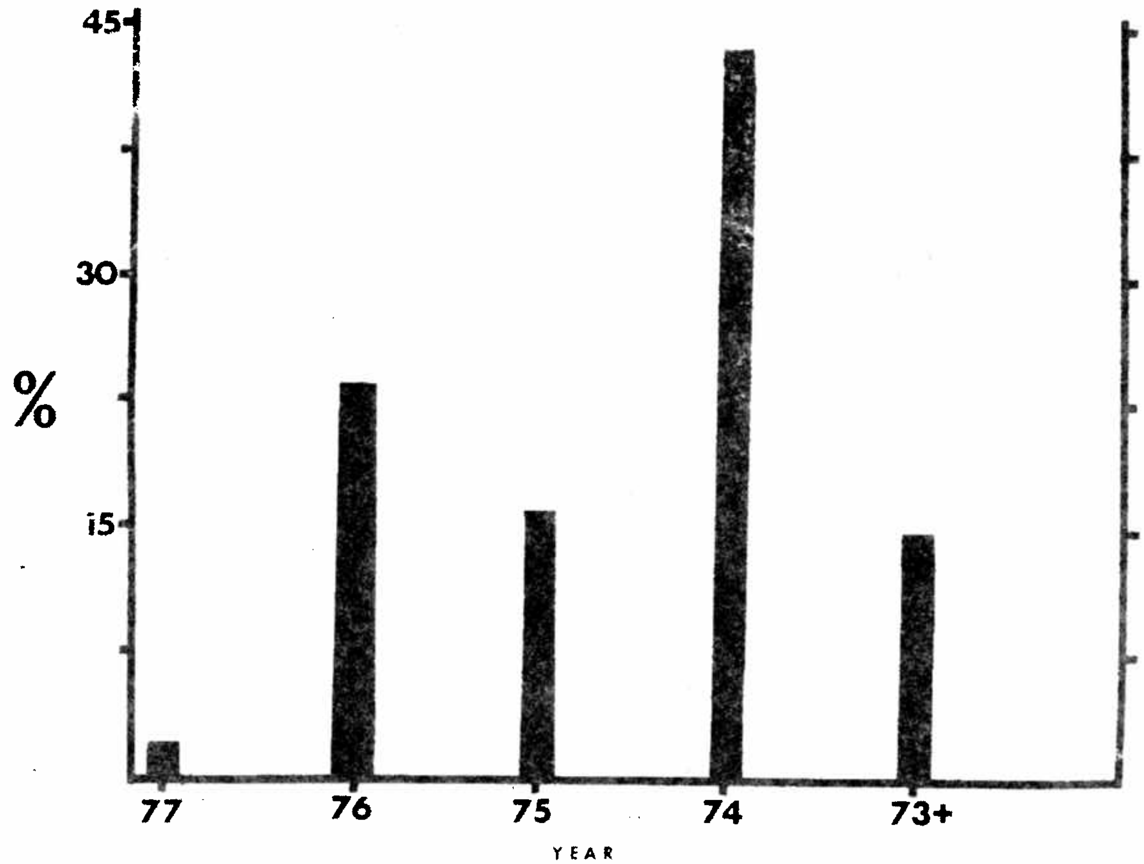

Figure I-10. Year class strength of smallmouth bass collected in the study area during April and May. 1979.

