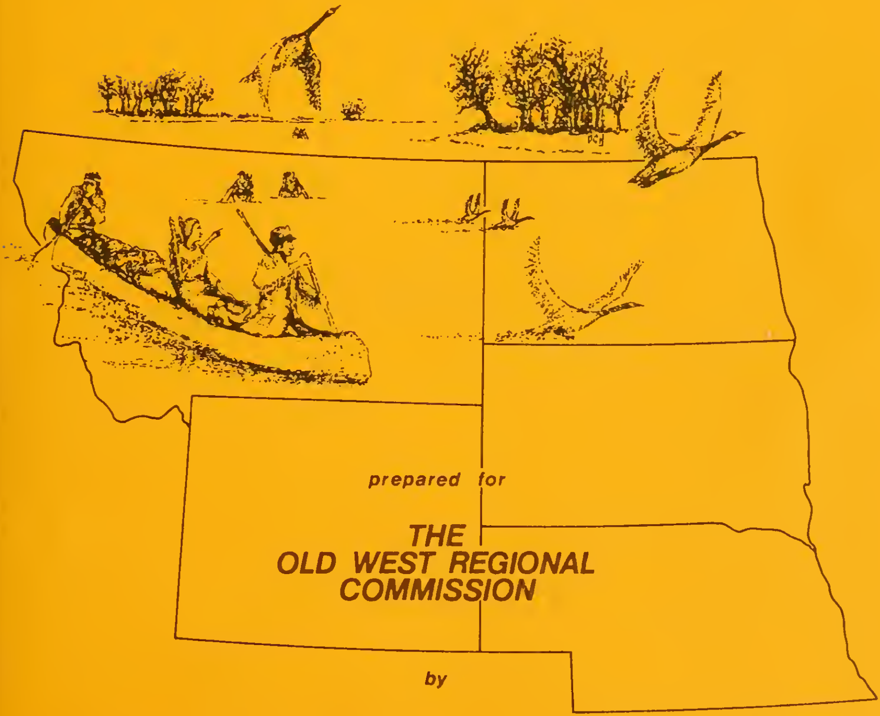
The effect of altered streamflow on fish of the Yellowstone and Tongue rivers, Montana

YELLOWSTONE IMPACT STUDY

TECHNICAL REPORT NO. 8



prepared for

THE OLD WEST REGIONAL COMMISSION

by

DNRC WATER RESOURCES DIVISION — JULY 1977

MONTANA DEPARTMENT OF NATURAL RESOURCES & CONSERVATION

The effect of altered streamflow on fish of the Yellowstone and Tongue rivers, Montana

by

Allen A. Elser, Fish and Wildlife Biologist Supervisor
Robert C. McFarland, Fish and Wildlife Biologist
Dennis Schwehr, Fish and Wildlife Biologist
Montana Department of Fish and Game

TECHNICAL REPORT NO. 8

YELLOWSTONE IMPACT STUDY

conducted by the
Water Resources Division
Montana Department of Natural Resources and Conservation
32 S. Ewing
Helena, MT 59601

Bob Anderson, Project Administrator
Dave Lambert, Editor

for the
Old West Regional Commission
228 Hedden Empire Building
Billings, MT 59101

Kenneth A. Blackburn, Project Coordinator

July 1977

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The Old West Regional Commission is a Federal-State partnership designed to solve regional economic problems and stimulate orderly economic growth in the states of Montana, Nebraska, North Dakota, South Dakota and Wyoming. Established in 1972 under the Public Works and Economic Development Act of 1965, it is one of seven identical commissions throughout the country engaged in formulating and carrying out coordinated action plans for regional economic development.

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Washington, D. C. 20006
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201 Main Street
Suite D
Rapid City, South Dakota 57701
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Suite 228
Heddon-Empire Building
Billings, Montana 59101
406/657-6665

FOREWORD

The Old West Regional Commission wishes to express its appreciation for this report to the Montana Department of Natural Resources and Conservation, and more specifically to those Department staff members who participated directly in the project and in preparation of various reports, to Dr. Kenneth A. Blackburn of the Commission staff who coordinated the project, and to the subcontractors who also participated. The Yellowstone Impact Study was one of the first major projects funded by the Commission that was directed at investigating the potential environmental impacts relating to energy development. The Commission is pleased to have been a part of this important research.

George D. McCarthy
Federal Cochairman

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Abbreviations used in this report

af	acre-feet
af/y	acre-feet/year
b/d	barrels/day
^{o}C	degrees Celsius
cc	cubic centimeters
cfs	cubic feet/second
$\underline{CI}$	confidence interval
$\bar{d}$	species diversity index
DCA	Department of Community Affairs
DNRC	Department of Natural Resources and Conservation
E	electivity index
^{o}F	degrees Fahrenheit
fl	fork length
ft/sec	feet/second
g	grams
ha	hectares
hm^3	cubic hectometers
in	inches
kg	kilograms
km	kilometers
lb	pounds
m	meters
mg/l	milligrams per liter
mi	miles
ml	milliliters
mm	millimeters
mmaf/y	million acre-feet/year
mmcfd	million cubic feet per day
mmt/y	million tons/year
mw	megawatts
m/sec	meters/second
m^3/sec	cubic meters/second
N	number
R	redundancy
t/d	tons/day
tl	total length
WSP	Water Surface Profile

Preface

THE RIVER

The Yellowstone River Basin of southeastern Montana, northern Wyoming, and western North Dakota encompasses approximately 180,000 km^2 (71,000 square miles), 92,200 (35,600) of them in Montana. Montana's portion of the basin comprises 24 percent of the state's land; where the river crosses the border into North Dakota, it carries about 8.8 million acre-feet of water per year, 21 percent of the state's average annual outflow. The mainstem of the Yellowstone rises in northwestern Wyoming and flows generally northeast to its confluence with the Missouri River just east of the Montana-North Dakota border; the river flows through Montana for about 550 of its 680 miles. The major tributaries, the Boulder, Stillwater, Clarks Fork, Bighorn, Tongue, and Powder rivers, all flow in a northerly direction as shown in figure 1. The western part of the basin is part of the middle Rocky Mountains physiographic province; the eastern section is located in the northern Great Plains (Rocky Mountain Association of Geologists 1972).

THE CONFLICT

Historically, agriculture has been Montana's most important industry. In 1975, over 40 percent of the primary employment in Montana was provided by agriculture (Montana Department of Community Affairs 1976). In 1973, a good year for agriculture, the earnings of labor and proprietors involved in agricultural production in the fourteen counties that approximate the Yellowstone Basin were over $141 million, as opposed to $13 million for mining and $55 million for manufacturing. Cash receipts for Montana's agricultural products more than doubled from 1968 to 1973. Since that year, receipts have declined because of unfavorable market conditions; some improvement may be in sight, however. In 1970, over 75 percent of the Yellowstone Basin's land was in agricultural use (State Conservation Needs Committee 1970). Irrigated agriculture is the basin's largest water use, consuming annually about 1.5 million acre-feet (af) of water (Montana DNRC 1977).

There is another industry in the Yellowstone Basin which, though it consumes little water now, may require more in the future, and that is the coal development industry. In 1971, the North Central Power Study (North Central Power Study Coordinating Committee 1971) identified 42 potential power plant sites in the five-state (Montana, North and South Dakota, Wyoming, and Colorado) northern Great Plains region, 21 of them in Montana. These plants, all to be fired by northern Great Plains coal, would generate 200,000 megawatts (mw) of electricity, consume 3.4 million acre-feet per year (mmaf/y) of water, and result in a large population increase. Administrative, economic, legal, and technological considerations have kept most of these conversion facilities, identified in the North Central Power Study as necessary for 1980, on the drawing board or in the courtroom. There is now no chance of their being completed by that date or even soon after, which will delay and diminish the economic benefits some basin residents had expected as a result of coal development. On the other hand, contracts have been signed for the mining of large amounts of Montana coal, and applications have been approved not only for new and expanded coal mines but also for Colstrip Units 3 and 4, twin 700-mw, coal-fired, electric generating plants.

In 1975, over 22 million tons of coal were mined in the state, up from 14 million in 1974, 11 million in 1973, and 1 million in 1969. By 1980, even if no new contracts are entered, Montana's annual coal production will exceed 40 million tons. Coal reserves, estimated at over 50 billion economically strippable tons (Montana Energy Advisory Council 1976), pose no serious constraint to the levels of development projected by this study, which range from 186.7 to 462.8 million tons stripped in the basin annually by the year 2000. Strip mining itself involves little use of water. How important the energy industry becomes as a water user in the basin will depend on: 1) how much of the coal mined in Montana is exported, and by what means, and 2) by what process and to what end product the remainder is converted within the state. If conversion follows the patterns projected in this study, the energy industry will use from 48,350 to 326,740 af of water annually by the year 2000.

A third consumptive use of water, municipal use, is also bound to increase as the basin population increases in response to increased employment opportunities in agriculture and the energy industry.

Can the Yellowstone River satisfy all of these demands for her water? Perhaps in the mainstem. But the tributary basins, especially the Bighorn, Tongue, and Powder, have much smaller flows, and it is in those basins that much of the increased agricultural and industrial water demand is expected.

Some impacts could occur even in the mainstem. What would happen to water quality after massive depletions? How would a change in water quality affect existing and future agricultural,industrial, and municipal users? What would happen to fish, furbearers, and migratory waterfowl that are dependent on a certain level of instream flow? Would the river be as attractive a place for recreation after dewatering?

One of the first manifestations of Montana's growing concern for water in the Yellowstone Basin and elsewhere in the state was the passage of significant legislation. The Water Use Act of 1973, which, among other things, mandates the adjudication of all existing water rights and makes possible the reservation of water for future beneficial use, was followed by the Water Moratorium Act of 1974, which delayed action on major applications for Yellowstone Basin water for three years. The moratorium, by any standard a bold action, was prompted by a steadily increasing rush of applications and filings for water (mostly for industrial use) which, in two tributary basins to the Yellowstone, exceeded supply. The DNRC's intention during the moratorium was to study the basin's water and related land resources, as well as existing and future need for the basin's water, so that

Yellowstone River Basin

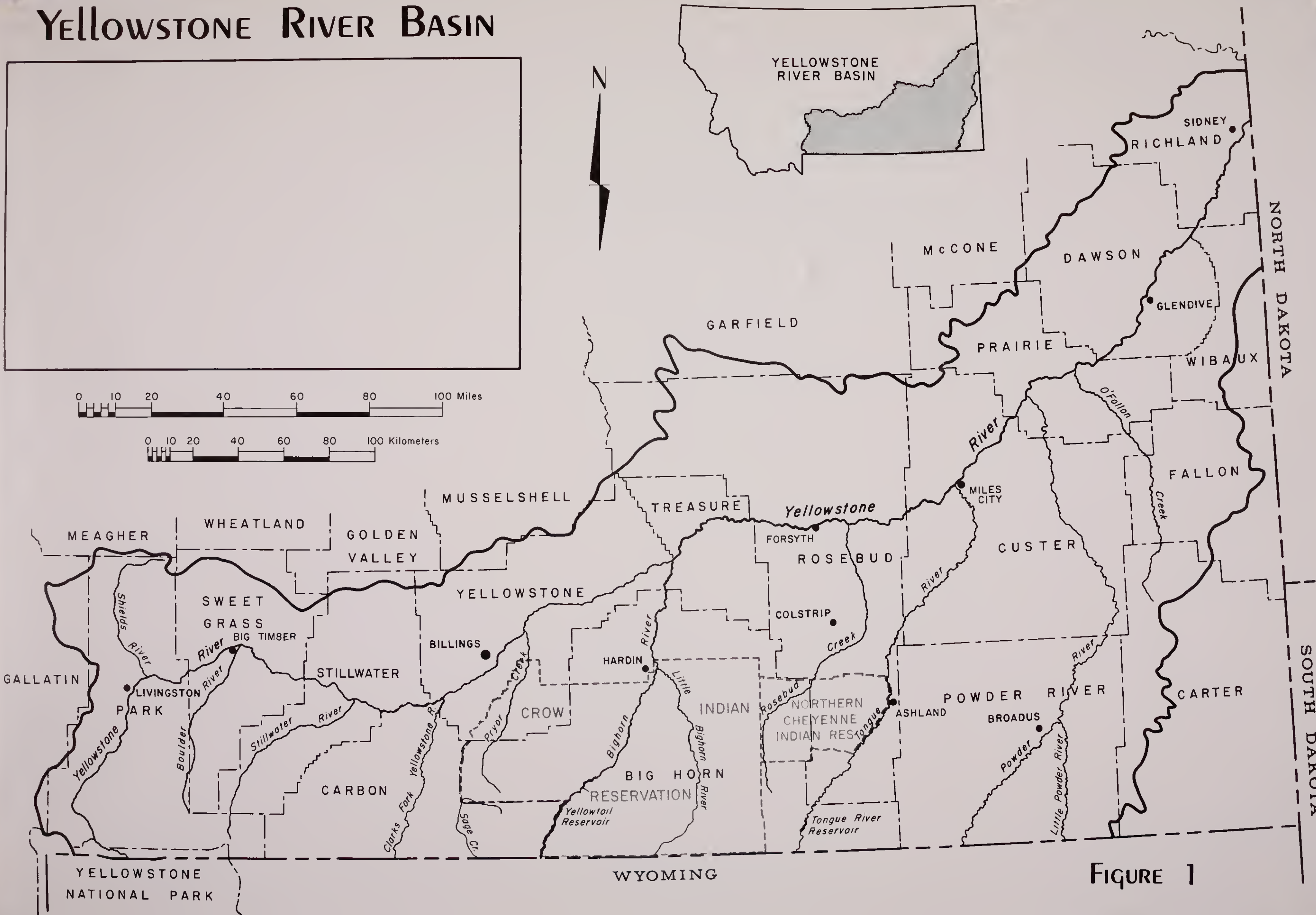

FIGURE 1

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the state would be able to proceed wisely with the allocation of that water. The study which resulted in this series of reports was one of the fruits of that intention. Several other Yellowstone water studies were undertaken during the moratorium at the state and federal levels. Early in 1977, the 45th Montana Legislature extended the moratorium to allow more time to consider reservations of water for future use in the basin.

THE STUDY

The Yellowstone Impact Study, conducted by the Water Resources Division of the Montana Department of Natural Resources and Conservation and financed by the Old West Regional Commission, was designed to evaluate the potential physical, biological, and water use impacts of water withdrawals and water development on the middle and lower reaches of the Yellowstone River Basin in Montana. The study's plan of operation was to project three possible levels of future agricultural, industrial, and municipal development in the Yellowstone Basin and the streamflow depletions associated with that development. Impacts on river morphology and water quality were then assessed, and, finally, the impacts of altered streamflow, morphology, and water quality on such factors as migratory birds, furbearers, recreation, and existing water users were analyzed.

The study began in the fall of 1974. By its conclusion in December of 1976, the information generated by the study had already been used for a number of moratorium-related projects--the EIS on reservations of water in the Yellowstone Basin, for example (Montana DNRC 1976). The study resulted in a final report summarizing all aspects of the study and in eleven specialized technical reports:

Report No. 1	Future Development Projections and Hydrologic Modeling in the Yellowstone River Basin, Montana.
Report No. 2	The Effect of Altered Streamflow on the Hydrology and Geomorphology of the Yellowstone River Basin, Montana.
Report No. 3	The Effect of Altered Streamflow on the Water Quality of the Yellowstone River Basin, Montana.
Report No. 4	The Adequacy of Montana's Regulatory Framework for Water Quality Control
Report No. 5	Aquatic Invertebrates of the Yellowstone River Basin, Montana.
Report No. 6	The Effect of Altered Streamflow on Furbearing Mammals of the Yellowstone River Basin, Montana.
Report No. 7	The Effect of Altered Streamflow on Migratory Birds of the Yellowstone River Basin, Montana.

Report No. 8 The Effect of Altered Streamflow on Fish of the Yellowstone and Tongue Rivers, Montana.

Report No. 9 The Effect of Altered Streamflow on Existing Municipal and Agricultural Users of the Yellowstone River Basin, Montana.

Report No. 10 The Effect of Altered Streamflow on Water-Based Recreation in the Yellowstone River Basin, Montana.

Report No. 11 The Economics of Altered Streamflow in the Yellowstone River Basin, Montana.

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This report was reviewed by and guidance received from John C. Orth, Director of the Montana Department of Natural Resources and Conservation; Orrin Ferris, Administrator of the DNRC's Water Resources Division; and Carole Massman, of the DNRC's Special Staff.

Other DNRC personnel providing assistance were Peggy Todd and Pam Tennis, who performed editing tasks, and Janet Cawlfield, Kris MacIntyre, and Linda Howell, typists. Graphics were coordinated and performed by Gary Wolf, with the assistance of Gordon Taylor, Dan Nelson, and June Virag. The cover was designed and executed by D. C. Howard.

Department of Fish and Game personnel who assisted with Part III of this report were Larry Peterman and Chris Estes, who performed sampling, analysis, and writing of the forage fish investigation. Much of the sampling for the food habits investigation of Part III was performed by DFG summer field crews.

Part 1

Tongue River fishery study

by

Allen A. Elser
Robert C. McFarland

Introduction

PURPOSE

In the fall of 1974 a two-year study was initiated on the Tongue River to assess fish populations present for these purposes:

1) To determine species composition and distribution,

2) To establish and evaluate diversity indices for various habitat zones or sections,

3) To evaluate the potential impacts of water withdrawals.

STUDY AREA

The Tongue River's name originated from the Indian word "La-zee-ka," meaning tongue, for a tree-covered limestone slab outlined by barren rock which resembled a buffalo tongue. The headwaters of the Tongue River rise on the eastern slope of the Bighorn Mountains of Wyoming and flow generally northeast through Montana to join the Yellowstone River at Miles City. The length of the Tongue River from the Montana-Wyoming border to its confluence with the Yellowstone River is 326.5 km (202.9 mi).

The Tongue River's flow in Montana is controlled by the Tongue River Dam. The dam, completed in 1940 for storage of irrigation water, impounds 84.9 hm^3 (69,000 af) with a surface area of 1,416 ha (3,500 acres).

The Tongue River drains approximately 13,932 km^2 (5,379 mi^2), 70 percent of which is in Montana, with an average annual discharge of 11.9 m^3/sec (420 cfs). The maximum recorded discharge was 377 m^3/sec (13,300 cfs) on June 15, 1962. The two typical stream bed formations found are: (1) in strong current, gravel cobblestones and outcropping of bedrock, and (2) in slack or slow current, silt and sand.

The average annual temperature for the basin varies from 4.4 to 11.1^{o}C (40-52^{o}F). Average annual precipitation varies from 22.9 to 40.6 cm (9 to 16 in).

The basin of the Tongue River is underlain by the Fort Union Formation of the early Tertiary (Eocene) Age which has a total thickness of about 610 m (2,000 ft). Ninety percent of the soils were formed on sandstones and shales laid down in the Cretaceous or Tertiary periods.

The river is an important source of water for irrigation, domestic use by man and livestock, recreational use, and industrial use. With the increase in coal development in the Tongue River drainage, the river takes on a new importance. The Decker-Birney Resource Study (U.S.D.I. 1974) conducted by the Bureau of Land Management in April of 1974 identified strippable coal reserves underlying 145,422 ha (359,333 acres) of the planning unit in the Tongue River Basin. Approximately 115,000 ha (285,000 acres) of this planning unit overlie superior reserves of 15 billion tons of coal economically feasible to mine. Other coal reserves exist outside that study's planning unit yet within the Tongue River Basin.

Figure 2 is a map of the Tongue River in Montana; figure 3 shows its longitudinal profile.

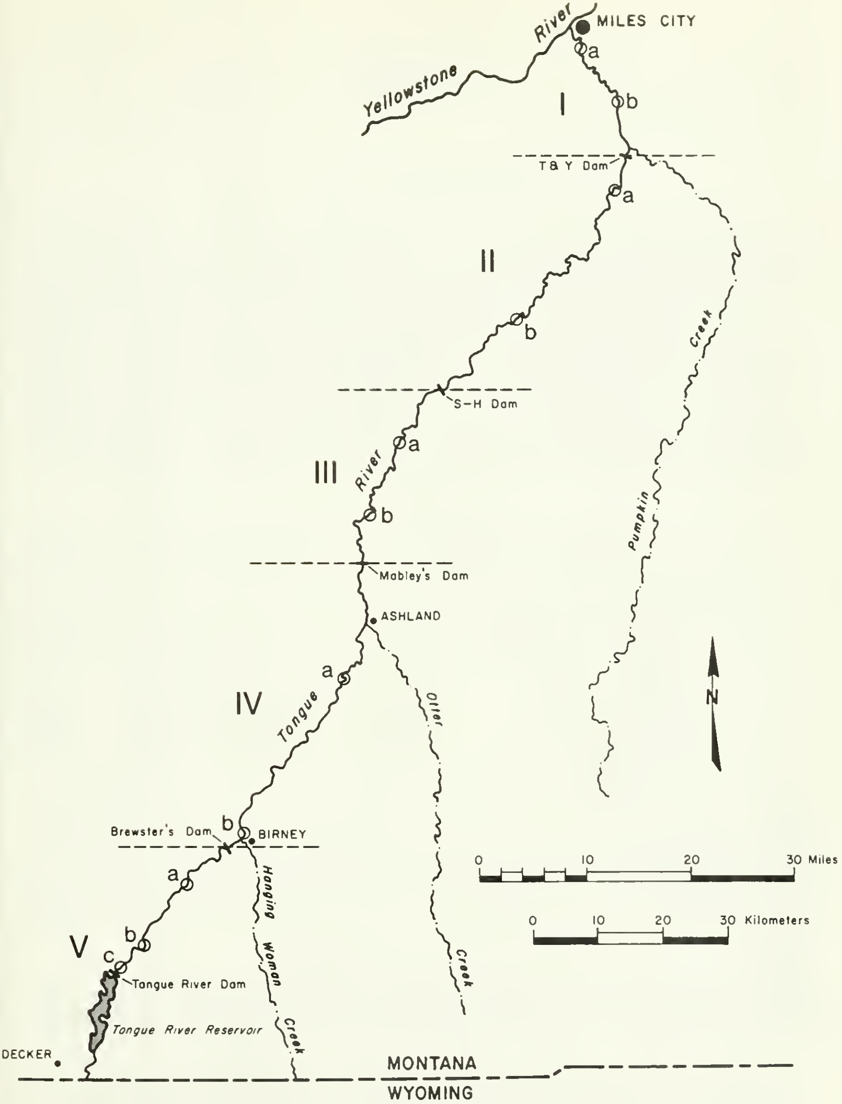


Figure 2. Tongue River in Montana: major diversions, tributaries and sampling sections.

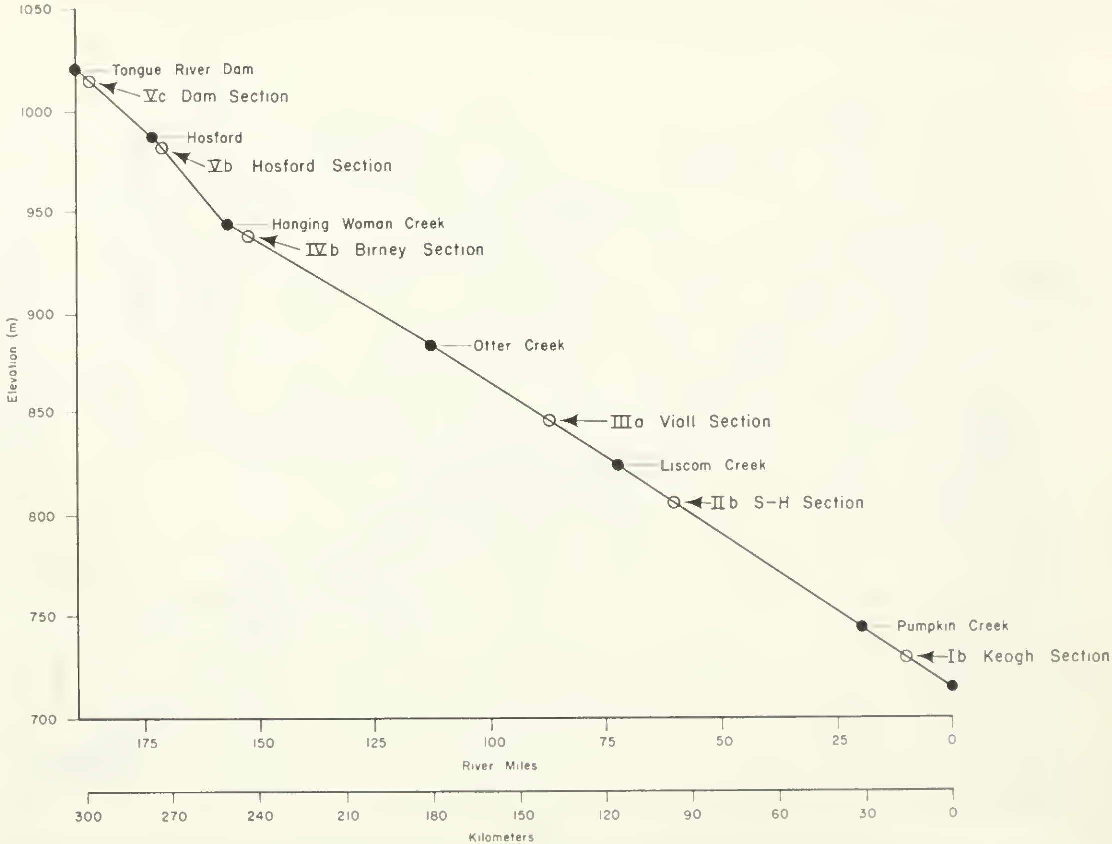


Figure 3. Longitudinal profile of the Tongue River in Montana.

Methods

STUDY SECTION DELINEATION

Study sections were selected on the basis of the location of diversion structures, access, fishing pressure, future and existing dam sites, and the various habitats present. The Tongue River downstream from Tongue River Dam was divided into five zones, identified by Roman numerals (figure 2). Primary sampling sections (Ib, IIb, IIIa, IVb, Vc) were established in relation to irrigation diversion structures to evaluate fish distribution (table 1). Another primary section, Vb, was established to obtain data for a reach of river which would be inundated by the New Tongue River Reservoir. These sampling sections were relatively short (2.5-4.1 km) and did not adjoin one another. In all, sampling sites were established on 11 sections of the river (see figure 2). Primary sections ranged in length from 2.5 to 4.1 km; gradients varied from 0.56 m/km (2.94 ft/mi) near the mouth to 1.22 m/km (6.45 ft/mi) in the canyon.

TABLE 1. Description of major sampling sections, Tongue River.

Section	Upstream Barrier	Location (km)[a]	Length (km)	Gradient (m/km)
Ib	T&Y Diversion	22.7	3.9	0.56
IIb	S-H Diversion	113.4	3.6	0.68
IIIa	Mobley's Diversion	145.8	4.1	0.76
IVb	Brewster's Diversion	252.1	3.6	0.65
Vc	Tongue River Dam	300.2	2.5	1.22

[a] River kilometers above the mouth

Major habitat zones and sampling sites were delineated through the use of aerial photos, USGS topographic maps, and ground measurements.

INSTREAM FLOW DETERMINATION

Instream flow levels were obtained through the use of the water surface profile (WSP) program (USDI 1968) following procedures outlined by Dooley (1975) and Spence (1975).

The validity of WSP and its potential use in determining instream flows for a warm-water stream were investigated. Flows for migration, spawning, and rearing were evaluated (Elser 1976). Predicted values for water surface elevation and mean velocity were found to be not significantly different from actual values. Although hydraulic characteristics predicted by WSP are mean values, they are adequate for use with current knowledge of fish requirements.

SAMPLING AND TAGGING

Six primary sampling stations were sampled six times in the fall of 1974. Two sections (IIb and Vb) were not sampled in the fall of 1975; the remaining four sections were sampled three times each. Only section IVb was sampled in the fall of 1976 to check on the reproduction of the smallmouth bass population. Four secondary sections (Ia, IIa, IVa, and Va) were sampled in the fall of 1974 for further definition of fish population distribution.

River fish populations were sampled by several methods. Electrofishing gear with an output of 0-500 volts variable direct current, fished either from a fiberglass boat as described by Vincent (1971) or from the banks of smaller streams, was utilized to sample fish populations in the river and tributaries. Baited trap nets (wire-frame, 3-ft hoop traps with 1-inch mesh webbing) were used for channel catfish. A 4-inch bar-mesh gill net was also utilized to sample fish.

Spring sampling concentrated on the migrant fish which utilize zone I, the lower 32.8 km (20.4 mi) of the river, for spawning. A portion (10.9 km; 6.8 mi) of this section was sampled extensively by use of traps, gill nets, and electrofishing techniques.

Each of three major tributaries to the Tongue River, Pumpkin, Otter, and Hanging Woman creeks, was spot sampled at 16-to-24-km (10-to-15-mi) intervals in 1974 to determine species composition and distribution.

SHOVELNOSE STURGEON

Shovelnose sturgeon *(Scaphirhynchus platorynchus)* were sampled by two means: (1) by drifting the 4-inch bar-mesh gill net through an area free of snags and (2) by electrofishing. The gill net was divided into ten 3 m segments to determine sturgeon distribution across the channel. The number of fish captured in each segment was recorded for each drift. Samples were taken at least three days each week of the run.

Several methods were used to tag sturgeon. In 1974, Floy anchor tags were inserted immediately posterior to the dorsal fin. Observed tag losses led to the use of No. 3 monel wing band tags placed over the anterior fin rays of the pectoral fin as described by Schmulbach (1974). Irritation to the pectoral fin caused by the monel tag resulted in the cessation of use of this tagging method. Tagging in 1975 was accomplished by inserting the Floy anchor tag in the pectoral girdle (Helms 1974), but tag loss associated with this method was also high. A numbered aluminum strap tag encircling the caudal peduncle at the base of the caudal fin as described by Christenson (1975) was used in 1976. Several sturgeon thus tagged were held at the Miles City National Fish Hatchery for observation. Severe irritation occurred within two weeks. Floy cinch-up tags (FT-4) were also placed around the caudal peduncle, assuming less irritation would occur. Test fish held at the hatchery showed similar irritation to the extreme that the caudal fin was lost. Finally, the Floy cinch-up tag was inserted through the flesh immediately ventral to the dorsal fin and tightened. Observations on recaptured fish suggested good tag retention and little irritation.

SAUGER

Sauger *(Stizostedion canadense)* samples were collected primarily by electrofishing. The boat was adapted, however, to provide an efficient two-man operation. The negative electrode remained on the bottom of the boat, but the positives were supported by a boom system. One man dipped fish while the other retained control of the boat. Sampling was conducted an average of four days a week. Sauger were measured, weighed, and tagged, and a scale sample was collected prior to release. The Floy anchor tag was inserted immediately posterior to the dorsal fin. Drift samples were taken in an attempt to collect sauger fry and eggs.

CHANNEL CATFISH

Channel catfish *(Ictalurus punctatus)* populations in the Tongue River were monitored by sampling with baited traps constructed from reinforcing bar material and chicken wire in three reaches of the river. Using rotten cheese as bait produced the most fish per trap night. Catfish were tagged with Floy anchor tags in 1974 and 1975, but high incidence of anchor tag loss reported in other studies prompted a change to other tagging methods. A numbered plastic disc attached to the fish with 0.81-mm (0.032-in) stainless steel wire immediately ventral to the dorsal fin was used in 1975 and 1976. Irritation associated with this tag resulted in the use of the Floy cinch-up tag. Preliminary results suggest good retention and minor irritation.

AGE AND GROWTH

Attempts to determine the age of shovelnose sturgeon by sectioning a pectoral fin ray as described by Priegel and Wirth (1975) for lake sturgeon were unsuccessful. The cross section was opaque and no annulus formation could be detected. An attempt to determine growth by comparing weights and lengths at marking and recapture was also unsuccessful, as is explained on page 47.

Age and growth of sauger were investigated by analysis of scales.

Pectoral spines taken from channel catfish were sectioned as described by Marzolf (1955) and Sneed (1951) using an instrument similar to the one described by Witt (1961). With this instrument, the spines were sectioned thin enough to eliminate further grinding. The sections were coated with glycerin and aged with the aid of a binocular microscope. The translucent rings were considered to be year marks when they were distinct and continuous in all areas of the section (Marzolf 1955).

POPULATION ESTIMATES

In order to assess the importance of the shovelnose sturgeon spawning run into the Tongue River, it was necessary to determine the strength of that run and variations in the number of fish using the river each year. The validity of population estimates based on mark-and-recapture techniques is based on certain assumptions:

1) marked fish do not lose their identifying marks and are recognizable upon recapture;

2) either marked fish are randomly redistributed throughout the population or the sampling effort is proportional to the density of the population;

3) both marked and unmarked fish are susceptible to the same degree of capture;

4) numbers of fish are not increased as a result of recruitment from growth or immigration; and

5) losses from death or emigration are equal for both marked and unmarked fish.

Since the sturgeon population is migrant, assumptions 4 and 5 are not met, with continual immigration and emigration. However, Ricker (1958) felt that the Schnabel estimator can still be useful even if not all conditions are met completely.

The population of shovelnose sturgeon utilizing the lower Tongue River was estimated using three formulas to compare and evaluate population strengths. As found in Ricker (1975), the formulas are:

Schnabel $$\hat{N} = \sum_t \frac{C_t M_t}{R_t}$$

Schumacher-Eschmeyer $$\hat{N} = \sum_t \frac{C_t M_t^2}{M_t R_t}$$

Chapman or Modified Schnabel $$\hat{N} = \sum_t \frac{C_t M_t}{R_t + 1}$$

where: $\hat{N}$ = population estimate
C_t = number of fish caught
M_t = number of fish marked
R_t = number of fish recaptured

All estimators are multiple censuses, involving the addition of marked fish in the population. Negative bias enters into the estimates if the combination of number of fish marked and number examined falls too low. Ricker (1975) suggested that this bias can be ignored whenever the number of recaptures is four or more.

The same methods were used to estimate the sauger population.

WATER TEMPERATURE

Water temperatures were monitored at stations Ia, IIIa, and Vc with Taylor 30-day recording thermographs. The recording sheets were changed monthly. All water temperatures were recorded in Fahrenheit degrees. Daily maximum and minimum temperatures were tabulated and are given in appendix B.

IMPACTS OF WATER WITHDRAWALS

Impacts were assessed by flow period. The year was divided into three segments corresponding to the life-history phases of the important fish species in the Tongue River: migration, spawning, and rearing (Stalnaker and Arnette 1976). Since incubation periods of warm-water fishes are short, incubation is ignored as a biological phase. It is generally agreed that depth and velocity are the most important limiting factors during these life history stages.

Depth is significant in maintaining suitable passage requirements and in supplying the necessary wetted areas for spawning and food production. In prairie stream ecosystems, Bovee (1975) suggested that if passage (migration) requirements were met, spawning requirements would also be met. Rearing, as a life stage, generally encompasses those times of the year when fish are not engaged in migration or spawning. Therefore, rearing flows are those which will maintain the habitat necessary for sustenance of the fish species present.

The fall flow period encompasses the months of August (late summer) through November. These flows coincide with late irrigation with late irrigation withdrawals and are accompanied by warm water temperatures. Temperature and water-quality requirements must be met during this time. A reduction in flow during these months may elevate water temperatures above tolerable limits and result in degraded water quality.

Winter (December, January, and February) is also a critical low-flow period. Dewatering results in accelerated freeze-up of riffles and depleted oxygen levels. It is during this time that fish population levels are reduced. Fall and winter are considered rearing phases.

Spring (March through May) is the migration and spawning season for most warm-water species. If adequate flows are maintained to ensure passage, it is assumed that adequate water will be available for spawning.

The peak run-off period, May through July, is also important for passage, spawning, and rearing. Additionally, spring peaks scour the channel, cleansing the substrate interstices for food production and successful reproduction.

Existing situation

FAUNAL ZONATION

Streams vary greatly in size, velocity, gradient, nature of the bed, temperature, and other features. Generally, streams change from steep torrents to sluggish meandering waterways as they proceed from source to mouth (Allen 1969). Usually there are stages between the two extremes which are characterized by specific environmental features and a particular assemblage of fish species.

Many attempts have been made to associate particular fish faunas with these defined zones. Huet (1959) devised a scheme for European streams using four categories, naming each zone from the characteristic fish found in them. In descending order of current velocity they are:

1) the trout zone
2) the grayling zone
3) the barbel zone
4) the bream zone

North American streams have been classified by Lagler et al. (1962) as follows:

1) grayling
2) stream char
3) flowing water minnows and pike
4) bass
5) catfish, suckers, and quiet water minnows

Each of these zones is characterized by a particular set of combinations of stream gradient and stream width. As the gradient diminishes, the headwater fishes disappear and are replaced successively by others better adapted to the changing environment. This was evident in the change of species diversity with progression downstream in the Tongue River.