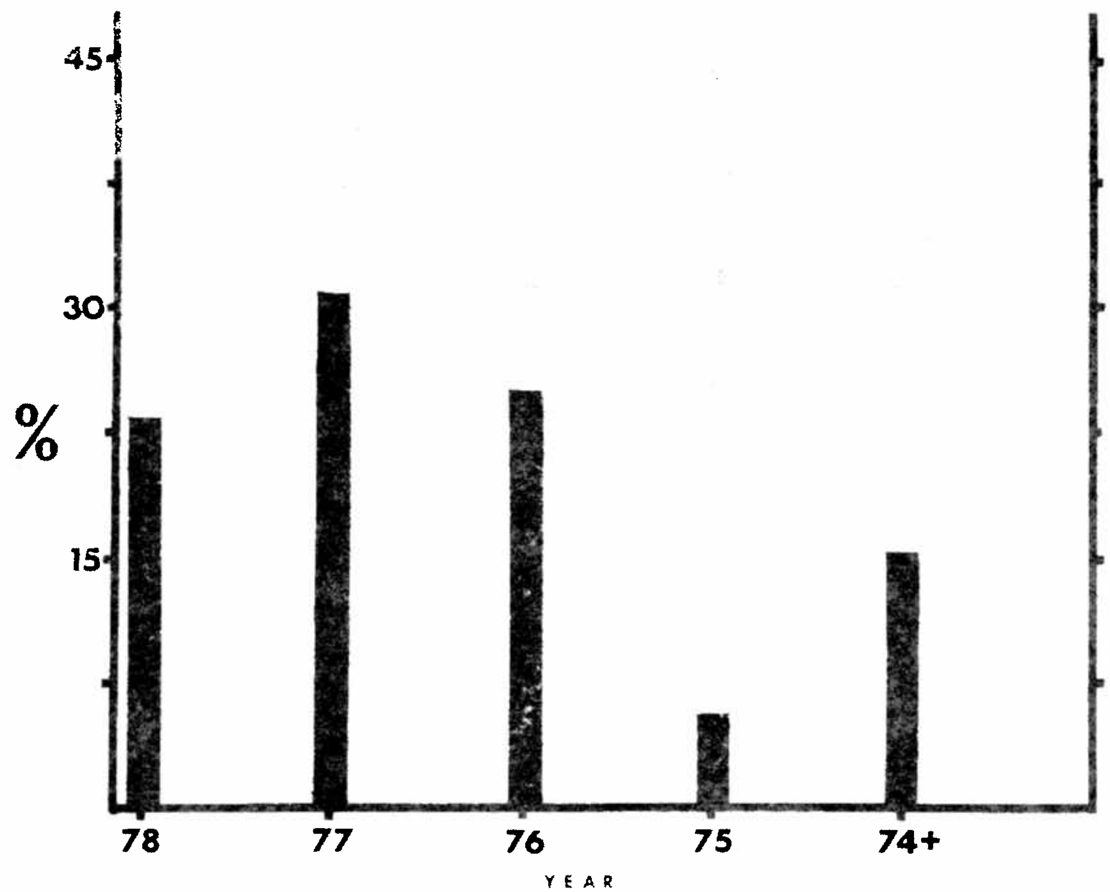

Figure I-11. Year class strengths of smallmouth bass collected in the study area during August and September 1979.

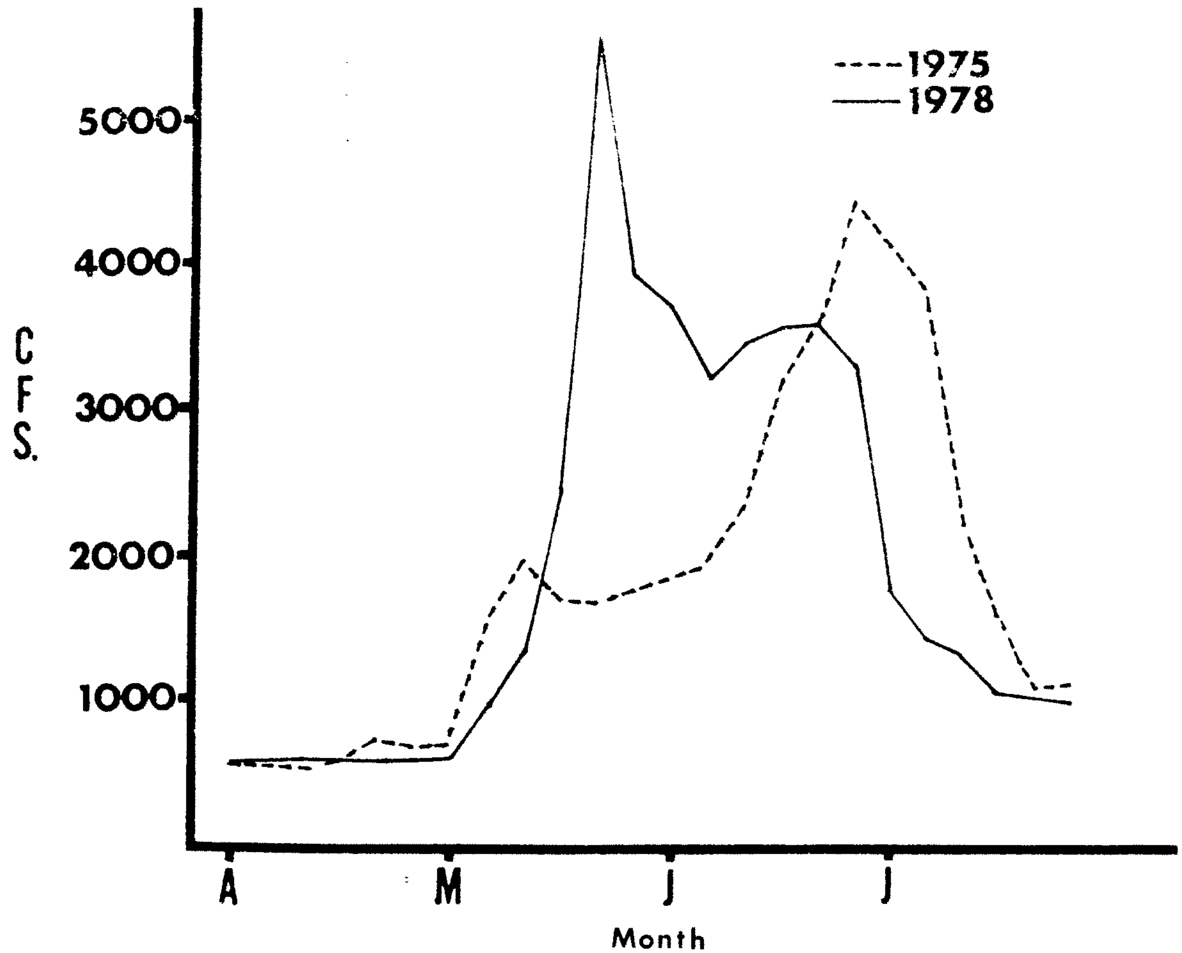

Figure I-12. Mean monthly discharge in the Tongue River (Brandenburg Bridge) during April-August, 1975 and 1978.

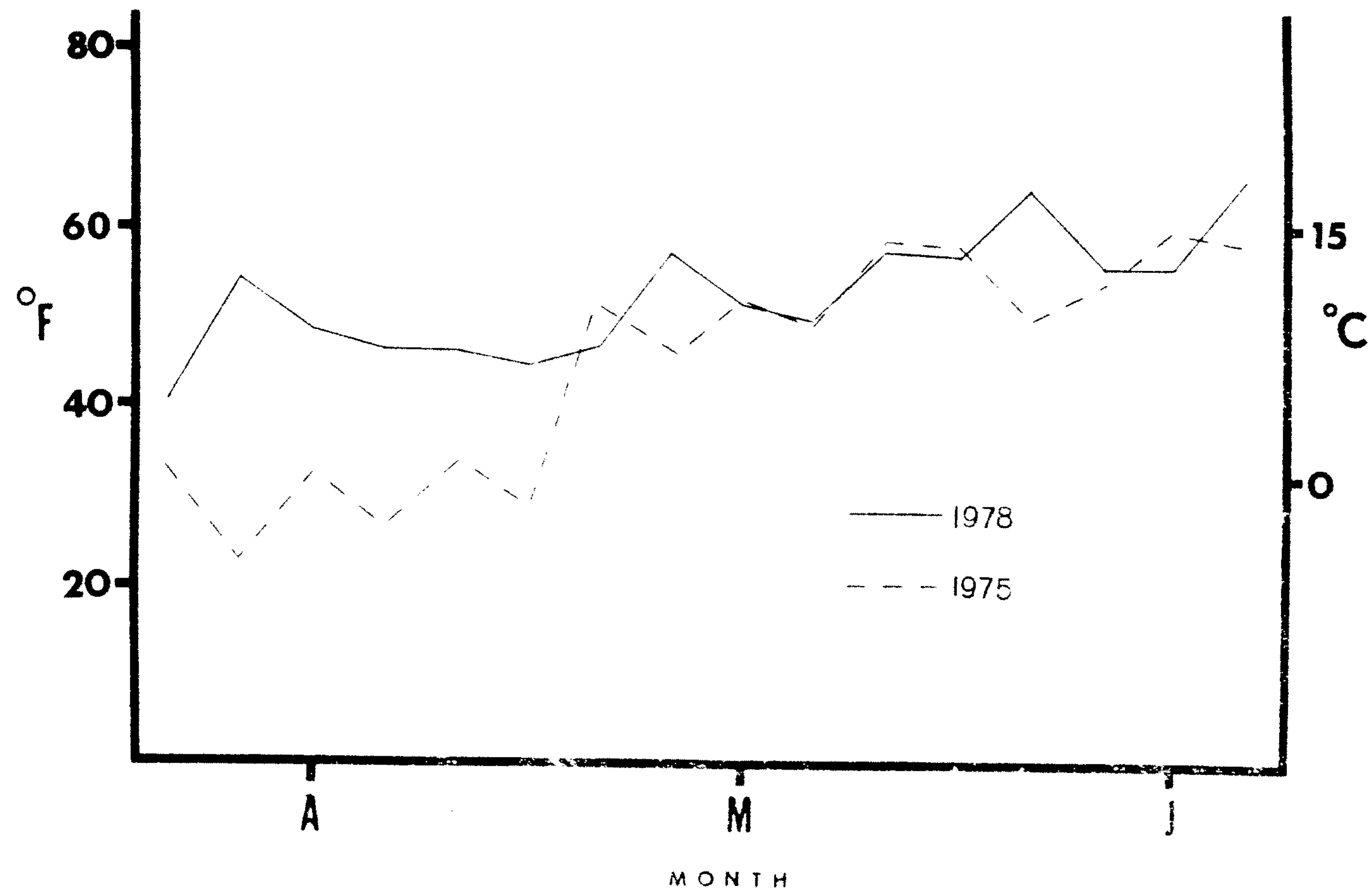

Figure I-13. Five day mean air temperatures in the study area during April-June, 1975 and 1978.