Fish population in the Tongue River exhibit a succession from torrent-zone fishes (trout) to the quiet-zone fishes (catfish and suckers). While the upper Tongue River in Montana cannot be considered a trout stream, the presence of brown trout and other species associated with fast-water habitats suggests zone 2 according to the classification given above.

RESIDENT FISH POPULATIONS

SPECIES DISTRIBUTION

Thirty-one species of fish representing 11 families were collected on the Tongue River during 1974 and 1975. Of these species, four (burbot, paddlefish, shovelnose sturgeon, and blue sucker) were taken only during the spring sampling near the mouth and are considered to be migrant species.

Qualitative distribution of these species is shown in table 2. Grouping by sections, though it obscures the variation encountered, illustrates broad trends of the stream. Moutain whitefish and brown trout are confined to the upstream zone.

TABLE 2. Distribution of fishes in the Tongue River by zones, 1974 and 1975.

	V	IV	III	II	I
Brown trout	*				
Whitefish	*				
Northern pike	*	*			
Yellow perch	*	*			
Black crappie	*	*			
Yellow bullhead	*	*			
Rainbow trout	*	*	*		
Rock bass	*	*	*	*	
Mountain sucker	*	*	*	*	
Pumpkinseed	*	*			*
Smallmouth bass	*	*		*	*
White crappie	*	*		*	*
River carpsucker	*	*	*	*	*
Carp	*	*	*	*	*
Stonecat	*	*	*	*	*
Shorthead redhorse	*	*	*	*	*
White sucker	*	*	*	*	*
Longnose sucker	*	*	*	*	*
Longnose dace	*	*	*	*	*
Black bullhead		*	*		
Green sunfish		*	*	*	
Channel catfish		*		*	*
Sauger		*	*	*	*
Flathead chub		*	*	*	*
Goldeye					*
Burbot					*
Walleye					*
Paddlefish					*
Shovelnose sturgeon					*
Blue sucker					*
Sturgeon chub					*
TOTAL No. Species	19	22	14	15	20

NOTE: Common names of fishes used correspond to those presented by the American Fisheries Society (1970). Corresponding scientific names are given in appendix C.

Longitudinal distribution of fish in the Tongue River is influenced by irrigation diversion structures. The T & Y Diversion is the upstream limit for goldeye, walleye, burbot, paddlefish, shovelnose sturgeon, blue suckers, and sturgeon chubs. Channel catfish did not occur above the Brewster Diversion. Flathead chubs are found upstream from the Mobley Diversion, but in limited numbers when compared to downstream sections.

Distributional patterns changed in 1975. Extensive high water during the spring and summer resulted in damage to Mobley's and Brewster's diversions, allowing fish passage. Five species (mountain sucker, yellow bullhead, pumpkinseed, smallmouth bass, and black crappie) which had not previously been found above Brewster's diversion were found in section Vc in 1975.

POPULATION NUMBERS AND SPECIES COMPOSITION

A comparison of the 1974 and 1975 electrofishing results is shown in table 3. Fish captured per trip expressed as numbers/km were similar between the two years. The number of species decreased in sections Ib and IIb and increased in sections IVb and Vc. In all cases, gains or losses were of rare species. Section Vc showed the greatest change in both number of fish (which increased from 231 to 292) and number of species (which increased from 11 to 15). In the same section, sucker composition changed from shorthead redhorse dominance to longnose sucker dominance, and white suckers showed a great increase.

Game fish concentrations were heaviest in section IVb where they made up 12.7 percent of the total number; the dominant game fish was smallmouth bass, which ranged in length from 53 to 342 mm (2.1 to 13.5 in). The preponderance of young-of-the-year fish indicates that smallmouth bass are successfully reproducing. They were also found downstream from the S-H Diversion, but the greatest concentration was near Birney.

Scales taken from smallmouth bass collected in section IVb were used to evaluate age-class strengths for 1974, 1975, and 1976. The distribution of age classes 0 through IV is shown in table 4. Age 0 smallmouth bass contributed 37.3, 7.3, and 73.3 percent of the total smallmouth sample in 1974, 1975, and 1976, respectively. The low reproductive success of bass in 1975 is reflected in the number of age class I fish collected in 1976. High discharges from the Tongue River Dam during the spring and summer of 1975 in preparation for repairs to the dam apparently reduced smallmouth reproduction. Reynolds (1965) suggested that water levels might be more important than temperatures in initiating spawning of smallmouth bass in tributaries of the Des Moines River, Iowa. In Courtois Creek, Missouri, smallmouth bass nesting always began during a period of stable or gradually declining water levels and was delayed or interrupted some years by floods (Pflieger 1975). Stable flows during the spawning and incubation periods were considered more important for successful smallmouth bass reproduction than a specific flow level (White and Cochnauer 1975). This philosophy was strongly considered when developing the minimum flow recommendations for the Tongue River discussed below under "Impacts of Water Withdrawals."

TABLE 3. Summary of electrofishing samples for the Tongue River, fall 1974 and 1975 (fish per kilometer)

Species	Ib 1974	Ib 1975	IIb 1974	IIb 1975	IVb 1974	IVb 1975	Vc 1974	Vc 1975
Goldeye	4	4						
Rainbow trout					1		2	3
Brown trout							1	1
Northern pike					1	1		
Carp	6	8	7	2	3	1	8	10
Flathead chub	14	8	16	9	1	1		
Sturgeon chub	1	1						
Longnose dace	2	-	1	1	1	1		
River carpsucker	3	3	14	3	5	2	30	20
Shorthead redhorse	9	9	22	36	29	37	80	37
Longnose sucker	1	2	5	9	6	10	16	77
White sucker	1	1	1	1	13	26	1	27
Mountain sucker			1	1			-	1
Yellow bullhead					-	1	-	1
Black bullhead					1	1	4	3
Channel catfish	1	1	3	2	-	1		
Stonecat	1	3	4	14	6	6		
Rock bass			1	1	3	7		
Green sunfish			1		1	1		
Pumpkinseed	1	-			1	1	-	1
Smallmouth bass	1	-	1	2	9	6	-	1
White crappie	1	-	1	-	1	1	1	1
Black crappie	1	1			1	1	-	1
Yellow perch					1	1	1	1
Sauger	6	9	1	1	1	1		
Walleye	1	1						
Burbot	1							
TOTAL	55	51	79	82	85	107	144	185
NO. SPECIES	18	13	15	13	19	20	10	15

NOTE: A hyphen (-) denotes a species present during one sampling period and absent during the other; a blank indicates absence during both years.

TABLE 4. Summary of age-class strength of smallmouth bass in the Tongue River, 1974-76.

Age Class	PERCENTAGE OF TOTAL SAMPLE		
	1974	1975	1976
0	37.3	7.3	73.3
I	37.3	65.5	8.4
II	12.0	16.4	13.3
III	10.7	9.1	3.3
IV	2.7	1.7	1.7

Northern pike were also captured in section IVb. The presence of small northerns (236 mm or less in length) suggests that these fish are reproducing in the river. The lower reaches of Hanging Woman Creek provide excellent northern pike spawning habitat and probably act as a nursery for the Tongue River population of northerns.

The Tongue River supports the only rock bass population in Montana. The greatest numbers of rock bass were found in sections IVb and Vb. All sizes were represented in the samples.

The greatest number of channel catfish was found in section IIb, with the largest fish weighing 4.88 kg (10.75 lb). Sauger were most abundant near the mouth, in section Ib, where they made up 13.1 percent of the total numbers captured. The largest sauger caught weighed 2.2 kg (4.9 lb).

SPECIES DIVERSITY

Measures of species diversity are another tool for the quantitative and qualitative description of a fishery. Investigations of longitudinal zonation in stream fishes reveal that, in relatively unpolluted systems, diversity increases downstream (Sheldon 1968), meaning the number of species increases with proximity to the river's mouth, as in the Tongue. Factors which determine the upstream limits of particular species also apparently contribute to the regulation of species diversity. A study by Tramer and Rogers (1973) found that variations in water quality upset the normal pattern of longitudinal zonation of fishes. Where streams are undergoing stress from pollution, species diversity may remain at levels similar to those in the headwaters throughout the entire system. The disappearance of some of the headwaters species is balanced by the appearance of others, and gains in the abundance of one species are canceled out by losses in another. Therefore, from baseline data, a change in water quality can be reflected by a change in species diversity. It is a generally accepted concept that a large-scale environmental stress exerted upon a diverse biological community results in a reduction in species diversity (Cairns 1969).

Species-diversity indices ($\bar{d}$) have been used by biologists to provide insight into the structure of natural communities and as indicators of qualitative aspects of their environments. A low diversity index indicates a largely monotypic community dominated by a few abundant species, and a high diversity index suggests a heterogeneous community in which abundance is distributed more evenly among a number of species. Redundancy (R) (see Report No. 5 in this series), also used as an index of the repetition of information within a community, expresses the dominance of one or more species and is inversely proportional to the abundance of the species (Wilhm and Dorris 1968).

While species-diversity indices have been used extensively with benthic macroinvertebrates to evaluate degradational environmental conditions, they have only recently been applied to fish populations (Sheldon 1968, Jackson and Harp 1973, and Harima and Mundy 1974). Shannon-Weaver diversity indices were calculated for the fall 1975 sample and combined sample of fall 1974 and fall 1975 (figure 4). The fall 1974 sample diversities were also plotted for comparison, but sections IIIa and Vb were omitted because they were not sampled in 1975. With the inclusion of more data, the diversity indices theoretically tend to the true population diversity, assuming no drastic change over time. All fish under 152 mm (6 in) were excluded from the sample to eliminate human sampling bias (the selection of the bigger fish when a choice occurs in sampling). Figure 5 shows the linear regressions between diversity indices (dependent variable) and the section (independent variable). Study section diversity indices increased with proximity to the river's mouth. In section Vc the index rise from 1974 to 1975 was attributed to a change in the number of fish/km (143 to 181) and a gain in the number of species (11 to 15). The probable reasons for these gains are two-fold: 1) prolonged high releases from the reservoir in 1975 are not characteristic of past flows and favor those species better adopted to fast-water habitats (mountain sucker and smallmouth bass); 2) inspections and drawdowns of the dam may have influenced the distribution patterns. The remaining sections had little change.

Tongue River diversities are similar in magnitude to those calculated for Rosebud Creek by Elser and Schreiber (1977). However, those on the Tongue River tended to be higher, ranging from 1.8 to 2.9, as compared to a range of 1.2 to 2.7 on Rosebud Creek.

SHOVELNOSE STURGEON

The shovelnose sturgeon (*Scaphirhynchus platorynchus*) is common in portions of the Mississippi, Missouri, and Ohio river drainages. Its distribution in the Missouri River has been limited by the construction of mainstem reservoirs (Held 1969). In Montana, the shovelnose is abundant in the mainstem of the Missouri below Great Falls and common in most of the larger primary and some secondary tributaries of this river (Brown 1971). Shovelnose are abundant in the Yellowstone River downstream from the Cartersville Diversion at Forsyth (Peterman and Haddix 1975). Anglers seek the

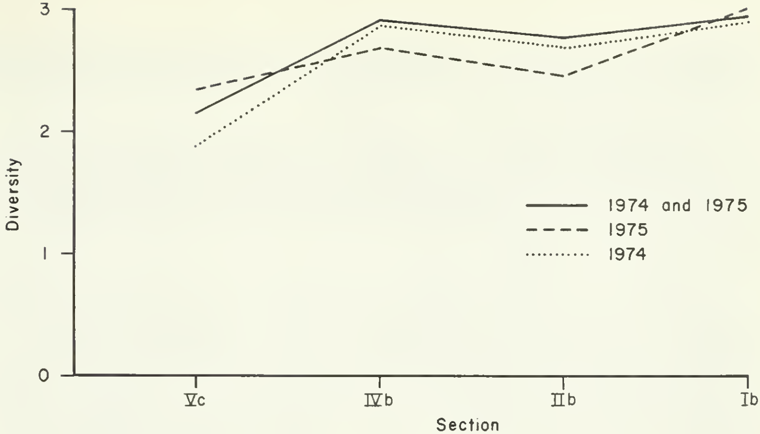


Figure 4. Comparison of diversity indices for 1974 (6 runs) and 1975 (3 runs) and combined fall sampling (9 runs) at each primary sampling station on the Tongue River.

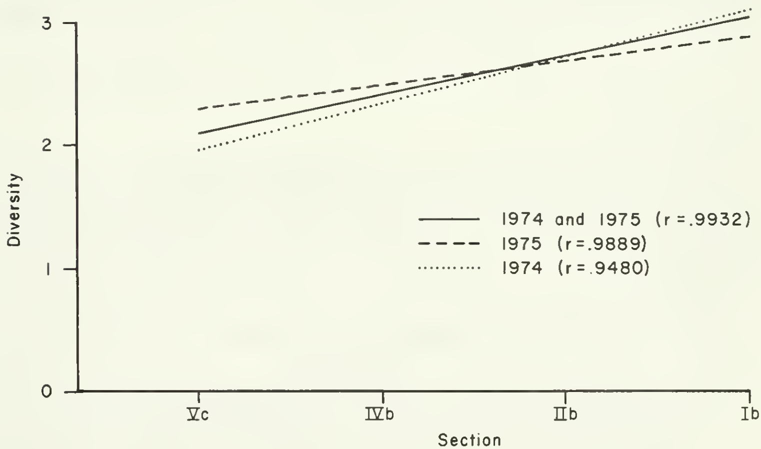


Figure 5. Comparison of the Shannon-Weaver diversity indices for 1974 and 1975 fall fish sampling in the Tongue River and the combined fall sampling at each of the primary sections excluding fish that were less than 150 mm in length.

shovelnose, but pressure is considered light. The Yellowstone River shovelnose offers an opportunity to evaluate the status of a relatively unfished population in an unregulated river.

Sampling during the spring of 1974 in the lower reaches of the Tongue River (downstream from the T&Y Diversion) produced a large number of shovelnose sturgeon. Gonadal development revealed that the fish were in spawning condition. Since previous sampling efforts in this reach of the river failed to produce sturgeon, it appeared that the fish were migrating into the Tongue to spawn.

In determining instream flow requirements for fish, if the life history requirements for a sensitive species are met, then requirements for less-sensitive species will also be met (Bovee 1974). The shovelnose sturgeon was selected as a sensitive species because of its migrational patterns and resulting passage and spawning flow needs. Passage flows are evaluated by identifying shallow bars which could become barriers to the passage of adult fish and determining the amount of water necessary to allow fish to pass (Thompson 1972). The spawning run of shovelnose into the Tongue provides an opportunity to investigate certain features of their life history and to evaluate the instream flow necessary to maintain their run.

The objectives of this segment of the study were to: (1) sample the shovelnose sturgeon spawning run into the lower Tongue River; (2) compare population strength with flow and temperature; (3) collect life history data on lengths, weights and sexes; (4) tag fish to aid in future studies to evaluate migrational patterns, delineate home range, and determine fisherman harvest.

FISH SIZE

Length Frequency

Fork lengths of sturgeon captured in the Tongue River in 1975 and 1976 are shown in table 5. Half of the fish sampled in 1975 fell in the range 710-785 mm (28.0-30.9 in). The size interval 725-800 mm (28.5-31.5 in) contributed 52.0 percent of the total sample in 1976. The average size and size range of shovelnose sturgeon taken in the Tongue were larger in 1976 than in 1975 (figure 6).

TABLE 5. Fork lengths of shovelnose sturgeon captured in the Tongue River in 1975 and 1976.

	Number of Fish Sampled	Fork Lengths (mm)		
		Range	Average	Mode
1975	776	625-917	752	710-730
1976	875	571-948	764	750-775

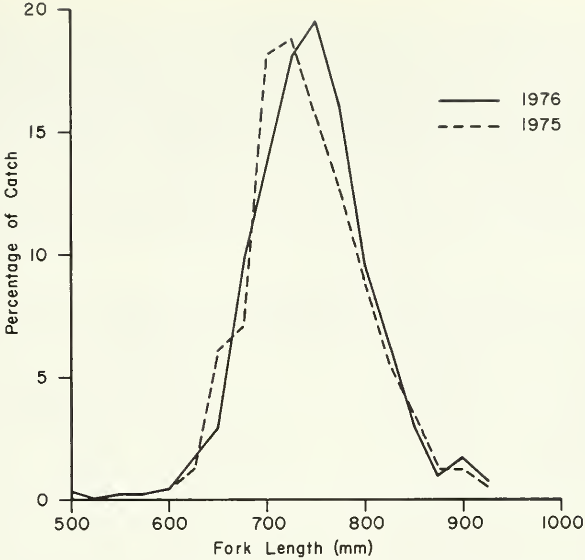


Figure 6. Comparison of the 1975 and 1976 shovelnose sturgeon fork length frequencies (by percentage of catch) in the Tongue River.

In 1974, 427 shovelnose sturgeon captured in the Tongue River were measured by Peterman and Haddix (1975). Since total lengths rather than fork lengths were recorded in 1974, their results were converted by the regression formula:

$$TL = 110.109 + 0.938 \; FL$$

where all measurements are in millimeters. The fork length range in 1974 was 449 mm (17.7 in) to 969 mm (38.1 in) with an average length of 700 mm (27.6 in).

The length frequency of shovelnose sturgeon sampled downstream from the Intake Diversion on the Yellowstone River in the spring of 1975 was plotted and compared to the Tongue River sample for the same time period (Peterman and Haddix 1975). Yellowstone River sturgeon ranged from 287-815 mm (11.3-32.1 in), with an average length of 508 mm (20.0 in). More than 50 percent of the sample fell in the size class 330-480 mm (13.0-19.0 in) with the modal interval of 386-404 mm (15.2-15.9 in). The length-frequency distribution of the Tongue River sample is compared to the Intake sample in figure 7. Sturgeon collected in the Tongue were considerably larger than those collected at Intake. Additionally, the length distribution is much wider for the Intake sample than the Tongue River sample, which was taken from a spawning population and is not representative of the entire population; the Intake sample was from the total population. The average length of shovelnose migrating into the Powder River was 761 mm (30.0 in), comparable to those sampled in the Tongue River (Rehwinkel et al. 1976).

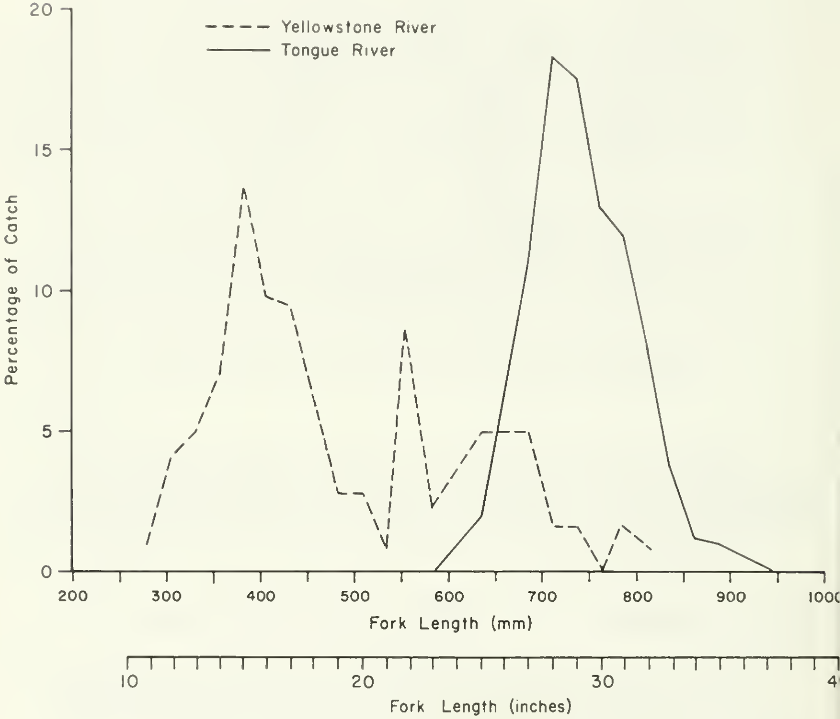


Figure 7. Comparison of the fork length frequencies of shovelnose sturgeon taken in the Tongue River with those taken in the Yellowstone River at Intake in the spring of 1975.

Weight Frequency

Table 6 gives weights of sturgeon captured in 1975 and 1976. Of the sturgeon examined in 1975, 23.7 percent exceeded 2.7 kg (6 lb), 7.6 percent exceeded 3.6 kg (8 lb), and 1.6 percent exeeded 4.5 kg (10 lb). In the 1976 sample, 21.6 percent exceeded 2.7 kg (6 lb), 6.7 percent exceeded 3.6 kg (8 lb), and 1.8 percent exceeded 4.5 kg (10 lb). The weights of the 1974 run were similarly distributed (Peterman and Haddix 1975). A sample of sturgeon migrating into the Powder River averaged 2.42 kg (5.33 lb), showing close agreement with the Tongue River samples (Rehwinkel et al 1976). Figures 8 and 9 are weight-frequency histograms of sampling in 1975 and 1976, respectively.

TABLE 6. Weights of shovelnose sturgeon captured in the Tongue River in 1975 and 1976

	Number of Fish Sampled	Weight (kg)		
		Range	Average	Mode
1975	709	0.98-6.02	2.48	1.80-2.25
1976	875	0.73-5.93	2.34	1.7 -2.2

Shovelnose sturgeon captured in the Tongue River during the spring migration were considerably larger than those reported elsewhere. In the lower Missouri River, the average weight was 0.45 kg (1.0 lb), with 1.8 kg (4.0 lb) fish considered rare (Schmulback 1974); Helms (1974) found that the average weight of Mississippi River shovelnose was about 1.1 kg (2.5 lb). Brown (1971) reported that 4.5 kg (10 lb) was considered maximum shovelnose weight and that 3.2 kg (7.0 lb) was the Montana record. While the Tongue River sample is of a spawning population, the presence of considerably larger fish appears significant.

Length-Weight Relationship

The length-weight relationship was calculated for 874 shovelnose sturgeon, utilizing the formula (Ricker 1975):

$$w = Cl^x$$

where: w = weight in grams

l = length in millimeters

C, x = constants

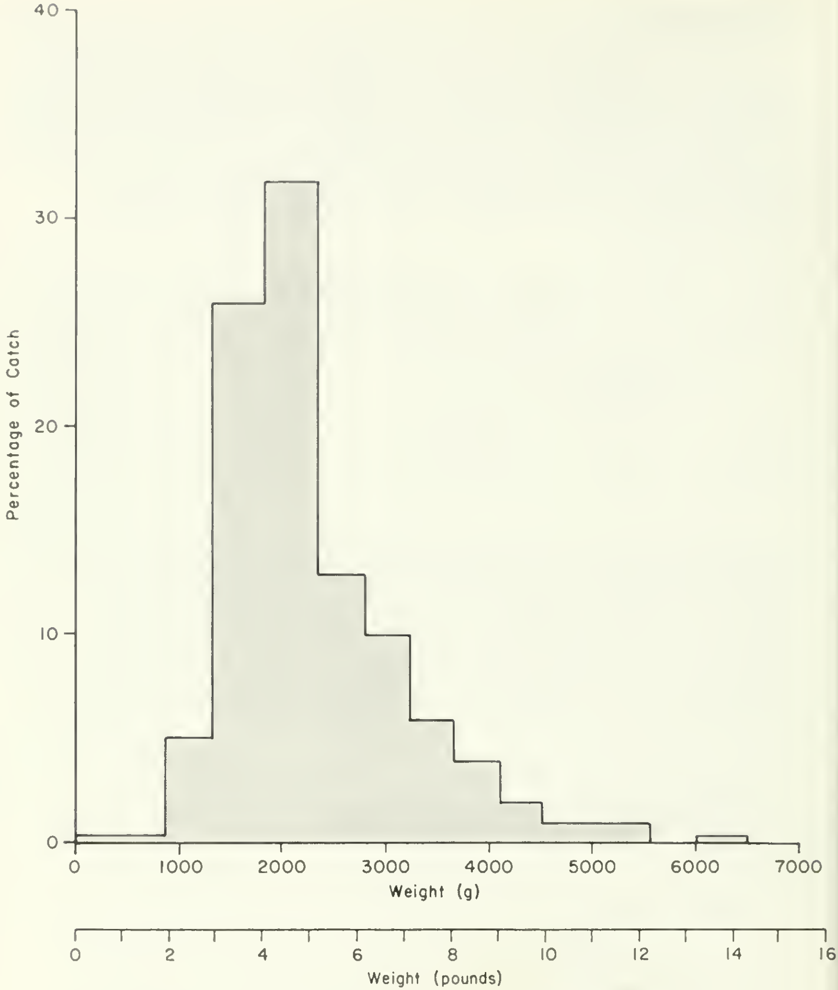


Figure 8. Weight-frequency histogram of the shovelnose sturgeon collected in the spring of 1975 in the Tongue River.

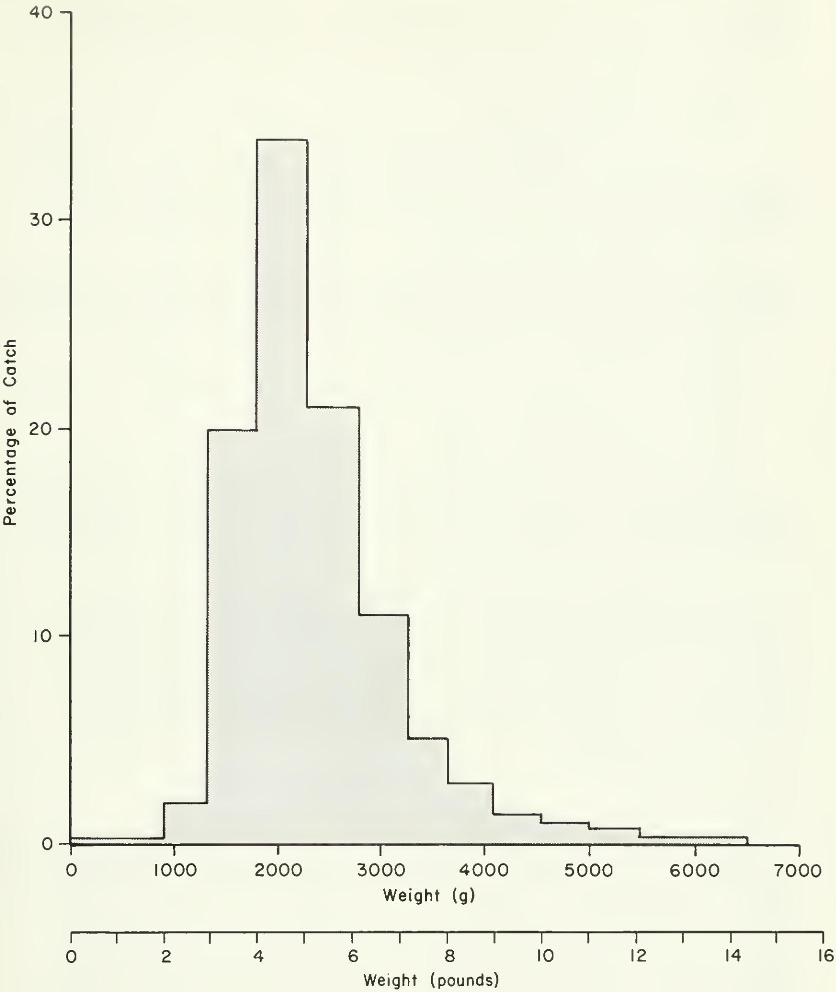


Figure 9. Weight-frequency histogram of the shovelnose sturgeon collected in the spring of 1976 in the Tongue River.

The following equation, with a correlation of $r = 0.8355$ (figure 10), was derived:

$$\log w = 3.3439 \log fl - 6.2839$$

where: w = weight in grams

fl = fork length in millimeters

Zweiacker (1967) found a length-weight relationship for Missouri River shovelnose sturgeon of:

$$\log w = 2.79128 \log fl + 0.68145$$

Helms (1974) reported the length-weight relationships of two pools (17 and 19) on the Mississippi River to be, respectively:

$$\log w = 3.526 \log fl - 2.2632$$

and

$$\log w = 3.083 \log fl - 2.3136$$

All the above length-weight relationship equations have similar slopes; the major difference between the Tongue River equation and the others is the constant, which is indicative of the larger size of the population migrating into the Tongue River to spawn.

A size difference was shown between males and females. Males were smaller, averaging 738 mm (29.1 in) with a range of 523-864 mm (21.0-34.0 in) in 1975 and 760 mm (29.9 in) with a range of 592-934 mm (23.3-36.7 in) in 1976. In 1975, females averaged 806 mm (31.7 in), ranging from 688 mm to 937 mm (27.1 to 36.9 in); in 1976, they averaged 832 mm (32.8 in), ranging from 592 mm to 934 mm (23.3-36.7 in). Weight differences were more apparent, with males averaging 1.95 kg (4.30 lb) in 1975 and 2.17 kg (4.78 lb) in 1976, while females averaged 3.20 kg (7.05 lb) and 3.62 kg (7.97 lb), respectively.

Size at Maturity

Since sexual dimorphism is absent in shovelnose sturgeon, sex determination was accomplished in two ways. Slight pressure exerted on the abdomen produced milt or eggs if the fish were nearing spawning condition. If reproductive products were not produced, sex was distinguished by dist nsion of the ovarian region and by the swelling of the ovipositor. If none of the criteria were met, fish were recorded as undesignated sex. These methods have been used to determine sex rations for other species (Snow 1963 and Casselman 1974). Observed sex ratios for males, females, and undesignated were 46.9, 12.9, and 40.2 percent, respectively, in 1975, and 63.6, 8.4, and 28.0 percent respectively, in 1976. The high incidence of undistinguishable fish probably tends to mask the true sex ratio. However, it appears that more males enter the run than females, a situation also true of paddlefish (Elser 1976).

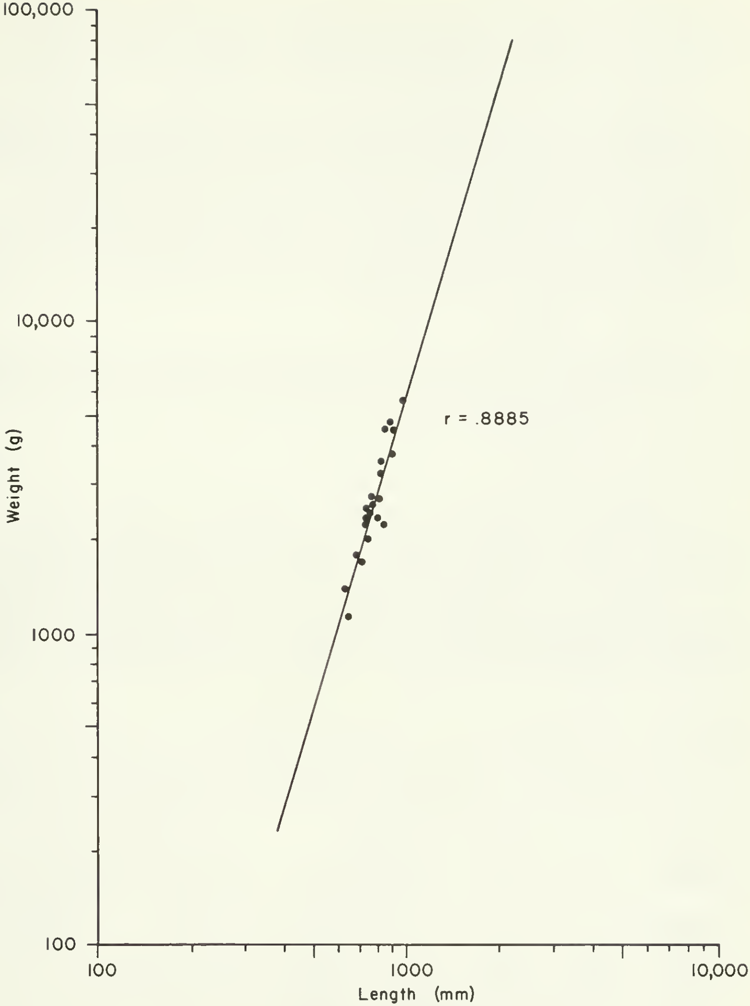


Figure 10. The length-weight relationship equation of all shovelnose sturgeon collected in the spring of 1976 in the Tongue River.

The minimum lengths of ripe male and female shovelnose were 523 mm (20.6 in) and 688 mm (27.1 in), respectively, in 1975 and 592 mm (23.3 in) and 743 mm (29.3 in), respectively, in 1976. Other workers have also reported male shovelnose sturgeon maturing at a smaller size than females (Christenson 1975 and Helms 1974).

Theoretically, a fish should lose weight after spawning. A straight-line relationship of weight at recapture versus weight at tagging would intersect the equilibrium (no weight lost or gained) at the maturity size, providing the fish were tagged prior to spawning and recaptured after spawning. Weights from shovelnose tagged in 1975 (x) were plotted against weights at recapture in 1976 (y) after spawning had occurred. Since only males could be positively identified both years, their weights were plotted (figure 11). The intersection of the growth line and the equilibrium line was at 850 g. Using the length-weight relationship of:

$$\log w = 3.3439 \log fl - 6.2839$$

a fork length of 569 mm at maturity was derived for males. This corresponds closely with the 561 mm reported for the Red Cedar and Chippewa river systems of Wisconsin (Christenson 1975).

POPULATION ESTIMATE

The estimated numbers of shovelnose sturgeon per kilometer of Tongue River sampled in 1975 and 1976 were similar using all three estimators (table 7). Since confidence interval overlap was evident between estimates of the same year and between different years, the differences do not appear to be significant. The Chapman estimator resulted in the lowest estimate, but also had narrowest confidence intervals. The largest estimate resulted from the Schumacher-Eschmeyer formula. While all requirements for a valid population estimate were not met, the close agreement of the Tongue River estimates suggests a valid estimate.

TABLE 7. Estimated number of shovelnose sturgeon per km of the Tongue River, 1975 and 1976.

	1975		1976	
Estimator	N/km	95% CI[a]	N/km	95% CI[a]
Schnabel	409.4	327.3-546.6	482.8	405.8-596.8
Schumacher-Eschmeyer	417.1	323.7-585.9	537.2	449.7-667.0
Chapman	402.8	388.0-418.8	478.6	402.3-590.5

[a] CI = confidence interval

TIME OF SPAWNING

In 1975, the first sturgeon was collected on May 9, with large concentrations appearing around May 21 (figure 12). The last sturgeon was collected on August 7, although sampling continued until August 10. The first ripe male (one from which milt could be stripped) was taken on June 3; no ripe females were caught in 1975. Internal examination of two sturgeon on July 10 revealed a few black eggs remaining in the body cavity. It was assumed that these fish had spawned in the Tongue River.

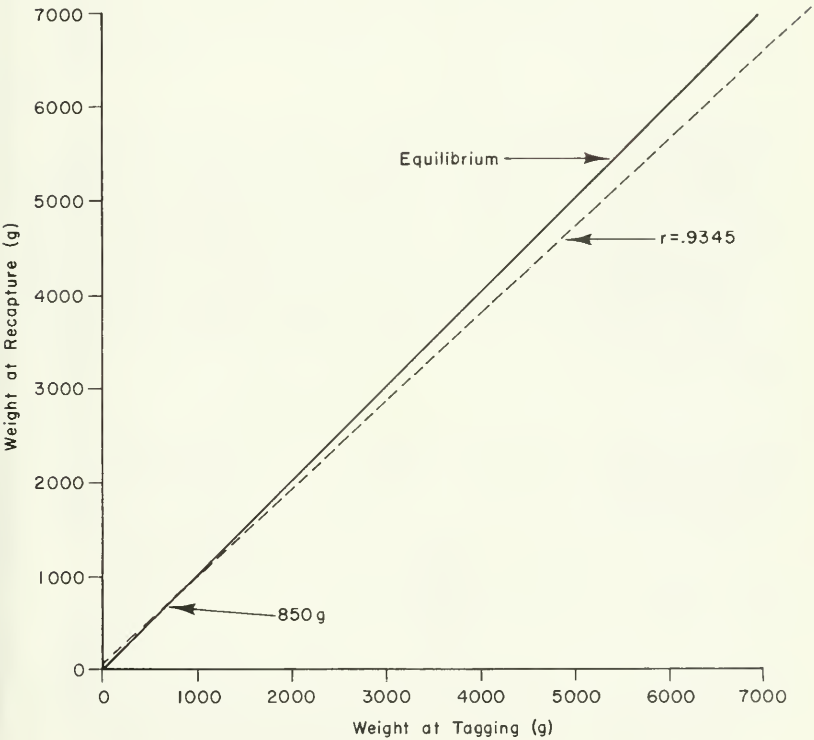


Figure 11. Linear regression analysis of the weight at tagging (before spawning) compared with the weight at recapture (after spawning) of shovelnose sturgeon in the Tongue River.