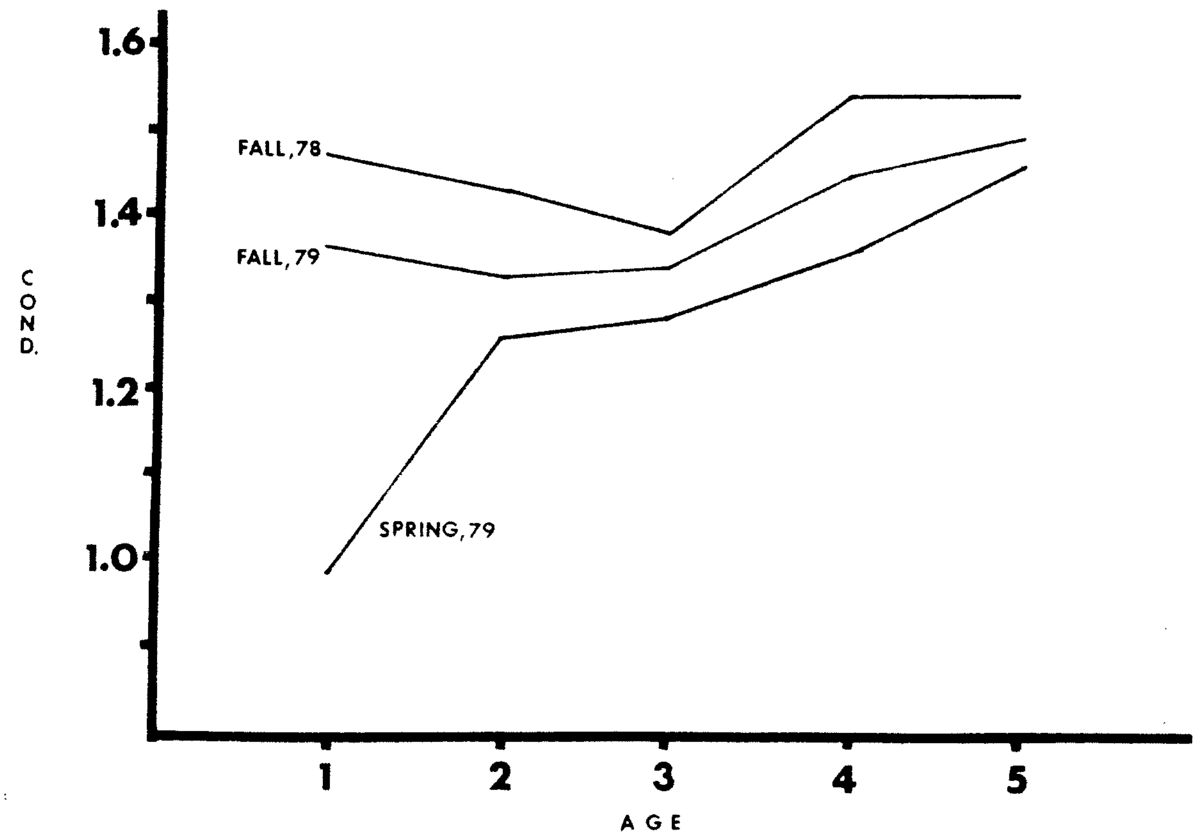

Figure I-14. Condition factors of smallmouth bass in the study area during 1978 and 1979.

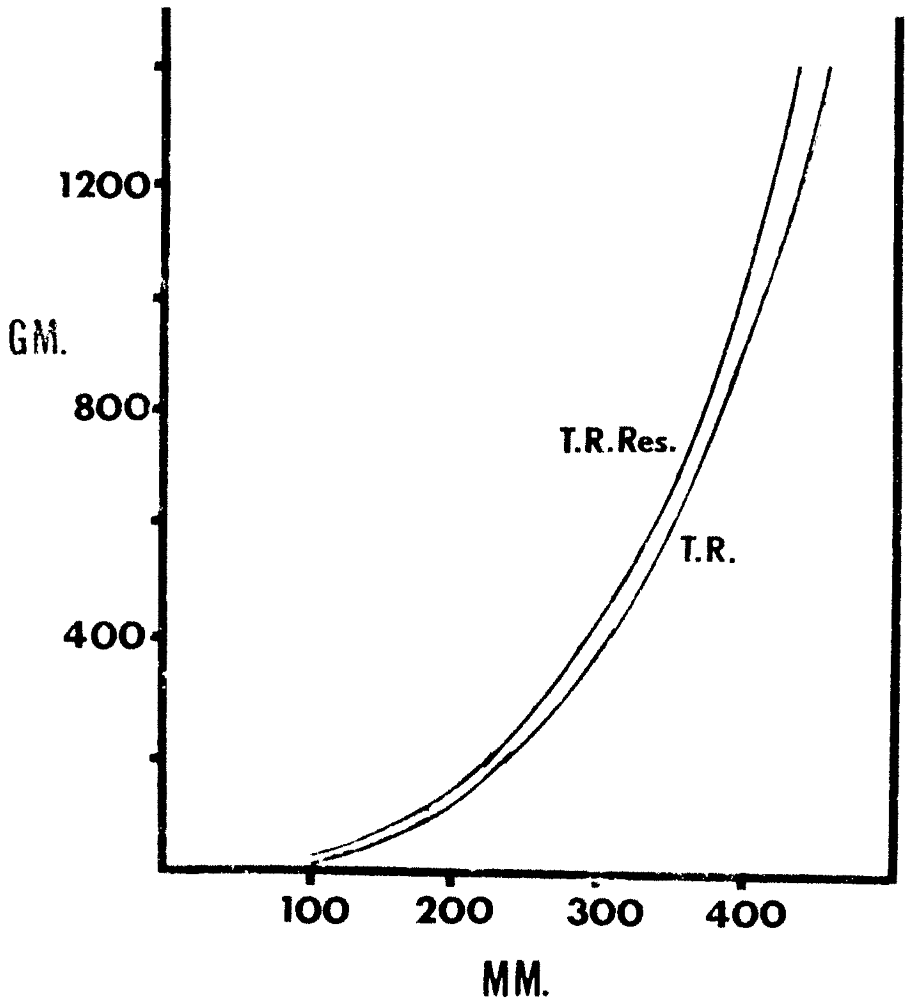

Figure I-15. Length-weight relationship of smallmouth bass in the Tongue River and Tongue River Reservoir.