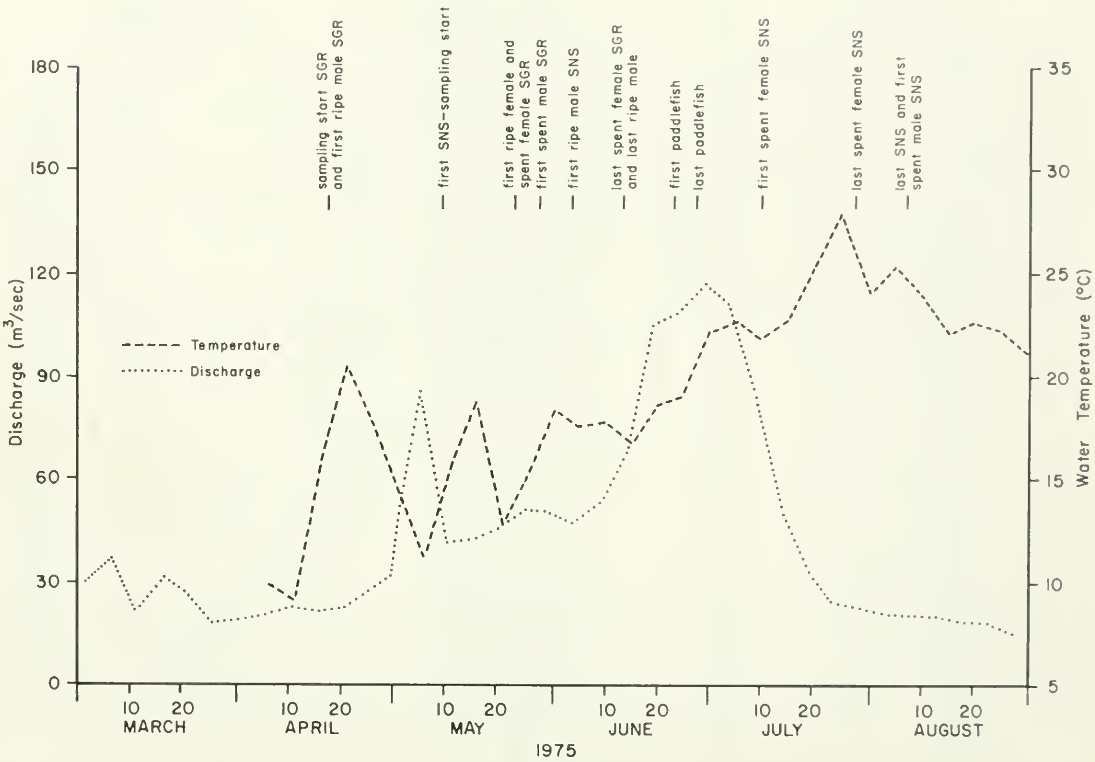


Figure 12. Five-day average temperatures (°C) and discharges in relation to the spawning activities of the shovelnose sturgeon and sauger in the spring of 1975 in the Tongue River.

The first shovelnose was collected on April 22 in 1976; large concentrations appeared on May 7 (figure 13). Sampling continued until July 27, but the last sturgeon was taken July 15. The first ripe male was collected on June 2 and the first ripe female on June 7. The last spent female was caught on June 29, but other females were taken after this date that had neither spawned nor were ready to spawn.

Spawning occurs in the Tongue River from early June until mid-July. In the Red Cedar River, Wisconsin, Christenson (1975) reported that shovelnose sturgeon spawned from the last week of May through the first week of June. Mississippi River sturgeon spawned from May 30 through June 14 (Helms 1974). Rehwinkel et al. (1976) reported the first 1976 sturgeon in the Powder River was taken on April 13 with the farthest upstream migrant taken on May 13. No ripe sturgeon were collected on the Powder River.

HABITAT PREFERENCE

Depth

The gill net used in sampling was marked off in three-meter intervals; the number of fish taken in each segment was recorded. One end of the net was always kept close to the shore. In a selected reach with a uniform bed, 85 shovelnose were taken throughout the season. The catch rate per net section was plotted against the bed profile (obtained from WSP) to determine depth preference (figure 14). The majority (61.2 percent) of the fish were taken from the more gently sloping edge of the stream 15 to 21 m (49 to 69 ft) from the shore. The mode of the sturgeon catch occurred at the thalweg. Depth preferred by the fish ranged from 0.43 m (1.4 ft) to 0.90 m (3.0 ft), with an average of 0.67 ±0.17 m (2.2 ±0.6 ft). These depths correspond to those found by Bovee (1976) for shovelnose sturgeon.

Discharge

Daily sturgeon catches were totaled for each week of the sampling season. To evaluate the catch rates in relation to discharge, two catch-per-effort rates were calculated.

1) The total catch for each week was divided by the length of river sampled during that week, resulting in the number of fish taken per km.

2) The week's catch was divided by the total number of sampling efforts made that week, producing the number of fish caught per trip.

Both catch rates were averaged over the week to avoid sectional bias, since one to three sections were sampled during any week. Optimum flow conditions were evaluated in terms of the catch rates; as Zakharyan (1972) showed, the scale of spawning depends on the number of fish taking part.

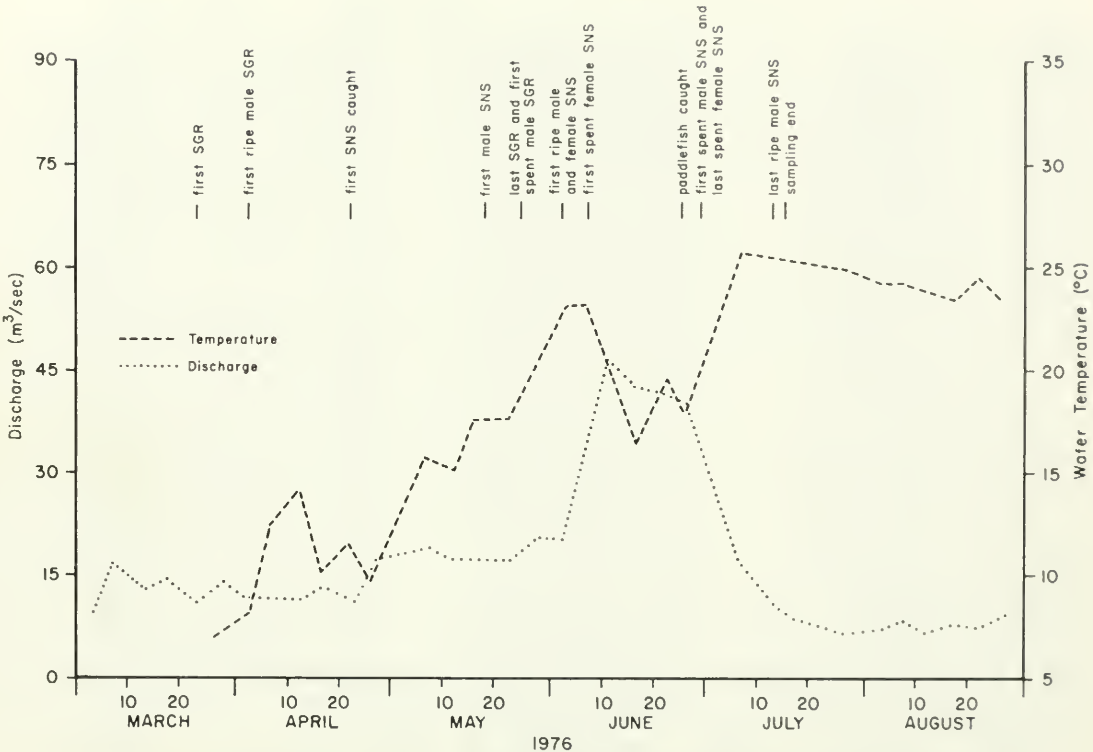


Figure 13. Five-day average temperatures (^{O}C) and discharges in relation to the spawning activities of the shovelnose sturgeon and sauger in the spring of 1976 in the Tongue River.

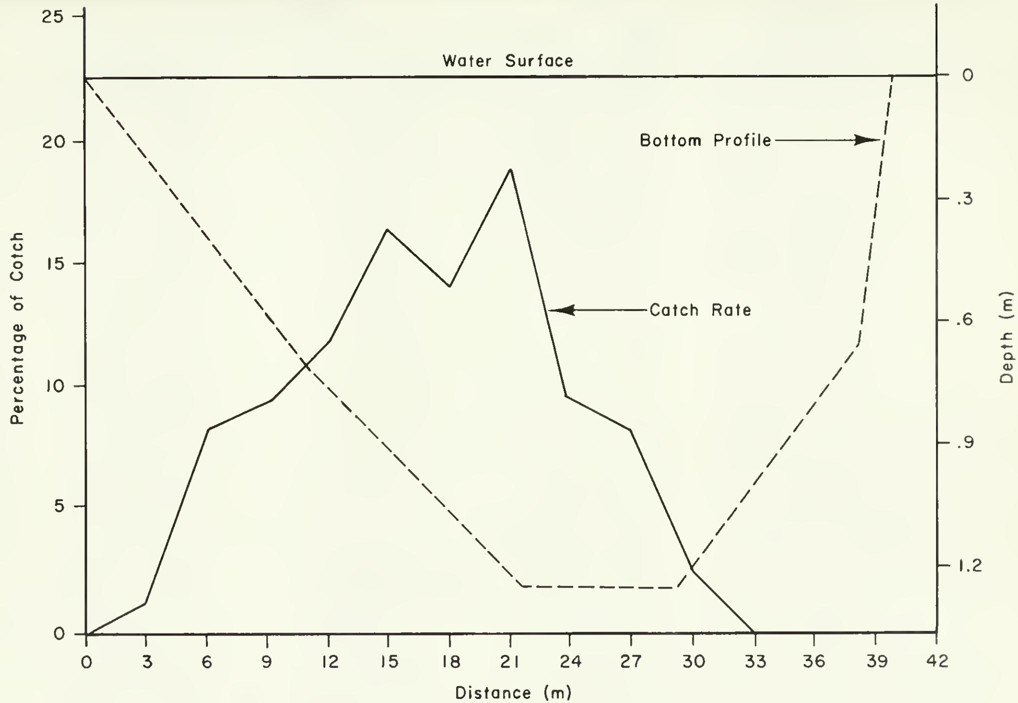


Figure 14. Comparison of the catch rates of shovelnose sturgeon with the bottom profile of the river channel for one reach of the Tongue River.

A quadratic regression was run with catch rates plotted against the average weekly discharge using the model:

$$Y = a_0 + a_1 x + a_2 x^2$$

where a_0, a_1, and a_2 are constants

This regression produces a hyperbola.

The graphs for the 1975 sturgeon run, depicted in figure 15, show that the optimum discharge for shovelnose sturgeon was between 65 m^3/sec (2300 cfs) and 68 m^3/sec (2400 cfs). Plotting discharge frequency for 1975 reveals that the most sturgeon were taken in the interval 34 m^3/sec (1200 cfs) to 45 m^3/sec (1600 cfs). The two discharge figures differ because the optimum is based on catch rates at predicted flows from the regression model and the second interval on the total number of fish caught at each flow. Sampling bias produced by varying section lengths resulted in the difference between the two discharge figures.

In 1976, the optimum discharges for the linear and trip catch rates were 30.90 m^3/sec (1090 cfs) and 34.91 m^3/sec (1233 cfs), respectively (figure 16). The majority (56.5 percent) of the sturgeon in the discharge frequency histogram were taken at discharges between 11.3 m^3/sec (400 cfs) and 22.7 m^3/sec (800 cfs). Runoff patterns for the years 1975 and 1976 differed, with 1975 considered a high water year. No sturgeon were taken either year when flows fell below 8.50 m^3/sec (300 cfs). Sampling efficiency decreased noticeably when flows exceeded 62.29 m^3/sec (2200 cfs) because the sampling equipment was more difficult to operate in higher flows.

Based on the quadratic regressions, it appears that a minimum flow of 8.50 m^3/sec (300 cfs) is necessary to provide shovelnose sturgeon passage. The upper limit was not estimated due to the decreased sampling efficiency at greater flows. The quadratic regression was utilized because, for any environmental condition, there is typically an intermediate range, with less favorable conditions above and below (Ricker 1975). For example, there may theoretically be flows too low or too high for successful migration; the optimum is intermediate.

Temperature

The linear and trip catch rates (dependent variables) of sturgeon were compared with the five-day average minimum and maximum water temperatures (independent variables) using the quadratic regression model described above. The graphs for the 1975 shovelnose run (figure 17) show an optimum minimum temperature of 18.3°C (65°F) for the linear catch rate and 16.9°C (62.5°F) for the trip catch rate. The optimum maximum temperatures for the linear and trip catch rates were 20.0°C (68°F) and 18.3°C (60.5°F), respectively. In 1976 the minimum linear and trip catch rate averages

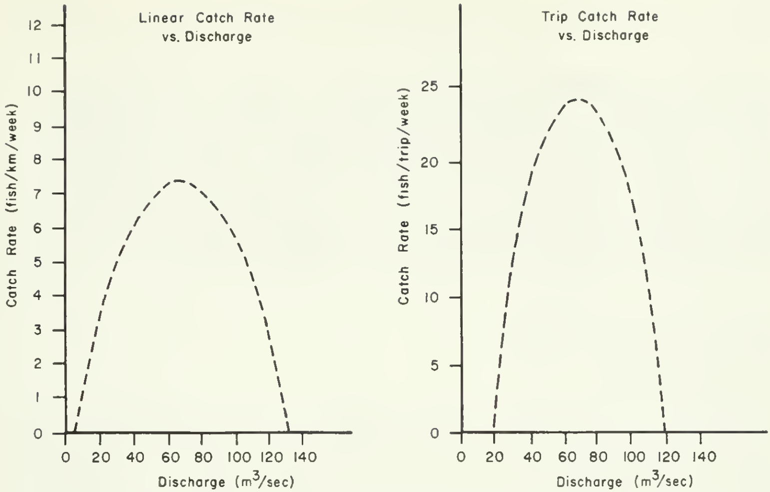


Figure 15. Quadratic regression analysis of discharge versus catch rates of shovelnose sturgeon in the Tongue River in the spring of 1975.

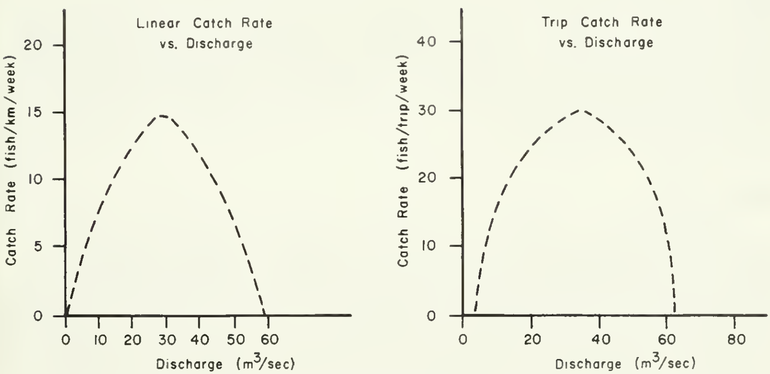


Figure 16. Quadratic regression analysis of discharge versus catch rates of shovelnose sturgeon in the Tongue River in the spring of 1976.

were 17.9°C (64.2°F) and 17.7°C (63.9°F), respectively (figure 18). Maximum temperatures were 21.2°C (70.2°F) and 21.5°C (71.7°F), respectively.

Therefore, the optimum temperature range for spawning of shovelnose sturgeon is between 16.9°C (62.5°F) and 21.5°C (70.7°F). The majority of the sturgeon were captured at temperatures from 18.9°C (66°F) to 25.6°C (78°F). Brown (1971) stated that shovelnose sturgeon spawn in Montana at temperatures between 15.6°C (60°F) and 21.7°C (70°F). This corresponds closely with the temperatures found in the Tongue River. In the Powder River the peak of the shovelnose sturgeon run occurred at 16°C (60.8°F); however, these fish were not considered ripe (Rehwinkel et al, 1976). Christenson (1975) found sturgeon spawning occurred in the Red Cedar River of Wisconsin at temperatures between 19.4-21.1°C (67-70°F).

SAMPLING AND TAGGING STUDIES

Egg and Fry Sampling

Egg and fry samples were taken at least once each week during the shovelnose sturgeon run in 1975 and 1976 by holding a fine mesh drift sampler in the current for 30 seconds. Three riffle areas were sampled and a drift taken at 10 m intervals across each riffle. Material collected in the net was sorted and washed at the time of collection. Samples were then preserved in 10 percent formalin and hand picked with the aid of a microscope. A few eggs and small fish were taken, but none were positively identified as shovelnose sturgeon.

Several attempts were made to artifically propagate shovelnose sturgeon. In one attempt, eggs were stripped from a ripe female, fertilized by one male, and incubated in a jar, agitated by air circulating through the eggs. Second, several sturgeon were held at the Miles City National Fish Hatchery until they were considered gravid. Eggs were stripped into a pan and milt added. Half of the eggs remained stationary and the otherhalf were stirred for 30 minutes, allowing the eggs to water harden. Both batches were then placed in hatching jars and kept moving to provide oxygenation. Eggs were cleared with glacial acetic acid to check on development. Because no development was apparent in either attempt, it was assumed that the eggs were not successfully fertilized.

Tagging Studies

Weight Losses. In 1975, 28 fish that had been tagged in 1974 with monel tags were recaptured. The monel tag returns demonstrated a significant weight loss of 0.36 kg (0.79 lb) per fish ($p \leq .001$). Eight sturgeon (4.5 percent) tagged with anchor tags in 1974 and recaptured in 1975 showed a weight gain of 0.36 kg (0.79 lb) per fish ($p = 0.015$). In the 1975 sampling, 7.9 percent (14 of 178) of the anchor-tagged fish and 12.8 percent (31 of 243) of the monel-tagged fish were returned from 1974. (Only 28 monel-tagged fish were recaptured; three of them were recaptured twice, producing a total of 31 recaptures.) Total returns in 1975 were 10.7 percent (45 of 421) of those fish tagged in 1974.

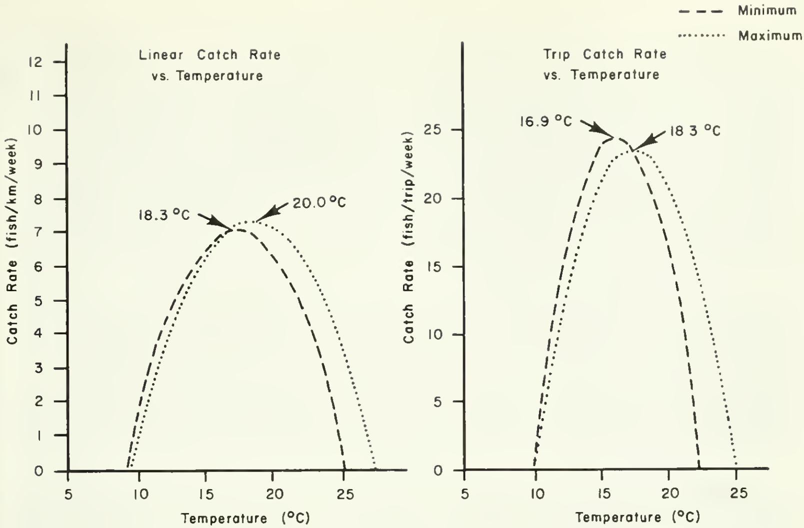


Figure 17. Quadratic regression analysis of minimum and maximum water temperatures versus catch rates of shovelnose sturgeon in the Tongue River in the spring of 1975.

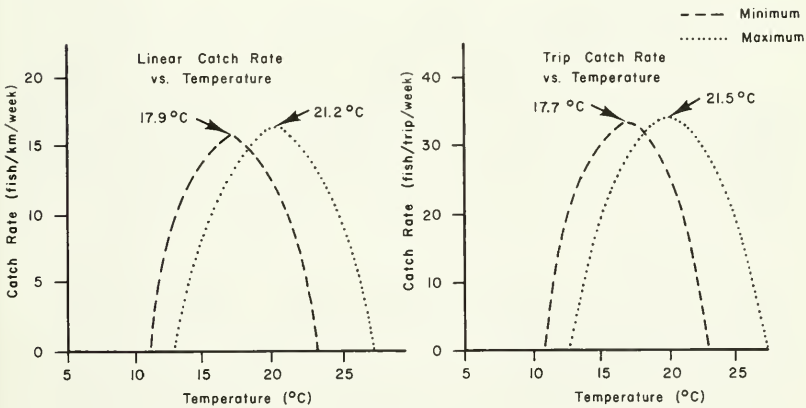


Figure 18. Quadratic regression analysis of minimum and maximum water temperatures versus catch rates of shovelnose sturgeon in the Tongue River in the spring of 1976.

Twenty-one fish (8.6 percent of the total sample) that had been tagged in 1974 with monels were recaptured in 1976. A weight loss of 0.62 kg (1.37 lb) per fish ($p = 0.19$) was demonstrated. Monel tags were not used in 1975; however, by considering the weight at recapture in 1975 as the tagging weight, weight loss or gain from 1975 to 1976 could be determined. Thus, monel-tagged fish lost an average of 0.10 kg (0.22 lb) per fish ($p = 0.05$) from 1975 to 1976. Twenty-two sturgeon (3.1 percent of total) tagged with the anchor tag in 1975 and recaptured in 1976 displayed a significant weight gain of 0.06 kg (0.13 lb) per fish ($p = 0.01$). Total returns in 1976 were 9.4 percent (67 of 709) of those tagged in 1975. The 1975 and 1976 rates of return are comparable.

The regression plot of weight at recapture versus weight at tagging reveals the significance of the weight loss or gain associated with the two tagging methods (figure 19). All regression lines for anchor-tagged fish fell above the equilibrium line (that line showing no weight gain nor loss), indicating that fish gained weight over the period shown. Monel-tagged sturgeon fell below the equilibrium line, suggesting weight loss over the time period. It is apparent that the monel tag caused a physiological stress in the sturgeon which resulted in a significant weight loss.

Movement. Of the 94 shovelnose sturgeon tagged and recaptured in 1976, the majority were recaptured in the same section in which they had been tagged. Time between tagging and recapture ranged from 1 to 60 days. The sampling period was stratified into monthly segments to detect differences in movement with time. As shown in table 8, upstream movement was greater than downstream movement in May and June. The differences were not considered significant because of the small sample size. In July, upstream and downstream movements were nearly equal.

In 1975, 90 percent (45 of 50) of the sturgeon tagged and recaptured that year showed no detectable movement. Six percent (3 of 50) showed upstream movement, while 4 percent moved downstream.

Comparisons were made between tagging locations and recapture location for fish recaptured in subsequent years. A fish was considered to be in a different location if there was a difference greater than 1.6 km (1 mi). No sturgeon tagged in 1974 and recaptured in 1975 was recaptured downstream from where it was tagged (table 9), and of those fish tagged in 1974 and recaptured in 1976, the majority (89.2 percent) were recaptured either upstream or in similar locations to where they were tagged. From 1975 to 1976, the sturgeon exhibited a strong tendency to return to the same place (75.0 percent).

Angler Returns. The shovelnose sturgeon provides an excellent spring fishery for those anglers who pursue them. Returns of tagged sturgeon by fishermen show a light harvest (table 10). Returns of 1974-tagged fish totaled 1.67 percent by 1975; 1975-tagged fish were returned at a rate of 1.41 percent (0.71 percent/year). Overall returns totaled 1.11 percent, indicating a lightly-utilized resource. An exploitation rate of 5.0 percent was considered an acceptable level for lake sturgeon on the Menominee River in Wisconsin (Priegel 1973). The lake sturgeon is a slow-growing, late-maturing fish which does not survive high levels of exploitation. The current exploitation rate for shovelnose sturgeon on the Tongue River is not excessive.

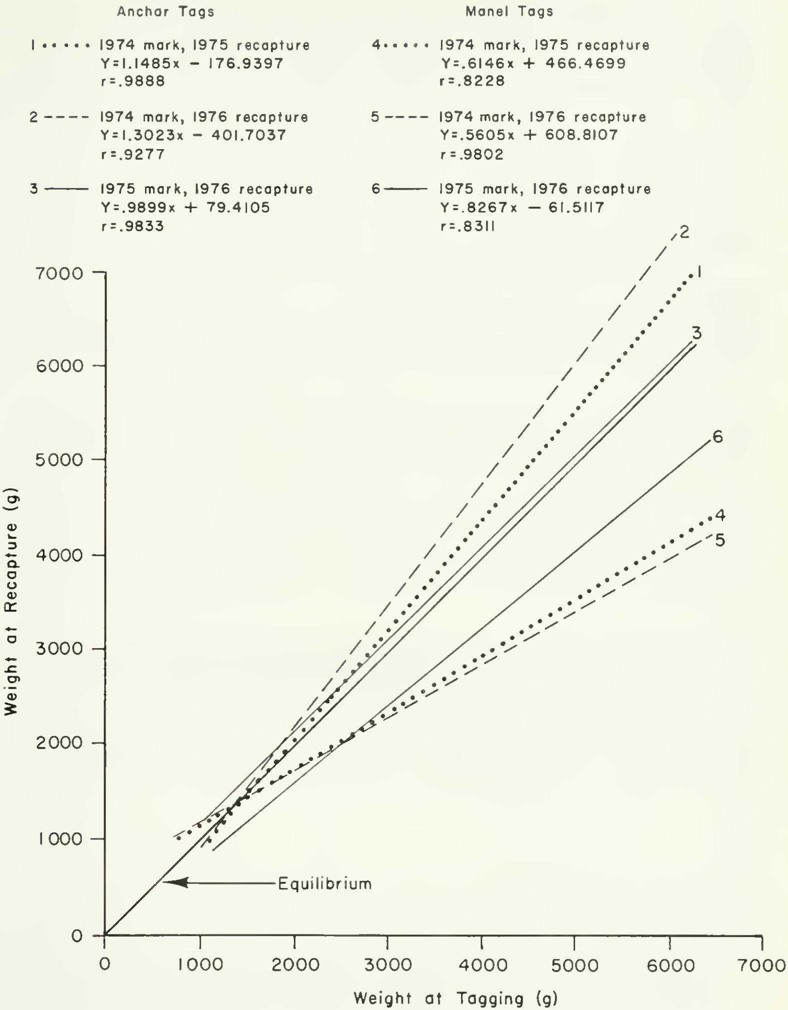


Figure 19. Comparison of the linear regression analysis of the weight at tagging versus the weight at recapture of monel- and anchor-tagged sturgeon over the three years of sampling in the Tongue River.

TABLE 8. Percentage and direction of shovelnose sturgeon movement for May, June, and July 1976 in the lower Tongue River

Month of Recapture 1976	Sample Size	Upstream Movement		Downstream Movement		No Movement
		1.6-6.4 km	6.4 km	1.6-6.4 km	over 6.4 km	
May	19	36.8	0.0	10.5	0.0	52.7
June	65	16.9	3.1	10.8	1.5	67.7
July	10	16.7	8.3	16.7	8.3	50.0

TABLE 9. Difference between place of tagging and recapture for shovelnose sturgeon in the lower Tongue River, 1974-76, expressed as percentage.

Year		Sample Size	Percentage Recaptured		
Tagged	Recaptured		Downstream	Same	Upstream
1974	1975	37	0.0	43.2	56.8
1974	1976	37	10.8	37.8	51.4
1975	1976	88	20.5	75.0	4.5

TABLE 10. Summary of tagged shovelnose sturgeon from the Tongue River returned by anglers, 1974-1976.

Year Tagged	Number	Year Returned			
		1974	1975	1976	Total
1974	420	3	4	0	7 (1.67%)
1975	709		9	1	10 (1.41%)
1976	761			4	4 (0.53%)
TOTAL	1890				21 (1.11%)

One angler who kept a log in 1975 caught 152 shovelnose, of which 10 (6.6 percent) had been tagged. Of the 80 kept and dressed, about 90 percent were females.

Growth. During the 1975 and 1976 spawning runs, 151 sturgeon were recaptured after having been at large 12 to 24 months. Empirical growth rates were divided into years and types of tags to assess differential growth rates as related to type of tagging. Sturgeon tagged with anchor tags lost an average of 1.5 mm (0.06 in) from 1974 to 1975 and gained an average of 2.2 mm (0.2 in) from 1975 to 1976 and 1.4 mm (0.06 in) in length from 1974 to 1976. Only the gain from 1975 to 1976 was significant ($p < .02$).

Shovelnose sturgeon tagged with monel tags showed significant length loss for each year. Fish tagged in 1974 and recaptured in 1975 lost an average 7.0 mm (0.3 in) while those tagged in 1975 and recaptured in 1976 lost an average of 5.2 mm (0.2 in). Average loss from 1974 to 1976 was 8.0 mm (0.3 in). All losses were significant ($p < .01$). Apparently the monel tag resulted in physiological change drastic enough to alter the growth rate of the sturgeon.

No conclusions could be made concerning the growth of shovelnose sturgeon based on individually marked fish because of the weight loss associated with the use of monel tags.

SAUGER

Sauger (*Stizostedion canadense)* and walleye *(Stizostedion vitreum)* are important to the sport fishery of the lower Yellowstone River. Native to Montana, the sauger inhabits the Missouri River drainage below Great Falls and the Yellowstone drainage below Billings. It was first recorded in Montana by the Lewis and Clark Expedition (1804-1806). Preferred habitat for sauger includes turbid rivers and shallow portions of lakes and reservoirs. Sauger generally spawn in gravelly or rocky areas in the spring when temperatures reach 4.4-10.0°C (40-50°F). Fish migrate upstream to spawn, often moving into tributary streams.

A sauger spawning run occurs in the Tongue River, with fish moving out of the Yellowstone in the spring. This migratory population offers an excellent opportunity for anglers to pursue the sauger. Sampling in the spring of 1974 indicated that large numbers of fish enter this run. Early high water, coupled with above-normal sedimentation, prevented good sampling in 1975. However, in 1976, a mild spring provided good sampling conditions, and a large sample was collected.

FISH SIZE

Length-Weight Relationship

In 1976, 1004 sauger were taken in the lower Tongue River. Lengths and weights were recorded for 1001 of these. The average length and weight of the total sample was 379 mm (14.9 in) and 441 g (0.97 lb), respectively. Sexes were differentiated by the presence of milt for males and/or a distended abdomen and protruding ovipositor for females. Ripe males were common in the sample, but no ripe females were taken. Males dominated the sample, contributing 85.7 percent, while females added 3.2 percent. The remaining 11.1 percent were of undetermined sex. Females were larger than males, averaging 454 mm (17.9 in) in length and weighing 1044 g (2.30 lb) while males averaged 374 mm (14.7 in) and 409 g (0.9 lb). Sauger taken in gill nets from five sampling areas of the lower Yellowstone River exhibited similar length and weight distributions (Peterman and Haddix 1975).

The weight-frequency distribution of the 1976 sauger sample is shown in figure 20. The peak of the sample occurred at 300 g (0.66 lb), with the greatest abundance falling in the size class 200-350 g (0.44-0.77 lb). Sauger length-frequency distribution for 1976 is shown in figure 21. Lengths ranged from 250 mm (9.8 in) to 545 mm (21.5 in) with the peak occurring at 375 mm (14.8 in). Three age classes were evident, and scale samples showed these ages to be IV (320 mm total length), V (375 mm total length), and VI (430 mm total length).

Using the 1001 lengths and weights and computing a linear regression on the Log_{10} of the weight (dependent variable) and Log_{10} of the length (independent variable), the resulting equation is:

$$\text{Log } w = 3.3438 \log tl - 6.016$$

with a correlation of $r = 0.9577$ (figure 22). The length-weight equation for 1,501 sauger from Lake Winnebago, Wisconsin (Priegel 1969) was:

$$\text{Log } w = 3.1309 \log l - 2.5091$$

Age and Growth

Scales from 274 sauger taken during the spring of 1976 were analyzed for age and growth. Ages ranged from three to nine years, with age group IV the dominant age (32.5 percent). Age groups IV, V, and VI made up 73.4 percent of the total sample (table 11). Growth rates for the sauger collected in the Tongue River are slower than those observed in other northern waters (table 12). The Tongue River sauger were collected in the spring; growth rates in other rivers may have allowed more of the season for additional growth.

TABLE 11. Age and mean length of sauger taken in the Tongue River, spring of 1976

Age	Number of Fish	Mean Length (mm)	Range (mm)
III	26	289	259-312
IV	89	332	277-385
V	62	374	332-404
VI	50	418	387-443
VII	31	444	419-475
VIII	12	478	453-565
IX	4	544	504-573

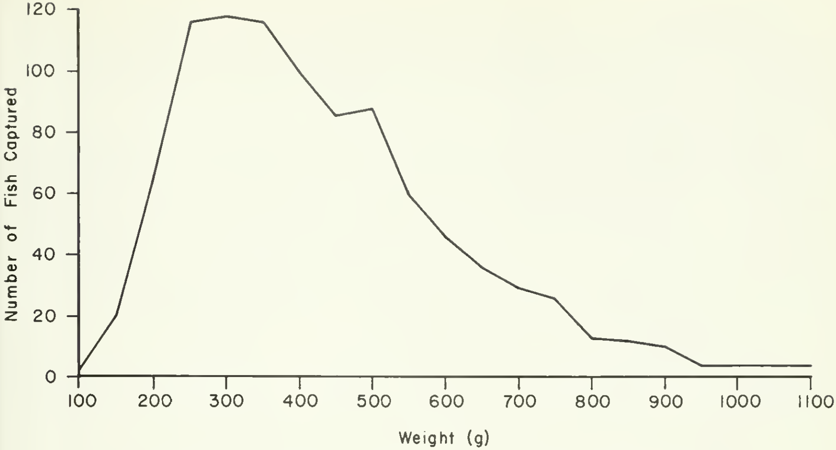


Figure 20. Weight-frequency graph of sauger collected in the spring spawning migration of 1976 in the Tongue River.

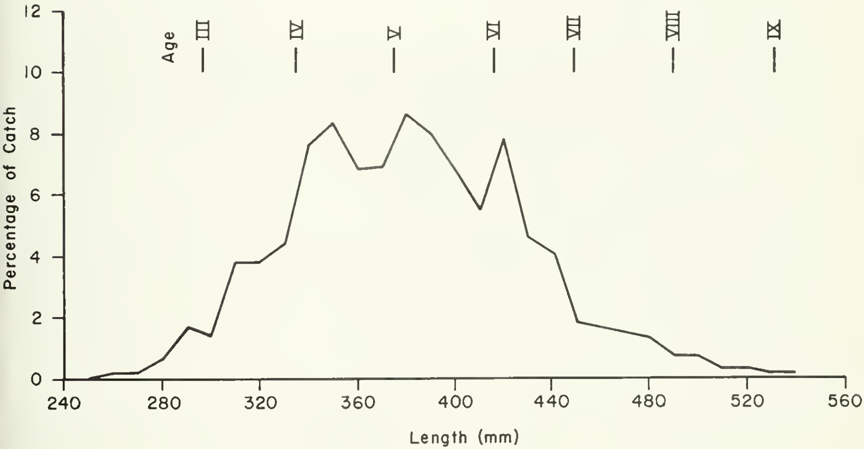


Figure 21. Comparison of the age and length frequency of sauger taken in the spring spawning migrations of 1976 in the Tongue River.

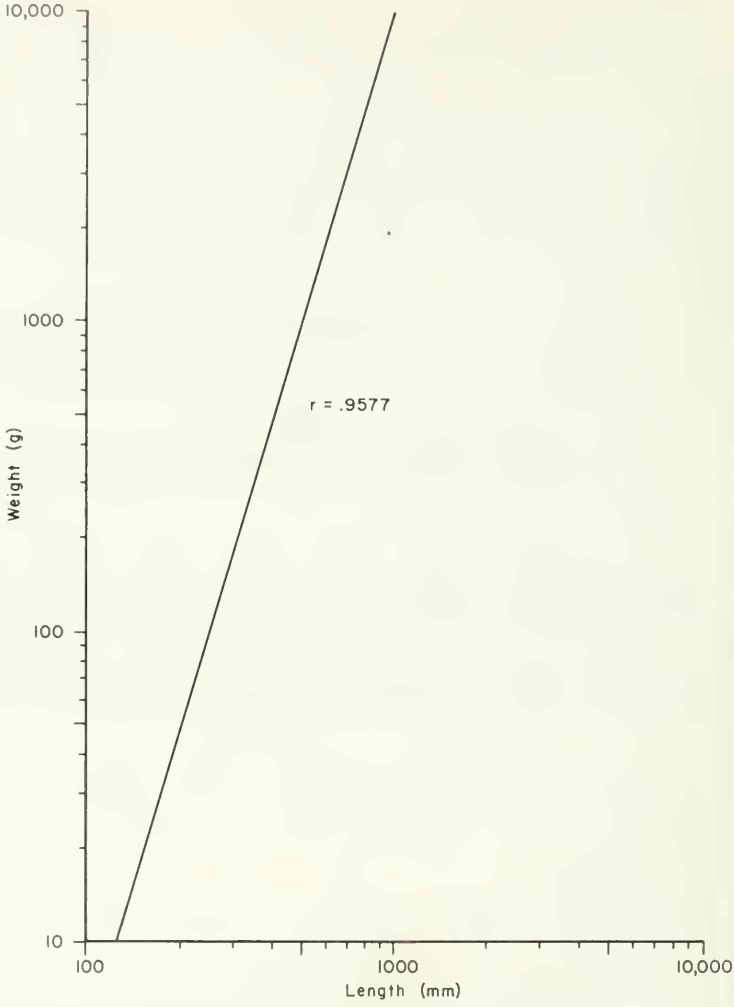


Figure 22. Length-weight relationship equation of all sauger collected in the spring of 1976 in the Tongue River.

TABLE 12. Comparison of calculated growth of Tongue River sauger with those from other northern waters (mm).

Water	Sample	Age								
		I	II	III	IV	V	VI	VII	VIII	IX
Tongue River	274			289	332	374	418	444	478	544
Yellowstone R.[a]	413	211	257	310	356	394	485	574		
L. Winnebago, Wisc.[b]	784	124	241	307	335	356	376	389	401	
Upper Mississippi R.[b]	42	124	228	302	345					
Lewis & Clark L. S. Dak.[b]	479	160	312	414	482	321	438			

[a] Haddix and Estes 1976.

[b] Summarized in Priegel 1969.

POPULATION ESTIMATES

The number of sauger moving into the lower Tongue River in 1976 was estimated using the Schnabel, Schumacher-Eschmeyer, and Chapman or Modified Schnabel estimators. Formulas and criteria to be considered for the population estimates were discussed on page 16 . The three estimates were similar, with the Chapman estimator showing the best degree of fit (table 13).

TABLE 13. Estimated populations of sauger moving into the lower Tongue River, spring 1976.

Estimator	N	95% CI
Schumacher-Eschmeyer	3796	3249-4564
Schnab	3710	3136-4542
Chapman	3680	3114-4498

HABITAT PREFERENCE

Daily catch rates were totaled for each week of the sampling season. The data were analyzed in two ways: by catch/kilometer and catch/trip. Calculation of discharge vs. catch rates was performed as discussed above for shovelnose sturgeon. The number of fish sampled in certain flow regimens (discharge-frequency histogram) is graphed in figure 23. The data points form only one side of the graph, but, since it can be assumed that there would be zero fish at zero flow, the other side can be interpolated. It is possible, however, that there would be zero fish before the flow reaches zero.

The quadratic regressions of trip and linear catch rates in relation to the discharge resulted in an optimum passage flow estimate of 13.6 m^3/sec (430 cfs) for both catch rates. Figure 24 indicates very little passage occurring at flows less than 8 m^3/sec (280 cfs).

Temperature

The temperature graph (number of fish caught within a specified range of temperatures) shows a near-normal distribution of sauger moving into the Tongue River (figure 25). A regression was run between the two catch rates and maximum and minimum temperatures as was done for the shovelnose sturgeon (see page 40 for model). A hyperbola with optimum values of 12.4°C (54°F) and 9.4°C (49°F), respectively, for the trip catch rate resulted. For linear catch rates, the maximum and minimum optimum temperatures were 12.3°C (54°F) and 9.3°C (49°F), respectively (figure 26). The preferred temperature regimens found in the Tongue River during the spawning migration correspond to those found in other areas (Brown 1971, Scott and Crossman 1973).

TAGGING STUDIES

A total of 646 sauger were tagged with Floy anchor tags in 1976. Of these, 22 (3.4 percent) were returned by anglers. The majority of the tags (81.8 percent) were returned from the Tongue River. Some local movement was shown, with many fish moving upstream to the T&Y diversion, 24 to 29 km (15 to 18 mi) upstream from where they were tagged. Four sauger were caught in the Yellowstone River, three moving upstream. The downstream migrant moved about 28 km (17.6 mi) in 50 days. Upstream movement ranged as follows: 1.6 km (1 mi), 19 days; 84 km (52.4 mi), 78 days; and 164 km (102 mi), 87 days. The range of movement demonstrated by the small sample suggests a mobile sauger population inhabiting the Yellowstone River. The low tag return rate by fishermen indicates that the fishery is not being utilized to its potential.

CHANNEL CATFISH

The channel catfish *(Ictalurus punctatus)* is probably the most sought-after game fish in the lower Yellowstone River Basin. The channel cat, native to Montana, was first reported by the Lewis and Clark Expedition. Preferred

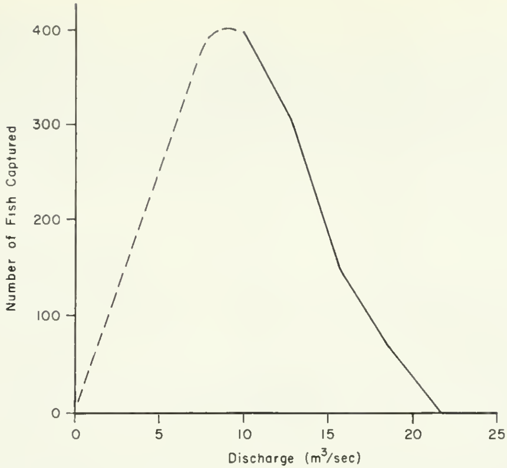
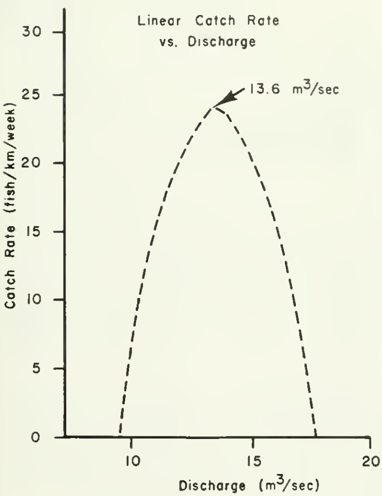


Figure 23. Plot of the quantity of sauger taken per interval of discharge in the spring spawning migration of 1976 in the Tongue River.



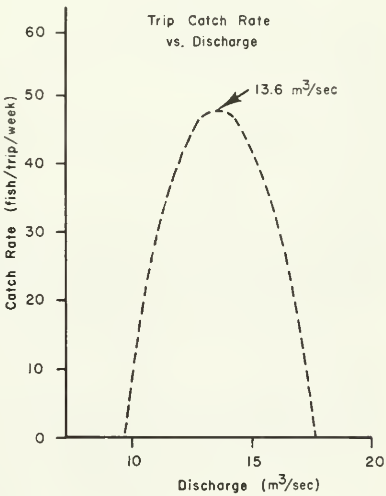


Figure 24. Quadratic regression analysis of discharge versus catch rates of sauger collected in the spring of 1976 in the Tongue River.

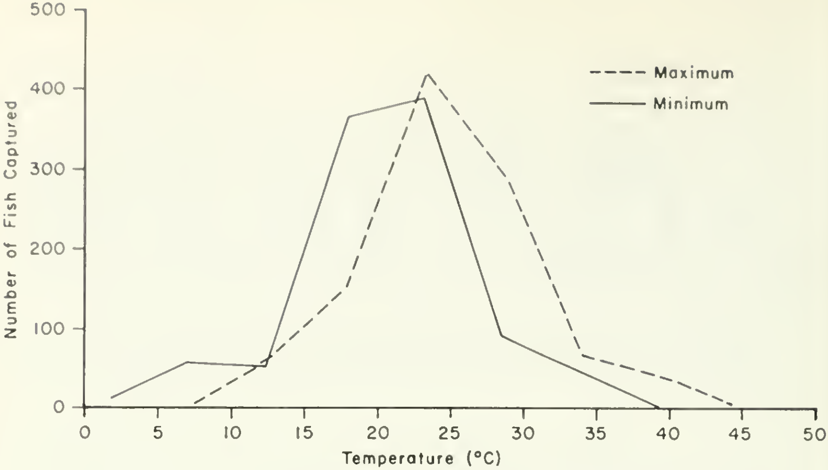


Figure 25. Plot of the quantity of sauger taken per interval of maximum and minimum water temperatures in the spring of 1976 in the Tongue River.

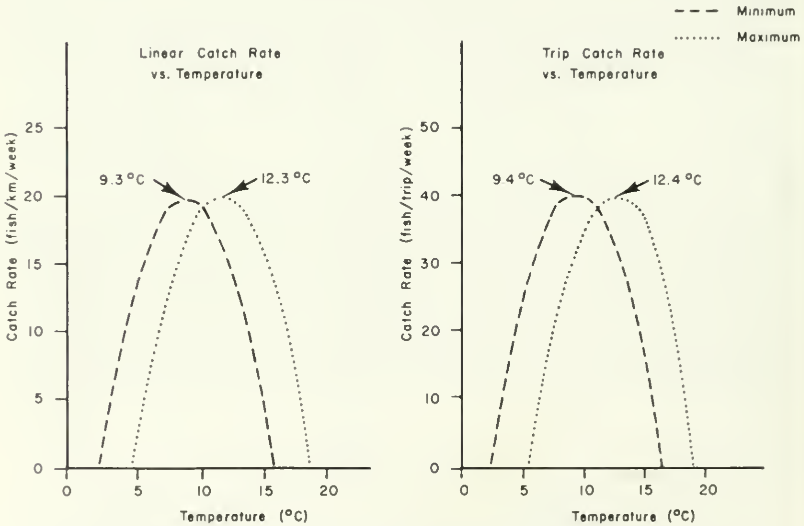


Figure 26. Quadratic regression analysis of maximum and minimum water temperature versus catch rates of sauger taken in the spring of 1976 in the Tongue River.

habitat is large rivers and lowland lakes, but channel cats are not tolerant of pollution and require well oxygenated water. Spawning occurs from May into July after water temperatures warm to 24°C (75°F), with 26.7°C (80°F) reported as optimum spawning temperature (Brown 1971). Nests are usually built in secluded, semidark areas around logs, undercut banks, or other cavities. The channel catfish received game fish status in Montana in 1975 as the result of legislative action.

FISH SIZE

Length-Weight Relationships

As shown in table 14, catfish taken in 1976 were smaller than fish taken in 1975.

TABLE 14. Average lengths and weights of catfish taken in the Tongue River in 1975 and 1976.

	1975		1976	
Study Section	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Ib	401	690	375	644
IIa	493	1270	---	---
IIb	452	1070	379	596

CONVERSIONS: 1 mm = .0394 in

1 g = .0022 lb

Age and Growth

In 1975, 337 spines were sectioned and aged; 132 were aged in 1976. The 1975 sample was divided into those catfish captured below the T&Y Diversion (table 15) and those captured between the T&Y and S-H diversions (table 16). Only fish sampled below the T&Y Diversion were analyzed in 1976 (table 17). Ages were comparable between years for the section downstream from T&Y Diversion.

The variation of lengths in a year class increased considerably at 9 years of age and greater in section Ib and at 13 years of age and greater in section IIb in 1975. The average growth per year in section Ib was 1.4 inches per year; in section IIb a pattern of strong growth every other year was established. In the "good growth" years the average was 1.6 inches; in the "poor growth" years the average growth was 0.3 inches.

TABLE 15. Average length and range of lengths for each age group of 231 channel catfish taken below T&Y Dam on the Tongue River in the summer of 1975.

Age Group	Number of Fish	Average Length at Capture (mm)	Range of Lengths at Capture (mm)
1	2	127	112-142
2	28	206	188-221
3	9	229	201-259
4	21	272	226-302
5	17	218	279-356
6	19	335	295-381
7	6	373	318-437
8	7	389	353-437
9	22	414	358-599
10	13	450	368-681
11	16	485	411-541
12	29	531	437-660
13	24	531	434-676
14	14	577	470-752
15	3	574	406-665
19	1	752	752-752

CONVERSIONS: 1 mm = .0394 in

TABLE 16. Average length and range of lengths for each age group of 106 channel catfish taken between T&Y Diversion and S-H Diversion on the Tongue River in the summer of 1975.

Age Group	Number of Fish	Average Length at Capture (mm)	Range of Lengths at Capture (mm)
2	1	213	213
4	1	269	269
5	2	305	302-305
6	17	318	297-348
7	2	361	307-411
8	3	363	343-383
9	19	386	323-429
10	7	432	396-475
11	8	446	409-490
12	6	485	447-513
13	10	493	381-570
14	10	541	472-610
15	5	544	498-592
16	7	629	574-671
17	3	569	533-617
18	5	612	505-688

CONVERSIONS: 1 mm = .0394 in

TABLE 17. Average lengths and range of lengths for each age group of 132 channel catfish taken in the lower Tongue River in the fall of 1976.

Age	Sample Size	Average Length (mm)	Range of Lengths (mm)
1	5	113	101-120
2	22	211	186-230
3	14	251	235-279
4	9	276	254-301
5	18	303	274-344
6	2	340	335-344
7	4	364	341-372
8	3	388	362-404
9	4	447	415-477
10	5	468	452-489
11	13	514	456-575
12	13	547	492-665
13	13	585	516-668
14	6	600	374-745
15	1	743	743-743

CONVERSIONS: 1 mm = .0394 in

Those catfish found in section IIb were considered to be part of a resident population since their movement is restricted by the T&Y and S-H diversions. Since growth rates were constant between years in section Ib, it is suggested that channel catfish may spawn every other year in section IIb. Meyer (1960) found through examination of annuli on paddlefish maxillary that the species spawned at intervals of 4-7 years. It is possible that the irregular growth pattern exhibited in section IIb by channel catfish is the result of alternate-year spawning activity.

DeRoth (1965) found smaller average lengths per age class in the channel catfish of Lake Erie than those found in the Tongue. The same held true with the catfish of the Lake of the Ozarks (Marzolf 1955). Witt (1966) found greater average growth per annulus in the Little Nemaha River. A growth rate similar to that shown in the Tongue River was found in the Des Moines River of Iowa as reported by Carlander (1969).

CATCH RATES

In 1975, 472 channel catfish were captured in 106 trap sets for a catch rate of 4.45 fish/trap. Catch rates for the three reaches were: section Ib

(Keogh), 4.70 fish/trap (349 in 74 sets); section IIa (Orcutt's), 2.00 fish/trap (24 in 12 sets); and section IIb (S-H), 4.95 fish/trap (99 in 20 sets). Catch rates in 1976 were lower, averaging only 2.34 fish/trap (138 catfish in 59 trap sets). Traps were fished in sections Ib and IIb in 1976; catch rates were the same in the two sections. Reduced flow levels and unusually high summer temperatures probably resulted in the lower catch rates.

TAGGING STUDIES

A total of 397 catfish were tagged in 1975, and 103 were tagged in 1976. Tag returns in subsequent trap sets averaged 6.3 percent in 1975 and 3.9 percent in 1976. Anglers returned 3.6 percent of the channel catfish tagged (18 of 500). Of those tagged in 1975, 5 (1.3 percent) were returned in 1975 and 10 (2.5 percent) were returned in 1976 for a total return rate of 3.8 percent. Only 3 (2.9 percent) of the fish tagged in 1976 have been returned by fishermen.

Movements of fish tagged in the Tongue River were varied. Eight (44.4 percent) of the returned fish were returned from the Yellowstone River rather than the Tongue River (table 18). Two of the fish tagged in 1975 and recaptured in 1975 were caught in the Yellowstone. One fish was taken at the confluence of the Yellowstone and Missouri rivers, about 303 km (188 mi) downstream from where it was tagged. Only one of the fish recaptured in the Yellowstone moved upstream after leaving the Tongue. Of the fish recaptured in the Tongue River, 50.0 percent (5 of 10 fish) were recaptured in the area where they were tagged. Four of these fish were recaptured the same year they were tagged. All fish taken in the Tongue River that showed movement showed upstream movement, but the eight that were returned from the Yellowstone River obviously moved down the Tongue before entering the Yellowstone.

INSTREAM FLOW REQUIREMENTS OF INDICATOR SPECIES

All fish, wildlife, and other aquatic organisms are dependent upon the natural flow regimen of a river system. Fish production in rivers depends upon the maintenance of spawning and rearing areas, sufficient shelter, adequate food supply, and water quality. The stream discharge, as influenced by channel configuration, must meet the hydrologic requirements necessary to provide these factors.

The State Water Planning Model simulated monthly streamflow conditions which would result from the implementation of several levels of agricultural or industrial development. Monthly Tongue River subbasin outflows and total dissolved concentrations estimated by the model provided the basis for predicting impacts on the fisheries. Four levels of industrial and three levels of irrigative withdrawals were considered.

As explained on page 17 , potential impacts were assessed on the basis of the effect on flows associated with three life-history stages of fish--passage, spawning, and rearing.

TABLE 18. Summary of angler returns of tagged channel catfish, Tongue River, 1975-76.

Tag Number	Tagged		Recaptured		Movement
	Date	Location[a]	Date	Location[a]	(km)[b]
1007	8/6/75	TR-Ib	5/22/76	YR	+3.2[c]
1021	8/6/75	TR-Ib	9/8/75	YR	-70.0[c]
1022	8/6/75	TR-Ib	9/14/75	TR	0
1024	8/6/75	TR-Ib	8/19/75	YR	-9.7[c]
1053	8/8/75	TR-Ib	8/19/75	TR	0
1075	8/13/75	TR-Ib	8/14/75	TR	0
1104	8/14/75	TR-Ib	8/11/76	YR	-4.8[c]
1124	8/17/75	TR-Ib	7/10/76	YR	-1.0[c]
1132	8/17/75	TR-Ib	3/29/76	YR	-8.1[c]
1136	8/20/75	TR-Ib	7/27/76	MR	-302.5[c]
1144	8/20/75	TR-Ib	4/7/76	TR	0
1157	8/22/75	TR-Ib	8/11/76	YR	+8.1[c]
1181	8/22/75	TR-Ib	6/5/76	TR	+29.0
1202	8/22/75	TR-Ib	9/18/76	TR	+29.0
1340	9/17/75	TR-IIb	10/19/75	TR	0
	3/23/76	TR-Ia	9/6/76	TR	+29.0
1372	5/7/76	TR-Ia	8/5/76	YR	-11.3[d]
2394	3/31/76	TR-Ib	5/21/76	TR	0
2982	7/29/75	TR-Ib	5/22/76	TR	+29.0

[a] YR = Yellowstone River

TR = Tongue River

MR = Missouri River

[b] + designates upstream movement and - downstream.

[c] These fishes moved downstream 1.5 km in the Tongue River before reaching the Yellowstone.

[d] This fish moved downstream 0.5 km in the Tongue River before reaching the Yellowstone.

Indicator species selected by Bovee (1974) for passage and spawning flows were paddlefish (larger rivers) and sauger (smaller streams). However, for the Tongue River, shovelnose sturgeon were substituted for paddlefish because of greater abundance. Channel catfish were added because they migrate and spawn later in the season.

PASSAGE AND SPAWNING FLOWS

Sauger are found moving out of the Yellowstone into the Tongue from March to June. According to Bovee (1974), the spawning depth criteria for sauger is 1.2-1.5 m (3.9-4.9 ft). Since it is assumed that if passage criteria are met then spawning criteria are also met, the converse was also assumed to be true. Therefore, only one flow level is recommended to meet the needs for both passage and spawning. Based on predicted flow conditions from the WSP program, flows ranging from 19.8 to 48.9 m^3/sec (700-1725 cfs) would provide adequate passage and spawning depths. The minimum sustaining discharge is defined as 75 percent of optimum (Bovee 1974). The recommended minimum passage and spawning flow for sauger for the months of March through June is 14.9 m^3/sec (525 cfs).

The spawning migration of the shovelnose sturgeon commences around the first of May. Depth requirements for shovelnose sturgeon are reported as 0.3-0.9 m (1 to 3 ft) (Bovee 1974). Sampling of shovelnose in the lower Tongue River revealed that nearly 80 percent of the fish sampled were taken in depths ranging from 0.6 to 1.0 m (2 to 3.3 ft). Based on WSP predicted flows, discharges of 23 to 62 m^3/sec (800-2200 cfs) are required to meet shovelnose sturgeon criteria. The recommended flow for shovelnose sturgeon during May, June, and half of July is 17 m^3/sec (600 cfs).

Channel catfish spawn at temperatures ranging between 23.9 and 29.5°C (75-85°F). Water temperatures in the Tongue River generally reach these levels during June, July, and August. Therefore, requirements for this species are established for this time period. Spawning depths for catfish have not been determined, but Bovee (1974) reported depth preferences ranging from 0.31 to 1.53 m (1.0 to 5.0 ft). Using WSP predicted flows for pool areas, flow ranges of 8.5 to 21 m^3/sec (300 to 750 cfs) were established. Based on 75 percent of optimum, the recommended flow for channel catfish is 6.4 m^3/sec (225 cfs).

REARING FLOWS

Rearing flows are needed during the remainder of the year. Dewatering will more severely affect areas of shallow, fast water than areas of deep, slow water. If these shallow areas are maintained, then the stream will be protected. Rearing flow recommendations are based upon the assumption that rearing is proportional to food production, which is in turn assumed proportional to wetted perimeter (White and Cochnauer 1975). Wetted perimeter was determined for several transects based on WSP predicted flows. Starting at zero discharge, wetted perimeter increases rapidly for small increases in discharge up to the point where the river nears its maximum width. Beyond this inflection point, wetted perimeter increases slowly while discharge increases rapidly. The optimum quantity of water for rearing is selected near this inflection point (figure 27). Optimum flow value for the Tongue is 7 m^3/sec (250 cfs), so the recommended minimum flow value (75 percent of optimum) is 5.4 m^3/sec (190 cfs). Bovee (1975) suggested using the stonecat as a rearing flow indicator species. The stonecat was selected for its preference of fast, shallow water areas. Stonecats sampled by Bovee in the Tongue River showed a marked depth preference ranging between .30 and .60 m

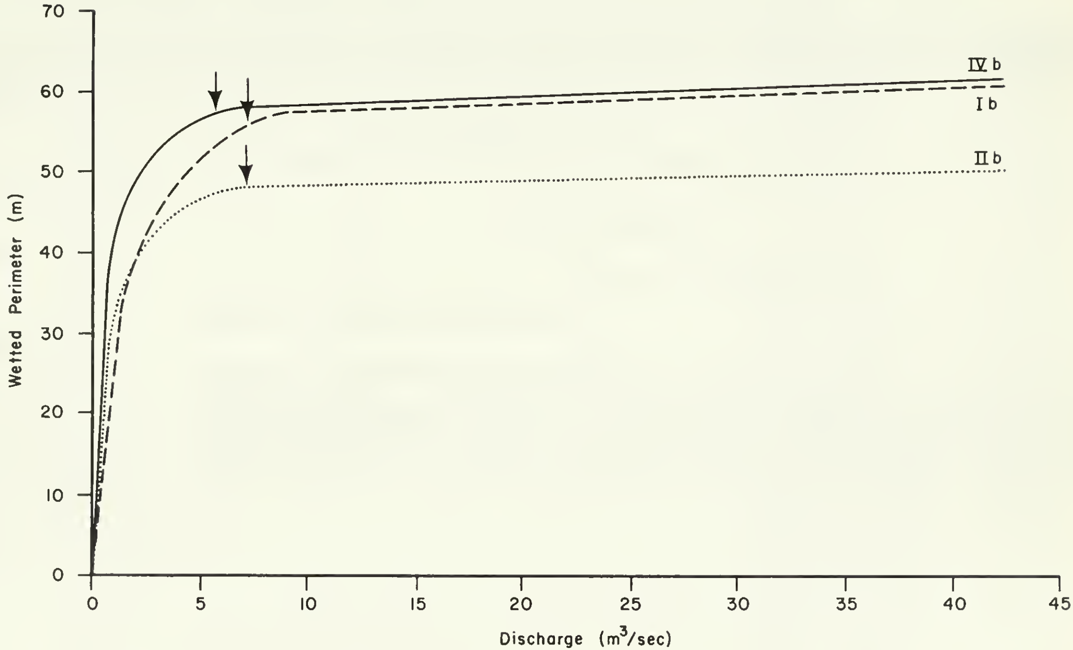


Figure 27. Wetted perimeter in relation to discharge for three sections of the Tongue River, showing the inflection point used to determine rearing flows.

(1 and 2 ft). Using WSP predicted flows for riffle transects, the flows at these depths range from 6.8 to 17 m^3/sec (240 to 600 cfs). Using 75 percent of optimum, a minimum rearing flow recommendation of 5 m^3/sec (180 cfs) is obtained.

MONTHLY INSTREAM FLOW REQUIREMENTS

Recommended minimum instream flows shown in figure 28 are the flows necessary for the species with the highest requirements for each month.

While the instream flows presented for each life history stage and each species are 75 percent of the optimum value, a flow was not recommended unless judged to be an adequate flow. Professional experience was utilized as a basis for determining if a flow was adequate.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
SAUGER												
spawning			14.9 →	→	→	→						
rearing	5.4 →	→					5.4 →	→	→	→	→	→
SHOVELNOSE STURGEON												
spawning					17.0 →	→	→					
CHANNEL CATFISH												
spawning						6.4 →	→	→				
rearing	5.4 →	→	→	→	→				5.4 →	→	→	→
STONECAT												
rearing	5.1 →	→	→	→	→	→	→	→	→	→	→	→
RECOMMENDED FLOW	5.4	5.4	14.9	14.9	17.0	17.0	17.0 / 6.4	6.4	5.4	5.4	5.4	5.4
MEAN NATURAL FLOW	5.3	7.8	18.7	15.4	23.3	45.5	14.6	4.5	5.8	8.1	8.8	6.1
LEVEL OF DEVELOPMENT												
low	4.8	8.8	22.0	14.5	25.5	48.9	9.4	1.5	2.1	3.7	4.8	4.8
intermediate	1.8	4.4	15.2	9.1	18.1	42.5	5.1	1.8	1.2	1.6	1.6	1.5
high	1.6	3.6	14.5	8.7	16.5	39.9	4.6	2.3	1.5	1.6	1.6	1.5

All values expressed in m^3/sec

Figure 28. Life history periodicity and minimum flow recommendations for selected species and projected flow values for the Tongue River from the T&Y Diversion to the mouth.

Impacts of water withdrawals

THE NATURALLY OCCURRING PATTERN OF LOW FLOWS

Because the aquatic biota of the Tongue River has developed in response to both high and low flows, the frequency and magnitude of naturally occurring low flows was examined. Shown in table 19 is a summary of historic flows and low-flow occurrences of the Tongue River near its mouth for the years 1931-75. Although this report refers to naturally occurring low flows, the term is misleading because 1) flows of the Tongue River are regulated by Tongue River Dam, and 2) the gaging station is located downstream from the lowermost irrigation diversion.

When comparing naturally occurring low flows in the Tongue with those that would occur after the projected levels of development, it is necessary to distinguish between basin outflows at the mouth of the river and instream flows occurring immediately below the Tongue River Dam. Because both the agricultural and industrial development projected would rely on increased storage, more water would be released during low-flow periods for downstream use. Hence, at least for the portion of the river just below the dam, instream flows after development would probably be high and more constant through the year (since release for industrial use would not vary) than are existing flows. However, those additional releases of water, plus much of the existing flow, would be diverted and consumed along the course of the river; at the river's mouth, flows after development would be much lower than are naturally occurring low flows, resulting in the severe impacts described in tables 20 and 21 as opposed to the lesser, naturally occuring impacts described in table 19.

Naturally occurring low flows also result in high TDS concentrations. Four months (October-January) commonly show levels greater than 700 mg/l. Two months, December and January, occasionally reach 1000 mg/l. However, these concentrations do not occur at critical fish life-history stages, and little impact occurs.

IMPACTS OF INCREASED FUTURE USE

PROJECTIONS OF FUTURE USE

In order to adequately and uniformly assess the potential effects of water withdrawals on the many aspects of the present study, it was necessary to make projections of specific levels of future withdrawals. The methodology by which this was done is explained in report No. 1 in this series, in which also the three projected levels of development, low, intermediate, and high, are explained in more detail. Summarized in appendix A, these three future levels of development were formulated for energy, irrigation, and municipal water use. Annual water depletions associated with the future levels of

TABLE 19. Summary of historic flows (1931-75) on the Tongue River as related to recommended instream flows by season.

Season	Flows and Impacts	
	Historic Flows	Low Flows
Fall	This season normally shows the year's lowest flow levels due to reduced streamflow and to irrigational demands in August. For the entire season, flows fall below the instream requests 49.3 percent of the time. Water temperatures may become intolerable for many resident fishes. In August, instream flow requests would have been met only 20 percent of the time. October and November show adequate flows over 70 percent of the time.	Critically low flows (those that provide less than half of the recommended instream levels) occur one out of every four years, resulting in reduced wetted perimeter and lowered velocities. In August, one out of two years shows extremely low flows. Most dry years are followed by two or three wet years, preventing long series of dry years.
Winter	This low-flow period is not influenced by irrigation demands. Still, one year out of two has flows below instream requests, resulting in riffle freeze-up and decreased oxygen levels.	Extreme low flows occur only 5.9 percent of the time.
Spring	Most erratic flow period; natural flows fall below instream requests 53.8 percent of the time.	One year out of four exhibits extremely low flows, reducing spawning habitat for sauger.
Runoff	Naturally occurring flows fall below recommended instream levels only 24.3 percent of the time. Natural impacts are lowest during this period.	Extremely low flows affecting spawning and passage of paddlefish and sturgeon occur once every eight years

NOTE: Impacts described by the percentage of time they would occur may be interpreted as occurring by the year rather than by the day For example, an impact described as occurring 90 percent of the time would occur nine years out of ten, on the average.

development were included in the projections. These projected depletions, and the types of development projected, provide a basis for determining the level of impact that would occur if these levels of development were carried through.

IMPACTS OF REDUCED STREAMFLOW

Agricultural Projection

Mean flow values for each projected level of development are compared with recommended instream flows and mean monthly natural flows in figure 28. Possible impacts associated with each development level are presented in table 20. Frequencies of low flow are relative to the 30-year period of flow records.

Fall. August flows for the low level of agricultural development would fall critically short. Flows necessary to ensure adequate channel catfish spawning during August are 6.4 m^3/sec (225 cfs); only one year in 30 showed enough water to maintain this flow. Low flows to 1 m^3/sec (36 cfs), which would drastically reduce wetted perimeter, lower velocity, and reduce depth, would result nearly 90 percent of the time (26 of 30 years).

Flows resulting from the intermediate level of development would fall short of channel catfish requirements all years. One year shows almost enough water but is still short. Flows associated with the high development level fall short all years and would decimate channel catfish spawning in this reach of the Tongue River.

September flows would be similar to those for August. With the low development level, flows would be adequate to meet rearing requirements only one year out of six. Intermediate and high development level flows would be inadequate in all years.

Low-development-level flows for October and November would be adequate for rearing one year out of four and one year out of two, respectively. Intermediate and high levels of development, however, would result in depleted flows at least nine years out of ten.

In summary, agricultural development would have its greatest impact on the fishery of the Tongue River during the fall months, since August and September are months of normal low flows and high irrigation use.

Winter. The low level of development would result in low flows one year out of two for December and January and one year out of 1.4 for February. The impacts would probably be minimal, however.

As with the fall period, both the intermediate and high levels of development would be expected to result in severe impacts for December and January. At least 85 percent of the time, rearing flows would not be maintained for these months. The intermediate projection would provide adequate flows one year out of 4.3 in February, but the high projection would have a severe impact in that month.

TABLE 20. Predicted impacts of three agricultural development levels on the flow of the Tongue River.

	Low	Intermediate	High
Fall	Low flows, no channel catfish spawning, reduced wetted perimeter, lower velocity, reduced depth 90% of time, rearing flows adequate an average of 1 out of 4 years. Greatest impact on fishery during this time of year.	Same impacts as low development, plus rearing flows are inadequate at least 9 out of 10 years. Greatest impact on fishery during this time of year.	Same impacts as intermediate development.
Winter	1 year out of 2 with low rearing flows. Impact minimal.	Rearing flows not maintained 85% of time. High impact on fishery would result.	Severe impact on fishery. Rearing flows inadequate especially during February. Flows inadequate 85% of time for rest of the months.
Spring or Spawning	Low flows during July (2 out of 3 years). Reduction of egg survival. High temperature. Impacts minimal	April would have inadequate flows 76.7% of time. Loss of sauger spawning habitat and reduction in shovelnose sturgeon egg survival. High impacts on sauger and shovelnose sturgeon in Tongue.	Impacts similar to intermediate scenario. Severe impact on shovelnose sturgeon and sauger fishery.
Runoff	Impacts minimal.	Flows in July would be moderate 83.3% of time, resulting in loss of shovelnose sturgeon spawning habitat. High impact on shovelnose sturgeon and channel catfish.	Inadequate flows during July would occur 90% of time, resulting in serious loss of shovelnose sturgeon and channel catfish spawning potential. Severe impact on shovelnose sturgeon and channel catfish fisheries.

NOTE: Impacts described by the percentage of time they would occur may be interpreted as occurring by the year rather than by the day. For example, an impact described as occurring 90 percent of the time would occur nine years out of ten, on the average.

Spring. The low level of development would have little impact on the fishery of the lower Tongue River. July would be the month of the highest impact, with inadequate flows two out of three years. Low flows during this period would result in excessive water temperatures which would be detrimental to sturgeon egg hatching. Predicted flows for May and June would have little or no negative impact. For sauger spawning, flows in March would be inadequate one out of two years and April flows would be inadequate 67 percent of the time. The impact during these months would probably be minimal.

At the intermediate level of development, July flows would be inadequate 83.3 percent of the time, resulting in high water temperatures, reduction in egg survival, and loss of spawning habitat. Impacts would be minor in May and June. April flows would be inadequate 76.7 percent of the time (23 of 30 years). This flow reduction would result in loss of habitat, loss of wetted perimeter, and loss of depth and velocity needed for sauger to spawn. The impacts during March would be similar to those of March under the low projection.

The effect of the high level of development during the spring spawning flows would be similar to that of the intermediate level with the exception of July. During July, flows would be insufficient 90 percent of the time, with impacts similar to those described previously. This would seriously affect shovelnose sturgeon spawning in the lower Tongue River.

Summary of Impacts. With the low level of agricultural development, there would be little impact except during fall. With the intermediate and high levels of development, there would be severe impacts on the fishery during the entire year, resulting in the loss of spawning and rearing flows necessary to maintain the sauger and channel catfish fishery. There would be a severe loss of spawning habitat for the shovelnose sturgeon during the spring (runoff) flows.

Industry Projection

A summary of possible impacts associated with each development level is presented in table 21.

No major impact associated with the low level of development could be predicted to occur on the Tongue River.

Impacts predicted for the intermediate level of development would be greatest during the spring, when an estimated 500,000 m^2 (5.4 million ft^2) of potential spawning habitat would be lost downstream from the T&Y Diversion. Winter flows less than 2.5 m^3/sec (90 cfs) would result in icing on riffles and, therefore, invertebrate losses (Bovee 1976). This would occur about 20 percent of the time at this level of development. These flows would adversely affect the fishery.

The intermediate development level, even with 60 percent of NGPRP instream flows (NGPRP 1974) guaranteed, would still have high impact. In many years there would be little or no flow in the river during the fall, and

TABLE 21. Summary of predicted impacts of three projected levels of industrial development of Tongue River water.

Season	Low	Intermediate	Intermediate (60% NGPRP)	High
Fall	Little impact, possible high temp. during Oct. (2.5% of the time).	Possible impact: 1 out of 8 years, no flow; 1 out of 2 years, possible high temp.	High impact: 1 out of 3 years no flow; over 90% of the time, possible problem with high temp.	Extreme impact: 98% of the time, no flow; remainder of flows inadequate to support fishery.
Winter	No impacts other than those occurring naturally.	Possible impact: 2 out of 9 years, ice would form on riffles, with possible O_2 depletion.	High impact: 4 of 5 years riffles would freeze, with probable O_2 depletion.	Extreme impact: over 90% of the time, no flow; 2% of time, adequate flows.
Spring	No impacts other than those occurring naturally.	Possible impact: 4 out of 10 years, spawning habitat reduced; 1 out of 10 years, inadequate flows; 1 out of 30 years, no flow.	Possible impact: 3% of time, no flow; spawning habitat reduced greatly all years.	High impact: almost 70% of the time, no flow; remaining years flows inadequate and spawning habitat lost.
Runoff	No impacts other than those occurring naturally.	Possible impact: 1 out of 4 years, no bedload movement, loss of scouring; 30% of time no flow; some possible high temp. problems.	High impact: over 30% of time, no flow; just under 30% of the time, flow inadequate for paddlefish spawning; high temp. problems possible also.	Extreme impact: over 60% of the time, no flow; almost 20% of the time, flows would be inadequate.