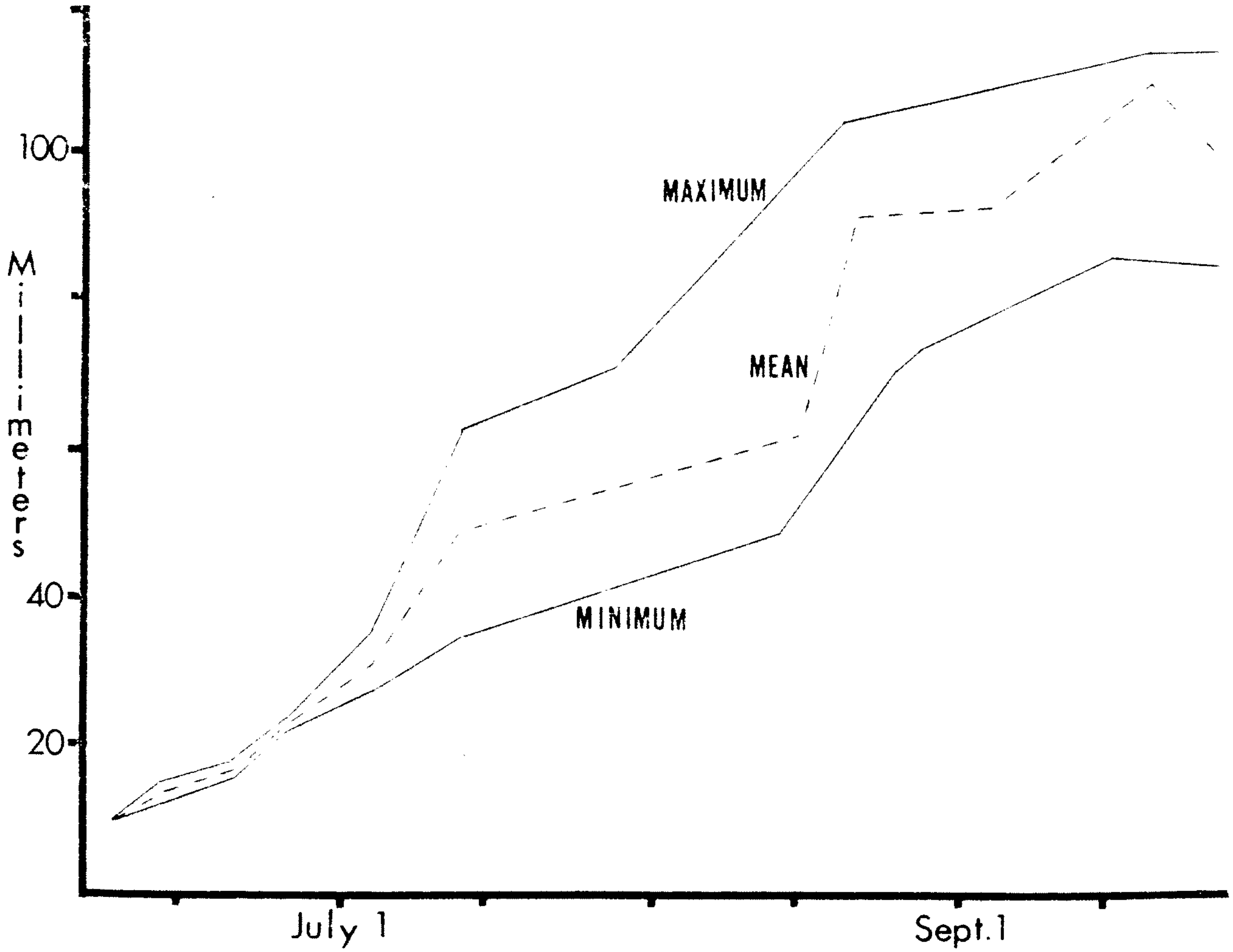

Figure I-16. Minimum, mean and maximum length of smallmouth bass young of the year collected during 1979 in the study area.

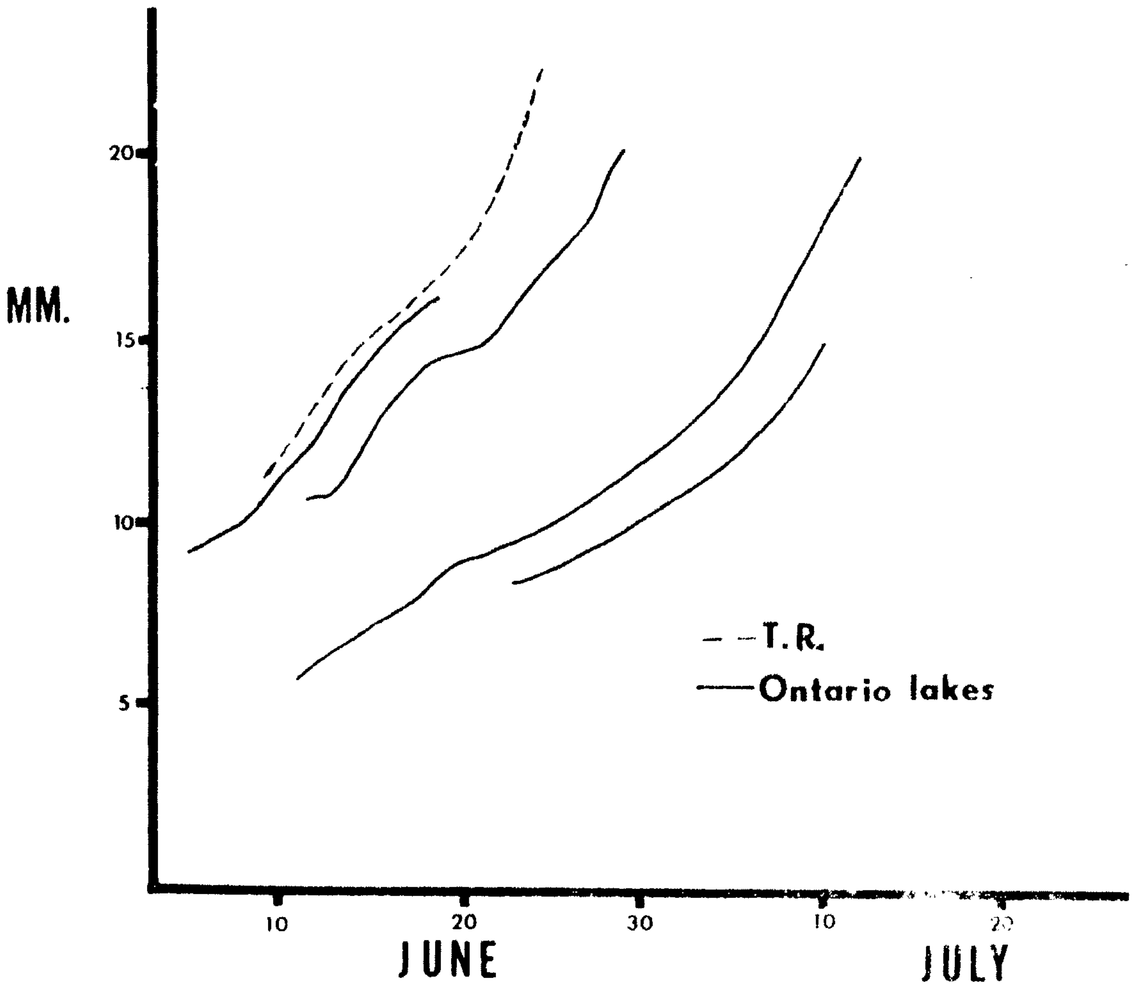

Figure I-17. Growth (mm) of smallmouth bass in the Tongue River during 1979 compared to growth in Ontario.