NOTE: Impacts described by the percentage of the time they would occur may be interpreted as occurring by the year rather than by the day. For example, an impact described as occurring 90 percent of the time would occur nine years out of ten, on the average.

riffles would freeze during the winter. Approximately 650,000 m^2 (7 million ft^2) of potential spawning habitat would be lost during the spring downstream from the T&Y Diversion. During run-off, no flow would be present about one-third of the time. Paddlefish would be unable to migrate upstream about one-fourth of the years in which there would be measurable flow. With these flow levels, there would be a minimal fishery downstream from the T&Y Diversion.

With the high projection, flows would be almost nonexistent downstream from the T&Y Diversion, and impacts would be extreme.

Since that portion of the river downstream from the T&Y Diversion provides a spawning and nursery area for fish from the Yellowstone River, a reduction in flows would also adversely affect the Yellowstone River fish population. Thus, impacts on the Yellowstone River fishery as well as on the Tongue River fishery would occur from reduced flow in the Tongue.

IMPACTS ON WATER QUALITY

The impacts of reduced flow on water quality were evaluated in terms of total dissolved solids (TDS) concentrations (salinity). Concentrations of TDS ranging from 670 milligrams per liter (mg/l) to a maximum of 1350 mg/l were considered the range for a good, mixed fishery in western alkaline streams (Klarich 1977). Some minor adverse effects would be expected at concentrations over 670 mg/l, becoming more severe as concentrations approached and exceeded 1350 mg/l. Therefore, TDS levels greater than 700 mg/l were considered to have an impact on the fishery.

Fall

Four months (August-November) would have TDS greater than 700 mg/l with the low level of development. August levels could be high enough to deter channel catfish migrations. With the intermediate level of development, all months would be greater than 700 mg/l; August through December would be greater than 1,000 mg/l. Channel catfish migration and spawning in August could be affected. All months would show levels greater than 1,000 mg/l with high development. Impacts would be the same as with intermediate development.

Winter

December and January would have TDS concentrations greater than 700 mg/l with low development, and all winter months (December-February) would have greater than 700 mg/l with intermediate development. December showed concentrations greater than 1,000 mg/l under both intermediate and high development. However, impacts should not be significant during this period.

Spring

No impact would be expected with low or intermediate development. Under high development, March and April show TDS concentrations greater than 700 mg/l, which could affect sauger migration and spawning.

Runoff

The low levels of development would have no water quality impact. July would show concentrations greater than 700 mg/l with the intermediate and high levels of development, which could affect channel catfish migration and spawning. The end of the shovelnose sturgeon and paddlefish runs could be affected, as could egg incubation.

OTHER LIMITING FACTORS

Thus far, discussion of impacts of future water withdrawals on the aquatic biota of the Tongue River has been limited to the impacts of low flows. Low flows result in decrease in depth, loss of physical habitat, reduction in velocity, and deterioration of water quality, all of which render the habitat less appealing. There are other factors associated with the lotic community which must be considered.

Temperature

As water levels are lowered, the heat budget of the stream is altered, and temperatures increase until an equilibrium (between standing water and the ambient air temperature) is reached. Temperature is a major limiting factor because aquatic organisms often have narrow tolerances. The life cycles of fish and invertebrates, day length, and water temperature are so interdependent that even a small change in temperature can have far-reaching effects. In an artifically warmed stream, insects or fish may hatch too soon to fit into the food chain and successfully compete. If temperatures are near the upper limits of tolerance, the fish will be placed under stress if not killed. Similar competitive disadvantages would result with a cooling of water.

Turbidity

Suspended materials limit the penetration of light, restricting photosynthetic activity. Sediment fills the interstices between gravel, thereby eliminating spawning areas and aquatic insect habitat. The ability of a stream to move this material and hence cleanse the stream bottom depends on the discharge, particularly during the spring runoff. Low flows reduce bedload movement and thereby limit fish production.

Concentration of Respiratory Gases

Oxygen and carbon dioxide concentrations are often limiting to the aquatic community. As flows are reduced and temperatures increased, concentrations of oxygen become critical. Eggs are especially vulnerable to oxygen lack because they depend upon oxygen diffusing into them at a rate sufficient to maintain the developing embryos.

An excess of "free" carbon dioxide may have adverse effects on aquatic organisms, ranging from avoidance reactions and changes in respiratory movements at low concentrations, through interference with gas exchange at higher concentrations, to narcosis (unconsciousness) and death if the concentration is increased further. According to the Federal Water Pollution Control Administration (1968) respiratory effects seem most likely of these impacts to be of concern.

Concentration of Salts

Fresh-water fish have a problem in regard to osmoregulation. Since the concentration of salts is greater in the internal fluids of the body than in the fresh-water environment, then either water tends to enter the body by osmosis if membranes are readily permeable to water or salts must be concentrated if membranes are relatively impermeable (Odum 1964). Increases in salts (TDS) may create a problem in fish habitat preference. The possibility exists of a barrier to migration being produced by a zone of high TDS concentration. Reduction in flow could produce a TDS problem by concentrating salts and by reducing the diluting force of the stream.

LIMITING FACTORS UNRELATED TO FLOW

Several factors not dependent upon discharge may also have an impact on the fishery of the Tongue River. These are: 1) fishing pressure, 2) land use practices, and 3) pollution.

Fishing pressure is an environmental factor which may be manipulated to increase both fish production and yield. Pressure is often too great or too small, in relation to the productive capacity of a stream, to give maximum yield. Tag returns from the Tongue River suggest that pressure and harvest are light. Therefore it is doubtful that this factor results in a significant impact on the fishery.

Land use practices such as overgrazing, cultivation of the floodplain, and channel disturbances all can produce a negative impact on the fishery by degrading the habitat. Stream-bank stability can be destroyed through overgrazing and many other agricultural activities, resulting in bank sloughing and siltation. Channel disturbances reduce spawning and food-producing areas, and stream realignment shortens the total length of the river. Land use practices along the Tongue River have historically produced examples of the above impacts. Future practices should not significantly increase problem areas.

The final factor, pollution, could possibly result from introduction of an allochthonous, toxic substance, such as an effluent from a steam generating plant containing substances harmful to the fish. Even if the materials were not in toxic concentrations, the basic fertility of the river could be altered, favoring another assemblage of fish species. An alteration of the natural heat budget of the river is another possible impact from coal conversion complexes. Since the Tongue River Basin has been identified as a potential site for such complexes, this impact looms as a threat.

Summary

A study was conducted on the Tongue River from 1974 to 1976 to determine fish species composition, distribution, and diversity and to evalute impacts of water withdrawals on the river system. Distribution of the 31 fish species taken in the Tongue River was found to be influenced by irrigation structures. Species migratory from the Yellowstone were restricted by the T&Y Diversion, 22.7 km upstream from the mouth. Smallmouth bass were the dominant resident game fish. Discharge patterns from the Tongue River Dam affected the reproductive success of the smallmouth bass population. Species diversity indices generally increased with progression downstream and appear to be a useful tool in describing the fishery of a prairie stream.

Migrant fish populations using the lower Tongue River were monitored. Shovelnose sturgeon moved into the Tongue River from the Yellowstone River during April, May, and June in 1975 and 1976. The majority of the sturgeon sampled were between 710-785 mm in length in 1975 and 725-800 mm in 1976. Compared with a spring sample taken on the Yellowstone River at Intake, the Tongue River fish were considerably larger. Weights to 6 kg, larger than shovelnose reported in other areas, were not uncommon. Schnable-type population estimates showed 400-500 sturgeon/km present during the spring runs both years. Quadratic equations comparing number of fish with discharge and temperature documented passage preferences. It appears from those regressions that a minimum discharge of 8.50 m^3/sec is necessary for shovelnose sturgeon passage and that the optimum temperature range for sturgeon spawning is from 16.9°C to 21.5°C. Fish tagged with monel bands on the pectoral fin lost weight between the times of tagging and recapture; those tagged with Floy anchor tags gained weight. Angler harvest of sturgeon in 1974-76 was light.

Sauger were sampled during April and May of 1976; 1,004 fish averaged 377 mm in length and 441 g in weight. A preferred passage flow for sauger was estimated at 13.6 m^3/sec using a quadratic regression of catch rate against discharge. Population estimates showed around 3,700 sauger moved into the lower river in 1976. The optimum temperature range for sauger spawning migration was from 9.3°C to 12.4°C. Tagging studies indicated that the Yellowstone River sauger population is mobile and underutilized by fishermen.

Channel catfish were sampled with baited traps both years. In 1975, average lengths of catfish from the three river study sections sampled ranged from 401 to 493 mm, and average weights from 690 to 1270 g. In 1976, fish were smaller; average lengths ranged from 375 to 379 mm and average weights from 596 to 644 g. Pectoral spines were taken, sectioned, and analyzed for age and growth. Tag returns by anglers of sturgeon, sauger, and catfish were low and suggested an underutilized resource.

Recommended flows for passage and spawning of three indicator species--sauger, shovelnose sturgeon, and channel catfish--were determined in order

to allow assessment of the impacts of lowered streamflow on fish populations. The recommended minimum passage and spawning flow for sauger from March through June is 14.9 m^3/sec. For shovelnose sturgeon, the recommended flow for passage and spawning for May, June, and half of July is 17 m^3/sec. Channel catfish spawn in the Tongue River in June, July, and August; the recommended flow for this species is 6.4 m^3/sec. For the remainder of the year, it is recommended that rearing flows of 5 m^3/sec (the recommended flow for rearing of stonecats) be maintained.

It is the naturally occurring flow regime, including low flows, that has resulted in the existing aquatic biota of the Tongue River. That naturally occurring pattern of low flows is described in this report and compared with the predicted flows after each of three future levels of development. Comparison of the predicted post-development low flows at the mouth of the river with the recommended passage and spawning flows given above shows that even for the low level of development, fall flows would not supply the recommended channel catfish spawning flow. Lowered flows resulting from the intermediate level of development would have a severe impact on all indicator fish species. At the high level of development, flows would be almost nonexistent downstream from the T&Y Diversion, and impacts on the fishery would be extreme. Water quality would also be affected by agricultural and industrial development and water use in the Tongue River Basin, with some adverse effect on the fishery. The potential alteration of other limiting factors, such as temperature, pollution, and turbidity, among others, is also discussed.

Part II

Tongue River Reservoir fishery study

by

Allen A. Elser
Robert C. McFarland

Introduction

PURPOSE

The objectives of this segment of the study are: (1) to inventory the fish populations of the Tongue River Reservoir so that changes associated with coal development can be detected and, if necessary, mitigative measures taken; (2) to determine angler use and harvest of major sport fish in the Tongue River Reservoir; and (3) to evaluate possible impacts associated with large-scale withdrawal projects.

STUDY AREA

Flow of the Tongue River in Montana is controlled by the Tongue River Dam, behind which lies the Tongue River Reservoir. The earthfill dam, completed in 1940, impounds over 84.9 hm^3 (69,000 af) of water with a surface area of 1,416 ha (3,500 acres). Firm annual yield is 49.2 hm^3 (40,000 af). Sheridan, Wyoming, the nearest city, is located approximately 32 km (20 mi) south of the reservoir. The dam is 13 km (8 mi) north of the Montana-Wyoming state line (see figure 1 on page 3), impounding water from a drainage area of 4403 km^2 (1,700 mi^2).

Decker Coal Company, a subsidiary of Peter Kiewit Sons' Co., began mining coal near the Tongue River Reservoir in 1973. Over 3 million tons of coal were removed by Decker in 1973; the 1976 level of production was 10.3 million tons. Currently, mining operations are confined to the west side of the reservoir, but Decker is expanding (subject to permit approval) to the north of current operations and to the east side of the reservoir (figure 29). When these extensions are in operation, the Decker operation will be the largest producing strip mine in the world, with an estimated annual production of 14.5 million tons by 1980.

The Tongue River and Tongue River Reservoir may be increasingly important in light of proposed coal development. While most coal mined in Montana now leaves the state, additional coal conversion plants (for example, for steam-fired generation, gasification, and liquefaction) close to the coal source have been proposed. Such energy complexes require great amounts of water, and the Tongue is considered an important source of industrial water. Montana Power Company took an annual option on 5.15 hm^3 (4,175 af) of Tongue River Reservoir water in 1972. A generation plant in Wyoming which would utilize Tongue River water has been suggested.

However, water for industrial development in the Tongue River Basin would not be firmly available without additional storage. In a 1969 study, Bechtel Corporation considered a new Tongue River dam site about 10 miles downstream from the existing site. Stage 1 of the proposed reservoir, flooding land in Montana only, would have an active storage of 395 hm^3 (320,000 af) and firm annual yield of 120 hm^3 (100,000 af). Stage 2 of the proposed reservoir, be-

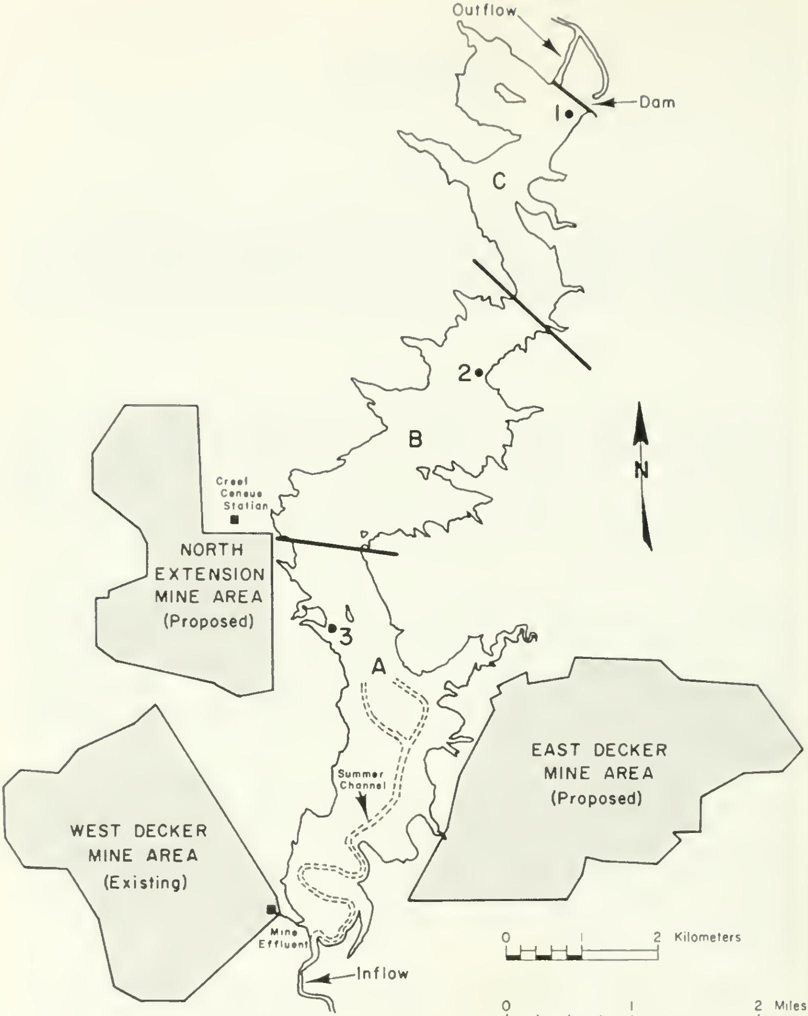


Figure 29. Tongue River Reservoir, Montana, showing zones and sampling stations.

cause it would flood land in Wyoming, is not considered likely in the foreseeable future. Raising the existing dam could provide a maximum storage of 170 hm^3 (140,000 af) and firm annual yield of 90 hm^3 (72,000 af) (Montana Department of Natural Resources and Conservation 1976).

Methods

SAMPLING FOR WATER CHEMISTRY ANALYSIS

Water samples were collected from the Tongue River Reservoir on a biweekly basis from icemelt until freeze-up (Whalen and Leath 1976). Samples were taken at three sites in the reservoir (figure 29), from the river above and below the mine discharge, and below the dam. Mine discharge samples were also taken. Reservoir samples were collected at two-meter intervals throughout the water column at all three stations with a four-liter Van Dorn Bottle. Additionally, samples were collected at one-meter intervals throughout the euphotic zone for phytoplankton standing crop and primary production estimates. Whalen and Leath (1976) summarize the analytical procedures used for water chemistry analyses.

FISH SAMPLING

Fish were collected using: 4-foot-by-6-foot frame trap nets with 1/2-inch and 1/4-inch mesh webbing and 50-foot leads; 125-foot experimental gill nets; a 100-foot, 1/4-inch-mesh beach seine; and a 50-foot, 1/4-inch-mesh bag seine. An electrofishing boat equipped to provide an output of 0-500 volts variable direct or alternating current was used to sample shoreline areas. Fish were also taken with a hook and line. Lengths and weights of captured fish were recorded, and sport fish were tagged with numbered Floy anchor tags. Scales were taken for analysis of age and growth.

POPULATION ESTIMATES

Population sizes of black and white crappie and northern pike were estimated from fish captured during the spring trap-net season. The modified Schnabel estimator was used (Chapman and Overton 1966), employing the expression:

$$\hat{N} = \sum_t \frac{C_t M_t}{R_t + 1}$$

where: $\hat{N}$ = estimated fish population
C_t = number of fish caught
M_t = marked fish at large
R_t = number of recaptures

Confidence limits (α = 0.05) were computed according to the formula:

$$P \{\underline{x} \leq \sum_t \frac{C_t M_t}{\hat{N}} \leq \overline{x}\} = 1 - \alpha$$

where $\underline{x}$ and $\overline{x}$ are the lower and upper confidence limits, respectively, of the Poisson variable, obtained from the table of expectations of Poisson variable

(Chapman and Overton 1966). Captured fish were taken to the midpoint of each zone prior to marking and released to prevent introducing a bias into the estimate.

CREEL CENSUS

A partial creel census designed to sample anglers as they left the reservoir was conducted in 1975 and 1976. A creel census station was established on the main access road to the reservoir (figure 29) and was operated from 10:00 A.M. until dark or until all fishermen had left the reservoir. Signs instructing fishermen to stop were erected on the approach to the station. Fishermen were interviewed to determine distance traveled, gender, license type, total hours fished, fishing method, bait, shore or boat, number of fish caught, and number of fish released. Lengths, weights, and scales were taken of the fish which had not been dressed. In 1975 the station was operated on subsequent days during the week (i.e. Monday one week, Tuesday the next week, etc.), and alternate weekend days. The 1976 fishing season was stratified by two week periods, with two weekdays and two weekend days randomly selected for each period. Data were recorded on creel census forms and transferred to computer cards for analysis.

Existing situation

LIMNOLOGY

The drawdown of Tongue River Reservoir in anticipation of repairs to the discharge tunnel which were scheduled for the fall of 1975 was begun in July 1975. Storage in the reservoir reached a minimum of 16.15 hm^3 (13,100 af) on September 30 and increased to 23.99 hm^3 (19,460 af) on November 1 when repairs began (figure 30). Discharge was maintained at approximately 0.57 m^3/sec (20 cfs) for the month of November while repairs were made. Due to reduced discharges, reservoir storage increased to 43.40 hm^3 (35,200 af) on December 31. The reservoir stage remained constant throughout the winter, increasing to a peak of 73.72 hm^3 (59,790 af) on June 30. Discharge was regulated in response to increased downstream demands in late summer, when it exceeded inflow, but was diminished in the fall relative to the inflow to increase storage to about 43.16 hm^3 (35,000 af) for the winter months.

The Tongue River Reservoir can be characterized as a bicarbonate water with calcium as its dominant cation (Whalen et al. 1976). Other abundant ions are SO_4, Mg, and Na. Winter O_2 sampling suggested a low potential for winter fish kill in the reservoir since O_2 did not fall below 10mg/1 during ice cover. Winter fish kill potential for cool-water fish does not become critical until O_2 concentrations fall below 5 mg/1. Even with increased organic production, little winter kill would probably result because of the short retention time of the reservoir. It was determined that the mine discharge water is altered ground water. The major alteration is an increase in conductivity as a result of increased Ca, HCO_3, Mg, and SO_4. Mine water flow was never greater than 0.47 percent of the Tongue River flow and thus had a negligible effect on the river because of dilution.

Van Voast and Hedges (1975) predict that, with three mines in operation, mine effluent will increase to 0.17 m^3/sec (6.0 cfs). Assuming this flow level under hypothetical flow and chemistry conditions, Whalen and Leath (1976) predicted little change in river quality.

FISH POPULATIONS

HISTORY

The Tongue River Reservoir and a portion of the drainage upstream were chemically treated in 1957 to remove undesirable fish species. Following rehabilitation, the reservoir was stocked with rainbow trout in an attempt to duplicate fishing which commonly follows the initial impounding of reservoirs. Over two million fingerling rainbow trout were planted during the years 1958-1960. Gill net sampling in November 1959 produced 80 rainbow per net night; sampling in 1960 took only seven rainbow per net night. Stocking with trout was stopped because the undesirable fish species had again built up to high population levels. However, correspondence in 1962 suggests that the reservoir was still producing some

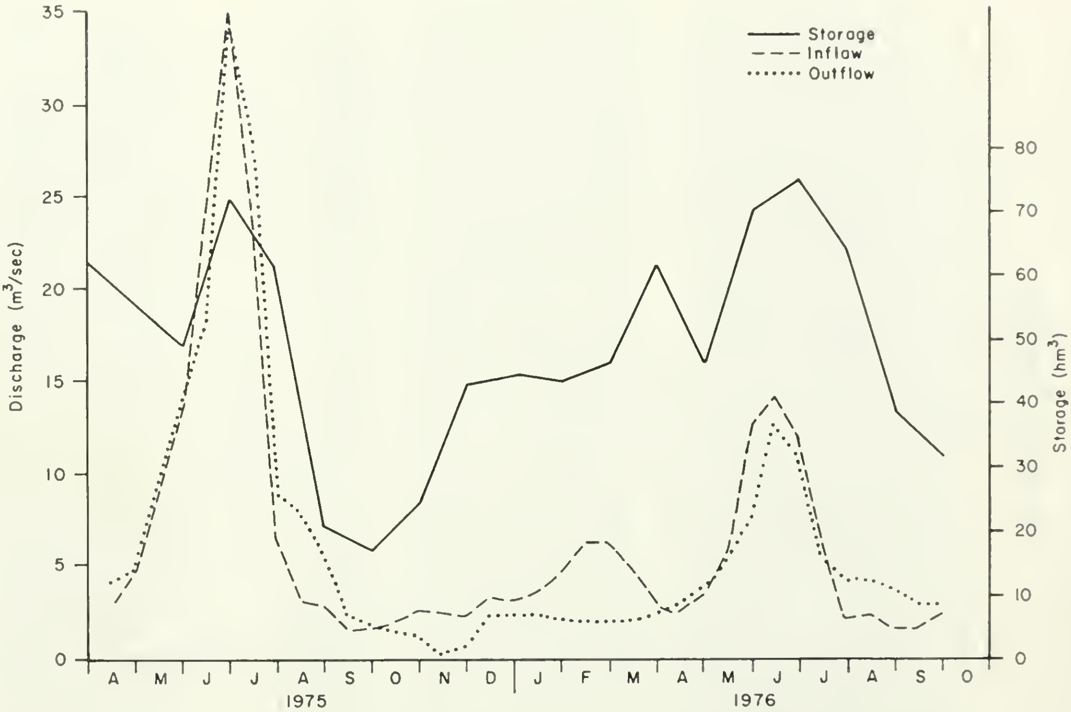


Figure 30. Inflow and outflow of Tongue River at Tongue River Reservoir compared with storage elevation of the reservoir from April 1975 to October 1976.

good catches of rainbow trout, with fish ranging from .7 to 2.7 kg (1½ to 6 lb) being harvested by anglers.

Stocking recommendations for a warm-water fishery in the reservoir were implemented in 1963 and are summarized in table 22. Northern pike fry and fingerling were stocked from 1963 through 1966 to develop a self-sustaining population. Northerns were not planted in 1967 and 1968, as a check on natural reproduction, but were again planted in 1969. Fingerlings, rather than fry, were planted from 1972 to 1976 to evaluate the effects of different numbers and sizes of fish. Channel catfish were introduced in 1963 and 1964, and largemouth bass were planted in 1964 and again in 1972 and 1973. Walleye were stocked from 1965 to 1969. Since the first plant of walleyes would have matured in 1970, this plant was discontinued as a check on spawning success.

SAMPLING RESULTS

Fish were collected for analysis using the methods explained on page 83. Results of frame trap net catches are tabulated by month and reservoir zone for each species collected in tables 23 (1975 collections) and 24 (1976 collections). As shown in table 25, the number of fish taken per net night with trap nets has increased since 1972. Catch rates per net night were similar from 1972 through 1974 but more than doubled from 1974 to 1975 and from 1975 to 1976. Fewer traps were fished in 1976, and efforts were concentrated on catching mature northern pike for an egg viability study.

Gill nets are utilized to follow fish population trends. Eighteen experimental gill nets were fished on the bottom for a 24-hour period each year. Gill net catches for the years 1964 through 1976 are summarized in table 26. Table 27 shows average lengths and weights, as well as number caught per net, for all species collected in overnight gill net sets.

Northern Pike

Habitat Preference. Marshes and warm, weedy bays constitute the preferred spawning habitats of northern pike *(Esox lucius)* in lakes and reservoirs. Spawning occurs in the early spring, immediately after the ice melts. Mature adults move into shallow, vegetated marshes and bays for spawning, scattering their eggs over the vegetation. The physical characteristics and water level management of the Tongue River Reservoir has resulted in a limited amount of good northern habitat. Marshes are present only during maximum storage; weedy bays are almost nonexistent. Natural reproduction has not been documented in the reservoir.

Catch Rates and Distribution. Frame trap nets fished during the spawning season in 1975 and 1976 caught a total of 176 and 132 northern pike, respectively (tables 23 and 24). In 1975, 29.5 percent (52 of 176) of the northerns were recaptured one or more times; in 1976, 35.6 percent (47 of 132) of the sample were recaptured fish.

Northern pike were taken almost exclusively in zone A in 1975 (91.5 percent of the total northern catch); in 1976 the catch was distributed between zones A (62.1 percent) and B (37.9 percent). Zone A represents the best northern habitat in the reservoir. In 1975, the greatest northern catch (55.1 percent) occurred in May. In 1976, most northerns (59.1 percent) were captured in April. Spring ice melt was late in 1975 (about April 24) as compared to 1976 (April 9), which accounts for the greater April catch rates in 1976.

TABLE 22. Summary of warm-water fish plants in the Tongue River Reservoir, 1963-75.

Year	Species	Size	Number
1963	Northern pike	Fry	210,000
	Northern pike	Fingerling	35,200
	Channel catfish	3-inch	20,608
1964	Northern pike	Fry	100,000
	Channel catfish	2-inch	99,180
	Largemouth bass	1-inch	150,000
1965	Northern pike	Fry	339,300
	Walleye	Fry	750,000
1966	Northern pike	Fry	210,500
	Walleye	Fry	100,000
1967	Walleye	Fry	197,750
1968	Walleye	Fry	601,214
1969	Northern pike	Fry	650,000
	Northern pike	Fingerling	513,200
	Walleye	Fry	92,480
1970	Northern pike	Fry	1,125,000
1971	Northern pike	Fry	360,000
1972	Northern pike	Fingerling	14,058
	Largemouth bass	2-inch	199,290
1973	Northern pike	Fingerling	13,184
	Largemouth bass	2-inch	27,540
1974	Northern pike	Fingerling	3,330
1975	Northern pike	Fingerling	32,775
1976	Northern pike	Fingerling	50,000

TABLE 23. Summary of trap net catches by zone in the Tongue River Reservoir, 1975

	April			May			June			Total			
	A	B	C	A	B	C	A	B	C	A	B	C	Total
Northern pike	67	1	1	89	6	2	5	4	1	161	11	4	176
Carp	195	23	27	264	53	34	10	8	3	469	164	64	697
Goldfish	21		1	11	1		1	8		33	9	1	43
Golden shiner	17	1	1	15	60	8	8	104	8	40	165	17	222
Shorthead redhorse	2			9	5	5	3	4	2	14	9	7	30
White sucker	5		2	1	5	8	2	36	53	8	41	63	112
Longnose sucker	0								1			1	1
Black bullhead	11	1		13	20	4	1	1	3	25	22	7	54
Yellow bullhead	2			2	33	10	1	6	2	5	39	12	56
Channel catfish	0												
Stonecat	0				3			2			5		5
Largemouth bass	0												
Smallmouth bass					9	1		1	1		10	2	12
Rock bass				1	7				1	1	7		8
Green sunfish	2			1	2	2				3	2	3	8
Black crappie	34		2	62	125	97	31	77	374	127	202	473	802
White crappie	83	2		211	717	89	577	3850	372	871	4569	461	5901
Sauger	2	3		11		2	3	1		16	4	2	22
Walleye	26	31	9	8	3	7	3	15		37	49	16	102
Yellow perch	75	11		9	83	542	2	1	17	86	95	559	740
TOTAL	542	73	43	707	1132	811	647	4198	838	1896	5403	1693	8991
NET NIGHTS	20	5	3	41	33	23	13	38	21	74	76	47	197
FISH PER NET NIGHT	27.1	14.6	14.3	17.2	34.3	35.3	49.7	110.5	39.9	25.6	71.1	36.0	45.6

TABLE 24. Summary of trap net catches by zone in the Tongue River Reservoir, 1976.

	April			May			June			Total			
	A	B	C	A	B	C	A	B	C	A	B	C	Total
Northern pike	50	28		32	22					82	50	0	132
Carp	19	5		2	2	1				21	7	1	29
Goldfish	8			1	3					9	3	0	12
Golden shiner	57			97	76					154	76	0	230
Shorthead redhorse	1	1			2	2				1	3	2	6
White sucker	2					3				2	0	3	5
Longnose sucker										0	0	0	0
Black bullhead	29			38	12					67	12		79
Yellow bullhead	4			71	18					75	18		93
Channel catfish	0												0
Stonecat	4				1					4	1		5
Largemouth bass	0									0	0	0	0
Smallmouth bass	2			2	7	3				4	7	3	14
Rock bass	2			3	4					5	4		9
Green sunfish	2			1						3	0	0	3
Black crappie	120	20	0	119	181	141			7	239	201	148	588
White crappie	776	6	0	1840	2312	127		42	6	2616	2360	133	5109
Sauger	34	1	2	9	4	6				43	5	6	54
Walleye	7	2	3	10	6					17	8	2	27
Yellow perch	73	1		35	17					108	18	3	129
TOTAL	1190	64	5	2260	2667	283		42	13	3450	2773	301	6524
NET NIGHTS	12	7	1	13	15	8		1	3	25	23	12	60
FISH PER NET NIGHT	99.2	9.1	5.0	173.8	177.8	35.4		42.0	4.3	138.0	120.6	25.1	108.7

TABLE 25. Comparison of trap net catches: Tongue River Reservoir, 1972-76 (expressed as numbers per net night).

	1972		1973		1974		1975		1976	
	No.	%	No.	%	No.	%	No.	%	No.	%
Northern pike	0.34	1.78	0.25	1.79	0.95	5.79	0.90	1.97	2.20	2.02
Carp	7.05	37.10	3.39	24.40	1.46	8.90	3.49	7.63	0.48	0.44
Goldfish	0.01	0.05	0.02	0.14	0.10	0.61	0.22	0.48	0.20	0.18
Golden shiner	0.09	0.47	0.11	0.79	0.04	0.24	1.24	2.71	3.80	3.50
Shorthead redhorse	0.13	0.68	0.21	1.51	0.29	1.77	0.16	0.35	0.10	0.10
White sucker	0.19	1.00	0.49	3.52	0.30	1.83	0.57	1.25	0.08	0.07
Longnose sucker			0.03	0.21	0.03	0.18	0.01	0.02		
Black bullhead	1.51	7.94	0.43	3.09	0.55	3.35	0.27	0.86	1.32	1.21
Yellow bullhead					0.26	1.59	0.28	0.61	1.55	1.43
Stonecat			0.01	0.07	0.01	0.06	0.03	0.06	0.08	0.07
Largemouth bass	0.01	0.05			0.02	0.12				
Smallmouth bass	0.01	0.05	0.01	0.07	0.03	0.08	0.06	0.13	0.23	0.21
Rock bass			0.01	0.07	0.01	0.06	0.04	0.08	0.15	0.14
Green sunfish			0.02	0.14	0.02	0.12	0.04	0.08	0.05	0.05
Black crappie	1.24	6.52	1.30	9.35	2.99	18.24	4.08	8.92	9.80	9.02
White crappie	1.99	10.47	3.50	25.19	7.96	48.55	29.95	65.50	85.15	78.34
Sauger			0.02	0.14	0.09	0.55	0.09	0.20	0.90	0.83
Walleye	0.38	2.00	0.12	0.86	0.33	2.01	0.47	1.03	0.45	0.41
Yellow perch	6.05	31.84	3.96	28.56	0.96	5.85	3.83	8.34	2.15	1.98
TOTAL	19.00		13.89		16.40		45.73		108.69	
NO. NET NIGHTS	85		121		168		197		60	

TABLE 26. Summary of gill net (bottom) sets in the Tongue River Reservoir, 1964-76, expressed as numbers of fish per net set.

	1964	1966	1968	1969	1970	1971	1972	1973	1974	1975	1976
Brown trout											0.1
Rainbow trout									0.1	0.1	
Northern pike	0.8	0.8	0.1	0.2	0.3	0.2	0.2	1.2	0.6	0.1	0.2
Carp	4.2	2.5	4.6	8.4	6.3	4.1	4.6	6.9	3.3	4.8	3.9
Golden shiner	12.0	0.3	0.7	0.6		0.1	0.2			0.1	
Goldfish			0.1	0.2	0.1	0.1		0.1			
Longnose sucker	0.5	0.3	0.1	0.2	0.1					0.1	
Shorthead redhorse	0.8	9.0	1.2	6.5	3.5	1.7	10.2	21.5	10.3	11.2	8.6
White sucker	16.8	3.8	5.0	1.3	2.9	0.6	3.3	4.7	1.9	2.2	4.1
Black bullhead	15.2	12.0	4.2	2.8	1.4	0.7	3.7	5.0		0.7	0.3
Yellow bullhead									2.7	6.4	3.2
Channel catfish							0.1			0.1	
Stonecat										0.1	0.1
Largemouth bass	0.5									0.1	
Smallmouth bass							0.1	0.3	0.3	1.0	1.9
Pumkinseed								0.2		0.1	
Rock bass								0.2	0.2		0.1
Black crappie							3.1	0.3	0.3	0.6	0.2
White crappie[a]	22.5	9.8	16.8	15.8	9.2	11.3	7.2	11.9	16.4	14.7	25.8
Sauger								0.6	1.0	1.4	1.0
Walleye pike		0.7	0.1	0.7	0.5	0.4	1.5	2.5	1.7	2.8	1.9
Yellow perch	1.5	10.0	4.0	7.7	4.1	8.4	5.6	4.3		1.7	1.2
TOTAL	74.8	48.2	36.9	44.4	28.4	27.6	39.9	59.7	40.8	47.9	52.6
NUMBER OF SETS	4	6	18	18	18	18	18	18	18	18	18

[a]Includes black and white crappie, 1964-71.

Numbers of northerns taken by gill net during the summer sampling period declined from 1.2 fish/net in 1973 to 0.1 fish/net in 1975, increasing slightly to 0.2 fish/net in 1976 (table 27).

TABLE 27. Catch statistics of 18 overnight gill net (bottom) sets, Tongue River Reservoir, July 1975 and 1976.

Species	1975				1976			
	No.	No./Net Set	Average Length (mm)	Average Weight (g)	No.	No./Net Set	Average Length (mm)	Average Weight (g)
Brown trout					1	0.1	287	220
Rainbow trout	1	0.1	185	140				
Northern pike	2	0.1	515	865	3	0.2	661	1470
Carp	87	4.8	410	837	70	3.9	429	978
Golden shiner	1	0.1	81	40				
Longnose sucker	1	0.1	237	110				
Shorthead redhorse	202	11.2	322	363	155	8.6	331	464
White sucker	40	2.2	299	464	73	4.1	377	641
Channel catfish	1	0.1	356	360				
Black bullhead	13	0.7	227	203	5	0.3	211	142
Yellow bullhead	116	6.4	219	152	58	3.2	223	174
Stonecat	1	0.1	210	100	2	0.1	175	90
Largemouth bass	1	0.1	147	40				
Smallmouth bass	18	1.0	269	285	34	1.9	217	168
Rock bass	2	0.1	168	178	1	0.1	110	10
Green sunfish					3	0.2	111	23
Pumpkinseed	1	0.1	126	40				
Black crappie	10	0.6	119	53	3	0.2	221	123
White crappie	265	14.7	198	128	465	25.8	206	121
Sauger	18	1.0	510	553	18	1.0	405	659
Walleye pike	51	2.9	398	772	34	1.9	430	869
Yellow perch	30	1.7	165	50	21	1.2	169	65
TOTAL	862	47.9			946	52.6		

CONVERSIONS: 1 mm = .0394 in
1 g = .0022 lb

Young-of-the-year northerns were taken by electrofishing coincidentally with smallmouth bass sampling in 1976. By September the young northerns had attained a length of 298 mm (11.7 in). While it was not possible to estimate survival of the 1976 spring plant, subsequent recapture of marked fish suggests a good survival rate and the possibilities of good year-class strength.

Size, Age, and Growth. Northerns ranged in length from 394 to 1,156 mm (15.5 to 45.5 in) in 1974, 282 to 1,301 mm (11.1 to 51.2 in) in 1975 and 571 to 1,165 mm (22.5 to 45.9 in) in 1976 (table 28). Average lengths were 719, 808, and 802 mm (28.3, 31.8, and 31.6 in), respectively, while the average weight increased from 2,937 g (6.46 lb) in 1974 to 3,236 g (7.12 lb) in 1976. The length-frequency distribution of northerns caught in the traps reveals distinct age groups in the spawning population (figure 31). The fingerlings planted in 1972 entered the spawning population in 1974 at a length interval of 450-650 mm (18 to 26 in). This age class increased to a length interval of 500-700 mm (20 to 28 in) in 1975 and 700-850 mm (28 to 33.5 in) in 1976. The reduction in the number of northerns planted in 1973 and 1974 is shown by lack of distinct age groups entering the spawning population in 1975 and 1976. The absence of these age groups further suggests limited natural reproduction in the reservoir.

TABLE 28. Average lengths and weights of northern pike caught in trap nets in the Tongue River Reservoir, 1972-76.

Year	No.[a]	Average Length (mm)	Range (mm)	Average Weight (g)
1972	29	747	597-1,080	3,746
1973	48	732	648-1,189	3,750
1974	140	719	394-1,156	2,937
1975	136	808	282-1,301	3,083
1976	133	802	571-1,165	3,236

CONVERSIONS: 1 mm = .0394 in
1 g = .0022 lb

[a]Does not include recaptures.

The average length of northern pike taken in gill nets for the years 1964-1976 shows wide variation (figure 32). The increase in length from 1964 to 1969 represents maturity of early plants. The reduction in 1970 followed by an increase reflects the discontinuance of stocking followed by stocking resumption.

A small sample of scales (17) taken from trap-netted pikes were analyzed for age class sizes. Three age classes (II - IV) were represented, and the mean length for each age class was 218 mm (four fish), 523 mm (nine) and 773 mm (four), respectively. These are within the ranges reported for other northern pike populations (Scott and Crossman 1973). The mean length of age group IV (773) corresponds closely with the mean of the 1972 age 0 class, as shown in the length-frequency distribution (figure 32).

Population Estimates. Population estimates were computed for northern pike based on the modified Schnabel estimator using trap-netted fish. Estimates of northern pike population greater than 275 mm were 272 in 1974, 228 in 1975, and 138 in 1976 (table 29). Confidence intervals at the 95 percent level showed a

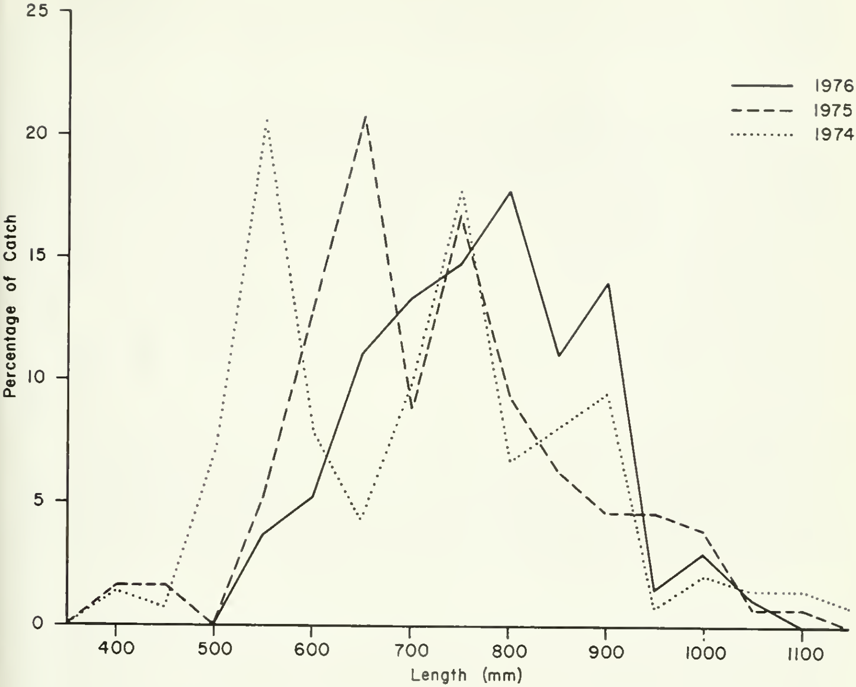


Figure 31. Length-frequency of northern pike captured in trap nets, Tongue River Reservoir, 1974-76, expressed as each size interval's percentage of the total sample.

significant decrease from 1975 to 1976. This reduction appeared to be in larger fish, as shown in figure 31. Based on the average weight of trap-netted fish, the northern pike standing crop was estimated at 0.564 kg/ha (.503 lb/acre) in 1974, 0.496 kg/ha (.442 lb/acre) in 1975, and 0.315 kg/ha (.281 lb/acre) in 1976. The standing crop of northerns in the Tongue River Reservoir is considerably lower than most others reported. For example, estimates of standing crops of northern pike in Wisconsin lakes ranged upward from 0.673 kg/ha (Snow and Beard 1972); in a southern Michigan lake, crops ranged from 3.5 to 5.3 kg/ha (Schneider 1971). Scott and Crossman (1973) reported standing crops

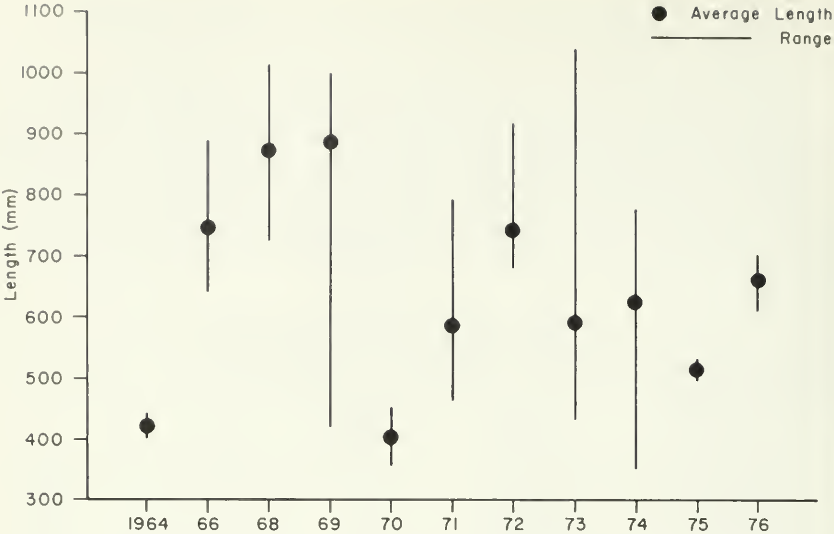


Figure 32. Average length and length range of northern pike from gill-net catches, Tongue River Reservoir, 1964-76.

of northern pike from various habitats across North America generally range between 1.5 and 4.6 kg/ha. The low population levels shown in this reservoir are probably the result of poor habitat quality and the lack of natural reproduction.

TABLE 29. Population estimates of northern pike determined from trap net catches, Tongue River Reservoir, 1974-76.

Year	Number Examined	Number Recaptured	Population Estimate	Confidence Intervals[a]
1974	169	36	272	
1975	180	52	228	218-238
1976	85	48	138	116-172

[a]Confidence interval not computed for northern pike in 1974 due to variation in recapture distribution.

Tagging. Tags have been placed in 274 adult northerns since 1973 (table 30). Angler returns have been consistent, with an average return of 13.9 percent (range 12.5 - 16.4 percent). The highest return rate occurred the same year the fish were tagged. An overall return rate of about 14 percent is similar to catch rates reported for other marginal northern pike waters.

TABLE 30. Summary of northern pike tag returns by year for Tongue River Reservoir,1973-76. (Number in parentheses is the percentage of total tagging)

Year Tagged	Number Tagged	Tag Returns, by Year 1973	1974	1975	1976	Total
1973	41	5 (12.2)			1 (2.4)	6 (14.6)
1974	110		8 (7.2)	6 (5.5)	2 (1.8)	16 (14.5)
1975	73			7 (9.6)	5 (6.8)	12 (16.4)
1976	50				4 (12.5)	4 (12.5)
TOTAL	274					38 (13.9)

Walleye and Sauger

Habitat Preference. Sauger *(Stizostedion canadense)* and walleye *(Stizostedion vitreum)* are tolerant of a great range of environmental situations, with both preferring large, shallow lakes. Sauger are also found in turbid, slow-flowing rivers. Sauger generally succeed over walleyes in very turbid waters. Both species are generally absent from vegetated waters. Spawning occurs in the spring, with both species moving either upstream or to suitable rocky areas. Eggs are deposited at random among the rocks to incubate.

The Tongue River Reservoir provides good walleye and sauger habitat, and both populations are doing well. Walleyes were introduced from 1965-1969 and are now successfully reproducing. Sauger were not taken in the reservoir until 1973. Personal communication with Wyoming Game and Fish personnel revealed that sauger were transplanted into the Tongue River near the Wyoming-Montana state line in about 1967. The fish apparently moved into the reservoir and have become an established population.

Catch Rates and Distribution. In 1975, the trap-net catch of walleyes was distributed about equally between zones A and B, which contribute 40.7 and 41.7 percent, respectively; in 1976, 63.0 percent of the walleyes were taken in zone A, and 29.6 percent in zone B (tables 23 and 24). These zones represent the best walleye habitat. However, the effort to obtain mature northern pike in 1976 precluded equal sampling effort, and the results may not represent the true species distribution in the reservoir. In 1975, the walleye catch was largest in April; in 1976 the catch was about equally distributed between April and May. Catch rates were consistent in 1975 and 1976 (table 25).

Sauger were absent from trap-net catches until 1973, when they contributed 0.02 fish per net night (table 25). Catch rates in 1974 and 1975 were 0.09, increasing to 0.90 in 1976. In 1975 and 1976, sauger were taken primarily in zone A (72.7 to 79.6 percent of sauger catch, respectively). This zone is generally turbid during the spring season and probably represents preferred sauger habitat.

The catch per gill-net set for walleye ranged from 0.1 to 0.7 from 1966 to 1969, increasing to 1.5 in 1972 and 2.5 in 1973. The highest catch was in 1975, 2.8 fish per net. Walleye increased in size from 1966 to 1971, then stabilized from 1972 to 1976 at a level just below the 1969-70 averages (figure 33). Sauger were not taken in gill nets until 1973, when 0.6 fish per set were taken, as compared to 1.4 and 1.0 fish per set taken in 1975 and 1976, respectively. Sauger appear to be increasing and are showing up in angler's creels.

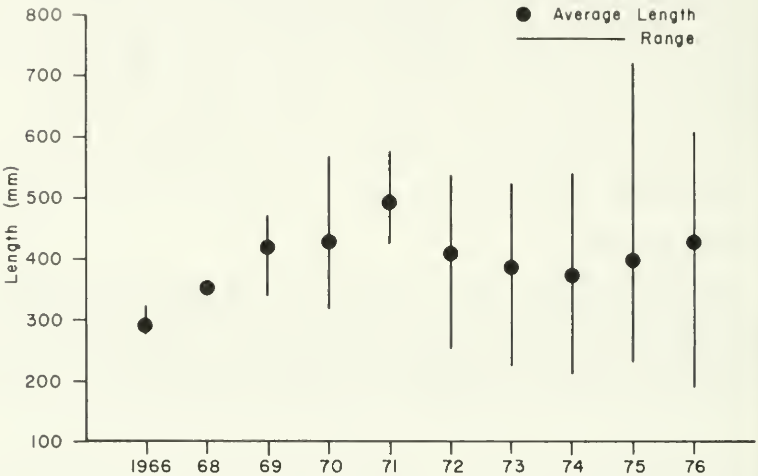


Figure 33. Average length and length range of walleyes from gill-net catches, Tongue River Reservoir, 1966-76.

Size, Age, and Growth. The average length of trap-netted walleye has varied only about 13 percent since 1972, although the average weight has varied by 25 percent (table 31). The presence of small fish in the sample indicates walleyes are successfully spawning in the reservoir.

Length-frequency distributions for walleye (1974-76) are shown in figure 34. The size interval of 575-624 mm was dominant in 1974, contributing 31.1 percent. In 1975, young fish with a peak length of 350 mm (300-400 mm) were dominant, comprising 43.9 percent. This size group shifted 100 mm in 1976, with a peak of 450 mm (range 400-600 mm). Small fish were absent in 1976, suggesting a weak year class entering the population. Scale samples taken during the spawning season suggest that walleyes enter the run at age IV+. Reservoir storage showed a poor pattern in 1972; maximum stage was reached during March, and water levels dropped during April with a slight increase during May. Thus,

TABLE 31. Average lengths and weights of walleye caught in trap nets in the Tongue River Reservoir, 1972-76.

Year	No.[a]	Average Length (mm)	Range (mm)	Average Weight (g)
1972	32	495	359-569	1,335
1973	24	541	353-645	1,643
1974	44	511	305-799	1,507
1975	90	470	269-813	1,217
1976	27	538	434-727	1,629

CONVERSIONS: 1 mm = .0394 in.
1 g = .0022 lb.

[a]Does not include recaptures.

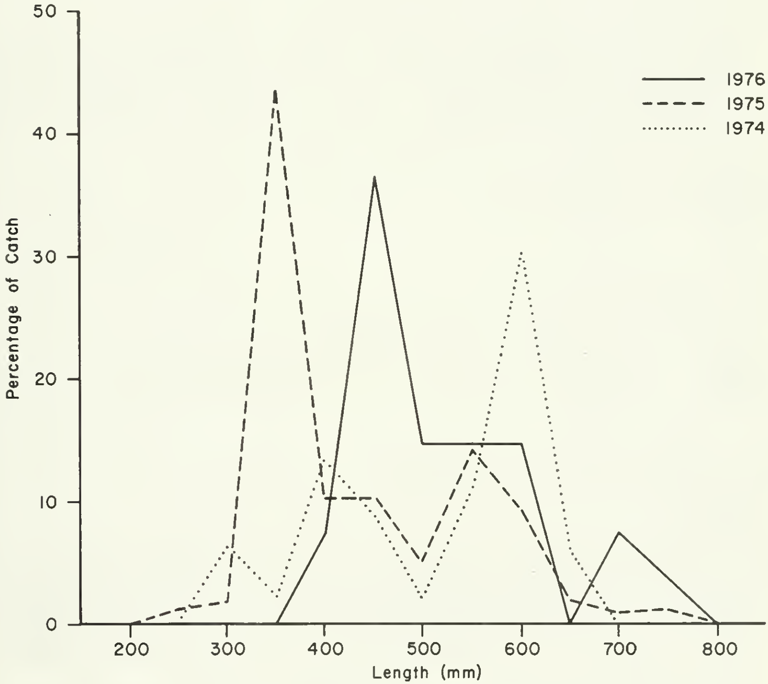


Figure 34. Length frequency of walleyes captured in trap nets, Tongue River Reservoir, 1974-76, expressed as each size interval's percentage of the total sample.

it is possible that the lowering of the water level in 1972 reduced the spawning success in 1976.

The average size of sauger taken in 1976 increased from 1975 levels of 324 mm and 464 g to 404 mm and 659 g.

Tagging. Since 1973, 244 walleye and 302 sauger have been tagged in the reservoir (table 32). Total angler returns of walleyes since then have been 5.3 percent (13 of 244), while sauger returns have been 2.0 percent (6 of 302). Almost 80 percent of the sauger were tagged in 1976, so the number returned should increase. Several returns have been reported with the numbered portion of the tag absent, and only the anchor remaining in the fish. If the incidence of this type of tag loss is high, the reported rate of return would be less than it should be since many tags would not be noticed and others would simply be discarded by the angler. However, the low rate of return suggests a harvest well within tolerance limits of the fish populations.

TABLE 32. Summary of walleye and sauger tagging and returns, Tongue River Reservoir, 1973-76. (Number in parentheses is the percentage of total tagging)

Year Tagged	No. Tagged	1973	1974	1975	1976	Total
			WALLEYE			
1973	10					0
1974	34		3 (8.8)			3 (8.8)
1975	129			3 (2.3)	6 (4.7)	9 (7.0)
1976	71				1 (1.4)	1 (1.4)
TOTAL	244					13 (5.3)
			SAUGER			
1974	11					0
1975	59			2 (3.4)	2 (3.4)	4 (6.8)
1976	232				2 (0.9)	2 (0.9)
TOTAL	302					6 (2.0)

Crappie

Both black *(Pomoxis nigromaculatus)* and white *(Pomoxis annularis)* crappie are found in the Tongue River Reservoir. Stocking records, dating to 1950, do not show introductions of crappies into the reservoir. Both species were present when the fish population was chemically removed in 1957. This panfish is the most abundant sport fish in the Tongue River Reservoir and is a popular target of anglers.

Catch Rates and Distribution. White crappie were the dominant fish in trap-net catches in 1974, 1975, and 1976 (tables 23 and 24), making up 48.6, 65.5, and 78.3 percent of the total catch, respectively. Black crappie were taken in the catch, but were less significant, contributing 18.2, 8.9, and

9.0 percent in those years. Catch rates for white crappie have increased from 1.99 fish per trap night in 1972 to 85.15 fish per trap night in 1976 (table 25). Black crappie have also increased since 1972, but not as dramatically. In 1975, both species were taken in greatest numbers during June, with 81.3 percent of the whites and 60.1 percent of the blacks taken that month. In 1976, 83.7 percent of the whites and 75.0 percent of the blacks were caught during May.

White crappie were the predominant species in gill-net catches in 1975 and 1976 (table 27). Blacks were represented in the gill nets at about the same levels as in trap nets (table 25). White crappie sample size almost doubled from 1975 to 1976 (265 to 465), resulting in a corresponding increase in the spring population estimate. The average size of white crappie was similar in 1975 and 1976.

Crappie exhibited a differential distribution pattern in the reservoir. In 1975, 59 percent of the blacks were taken in zone C, while only 7.8 percent of the whites were captured in that zone. Zone B produced the majority of the white crappie in 1975 (77.4 percent). The 1976 results are masked somewhat, since traps were not fished in zone C equally as in zones A and B. Still, white crappie were found almost exclusively in zones A and B (97.4 percent), while blacks were distributed more evenly; Zone C produced 25.2 percent of the blacks. Catch rates in zones A, B, and C in 1976 for white crappie were 104.6, 102.6, and 11.1 fish per net night respectively, as compared to 9.6, 8.7, and 12.3 fish per net night, respectively, for black crappie. The distribution pattern probably reflects a difference in water quality between the upper (zone A) and lower (zone C) ends of the reservoir. The difference in distribution reflects the habitat preferences of each species, with blacks preferring clearer water (Brown 1971).

Size, Age, and Growth. Length-frequency distribution for black and white crappie for 1975 and 1976 trap-net catches is shown in figure 35. Black crappie show a greater distribution of lengths, ranging from under 100 to 499 mm (3.9 to 19.6 in), while white crappie ranged from 100 to 399 mm (3.9 to 15.7 in). Black crappie produce larger fish, with specimens to 1,362 g (3 lb) common. In both years, the modal size for whites was 225 mm (8.9 in), compared with 250 mm (9.8 in) for blacks.

Scales taken during the spring (April-May) 1975 trap net season from black and white crappie were analyzed for age and growth. A summary of lengths and masses is shown in table 33. The oldest white crappie taken were of age group X; the oldest black crappie were of age group VIII. White crappie grew faster until age V, at which time the blacks took over. By weight, blacks caught up with whites at age IV. A comparison of lengths of fish taken in June and July shows a faster growth rate for blacks than whites. Comparing the age data with figure 35, age III fish contribute the greatest percentage of the spawning population. A comparison of age data on black and white crappie with data from other northern waters (Nelson 1974, Scott and Crossman 1973) shows that the fish in the Tongue River Reservoir grow at similar rates.

Population Estimates. Population strengths of black and white crappie were estimated in 1975 and 1976 (table 34). The total crappie estimate in 1975 was 46,613 fish, with whites contributing 94.6 percent of the total. The population increased in 1976, with a total estimate of 95,684 crappie

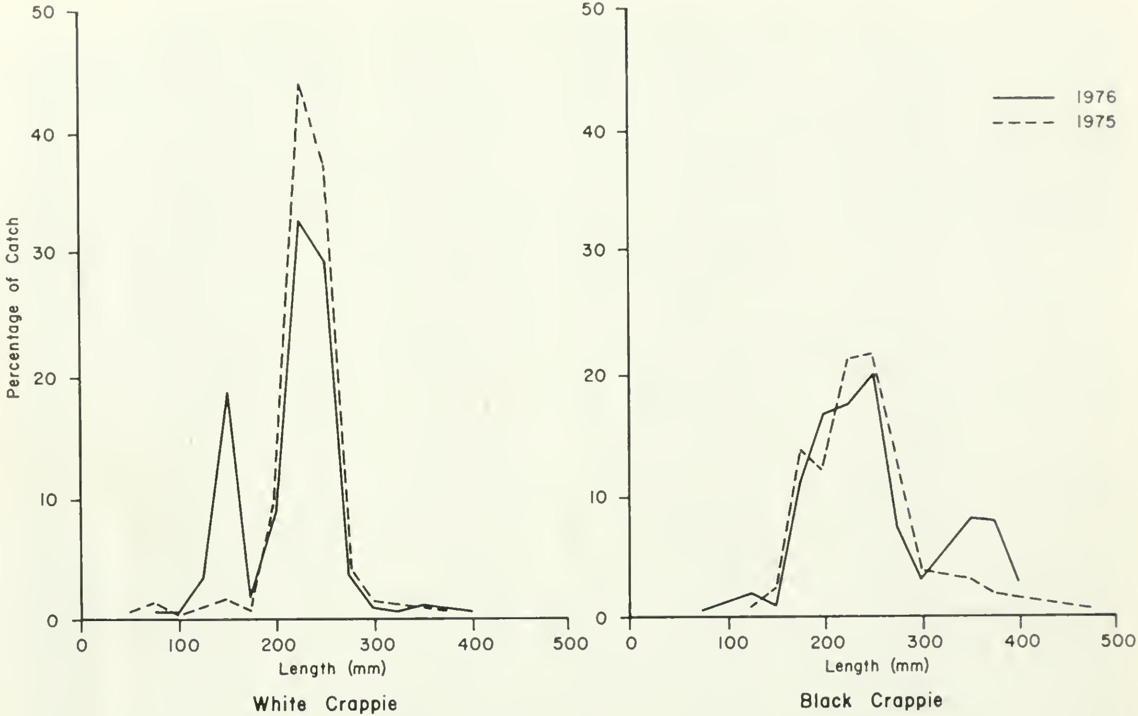


Figure 35. Length-frequency distribution of white and black crappie taken in trap nets, Tongue River Reservoir, 1975-76, expressed as each size interval's percentage of the total sample.

TABLE 33. Average lengths and weights of black and white crappie, Tongue River Reservoir, April-May 1975.

	White Crappie			Black Crappie		
Age	No.	Average Length (mm)	Average Weight (g)	No.	Average Length (mm)	Average Weight (g)
II	3	173	50	7	137	34
III	10	219	174	21	195	111
IV	30	245	222	23	237	222
V	16	262	277	20	272	345
VI	13	280	349	13	311	537
VII	2	286	415	9	361	781
VIII	1	382	318	5	396	1090
IX	1	423	1160			
X	2	363	887			

Conversions: 1 mm = .0394 in
1 g = .0022 lb

(90.8 percent whites). Estimates of standing crop for white crappie in 1975 and 1976 were 6.2 kg/ha (5.5 lb/acre) and 12.3 kg/ha (11.0 lb/acre), respectively, and 0.535 kg/ha (.478 lb/acre) and 1.9 kg/ha (1.7 lb/acre), respectively, for black crappie. The estimated crappie population doubled from 1975 to 1976. Bennett (1954) reported that a late summer drawdown similar to the lowering of the reservoir in 1975 may benefit piscivorous fishes. Small fishes and aquatic invertebrates are forced out of vegetation. The dislocation of these animals makes them more easily hunted by the larger fishes. Since crappie do feed heavily on other fishes, it is possible that their overwinter survival was enhanced by the fall drawdown.

TABLE 34. Population estimates of black and white crappie determined from trap net catches, Tongue River Reservoir, 1974-76.

	Year	Number Examined	Number Recaptured	Population Estimate		Confidence Intervals[a]
				Total Number	Number/ha	
Black crappie	1975	861	117	2,526	1.8	2,458 - 2,598
	1976	574	18	8,792	6.2	5,937 -16,935
White crappie	1975	5,817	348	44,087	31.1	43,389 -44,808
	1976	4,896	146	86,892	61.4	

CONVERSIONS: number/ha = 2.47 number/acre

[a]Confidence interval not computed for white crappie in 1976 due to variation in recapture distribution.

<u>Tagging</u>. Large black and white crappie (91 blacks and 9 whites) taken during the trap-net season have been tagged to evaluate movements and fisherman harvest. Angler returns of blacks averaged only 3.3 percent (3 of 91) over the three-year period, and none of the tagged whites were returned by fishermen. In 1975 and 1976, of 36 blacks and 3 whites of taggable size taken in trap nets, 41.7 percent(15) of the blacks and 66.7 percent (2) of the whites were recaptures

of previously tagged fish. The low angler return and high return to traps suggests that the population of large crappie is small.

Bass

Largemouth bass *(Micropterus salmoides)* were introduced into the reservoir in 1964 and again in 1972-73, but are rarely taken by fishermen. While smallmouth bass *(Micropterus dolomieui)* have never been stocked in the reservoir, they are reproducing and beginning to play an important part in the angler's harvest. Correspondence from the Wyoming Game and Fish Department (Mueller 1973) indicates that smallmouth bass were stocked in a strip-mine pond near Sheridan and that high spring flows from the Tongue River washed into the ponds, introducing smallmouth into the river and subsequently into the reservoir.

Catch Rates and Distribution. Catches of smallmouth bass have been small in trap nets, ranging from 0.01 fish per net night in 1972 and 1973 to 0.06 fish per net night in 1975 (table 25). In 1976, however, the catch increased to 0.23 smallmouth per net night. Zone B produced 83.3 percent of the catch in 1975 and 50.0 percent in 1976. The largest number of smallmouth were taken in May both years. Largemouth bass have been nearly absent from trap-net samples.

Gill nets produced smallmouth beginning in 1972, and catch rates increased from 0.1 fish per net in 1972 to 1.9 fish per net in 1976 (table 26). Largemouth have been absent from gill nets also. The average length and weight of smallmouth taken in gill nets decreased from 251 mm to 304 g in 1975 to 217 mm and 168 g in 1976, indicating the recruitment of young fish into the population.

A baseline index of reproductive success was established with 100-ft shore seine and a 50-ft bag seine. Seine hauls covering approximately 15-30 m of shore were made to obtain bass fry and juveniles. When all size groups were combined, date from 1975-50-ft seine, the 1974-100-ft seine, and the 1975-100-ft seine were relatively consistent. (table 35). Zone A had the fewest smallmouth and largemouth fingerlings per 100 m of shoreline; zone C had the most (Gregory and Penkal 1975). There were more largemouth than smallmouth fingerlings per 100 m in zones C and A and fewer in B. For all areas combined, largemouth bass made up 78.0 percent of the fingerling catch and smallmouth the other 22.0 percent.

Size, Age, and Growth. Penkal (1977) found that scale annuli of smallmouth bass in the Tongue River Reservoir were formed beginning in July and were complete by early August. The scale-length relationship was calculated and used as a correction factor for back calculation of smallmouth bass growth (table 36). Growth of smallmouth bass in the Tongue River Reservoir is above average for a northern lake. Calhoun (1966) reported a range for northern lakes of 246 mm (Michigan) to 310 mm (Minnesota) for fish at their fourth annuli. The average length of the 1972 age 0 class in the Tongue River Reservoir was 308.3 mm. This good growth could be attributed to the smallmouth's recent exploitation of the new habitat or to favorable environmental conditions.

The growth of largemouth bass in the reservoir was also investigated by Penkal (1977). A summary of the back-calculated growth of largemouth is shown

TABLE 35. Number of bass per 100 m of shoreline, Tongue River Reservoir, 1974-75.

	100-ft Seine		50-ft Seine
	1974	1975[a]	1975[a]
Fry LMB[b]		36.3	39.8
Fry SMB[b]		14.2	18.1
Juvenile LMB		1.8	0.1
Juvenile SMB		11.8	11.4
All LMB	56.3	38.3	39.9
All SMB	14.0	26.9	30.1
All LMB & SMB	70.3	65.2	70.0

[a]Gregory and Penkal 1975

[b]LMB = largemouth bass
SMB = smallmouth bass

TABLE 36. Back-calculated lengths (mm) of smallmouth bass, Tongue River Reservoir, 1976.

		Age Class					
Year Class	No.	I	II	III	IV	V	VI
Zone A							
1971	6	97	226	286	359	389	
1972	1	80	242	326	371		
1973	7	81	170	258			
1974	5	85	211				
1975	106	76					
Zone B							
1970	1	84	245	332	358	390	419
1971	3	86	169	281	351	386	
1972	3	79	177	230	293		
1973	11	89	151	235			
1974	23	86	190				
1975	157	80					
Zone C							
1970	1	90	252	351	411	433	465
1971	2	85	194	291	352	388	
1972	1	117	245	332	394		
1973	13	88	178	248			
1974	37	86	191				
1975	55	79					

SOURCE: Penkal 1977

CONVERSION: 1 mm = .0394 in

in Table 37. Largemouth bass growth also appears to be better in the Tongue River Reservoir when compared to other studies from northern lakes. A range of 292 mm (Kuehn 1949) to 318 mm (Bennett 1937) was reported for largemouth bass at their fourth annuli in Minnesota and Wisconsin, respectively. In the Tongue River Reservoir, the average calculated length of the 1972 year class was 329 mm. It may be concluded that the habitat conditions in the Tongue River Reservoir are favorable for bass growth.

TABLE 37. Back-calculated lengths (mm) of largemouth bass, Tongue River Reservoir, 1976.

Year Class	No.	Age Class I	II	III	IV	V	VI	VII
1969	2	100	244	319	382	416	445	459
1970	2	87	249	342	385	412	442	
1971	11	92	204	286	355	388		
1972	5	87	203	270	329			
1973	31	87	166	245				
1974	65	86	192					
1975	318	79						
WEIGHTED GRAND MEAN[a]		81	189	264	354	395	444	459

CONVERSIONS: 1 mm = .0394 in

[a]Weighted on basis of percentage of year class in population.

Tagging. One thousand smallmouth bass and 166 largemouth bass were tagged in the reservoir from 1973 through 1976 (tables 38 and 39). As with the other species in the reservoir, tag return rates by anglers have been low. Smallmouth bass averaged 1.7 percent return, while largemouth averaged 1.8 percent. The low rate of return suggests a good population of bass not being exploited by anglers.

TABLE 38. Summary of smallmouth bass tagging and angler returns by year, Tongue River Reservoir, 1973-76.

Tagging: Year Tagged	No. Tagged	Returns: Year Returned 1975	1976	Total
1973	2			0
1974	3			0
1975	105	4 (3.8)	5 (4.8)	9 (8.6)
1976	890		8 (0.9)	8 (0.9)
TOTAL	1000			17 (1.7)

NOTE: Numbers in parentheses are the percentage of fish tagged in the year indicated.

TABLE 39. Summary of largemouth bass tagging and angler returns by year, Tongue River Reservoir, 1974-76.

Tagging: Year Tagged	No. Tagged	Returns: Year Returned 1975	1976	Total
1974	2			0
1975	15	1		1 (6.7)
1976	149		2 (1.3)	2 (1.3)
TOTAL	166			3 (1.8)

NOTE: Numbers in parentheses are the percentage of fish tagged in the year indicated.

CREEL CENSUS

Using the methods explained on page 84 , 365 parties of anglers were interviewed in 1975 and 423 in 1976 (table 40). Shore fishermen were more numerous than boat fishermen in 1975, contributing 53.2 percent of the total; boat fishermen were dominant in 1976, adding 65.0 percent. Anglers expended more time in 1976 than in 1975, and caught almost three times more fish. Anglers nonresident to Montana traveling less than 50 miles made up the majority of the fishermen (50.4 percent), followed by Montana residents traveling more than 50 miles (38.7 percent).

TABLE 40. Miscellaneous statistics of Tongue River Reservoir creel census, 1975-76.

	1975	1976
Parties interviewed	365	423
Length of trip (hrs)	4.42	6.05
Total hours fished[a]	12,522	20,053
Total fish caught[a]	4,088	11,538

[a]These are estimated figures for the entire season, all anglers.

An estimated 2,802 anglers expended 12,522 hours of fishing pressure on the reservoir in 1975. In 1976, the pressure increased to 3,315 anglers and 20,053 hours. The estimated annual fishing pressure for the summer was 8.84 hours/ha (3.58 hours/acre) and 14.16 hours/ha (5.73 hours/acre) in 1975 and 1976, respectively. Monthly, the pressure varied in 1975 from a low of 0.28 hours/ha (.11 hours/acre) in October to a high of 1.59 hours/ha (.64 hours/acre) in May and in 1976 from 0.45 hours/ha (.18 hours/acre) in October to 4.43 hours/ha (1.79 hours/acre) in June (figure 36). Fishing pressure fell off during the late summer both years, increasing again with cooler temperatures in the fall.

Pressure on the Tongue River Reservoir is less than reported on other cool water lakes in northern latitudes. Kempinger et al. (1975) summarized fishing pressure on other northern latitude lakes and showed a range of 42 hours/ha (17 hours/acre) to 462 hours/ha (187 hours/acre). The low pressure estimates on the Tongue River Reservoir suggest that it is a lightly used fishing resource. However, as coal development expands in the Decker area and new recreation areas are developed, fishing pressure will increase. Continued efforts must be expended to ensure that fish populations will be able to withstand the added pressure.

Estimated angling effort and harvest rates for the sport fishery are summarized in table 41. Crappie dominated the catch both years, contributing 66.3 and 75.3 precent in 1975 and 1976, respectively. All sport fish showed an increased total catch from 1975 to 1976. The catch rate for crappie increased from 0.172 fish per hour in 1975 to 0.382 fish per hour in 1976. The increase of crappie in the angler's creel is consistent with other sampling conducted in 1976. Catch per hour for northern pike decreased from 1975 to 1976.

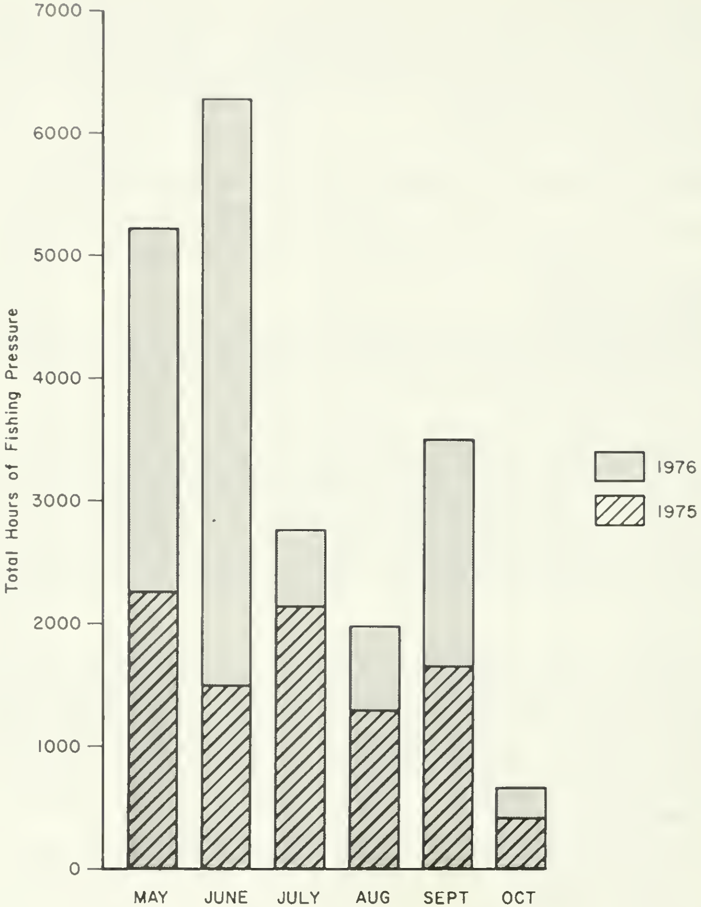


Figure 36. Monthly distribution of fishing pressure, Tongue River Reservoir, 1975-7

TABLE 41. Estimated total angling effort and harvest of sport fish, Tongue River Reservoir, 1975 and 1976.