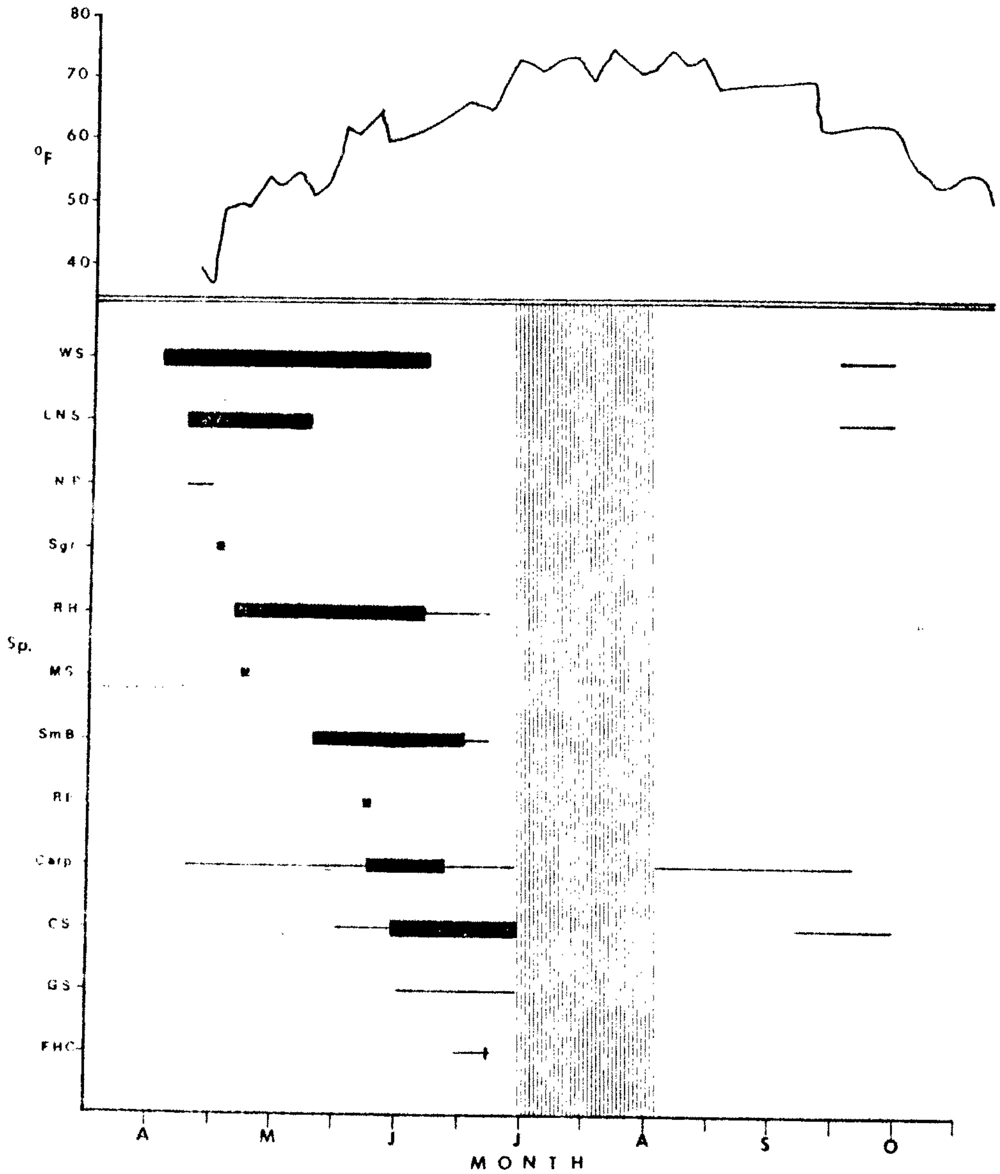

Figure I-18. Five day mean air temperatures and occurrence of mature fish in the study area during 1979. The wide lines and narrow lines represent females and males, respectively. The shaded area during July indicates that no collections were taken.