	1975	1976
Total man-trips	2,802	3,315
Total man-hours	12,522	20,053
Total catch (number of fish)		
Northern pike	128	132
Bass[a]	604	1,241
Crappie[b]	2,149	7,655
Walleye	361	1,137
Total catch (kg)	3,242	10,165
Northern pike	202.7	205.9
Bass[a]	151.0	310.4
Crappie[b]	516.2	1,838.2
Walleye	337.1	1,061.9
Total weight (kg)	1,207.0 (0.84 kg/ha)	3,416.4 (2.41 kg/ha)
Catch success (fish per man-hour)		
Northern pike	0.010	0.007
Bass[a]	0.048	0.062
Crappie[b]	0.172	0.382
Walleye	0.029	0.057
TOTAL CATCH SUCCESS	0.259	0.508

[a]Includes both smallmouth and largemouth
[b]Includes both black and white

Fishing success for sport fish in the reservoir averaged 0.259 fish per hour in 1975 and 0.508 fish per hour in 1976. These catch rates are low in comparison to other cool-water fisheries. Reported catch rates ranged from 0.48 fish per hour (similar to the highest recorded on the Tongue) to 1.25 fish per hour (Kempinger et al.1975). The annual yield on the Tongue River Reservoir varied from 1207.0 kg (0.84 kg/ha) in 1975 to 3416.4 kg (2.41 kg/ha) in 1976. These figures are also lower than reported for other cool-water lakes.

The seasonal contribution of each sport species to the 1976 total catch is shown in figure 37. Crappie dominated the catch in May and June, falling off throughout the remainder of the summer. Walleye began showing up in June and peaked in July, while bass increased in July to peak in August and September. Northern pike contribute little to the catch. It is apparent that stocking rates are not adequate to produce a good northern pike fishery in the reservoir.

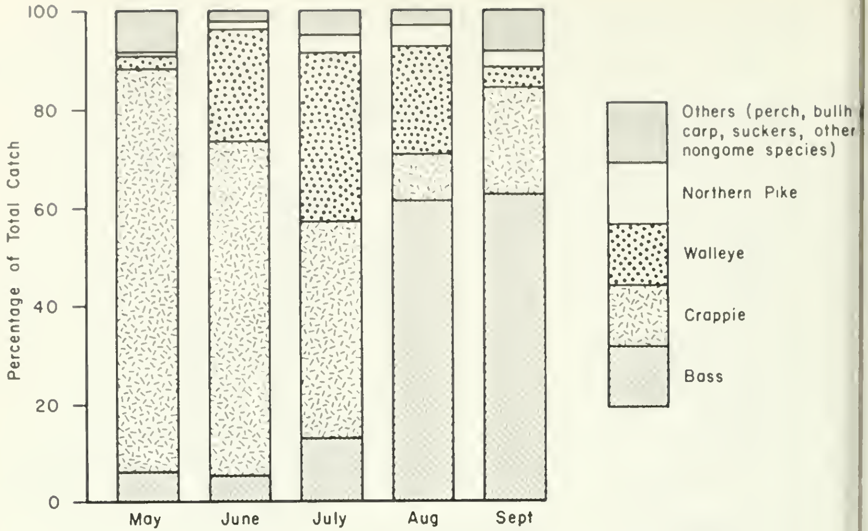


Figure 37. Monthly distribution of species as determined by creel census, Tongue River Reservoir, 1976.

Impacts of water withdrawals

PROJECTIONS OF FUTURE USE

In order to adequately and uniformly assess the potential effects of water withdrawals on the many aspects of the present study, it was necessary to make projections of specific levels of future withdrawals. The methodology by which this was done is explained in Report No. 1 in this series, in which also the three projected levels of development, low, intermediate, and high, are explained in more detail. Summarized in appendix A, these three future levels of development were formulated for energy, irrigation, and municipal water use. Annual water depletions associated with the future levels of development were included in the projections. These projected depletions, and the types of development projected, provide a basis for determining the level of impact that would occur if these levels of development were carried through.

IMPACTS ON THE RESERVOIR FISHERY

Through the State Water Planning Model (see Report No. 1 of this series), the depleted streamflows for the Tongue River Basin which would result from implementation of three alternative levels of energy or irrigation use were calculated. For the low projected level of development for either type of use, the storage capacity of the existing Tongue River Reservoir was increased from 69,000 af to 125,000 af. The intermediate and high levels of development required the High Tongue River Dam, which would have an active capacity of 320,000 af and would provide a firm annual yield of 134,000 af.

The impacts of development on the reservoir fishery were evaluated. Sport fishes in the reservoir, which spawn during April and May, depend on stable or rising water levels during this period. A decreasing water level would result in a loss of available spawning habitat and would desiccate incubating fish eggs. Storage patterns projected were judged detrimental if they required reservoir level decreases in April and May.

For the low level of energy development, only one year out of 29 resulted in poor reproductive potential. The intermediate level showed six years with poor spawning potential. With the high projection, storage patterns resulted in poor reproductive potential in 10 years out of 29, an average of one year out of three with the possibility of reduced spawning. Even with poor reproduction every third year, a good fishery should result from the remaining years' reproduction.

Storage patterns associated with the three levels of irrigation development showed no serious problems. Impacts on the fishery of the Tongue River Reservoir would be minimal.

Summary

The Tongue River Reservoir is a unique fishery in an area with a low human population. Fish population estimates, with the exception of those for northern pike, suggest a healthy, reproducing fishery. Spawning habitat for northerns is lacking, and present water-level management does not favor the reproduction of this species. Stocking with northern pike fingerlings has been effective. Crappie, bass, walleye, and sauger are reproducing. The low annual pressure estimates and catch rates indicate that this fishery's potential is not being utilized to its fullest.

Trap-net catch rates range from 45.7 fish per net night in 1975 to 108.7 in 1976. Crappie showed the greatest increase in number from one year to the next. Game fish made up 3.3 percent of the 1975 sample and 3.5 percent of the 1976 sample. Population estimates computed for northern pike, black crappie, and white crappie were comparable to those in other northern lakes. A partial creel census conducted in 1975 and 1976 showed a catch rate of 0.259 fish per man hour in 1975 and 0.508 fish per man hour in 1976. Harvest rates and yield were lower than those reported for other states.

Impacts of water withdrawals on the reservoir and its fishery are discussed. An evaluation of the drawdown which occurred in 1975 indicates that it was not extremely harmful to the fishery. In fact, the crappie population may have increased. Examination of projected reservoir levels associated with three levels of proposed energy and agricultural development shows minimal impacts on the reservoir's fishery. However, provision of instream flows for fish and wildlife downstream from the dam were not considered as part of these projections. With an increase in release for instream needs, storage patterns could be altered. Still, as shown by the short-term drawdown in 1975, if the magnitude and duration of water-level reduction are not extreme, the impacts should not be severe. An extreme drawdown for long periods of time would be devastating.

As industrial development proceeds in this region, water-based recreation provided by the Tongue River Reservoir will become increasingly important.

Part 111

Food habits and forage fish

by

Dennis Schwehr

Introduction

The characteristics of insect and fish populations in streams are determined to a large degree by discharge and by the environmental conditions created by discharge. The composition of the insect community, the food base of most fish populations, is related to water velocity, a function of discharge. To assess the impact of dewatering on fish foods and habitat, it is necessary to determine the importance of the benthic insects to the fishes. In addition, the maintenance of the piscivorous sport and nonsport fish populations in the lower Yellowstone (walleye, sauger, northern pike, burbot, and channel catfish all commonly utilize other fish for all or part of their diet) depends, in part, on an adequate forage fish base.

PURPOSE

Fish populations, relative abundances, and food chains vary widely among aquatic ecosystems. Each fish species is adapted to an omnivorous, herbivorous, or carnivorous diet, but the proportions of specific foods eaten differ in each habitat. Prey organisms that are important in one habitat may not exist in other areas which contain the same predator species. Seasonal changes occur in food habits of fish as relative abundances and composition of insect species are altered during the life cycles of insects. Food habits of resident populations must be determined for individual water bodies in order to assess the potential for impact. Impacts on fish populations are dependent on the amount of stress placed on the food supply in a particular habitat. It is important to establish which food species are most critical in fish diets and how environmental change will affect the food supply.

The objectives of this investigation were: (1) to determine the foods of selected fish species during the period of study, (2) to establish those species' selection for preferred food items relative to their availability, and (3) to describe the possible changes in the fish community based on alterations in the food supply caused by potential flow reductions.

SCOPE

The efforts of this phase of research are concentrated on the food habits of some of the major fish species of the lower Yellowstone River, primarily shovelnose sturgeon *(Scaphirhynchus platorynchus)*, goldeye *(Hiodon alosoides)*, channel catfish *(Ictalurus punctatus)*, burbot *(Lota lota)*, and sauger *(Stizostedion canadense)*. Small numbers of northern pike *(Esox lucius)*, carp *(Cyprinus carpio)*, white sucker *(Catostomus commersoni)*, smallmouth bass *(Micropterus dolomieui)*, white crappie *(Pomoxis annularis)*, walleye *(Stizostedion vitreum)*, freshwater drum (*Aplodinotus grunniens)*, and flathead chub *(Hybopsis gracilis)* were collected for food analysis.

Broadly defined, a forage fish is any utilized by another fish as a food source. Most fish species during their first year of life are small enough to be utilized as food and should be considered as part of the forage base. The availability of age 0 game and nongame species depends on their habits. Species whose young are pelagic and typically exhibit schooling patterns would be more susceptible to predation than those species whose young do not normally school and commonly seek shelter among the rocks, brush piles, or instream debris. Since the habitat requirements of most age 0 stream fishes are poorly understood, it is not possible to determine the availability of age 0 game and nongame fishes as forage at this time. For this study, forage fish are defined as those species which, as adults, seldom exceed six inches in length. This would include all of the cyprinids and certain others such as the stonecat and mountain sucker. These species usually remain a food source for their entire lives.

STUDY AREA

From the mouth of the Bighorn River, the lower Yellowstone flows a distance of 476 km (295 mi) to its confluence with the Missouri River. The river gradient averages less than .50 m/km (2.6 ft/mi). Average flow at Miles City in August 1975 was 460 m^3/sec and 260 m^3/sec in September. At Sidney, 248 km (154 mi) below Miles City, average discharges were 460 m^3/sec and 275 m^3/sec during the same months.

The Yellowstone River, including the sections from the Bighorn River to Forsyth and from Glendive to the mouth, is essentially a braided river with numerous side channels. Only the 228 km of river from Forsyth to Glendive can be described as meandering. Many side channels contain water only during the spring runoff. As the water level drops in midsummer, still backwater areas remain at the lower end of the side channels.

The morphology of the river is maintained by annual high flows. The physical character of the river provides a variety of habitats including shallow and deep riffles, pools, and still backwaters. This natural diversity creates the conditions which allow the presence of a diverse aquatic community. Forty-five of 49 fish species in the Yellowstone River are present in the lower river, which supports a warm-water fishery (Peterman and Haddix 1975). Twelve species are classified as game fish by the Montana Fish and Game Department. More than 70 species of benthic macroinvertebrates are reported for the lower river (see Report No. 5 in this series).

Methods

FOOD HABITS ANALYSES

Food habits of fish common to the lower Yellowstone have been investigated in other waters by a number of workers. Unfortunately, many of the studies were conducted for lake (lentic) populations, where species composition differs from that of lotic waters. Also, few investigations addressed food availability, making it impossible to determine selection for specific prey organisms. For these reasons, and because each aquatic ecosystem is unique, many of the conclusions of other researchers cannot be applied to this study.

Most fish collected for this study were captured near Miles City or below the Intake diversion dam. Some channel catfish were taken above the mouth of the Tongue River. A few sauger and burbot were caught at Forsyth. Most fish were taken from July through October during 1975 and 1976, using several methods. The majority were captured by electrofishing at Miles City and Intake, although fish were taken in seine hauls at the same locations. Catfish from the Tongue River were trapped. Some burbot were caught by fishermen near Forsyth in January. Sampling was limited primarily to backwaters and to slower currents along the shore.

Digestive tracts were removed from the fish, preserved in 10 percent formaldehyde, and taken to the laboratory for analysis. Food items from the esophagus and intestines were not analyzed. Stomach contents were identified to the species level when possible, using descriptions and keys by Cross (1967) and Brown (1971). Invertebrates found in fish stomachs are listed taxonomically in appendix D. Many of the fish in the stomachs were digested beyond recognition. Food items were counted and measured volumetrically by water displacement in graduated cylinders (appendix E). Methods of analysis are discussed by Lagler (1964).

Calculations were made to determine: (1) the percentage of stomachs in which each food type was present (frequency of occurrence), (2) the average number of organisms of each type in the stomachs which contained that food type, (3) the percentage of total number of food organisms, and (4) the percentage of the total food volume.

Ivlev's (1961) electivity index was used to determine selection for specific food types. The index is a forage ratio of the relative portion of a food type in the diet to the portion that exists in the environment. It takes the form:

$$E = \frac{r_i - p_i}{r_i + p_i}$$

where r_i = the relative portion of food type i in the ratio, expressed as the percentage of the total number of food items, and

p_i = the relative portion of food type i in the environment, expressed as the percentage of the total number of food items available.

Values range from -1.0 to 1.0. Negative values indicate that the fish is selecting against a food type, which means that the percentage of a specific food organism in the ratio is lower than the percentage of the food type in the environment. Active selection for a particular food suggests a preference for the food and yields a positive value. A value near 0 indicates that a fish consumes a food type in the same proportion in which it is available.

The use of the index requires knowledge of the population numbers of prey organisms that occur in the predators' habitat. Relative abundance data for forage fish species were not adequate for purposes of this study; therefore, food selection by sauger and burbot, which feed primarily on forage fish, could not be determined. Ivlev's index was used to determine selection for benthic macroinvertebrates by shovelnose sturgeon, goldeye, and channel catfish. The data from quantitative bottom samples of benthic organisms taken by Robert Newell at Miles City and Intake in August and September 1975 (see Report No. 5 in this study) were used in this study. Newell's data did not include weight or volumetric measurements of benthos, so electivity was determined on the basis of organism numbers alone.

Sample sizes of captured fish were too small to divide the individuals into groups by date or location of sampling. The one exception was shovelnose sturgeon, which were separated into two groups by date of capture prior to stomach analysis.

A few individuals of northern pike, carp, white sucker, smallmouth bass, white crappie, walleye, freshwater drum, and flathead chub were also taken. For these species, only qualitative results are listed.

FORAGE FISH SURVEY

Forage fish samples were collected during 1974 in the vicinities of Myers, Forsyth, Miles City, Sunday Creek, Glendive, Intake, and Sidney. The main channel and backwater areas were sampled with a 50 foot x 6 foot x 1/4 inch bag seine and by electrofishing. In 1975 additional samples were collected at eight locations on the lower river: Hysham, Forsyth, Miles City, the mouth of Sunday Creek, the mouth of the Powder River, Terry, Intake, and Sidney. These samples were also obtained from main channel and backwater areas. In addition to the 50 foot x 6 foot x 1/4 inch bag seine and electrofishing, a 100 foot x 8 foot x 1/4 inch loose-hung seine was utilized.

STOMACH CONTENTS

The lengths, weights, and numbers of fish collected for quantitative stomach analysis are presented in table 42. Most of the fish were at least two years old. Fingerlings and fry of sturgeon, burbot, sauger, and goldeye were not captured. The results of stomach contents analyses are given in tables 43-50 and in appendix F.

TABLE 42. Numbers, lengths, and weights of fish collected for stomach analysis.

	Number of Fish Collected	Number of Stomachs Containing Food	Total Length (mm)		Fork Length (mm)		Weight (g)	
			Range	Average	Range	Average	Range	Average
Shovelnose sturgeon	41	41	330-889	533	305-826	493	100-3334	726
Goldeye	18	17	292-335	312			159-354	259
Channel catfish	47	20	236-742	495			109-4763	1279
Burbot	22	13	318-645	421			136-1515	367
Sauger	114	43	201-546	295			41-1052	236

All sturgeon stomachs contained food items. Digestion in the sturgeon was apparently slow, because food organisms were usually intact and relatively easy to identify. At the other extreme, digestion in the sauger stomachs was rapid; only 43 of 114 stomachs contained food, much of which was difficult or impossible to identify.

SAUGER

Small forage fish were, in general, the dominant staple of the larger sauger (table 43). Channel catfish fry were the most abundant of the forage fish in the diet. Although the channel catfish is a game species, for the purpose of this study, any fish of sufficiently small size to be ingeested by predators is considered a forage fish. Catfish volume was exceeded by that of flathead chub, longnose dace *(Rhinichthys cataractae)*, and stonecats *(Noturus flavus)*. Most of the unidentified fish and fish remains, 38.4 percent of the volume, probably consisted of species listed in table 43. Except

TABLE 43. Stomach contents of 43 sauger collected from the lower Yellowstone River during 1975 and 1976.

Food Type	Frequency of Occurrence	Average Number of Organisms in Stomachs Containing Them	Percentage of Total Number	Percentage of Total Volume
		FISH		
Shovelnose sturgeon	2.3	1.0	0.6	1.7
Flathead chub	9.3	1.5	3.3	20.3
Sturgeon chub	4.7	2.0	2.2	3.4
Longnose dace	9.3	1.5	3.3	10.3
Minnow *(Hybognathus)*	7.0	1.0	1.7	3.1
Channel catfish	18.6	1.4	6.1	7.9
Stonecat	2.3	1.0	0.6	13.0
Unidentified fish and remains	58.1			38.4
TOTAL				98.1
		INVERTEBRATES		
Traverella albertana	11.6	28.2	77.9	1.5
Heptagenia elegantula	2.3	1.0	0.6	0.0
Ephoron album	2.3	1.0	0.6	0.0
Hydropsychidae	9.3	1.5	3.3	0.1
Unidentified insect parts	9.3			0.1
TOTAL				1.7
		MISCELLANEOUS		
Woody debris	7.0			0.2

for catfish and stonecats, which were readily identified, the percentages given for the forage species are probably low due to the large volume of unidentified fish parts.

Aquatic macroinvertebrates were found mainly in the smaller sauger. Insects, of which *Traverella albertana*, the only *Traverella* species in the lower Yellowstone, was the most abundant, accounted for 1.7 percent of the food, a low percentage because few small fish were taken. Lengths of sauger ranged from 201 to 546 mm (7.91 to 21.50 in). Sauger containing only insects in their stomachs averaged 246 mm (9.69 in); those which ate only fish averaged 300 mm (11.81 in). No sauger over 282 mm (11.10 in) in length contained insects. The evidence suggests that macroinvertebrates are an important food only for young sauger. It is expected that insects form the major portion of the diet in fry and fingerlings. Priegel (1970) found that most of the insects consumed by sauger and walleye in Lake Winnebago, Wisconsin, were taken by fish under 275 mm (10.83 in) in length. In another lake study, Nelson (1968) observed that sauger fry feed on zooplankton and some insects until they attain lengths of 70 to 100 mm (2.76 to 4.33 in). Beyond this length, fish become more important in the diet. Cross (1967) and Brown (1971) state that the food of young sauger is almost entirely aquatic insects.

BURBOT

Table 44 shows that 94.0 percent of the volume in burbot stomachs consisted of fish. The major prey species were flathead chub, stonecats, and minnows of the genus *Hybognathus*. The brassy minnow (*H. hankinsoni)*, plains minnow (*H. placitus)* and silvery minnow *(H. nuchalis)* are the only species of *Hybognathus* present in the lower Yellowstone River (Brown 1971).

Benthic insects formed 3.0 percent of the food volume of burbot. As with the sauger, insects occur more frequently in the diet of small fish. The smallest burbot captured for this study was 318 mm (12.52 in). Studies by a number of researchers agree that insects and other invertebrates are the dominant foods of first-year burbot (Bailey 1972, Bjorn 1940, Hewson 1955, Lawler 1963, Miller 1970, and Volodin and Ivanova 1969).

CHANNEL CATFISH

Aquatic and terrestrial insects were the most abundant food types of the channel catfish (table 45). Mayflies, especially *Traverella*, and grasshoppers composed a large part of the insect bulk. It was noted that many of the *Traverella* were emergent adults. Several stomachs contained a large number of small Hymenoptera. Only two fish were found in the stomachs of catfish, one of them a large shorthead redhorse (*Moxostoma macrolepidotum)* which displaced 396.0 ml of water. The volume percentages of food types were distorted by the presence of the shorthead redhorse; table 45 shows that insects accounted for 25.6 percent of the volume, but, if the sucker were not included, the insect volume would increase to 60.8 percent.

TABLE 44. Stomach contents of 13 burbot collected from the Yellowstone River below Miles City in January 1976.

Food Type	Frequency of Occurrence	Average Number of Organisms in Stomachs Containing Them	Percentage of Total Number	Percentage of Total Volume
		FISH		
Carp	7.7	2.0	3.4	6.5
Flathead chub	23.1	3.7	19.0	27.3
Sturgeon chub	7.7	1.0	1.7	0.9
Minnow *(Hybognathus)*	38.5	1.6	13.8	15.1
Flathead minnow	7.7	1.0	1.7	5.4
Sucker (Catostomidae)	7.7	1.0	1.7	3.1
Stonecat	23.1	2.7	13.8	11.4
Unidentified fish and remains	61.5			24.2
TOTAL				94.0
		INVERTEBRATES		
Isogenus sp.	7.7	13.0	22.4	2.2
Hydropsychidae	15.4	4.5	15.5	0.2
Rhithrogena undulata	15.4	2.0	6.9	0.1
Unidentified insect parts	15.4			0.5
TOTAL				3.0
		MISCELLANEOUS		
Algae	7.7			0.7
Gravel	23.1			2.3
TOTAL				3.0

Orthoptera, Hymenoptera, and *Traverella* nymphs and imagoes were present in large numbers during the period of collection but are rare during the remainder of the year. These insects were probably taken from the water surface by catfish, suggesting that this fish is an opportunist. The catfish is likely to alter its food habits considerably during other seasons as food composition changes. Brown (1971) states that the channel catfish is omnivorous and eats whatever is available.

TABLE 45. Stomach contents of 20 channel catfish collected from the Yellowstone River near Miles City and Intake and from the mouth of the Tongue River from July through September, 1975 and 1976.

Food Type	Frequency of Occurrence	Average Number of Organisms in Stomachs Containing Them	Percentage of Total Number	Percentage of Total Volume
		INVERTEBRATES		
Ephemeroptera				
Baetis spp.	10.0	3.5	0.1	0.0
Heptagenia elegantula	5.0	7.0	0.1	0.0
Rhithrogena undulata	5.0	7.0	0.1	0.0
Traverella albertana	50.0	581.8	88.5	16.4
Ephoron album	5.0	1.0	0.0	0.0
Trichoptera				
Hydropsychidae	60.0	9.3	1.7	0.3
Plecoptera				
Isoperla spp.	5.0	4.0	0.1	0.0
Diptera				
Chironomidae	20.0	18.5	1.1	0.1
Simulium sp.	10.0	24.5	0.7	0.1
Hemiptera				
Corixidae	5.0	1.0	0.0	0.0
Coleoptera[a]	10.0	1.0	0.0	0.0
Hymenoptera[a]	20.0	88.8	5.4	0.2
Orthoptera[a]	40.0	16.3	2.0	3.8
Oligochaeta	10.0	3.5	0.1	0.0
Unidentified insect parts	65.0			4.7
TOTAL				25.6
		FISH		
Shorthead redhorse	5.0	1.0	0.0	65.5
Stonecat	5.0	1.0	0.0	1.7
Unidentified fish remains	20.0			1.0
TOTAL				68.2
		MISCELLANEOUS		
Bird	5.0	1.0	0.0	3.6
Algae	10.0			2.0
Vascular plant materials	10.0			0.4
Rocks	10.0			0.2
TOTAL				6.2

[a] Terrestrial

It has been shown in other studies that insects are significant in the catfish diet. Stomachs of channel catfish from the Mississippi River in Iowa contained a dominance of insects, of which 68.0 percent were *Hexagenia* nymphs, a still-water bottom burrower, and imagoes of the same species (Hoopes 1960). Hoopes collected catfish from April to October, during the peak of insect emergences. In another study, also conducted from April through October, Bailey and Harrison (1948) found that insects were an important part of the diet of the southern channel catfish *(Ictalurus lacustris punctatus)*; 98 percent of the stomach volume of catfish up to 100 mm (3.94 in) consisted of insects. For fish exceeding 300 mm (11.81 in), the insect volume was 28.0 percent, and the fish volume was 35.0 percent.

GOLDEYE

Goldeye fed almost exclusively on insects (table 46). *Traverella albertana,* the dominant aquatic species, accounted for 70.5 percent of the volume of identified insects. This was similar to Hoopes' (1960) results in which 56.0 percent of the goldeye diet consisted of *Hexagenia* nymphs, another Ephemeroptera genus. Grasshoppers were also present in many goldeye stomachs from the Yellowstone River. More than 52.0 percent of the total volume consisted of unidentified insect parts, which implies that digestion occurs rapidly in the goldeye.

SHOVELNOSE STURGEON

As with the goldeye, insects comprised more than 95.0 percent of the stomach contents of shovelnose sturgeon. Sturgeon collected in May and June had fed heavily on hydropsychid caddisflies (table 47). In most stomachs, the heads of caddis larvae were separated from the bodies, and generic identification was not possible. The larval bodies were complete in two stomachs which contained a total of 491 *Hydropsyche,* 7 *Cheumatopsyche,* and 53 damaged caddis larvae.

Hydropsychid caddisflies were present in 90.5 percent of the stomachs of sturgeon captured from July through September (table 48), but amounted to only 1.9 percent of the volume. During this period, *Traverella,* the primary food organisms, comprised 46.2 percent of the diet.

Fine gravel particles were present in several sturgeon stomachs. Most of this material was from the pupal cases of Trichoptera.

In a one-year study of food habits of the shovelnose sturgeon in the lower Missouri River, Moode (1973) found that chironomid larvae formed the bulk of the sturgeon diet from April through September. During the remainder of the year, *Hydropsyche* was the dominant food organism. Sturgeon stomachs collected by Held (1966) in June contained a chironomid volume of almost 54.0 percent. Hydropsychid larvae accounted for 75.0 percent of the sturgeon diet in the Mississippi River (Hoopes 1960).

TABLE 46. Stomach contents of 17 goldeye collected from the Yellowstone River at Miles City in August, 1975 and 1976.

Food Type	Frequency of Occurrence	Average Number of Organisms in Stomachs Containing Them	Percentage of Total Number	Percentage of Total Volume
		INVERTEBRATES		
Ephemeroptera				
Baetis spp.	23.5	7.5	3.8	0.8
Heptagenia elegantula	5.9	1.0	0.1	0.0
Rhithrogena undulata	17.6	1.3	0.5	0.1
Traverella albertana	35.3	99.7	74.9	32.0
Ephemerella inermis	5.9	11.0	0.1	0.0
Trichoptera				
Hydropsychidae	35.3	4.5	3.4	1.0
Plecoptera				
Isogenus spp.	5.9	1.0	0.1	0.0
Isoperla spp.	5.9	2.0	0.3	0.1
Diptera				
Chironomidae	29.4	7.2	4.5	0.6
Tipulidae	5.9	1.0	0.1	0.3
Hemiptera				
Corixidae	17.6	2.7	1.0	0.7
Coleoptera				
Dytiscidae	5.9	1.0	0.1	0.0
Odonata				
Coenagrionidae	5.9	1.0	0.1	0.6
Orthoptera[a]	58.8	1.3	1.6	8.2
Hymenoptera[a]	5.9	74.0	9.3	0.9
Unidentified insect parts	100.0			52.4
TOTAL				97.7
		MISCELLANEOUS		
Vascular plant materials	23.5			2.3

[a] Terrestrial

TABLE 47. Stomach contents of 20 shovelnose sturgeon collected from the Yellowstone River near Miles City and Intake during May and June, 1975 and 1976.

Food Type	Frequency of Occurrence	Average Number of Organisms in Stomachs Containing Them	Percentage of Total Number	Percentage of Total Volume
		INVERTEBRATES		
Ephemeroptera				
Baetis spp.	70.0	13.4	5.6	1.8
Heptagenia elegantula	45.0	18.1	4.9	2.6
Rhithrogena undulata	25.0	1.8	0.3	0.1
Ephemerella inermis	30.0	12.5	2.2	1.4
Trichoptera				
Hydropsychidae	100.0	76.1	45.7	34.7
Plecoptera				
Isogenus spp.	70.0	5.1	2.2	8.3
Isoperla spp.	75.0	41.9	18.8	4.8
Diptera				
Chironomidae	95.0	32.7	18.6	2.6
Simulium sp.	15.0	1.0	0.1	0.0
Hexatoma sp.	60.0	4.0	1.4	0.9
Atherix variegata	5.0	1.0	0.0	0.1
Oligochaeta	10.0	1.5	0.1	0.0
Coleoptera[a]	5.0	1.0	0.0	0.0
Unidentified insect parts	100.0			38.1
TOTAL				95.4
		MISCELLANEOUS		
Vascular plant material	25.0			2.2
Rocks	30.0			2.4
TOTAL				4.6

[a] Terrestrial

TABLE 48. Stomach contents of 21 shovelnose sturgeon collected from the Yellowstone River below Intake from July to September, 1975 and 1976.

Food Type	Frequency of Occurrence	Average Number of Organisms in Stomachs Containing Them	Percentage of Total Number	Percentage of Total Volume
		INVERTEBRATES		
Ephemeroptera				
Baetis spp.	100.0	32.1	12.5	4.7
Heptagenia elegantula	28.6	1.8	0.2	0.2
Rhithrogena undulata	19.0	8.8	0.6	0.4
Traverella albertana	95.2	106.5	39.4	46.2
Ephemerella inermis	4.8	1.0	0.0	0.0
Tricorythodes minutus	9.5	7.5	0.3	0.1
Ephoron album	4.8	1.0	0.0	0.0
Trichoptera				
Hydropsychidae	90.5	5.5	1.9	1.9
Leptocella sp.	4.8	21.0	0.4	1.1
Plecoptera				
Isogenus spp.	19.0	1.8	0.1	0.1
Isoperla spp.	14.3	2.3	0.1	0.1
Diptera				
Chironomidae	90.5	107.2	37.7	4.5
Simulium sp.	66.7	25.2	6.5	2.4
Odonata				
Gomphidae	4.8	1.0	0.0	0.0
Hemiptera				
Corixidae	4.8	1.0	0.0	0.0
Orthoptera[a]	9.5	1.0	0.0	0.2
Hymenoptera[a]	9.5	2.5	0.1	0.1
Unidentified insect parts	100.0			35.5
TOTAL				97.5
		MISCELLANEOUS		
Vascular plant materials	9.5			0.9
Algae	9.5			0.5
Rocks	19.0			1.1
TOTAL				2.5

[a] Terrestrial

TABLE 49. Food types of miscellaneous fish species.

Food Type	Northern Pike (2)	Carp (1)	White Sucker (1)	Smallmouth Bass (3)	White Crappie (1)	Walleye (1)	Freshwater Drum (2)
Fish							
Flathead chub				X	X	X	
Sturgeon chub	X						
Channel catfish				X			
Unidentified fish remains	X			X			
Invertebrates							
Baetis		X					X
Traverella			X				X
Heptagenia							X
Rhithrogena							X
Ephoron							X
Hydropsychidae		X	X				X
Chironomidae			X				X
Simulium							X
Unidentified insect parts							X
Organic detritus		X	X				

NOTE: The number of fish sampled of each species is given in parentheses after the name of each species above.

FLATHEAD CHUB

The stomach contents of 19 flathead chub were removed and analyzed qualitatively. Food organisms were well digested. An estimated 40-50 percent of the volume consisted of Cladocera. The remainder included remains of Corixidae, Hydropsychidae, *Isogenus*, and unidentified organisms.

OTHER SPECIES

The qualitative results of stomach analyses for miscellaneous fish species is presented in table 49. Forage fish were found in the stomachs of northern pike, smallmouth bass, white crappie, and walleye. The carp, white sucker, and freshwater drum fed on insects and organic detritus.

FOOD SELECTION

The values for Ivlev's electivity index (E) were calculated for the major benthic food organisms eaten by shovelnose sturgeon, goldeye, and channel catfish (table 50). The shovelnose sturgeon and goldeye selected for *Baetis* and Chironomidae, but selected against *Heptagenia*, *Rhithrogena*, and Hydropsychidae. The sturgeon consumed *Traverella* in proportions equal to its availability, while the goldeye showed preference for *Traverella*. *Traverella* nymphs and adults on the water surface were preferred by channel catfish over other aquatic species during the study period. Sturgeon and goldeye select for insects characteristic of a riffle habitat, while catfish appear to take advantage of plentiful food types in any habitat.

TABLE 50. Ivlev's electivity index for benthic food organisms eaten by shovelnose sturgeon[a], goldeye, and channel catfish.

Food Type	Shovelnose Sturgeon	Goldeye	Channel Catfish
Baetis	0.58	0.15	-0.99[b]
Heptagenia	-0.43[bc]	-0.92[b]	-0.85[b]
Rhithrogena	-0.60[b]	-0.65[b]	-0.83[b]
Traverella	-0.04	0.63	0.76
Hydropsychidae	-0.88	-0.78	-0.92
Chironomidae	0.81	0.40	-0.75
Simulium	0.78[c]	-1.00[b]	-0.79[b]

[a] Because relative abundances of insects were unknown for these months, sturgeon collected in May and June were excluded.

[b] Less than 1 percent of benthic food items

[c] Less than 1 percent of benthic population

Selection for food types is difficult to measure. Preferences for aquatic organisms may vary seasonally as larvae grow in size or emerge as adults. Unfortunately, fish were not collected during all seasons. During the period of capture, *Traverella* nymphs were mature while other species such as *Hydropsyche* were relatively small. Food habits of the insect-feeding fish species may be different during the winter and spring months when caddis larvae are approaching mature size and *Traverella* nymphs and terrestrial insects are rarely available.

Ivlev's index and other forage ratios are based on the relative portions of food organisms that occur in the environment, but not all foods are readily available to a predator (Leonard 1941). *Baetis*, a fast swimmer, is capable of functioning in fast water without the protection of the bottom substrate. *Baetis*, therefore, was accessible to sturgeon and goldeye. *Heptagenia* and *Rhithrogena* are capable of crawling beneath stones where they are unavailable to predators. Hydropsychid larvae are found in rock crevices or between stones, but may also be exposed on rock surfaces. Chironomid larvae are somewhat immobile and vulnerable to predators (Hess and Swartz 1941, Klarberg and Benson 1975).

The present study illustrates the importance of aquatic insects in the diets of sturgeon, goldeye, and catfish. The sturgeon was restricted to bottom insects of riffles. The goldeye fed exclusively on insects as well and included a small amount of terrestrial insects in the diet. Insects were significant in the catfish diet, but some fish were also taken. Young sauger and burbot were highly dependent on macroinvertebrates for their food source. Insects were present in the stomachs of carp, white sucker, and freshwater drum. Other common fish species of the lower Yellowstone River which are dependent on aquatic macroinvertebrates for a large portion of their diet include longnose sucker (*Catostomus catostomus*), shorthead redhorse, river carpsucker (*Carpoides carpio*), blue sucker (*Cycleptus elongatus*), smallmouth buffalo (*Ictiobus bubalus*), bigmouth buffalo (*I. cyprinellus*), black bullhead (*Ictalurus melas*), and stonecat. Insects were also important foods for young individuals of crappie, bass, and walleye (Brown 1971).

Little is known of the habitat requirements and foods of forage fish of the lower river. During the period of study, the flathead chub appears to depend on the backwaters for its food supply of Cladocera and insects. This species is abundant in the river and is a common food item of predator species.

In the genus *Hybognathus*, the silvery minnow inhabits backwater areas (Cross 1967) and feeds on bottom ooze and algae (Brown 1971). The plains minnow and brassy minnow are common in small streams and the slow waters of large rivers. Their food habits are similar to those of the silvery minnow.

Unlike many of the forage species, the longnose dace is adapted to the fast water of riffles. Insect larvae are the main food of this species (Brown 1971).