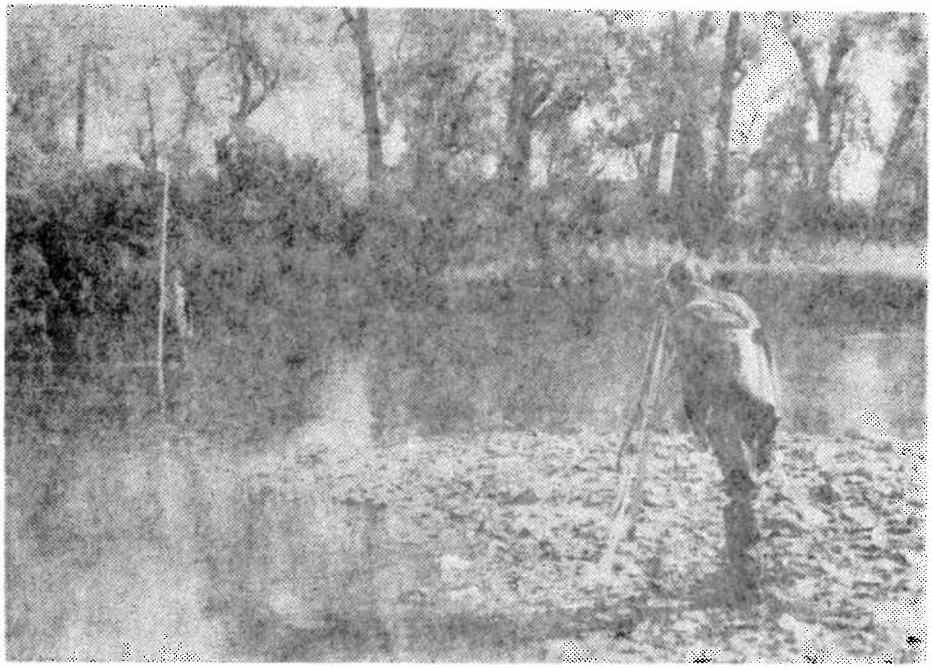

Figure 1-19. Field measurement of water surface profiles.

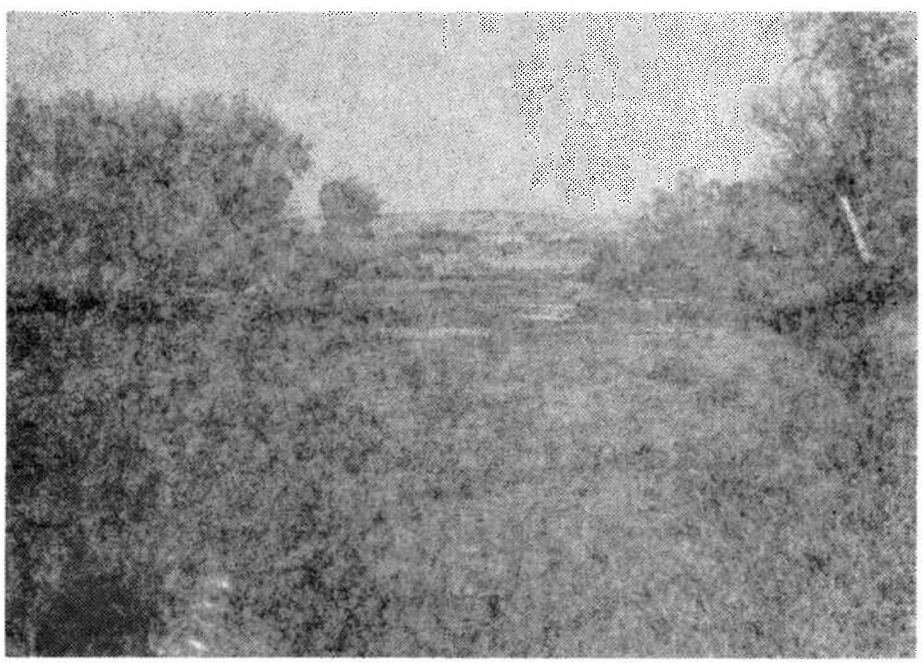

Figure 1-20. Riffle area measured for instream flow recommendations.

Figure 1-21. Backwater area measured for instream flow recommendations.

Figure 1-22. Pool area measured for instream flow recommendations.

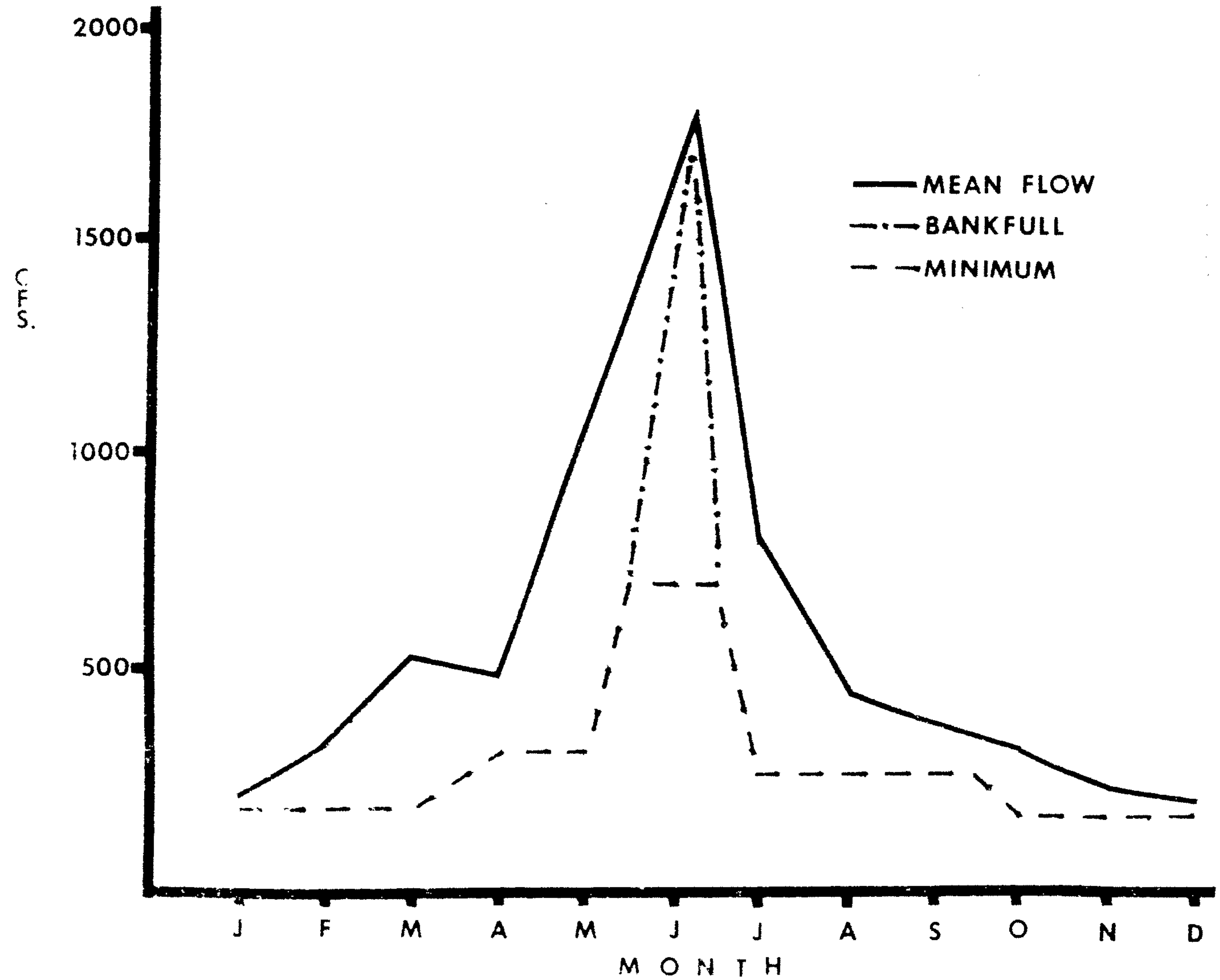

Figure I-23. Mean, bankfull and recommended minimum instream flows in the study area.

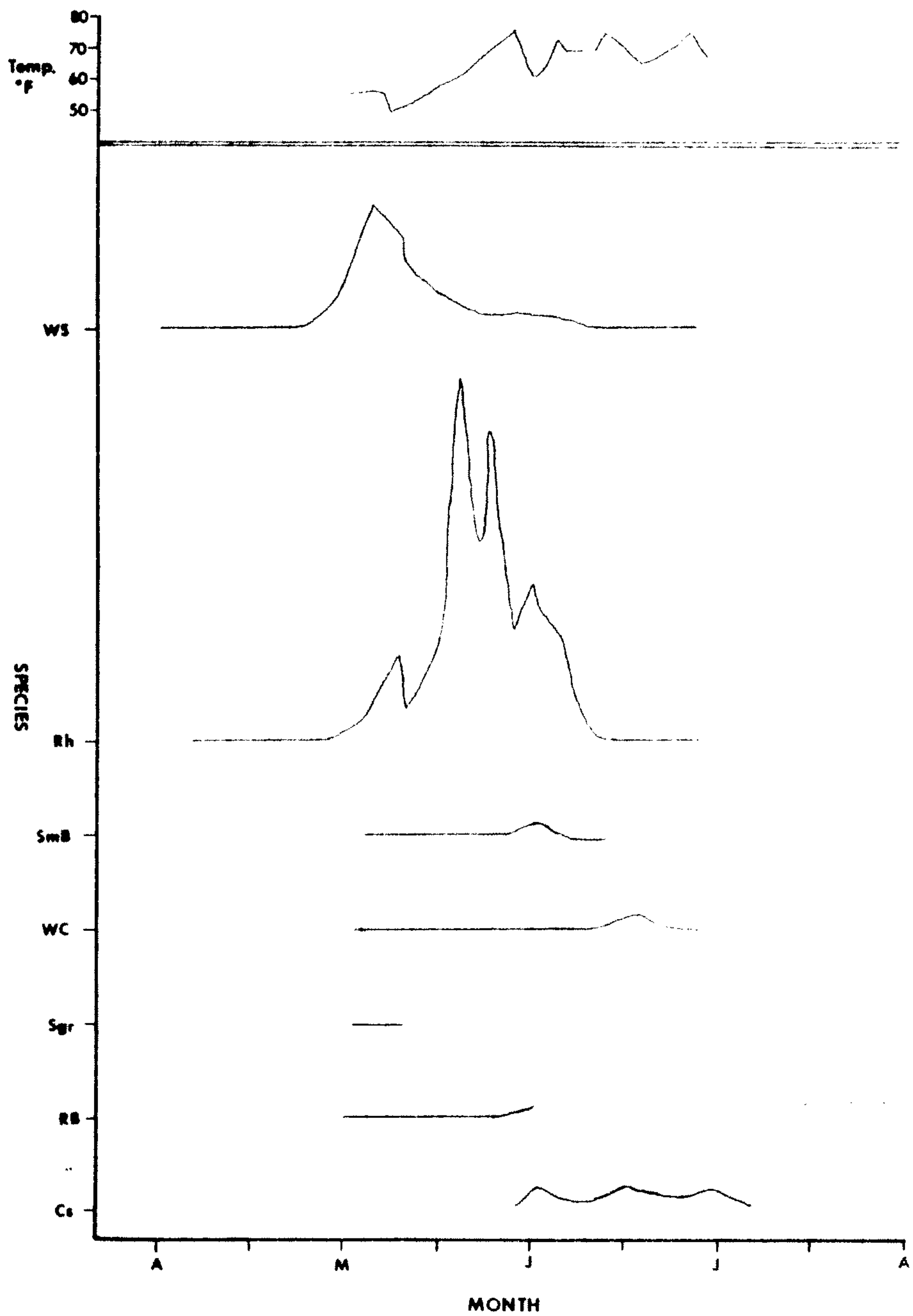

Figure I-24. Midday water temperatures and peak numbers of fish captured in Otter Creek trap during 1979.