FORAGE FISH SURVEY

Results of the forage fish survey are presented in table 51. The most common species, the flathead chub and emerald shiner, frequently occur in both

TABLE 51. Forage fish species list for lower Yellowstone River showing location, date of collection, and habitat sampled.

BACKWATER			MAIN CHANNEL		
Location	Date	Species	Location	Date	Species
Below Myers Bridge	10-30-74	Emerald shiner Plains minnow	Below Rosebud Diversion	10-17-74	Emerald shiner Plains minnow
Across from mouth of Tongue	7-23-74	Plains minnow Emerald shiner Brassy minnow	Above Miles City	7-25-74	Emerald shiner Flathead chub Mountain sucker
Across from mouth of Tongue	10-23-74	Plains minnow	Below Tongue	10-16-74	Mountain sucker Flathead chub Plains minnow
Mouth of Sunday Creek	9-12-74	Sturgeon chub	Across from Hysham Backwater	9-29-75	Flathead chub Lake chub Mountain sucker
Glendive	10-9-74	Flathead chub	Across from and above mouth of Tongue River	7-24-75	Longnose dace Flathead chub
	10-10-74	Flathead chub			
	10-18-74	Flathead chub Emerald shiner Lake chub	Below Terry	9-30-75	Flathead chub Emerald shiner Silvery minnow
Hysham	9-29-75	Emerald shiner Mountain sucker	Below Powder River	9-30-75	Flathead chub Fathead minnow
Below Forsyth	9-29-75	Flathead chub Emerald shiner Silvery minnow Fathead minnow mountain sucker	Intake	8-21-75	Plains minnow Sturgeon chub Emerald shiner
				9-18-75	Emerald shiner Flathead chub Longnose dace Sturgeon chub

TABLE 51. continued

BACKWATER			MAIN CHANNEL		
Location	Date	Species	Location	Date	Species
Cheyenne Island	10-1-75	Flathead chub Emerald shiner Silvery minnow Fathead minnow	Intake	10-3-75	Finescale dace Flathead chub Plains minnow Silvery minnow Emerald shiner
Below Terry	9-30-75	Flathead chub Emerald shiner Sand shiner Fathead minnow	Sidney	10-3-75	Flathead chub Sturgeon chub Fathead minnow Silvery minnow
Intake	10-3-75	Flathead chub Sturgeon chub Plains minnow Silvery minnow Emerald shiner		10-29-75	Flathead chub Emerald shiner Plains minnow Silvery minnow Fathead minnow
Sidney	10-3-75	Flathead chub Emerald shiner Silvery minnow Fathead minnow		10-30-75	Sturgeon chub Flathead chub

backwaters and main channel areas. Two species previously reported from the Yellowstone (Brown 1971), the pearl dace (*Semotilus margarita*) and creek chub (*S. atromaculatus*), were not taken during this survey. Brown called the creek chub "quite rare" and the pearl dace not abundant.

Notably absent from the forage fish collections is the stonecat. Stonecats generally prefer swift-current riffle areas with large gravel or cobble substrates (Trautman 1957). Available techniques were inadequate for such areas. Although not collected during current sampling, stonecat are common in the lower Yellowstone and are an important forage fish for some species. A forage fish species list for the lower Yellowstone is included in appendix G.

Impacts of water withdrawals

This study investigated not only the food preferences of river fishes but also the importance of all organisms in the food chain of the river ecosystem. Fish species adaptations and preferences for particular habitats are often related to their food habits. Research of food habits assists in an understanding of the interrelationships among organisms and their environment. Impacts on one segment of an ecosystem can affect other segments.

Impacts on fish populations from reduced flow vary for each species depending on food habits. Riffle insects provide food for sturgeon, goldeye, catfish, longnose dace, and for immature burbot and sauger. Mature sauger, burbot, and catfish rely (in part) on the backwater areas for their supply of forage fish. Reduced flow would affect both riffles and backwaters.

RIFFLE HABITAT

Riffle insects rely on current for food, oxygen, and protection from predators. Reduced discharge is detrimental to benthic populations because: (1) velocity requirements of riffle species are no longer met and (2) the wetted bottom area of the channel is decreased. R. L. Newell (see Report No. 5 in this series) estimated that insect density at Intake could decrease by 10 percent for each 28.3 m^3/sec (1000 cfs) reduction in discharge below 255 m^3/sec (9000 cfs).

Insects which prefer the greatest velocities, such as *Traverella* and *Hydropsyche*, would be among the first organisms to feel the impact of reduced flows. According to Report No. 5 in this series, peak densities of *Traverella* occurred at .69 m/sec (2.25 ft/sec) in August and .76 m/sec (2.5 ft/sec) in October. Numbers of *Hydropsyche* were highest at velocities of .46 m/sec (1.5 ft/sec) in October and .61 m/sec (2 ft/sec) in November. Faster currents are preferred by caddis larvae in later months as they grow in size.

Low flows decrease the wetted perimeter of the river channel. The loss of habitable space varies with the depth and width of the channel, the greatest reduction occurring where riffles are wide and shallow. Insects are concentrated in higher densities as flows diminish. Glass and Bovbjerg (1969) found that when numbers of *Cheumatopsyche* larvae are high, aggression among individuals maintains tolerable spacing. Invertebrates remove from riffles by drifting when flows are reduced (Minshall and Winger 1968, Pearson and Franklin 1968).

This study has shown that *Traverella* was the most important food item of goldeye, catfish, and sturgeon during August and September. *Traverella albertana* comprised 60 percent of the number of benthic fauna at Intake in August (Report No. 5). Due to the high density of this mayfly species and its water velocity preference, a reduction in *Traverella* numbers could be a critical loss to insect-feeding fish during abnormally low flows in late summer.

At Intake, *Traverella* relative abundance declined from 60 percent in August to less than 1 percent in November, while *Hydropsyche* increased from 14 percent of the organisms to 54 percent during the same period (Report No. 5). With the loss of *Traverella*, *Hydropsyche* becomes the dominant food item in the riffle habitat. Hydropsychids were the major food item of sturgeon captured from the Yellowstone in May and June. Hoopes (1960) and Modde (1973) also point out the importance of Hydropsychids in the sturgeon diet. *Hydropsyche*, being sensitive to changes in velocity (Edington 1965 and 1968), may be affected more adversely than most other riffle species. A reduction in hydropsychids could, by altering food habits, be detrimental to fish that feed in the riffles, especially the shovelnose sturgeon, which is highly adapted for riffle feeding.

In addition to reducing numbers of food organisms, a drop in discharge concentrates fish into a smaller habitat. Forage fish and the remaining benthic organisms become more vulnerable to predation from the high-density fish community. Decreased food and space can limit the fish population growth to the point that predator biomass may decline in amounts equal to the loss of riffle insect biomass.

SLOW-WATER HABITAT

The specific habitat requirements of forage and game fish species of the Yellowstone are not known, but large numbers of forage fish, burbot, sauger, and catfish were collected in the backwaters and slow littoral waters. To maintain the present populations of carnivorous species, it is necessary to preserve the backwater habitats. Backwaters are common to the braided section of the river. A dominant discharge (that high flow recurring every 1½ to 2 years which, through a combination of magnitude and frequency, accomplishes the most geomorphic work in a channel over the long term) is necessary to retain the characteristics of the main and side channel morphology. Periodic flows in the side channels prevent the invasion of riparian vegetation. Without side channels, backwaters would fill with silt, causing a reduction in wetted perimeter and depth, eventually destroying the backwater habitat. Martin (see Report No. 2 in this series) reports a 43 percent reduction in the number of islands on the Bighorn River as a result of reduced flows due to water impoundments. Islands became part of the mainland, eliminating the side channels and backwaters. Similar results could be expected on the lower Yellowstone following reduction of spring flows, changing the river from a braided to a meandering stream.

Even if sufficient flows were preserved to maintain the existence of side channel flow during the spring runoff, it would still be necessary to ensure that the needed volume of water is available to keep the backwaters full during the remainder of the year to maintain slow-water habitat.

The growth rate of most aquatic organisms is greatest during summer months when water temperatures are at a peak (Hynes 1970). During this period of receding flows and heavy water diversions for irrigation, food and habitable area are of critical importance to the growth of insects and fishes. The most severe impacts on aquatic communities are likely to occur if excessive water withdrawals are made during August and September.

Discharge of the Yellowstone is lowest during winter months prior to spring runoff. Excessive water withdrawals for industrial use in this period of low flow would take its toll on benthic organisms. This would result not only from further reductions in velocity and wetted bottom area, but from the increased dangers of ice accumulation. Formation of anchor ice in riffle areas at night tends to impede the flow. As ice melts during the day, the churning action of loose ice scours the benthos, removing algae, detritus, and invertebrates (Hynes 1970, Maciolek and Needham 1951).

Summary

Fish of several species were collected from the Yellowstone River near Miles City and Intake. Most of them were captured by electrofishing in August of 1975 and 1976. Stomach contents from 145 mature fish were identified, counted, and measured volumetrically. Quantitative results were tabulated for shovelnose sturgeon, goldeye, channel catfish, sauger, and burbot.

Insects were the major foods of sturgeon, goldeye, and catfish. Aquatic insects of riffles were of greatest importance to all three species but were consumed in greatest amounts by shovelnose sturgeon. Goldeye and catfish stomachs contained terrestrial insects as well. Only the catfish diet included fish.

From a previous study of the aquatic food organisms available in August and September, *Traverella albertana* was the most abundant (Report No. 5 in this series). Ivlev's electivity index revealed that this species of mayfly was eaten by sturgeon in portions equal to its availability, but goldeye and catfish selected it over other foods.

Hydropsyche is the dominant species of riffle insects during the fall and winter months on the river (Report No. 5). Based on that fact and on the results of studies in other rivers, it is expected that this genus of caddisfly becomes the major food item of sturgeon following the emergence of *Traverella* in September.

Flathead chubs and minnows of the genus *Hybognathus* were common in the diets of sauger and burbot. In addition, sauger stomachs contained longnose dace and catfish fry. Stonecats were important in the burbot diet. Young sauger and burbot are highly dependent on invertebrates for food.

The impact of reduced flows would be felt by all members of the food chain. *Traverella* and *Hydropsyche*, the most abundant benthic insects, are the most important foods of riffle fishes and prefer relatively high water velocities; they would suffer the greatest loss during low flows. As food and riffle space declines, fish growth is restricted until predator populations stabilize or fall to levels that can be supported by the altered habitat. Of the fish that feed on benthic insects, reduced flows would be most detrimental to the growth and production of shovelnose sturgeon, goldeye, channel catfish, and young-of-the-year sauger and burbot.

The maintenance of side channels and backwaters is dependent on high spring flows. As side-channel flow diminishes in late summer, sufficient discharge must remain to ensure the existence of backwater areas. A reduction in backwaters would result in a direct loss of habitat to fish species which frequent these still waters. Piscivorous species affected by such alteration include mature sauger and burbot, channel catfish, northern pike, and crappie.

Appendixes

Appendix A

PROJECTIONS OF FUTURE USE

FIGURES

A-1. The Nine Planning Subbasins of the Yellowstone Basin. 147

TABLES

A-1. Increased Water Requirements for Coal Development in the Yellowstone Basin in 2000. 147

A-2. The Increase in Water Depletion for Energy by the Year 2000 by Subbasin. 148

A-3. Feasibly Irrigable Acreage by County and Subbasin by 2000, High Level of Development. 149

A-4. The Increase in Water Depletion for Irrigated Agriculture by 2000 by Subbasin 150

A-5. The Increase in Water Depletion for Municipal Use by 2000 . . . 150

A-6. The Increase in Water Depletion for Consumptive Use by 2000 by Subbasin 151

In order to adequately and uniformly assess the potential effects of water withdrawals on the many aspects of the present study, projections of specific levels of future withdrawals were necessary. The methodology by which these projections were done is explained in Report No. 1 in this series, in which also the three projected levels of development, low, intermediate, and high, are explained in more detail. Summarized below, these three future levels of development were formulated for energy, irrigation, and municipal water use for each of the nine subbasins identified in figure A-1.

ENERGY WATER USE

In 1975, over 22 million tons of coal (19 million metric tons) were mined in the state, up from 14 million (13 million metric) in 1974, 11 million (10 million metric) in 1973, and 1 million (.9 million metric) in 1969. By 1980, even if no new contracts are entered, Montana's annual coal production will exceed 40 million tons (36 million metric tons). Coal reserves, estimated at over 50 billion economically strippable tons (45 billion metric tons) (Montana Energy Advisory Council 1976), pose no serious constraint to the levels of development projected, which range from 186.7 (170.3 metric) to 462.8 (419.9 metric) million tons stripped in the basin annually by the year 2000.

Table A-1 shows the amount of coal mined, total conversion production, and associated consumption for six coal development activities expected to take place in the basin by the year 2000. Table A-2 shows water consumption by subbasin for those six activities. Only the Bighorn, Mid-Yellowstone, Tongue, Powder and Lower Yellowstone subbasins would experience coal mining or associated development in these projections.

IRRIGATION WATER USE

Lands in the basin which are now either fully or partially irrigated total about 263,000 ha (650,000 acres) and consume annually about 1,850 hm^3 (1.5 mmaf) of water. Irrigated agriculture in the Yellowstone Basin has been increasing since 1971 (Montana DNRC 1975). Much of this expansion can be attributed to the introduction of sprinkler irrigation systems.

After evaluating Yellowstone Basin land suitability for irrigation, considering soils, economic viability, and water availability (only the Yellowstone River and its four main tributaries, Clarks Fork, Bighorn, Tongue, and Powder, were considered as water sources), this study concluded that 95,900 ha (237,000 acres) in the basin are financially feasible for irrigation. These acres are identified by county and subbasin in table A-3; table A-4 presents projections of water depletion.

Three levels of development were projected. The lowest includes one-third, the intermediate, two-thirds, and the highest, all of the feasibly irrigable acreage.

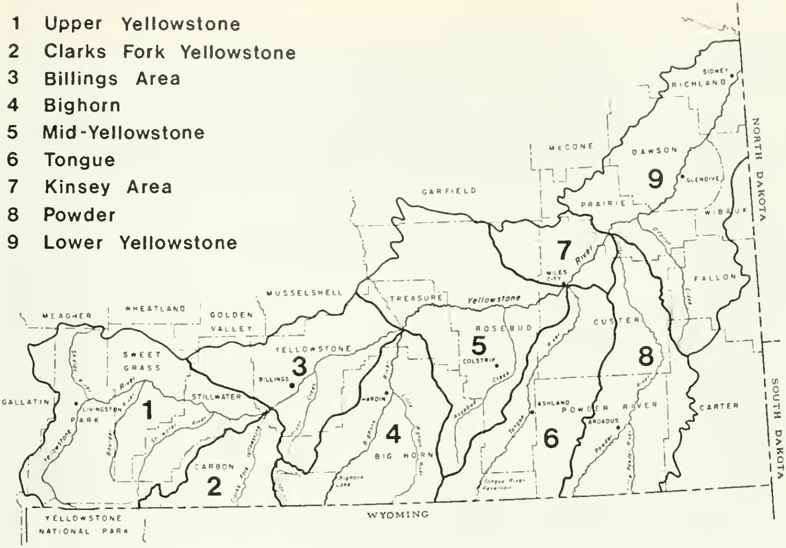


Figure A-1. The nine planning subbasins of the Yellowstone basin.

TABLE A-1. Increased water requirements for coal development in the Yellowstone Basin in 2000.

Level of Development	Coal Development Activity						
	Electric Generation	Gasification	Syncrude	Fertilizer	Export	Strip Mining	Total
			COAL MINED (mmt/y)				
Low	8.0	7.6	0.0	0.0	171.1		186.7
Intermediate	24.0	7.6	0.0	0.0	293.2		324.8
High	32.0	22.8	36.0	3.5	368.5		462.8
			CONVERSION PRODUCTION				
Low	2000 mw	250 mmcfd	0 b/d	0 t/d			
Intermediate	6000 mw	250 mmcfd	0 b/d	0 t/d			
High	8000 mw	750 mmcfd	200,000 b/d	2300 t/d			
			WATER CONSUMPTION (af/y)				
Low	30,000	9,000	0	0	[a]	9,350	48,350
Intermediate	90,000	9,000	0	0	31,910	16,250	147,160
High	120,000	27,000	58,000	13,000	80,210	22,980	321,190

CONVERSIONS: 1 mmt/y (short) = .907 mmt/y (metric)
1 af/y = .00123 hm^3/y

[a]No water consumption is shown for export under the low level of development because, for that development level, it is assumed that all export is by rail, rather than by slurry pipeline.

TABLE A-2. The increase in water depletion for energy by the year 2000 by subbasin.

Subbasin	INCREASE IN DEPLETION (af/y) Elec. Generation	Gasification	Syncrude	Fertilizer	Export	Strip Mining	Total
LOW LEVEL OF DEVELOPMENT							
Bighorn	0	0	0	0	0	860	860
Mid-Yellowstone	22,500	9,000	0	0	0	3,680	35,180
Tongue	7,500	0	0	0	0	3,950	11,450
Powder	0	0	0	0	0	860	860
Lower Yellowstone	0	0	0	0	0	0	0
Total	30,000	9,000				9,350	48,350
INTERMEDIATE LEVEL OF DEVELOPMENT							
Bighorn	0	0	0	0	4,420	1,470	5,890
Mid-Yellowstone	45,000	9,000	0	0	15,380	6,110	75,490
Tongue	30,000	0	0	0	9,900	7,000	46,900
Powder	15,000	0	0	0	2,210	1,670	18,880
Lower Yellowstone	0	0	0	0	0	0	0
Total	90,000	9,000			31,910	16,250	147,160
HIGH LEVEL OF DEVELOPMENT							
Bighorn	15,000	0	0	0	11,100	2,050	28,150
Mid-Yellowstone	45,000	18,000	29,000	0	38,700	8,710	139,410
Tongue	45,000	9,000	29,000	0	24,860	10,170	118,030
Powder	15,000	0	0	0	5,550	2,050	22,600
Lower Yellowstone	0	0	0	13,000	0	0	13,000
Total	120,000	27,000	58,000	13,000	80,210	22,980	321,190

CONVERSIONS: 1 af/y = .00123 hm^3/y

NOTE: The four subbasins not shown (Upper Yellowstone, Billings Area, Clarks Fork Yellowstone, Kinsey Area) are not expected to experience water depletion associated with coal development.

TABLE A-3. Feasibly irrigable acreage by county and subbasin by 2000, high level of development.

County	Upper Yellowstone	Clarks Fork	Billings Area	Big Horn	Mid Yellowstone	Tongue River	Kinsey Area	Powder River	Lower Yellowstone	County Totals
Park	21,664									21,664
Sweet Grass	10,204									10,204
Stillwater	6,208									6,208
Carbon		2,160								2,160
Yellow-stone			19,412							19,412
Big Horn				13,037		2,185				15,222
Treasure					9,591					9,591
Rosebud					11,408	9,727				21,135
Powder River								46,853		46,853
Custer					4,230	10,035	3,092	26,438		43,795
Prairie							1,644	1,914	8,231	11,789
Dawson									18,355	18,355
Richland									10,421	10,421
Wibaux									633	633
BASIN TOTALS	38,076	2,160	19,412	13,037	25,229	21,947	4,736	75,205	37,670	237,472

CONVERSIONS: 1 acre = .405 ha

NOTE: The number of irrigable acres for the low and intermediate development levels are one-third and two-thirds, respectively, of the numbers given here. This table should not be considered an exhaustive listing of all feasibly irrigable acreage in the Yellowstone Basin; it includes only the acreage identified as feasibly irrigable according to the geographic and economic constraints explained elsewhere in this report.

MUNICIPAL WATER USE

The basin's projected population increase and associated municipal water use depletion for each level of development are shown in table A-5. Even the 13 hm^3/y (10,620 af/y) depletion increase by 2000 shown for the highest development level is not significant compared to the projected depletion increases for irrigation or coal development. Nor is any problem anticipated in the availability of water to satisfy this increase in municipal use.

WATER AVAILABILITY FOR CONSUMPTIVE USE

The average annual yield of the Yellowstone River Basin at Sidney, Montana, at the 1970 level of development, is 10,850 hm^3 (8.8 million af). As shown in table A-6, the additional annual depletions required for the high projected level of development total about 999 hm^3 (812,000 acre-feet). Comparison of these two numbers might lead to the conclusion that there is ample water for such development, and more. That conclusion would be erroneous, however, because of the extreme variation of Yellowstone Basin streamflows from year to year, from month to month, and from place to place. At certain places and at certain times the water supply will be adequate in the foreseeable future. But in some of the tributaries and during low-flow times of many years, water availability problems, even under the low level of development, will be very real and sometimes very serious.

TABLE A-4. The increase in water depletion for irrigated agriculture by 2000 by subbasin.

Subbasin	Acreage Increase	Increase in Depletion (af/y)
HIGH LEVEL OF DEVELOPMENT		
Upper Yellowstone	38,080	76,160
Clarks Fork	2,160	4,320
Billings Area	19,410	38,820
Bighorn	13,040	26,080
Mid-Yellowstone	25,230	50,460
Tongue	21,950	43,900
Kinsey Area	4,740	9,480
Powder	75,200	150,400
Lower Yellowstone	37,670	75,340
TOTAL	237,480	474,960
INTERMEDIATE LEVEL OF DEVELOPMENT		
BASIN TOTAL	158,320	316,640
LOW LEVEL OF DEVELOPMENT		
BASIN TOTAL	79,160	158,320

CONVERSIONS: 1 acre = .405 ha
1 af/y = .00123 hm^3/y

NOTE: The numbers of irrigated acres at the low and intermediate levels of development are not shown by subbasin; however, those numbers are one-third and two-thirds, respectively, of the acres shown for each subbasin at the high level of development.

TABLE A-5. The increase in water depletion for municipal use by 2000.

Level of Development	Population Increase	Increase in Depletion (af/y)
Low	56,858	5,880
Intermediate	62,940	6,960
High	94,150	10,620

CONVERSIONS: 1 af/y = .00123 hm^3/y

TABLE A-6. The increase in water depletion for consumptive use by 2000 by subbasin.

Subbasin	Increase in Depletion (af/y)			
	Irrigation	Energy	Municipal	Total
	LOW LEVEL OF DEVELOPMENT			
Upper Yellowstone	25,380	0	0	25,380
Clarks Fork	1,440	0	0	1,440
Billings Area	12,940	0	3,480	16,420
Bighorn	8,700	860	negligible	9,560
Mid-Yellowstone	16,820	35,180	1,680	53,680
Tongue	14,640	11,450	negligible	26,090
Kinsey Area	3,160	0	0	3,160
Powder	50,140	860	360	51,360
Lower Yellowstone	25,120	0	360	25,480
TOTAL	158,340	48,350	5,880	212,570
	INTERMEDIATE LEVEL OF DEVELOPMENT			
Upper Yellowstone	50,780	0	0	50,780
Clarks Fork	2,880	0	0	2,880
Billings Area	25,880	0	3,540	29,420
Bighorn	17,380	5,890	300	23,570
Mid-Yellowstone	33,640	75,490	1,860	110,990
Tongue	29,260	46,900	300	76,460
Kinsey Area	6,320	0	0	6,320
Powder	100,280	18,880	600	119,760
Lower Yellowstone	50,200	0	360	50,560
TOTAL	316,620	147,160	6,960	470,740
	HIGH LEVEL OF DEVELOPMENT			
Upper Yellowstone	76,160	0	0	76,160
Clarks Fork	4,320	0	0	4,320
Billings Area	38,820	0	3,900	42,720
Bighorn	26,080	28.150	480	54,710
Mid-Yellowstone	50,460	139,410	3,840	193,710
Tongue	43,900	118,030	780	162,710
Kinsey Area	9,480	0	0	9,480
Powder	150,400	22,600	1,140	174,140
Lower Yellowstone	75,340	13,000	480	88,820
TOTAL	474,960	321,190	10,620	806,770

CONVERSIONS: 1 af/y = .00123 hm^3/y

Appendix B

TONGUE RIVER WATER TEMPERATURES

In general, temperatures increased with progression downstream. Temperatures greater than 21°C (70°F) were common in the lower river; in the mid-reach, these temperatures were near the maximum. Immediately downstream from the dam, maximum temperatures were 22°C (72°F).

FIGURES

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B-2	Monthly mean of daily minimum and maximum water temperatures for 1975 and 1976 for the Tongue River at station IIIa	155
B-3	Monthly mean of daily minimum and maximum water temperatures for 1976 for the Tongue River at station Vc	156

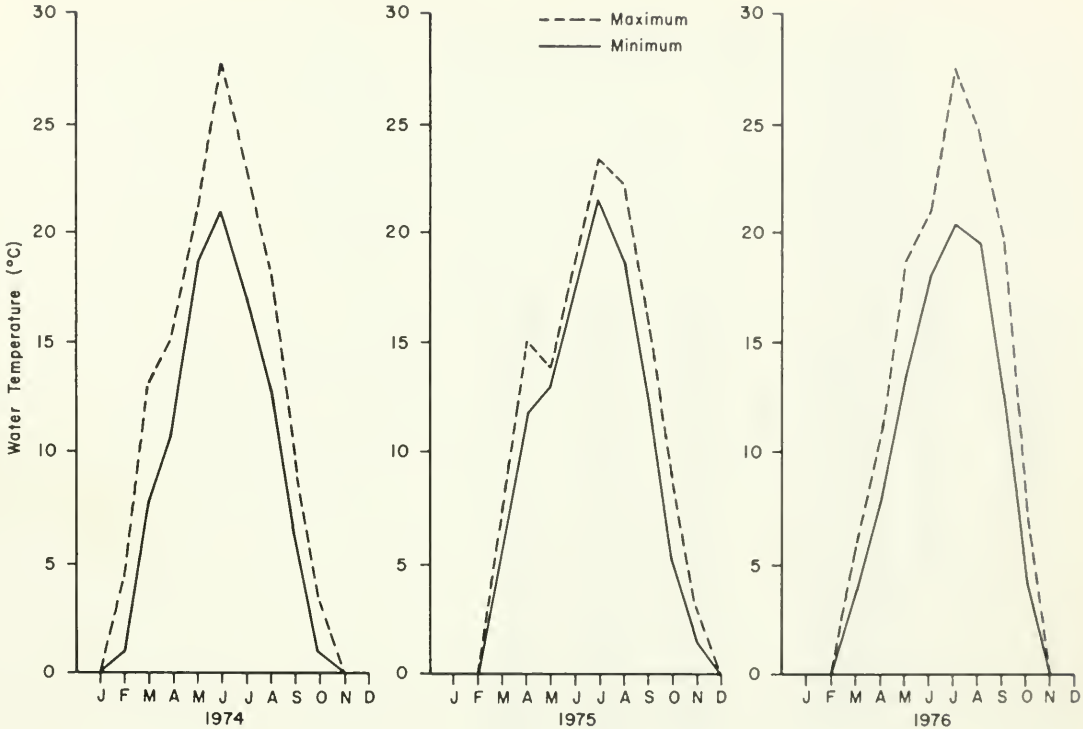

Figure B-1. Monthly mean of daily minimum and maximum water temperatures for 1974, 1975, and 1976 for the Tongue River at station Ia.

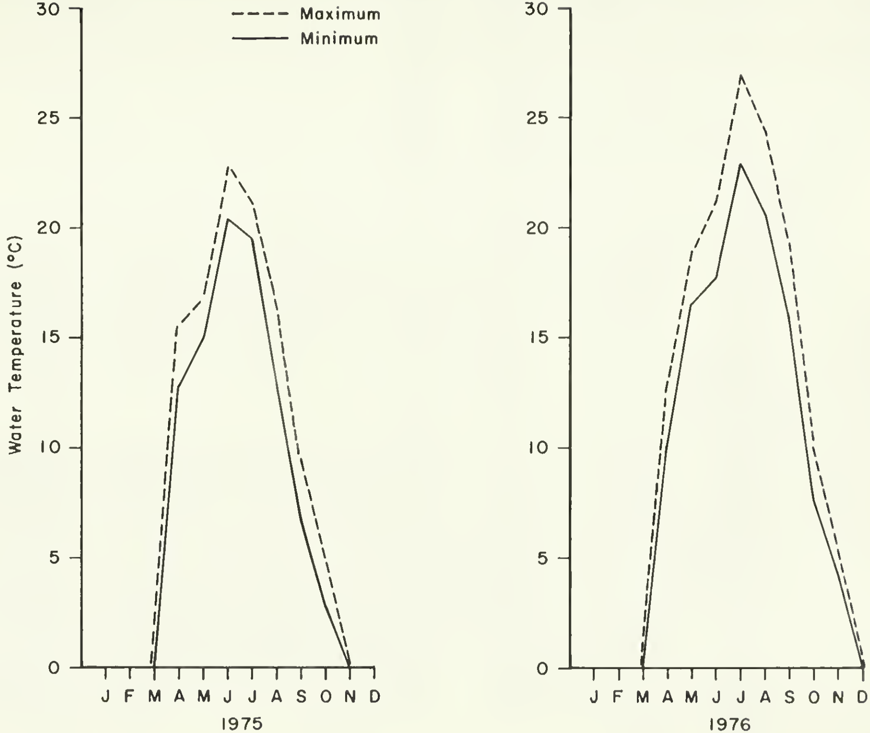

Figure B-2. Monthly mean of daily minimum and maximum water temperatures for 1975 and 1976 for the Tongue River at station IIIa.

Figure B-3. Monthly mean of daily minimum and maximum water temperatures for 1976 for the Tongue River at station Vc.

Appendix C

TAXONOMY OF FISH SPECIES ENCOUNTERED IN THESE STUDIES

FAMILY		SPECIES	
Common name	Scientific name	Common name	Scientific name
Sturgeon	Acipenseridae	Shovelnose sturgeon	*Scaphirhynchus platorynchus* (Rafinesque)
Paddlefish	Polyodontidae	Paddlefish	*Polyodon spathula* (Walbaum)
Mooneye	Hiodontidae	Goldeye	*Hiodon alosoides* (Rafinesque)
Trout	Salmonidae	Mountain whitefish	*Prosopium williamsoni* (Girard)
		Rainbow trout	*Salmo gairdneri* Richardson
		Brown trout	*Salmo trutta* Linnaeus
Pike	Esocidae	Northern pike	*Esox lucius* Linnaeus
Minnow	Cyprinidae	Carp	*Cyprinus carpio* Linnaeus
		Goldfish	*Carassius auratus* (Linnaeus)
		Golden shiner	*Notemigonus crysoleucas* (Mitchill)
		Pearl dace	*Semotilus margarita* (Cope)
		Creek chub	*Semotilus atromaculatus* (Mitchill)
		Finescale dace	*Phoxinus neogaeus* Cope
		Flathead chub	*Hybopsis gracilis* (Richardson)
		Sturgeon chub	*Hybopsis gelida* (Girard)
		Lake chub	*Couesius plumbeus* (Agassiz)
		Emerald shiner	*Notropis atherinoides* Rafinesque
		Sand shiner	*Notropis stramineus* (Cope)
		Brassy minnow	*Hybognathus hankinsoni* Hubbs
		Plains minnow	*Hybognathus placitus* Girard
		Silvery minnow	*Hybognathus nuchalis* Agassiz
		Fathead minnow	*Pimephales promelas* Rafinesque
		Longnose dace	*Rhinichthys cataractae* (Valenciennes)
Sucker	Catostomidae	River carpsucker	*Carpoides carpio* (Rafinesque)
		Blue sucker	*Cycleptus elongatus* (LeSueur)
		Shorthead redhorse	*Moxostoma macrolepidotum* (LeSueur)
		Longnose sucker	*Catostomus catostomus* (Forster)
		White sucker	*Catostomus commersoni* (Lacepede)
		Mountain sucker	*Catostomus platyrhynchus* (Cope)

Appendix C (Continued)

FAMILY		SPECIES	
Common name	Scientific name	Common name	Scientific name
Catfish	Ictaluridae	Black bullhead	*Ictalurus melas* (Rafinesque)
		Yellow bullhead	*Ictalurus natalis* (LeSueur)
		Channel catfish	*Ictalurus punctatus* (Rafinesque)
		Stonecat	*Noturus flavus* Rafinesque
Codfish	Gadidae	Burbot	*Lota lota* (Linnaeus)
Sunfish	Centrarchidae	Rock bass	*Ambloplites rupestris* (Rafinesque)
		Green sunfish	*Lepomis cyanellus* Rafinesque
		Pumpkinseed	*Lepomis gibbosus* (Linnaeus)
		Smallmouth bass	*Micropterus dolomieui* (Lacepede)
		Largemouth bass	*Micropterus salmoides* (Lacepede)
		White crappie	*Pomoxis annularis* Rafinesque
		Black crappie	*Pomoxis nigromaculatus* (LeSueur)
Perch	Percidae	Yellow perch	*Perca flavescens* (Mitchill)
		Sauger	*Stizostedion canadense* (Smith)
		Walleye	*Stizostedion vitreum* (Mitchill)
Drum	Sciaenidae	Freshwater drum	*Aplodinotus grunniens* Rafinesque

SOURCE: Adapted from Brown (1971)

Appendix D

TAXONOMY OF INVERTEBRATES FOUND IN FISH STOMACHS

Aquatic organisms

- Order Ephemeroptera (mayflies)
  - Family Baetidae
    - *Baetis* sp.
  - Family Heptageniidae
    - *Heptagenia elegantula* (Eaton)
    - *Rhithrogena undulata* (Banks)
  - Family Leptophlebiidae
    - *Traverella albertana* (McD.)
  - Family Ephemerellidae
    - *Ephemerella* sp.
  - Family Tricorythidae
    - *Tricorythodes minutus* Traver
  - Family Polymitarcidae
    - *Ephoron album* (Say)
- Order Plecoptera (stoneflies)
  - Family Perlodidae
    - *Isogenus* sp.
    - *Isoperla* sp.
- Order Trichoptera (caddisflies)
  - Family Hydropsychidae
    - *Cheumatopsyche* sp.
    - *Hydropsyche* sp.
- Order Hemiptera (bugs)
  - Family Corixidae
- Order Odonata (dragonflies)
  - Family Gomphidae
- Order Coleoptera (beetles)
- Order Diptera (flies)
  - Family Chironomidae
  - Family Simuliidae
    - *Simulium* sp.
  - Family Tipulidae
    - *Hexatoma* sp.
  - Family Rhagionidae
    - *Atherix variegata* Walker
- Order Oligochaeta

Terrestrial organisms

- Order Orthoptera
- Order Hymenoptera

Appendix E

AVERAGE BODY VOLUME OF MAJOR ORGANISMS FOUND IN FISH STOMACHS

Insects	Vol. (ml)
Baetis sp.	.0034
Heptagenia elegantula	.0087
Rhithrogena undulata	.0065
Traverella albertana	.0156
Isoperla sp.	.0040
Isogenus sp.	.0667
Hydropsychidae	.0123
Simulium sp.	.0028
Chironomidae	.0010
Fish	
Hybopsis gracilis	2.00
Hybopsis gelida	0.82
Hybognathus sp.	0.92
Rhinichthys cataractae	1.85
Ictalurus punctatus	0.78
Noturus flavus	2.91

NOTE: These average volumes were derived by dividing the total volume of each category of food organisms (determined by water displacement in a graduated receptacle) by the number of organisms in each category.

Appendix F

RESULTS OF FOOD HABITS ANALYSES
OF SAUGER, BURBOT, GOLDEYE,
CHANNEL CATFISH, AND SHOVELNOSE STURGEON

TABLES

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TABLE F-I. Numbers of major identifiable food items in sauger stomachs.

Total Length (mm)	Weight (m)	Location	Date	Ephemeroptera	Trichoptera	Flathead Chub	Sturgeon Chub	Longnose Dace	*Hybognathus* sp.	Channel Catfish Fry	Stonecat
203	77	Intake	9/12/75				1				
208	41	Intake	9/12/75	7	1						
228	82	Intake	9/12/75	27	2						
230	95	Miles C.	8/05/76							1	
250	113	Miles C.	8/05/76			1					
250	181	Miles C.	9/10/75	2						1	
255	136	Intake	8/20/75					1			
260	113	Intake	9/12/75	20	1						
260	113	Intake	9/12/75	8	2						
263	145	Intake	8/20/75				3		1		
263	154	Intake	8/20/75			1		2	1		
273	209	Miles C.	9/10/75							1	
278	154	Intake	9/12/75	79							
278	227	Miles C.	9/10/75							3	
290	181	Miles C.	8/05/76							1	
293	204	Miles C.	8/17/76					2			
295	191	Miles C.	8/26/76			1					
300	204	Miles C.	8/05/76							1	
310	200	Miles C.	8/27/75							1	
320	254	Forsyth	10/23/75					1			
360	399	Miles C.	9/10/75							2	
375	?	Miles C.	1/29/75						1		
450	?	Miles C.	1/29/75			3					
450	971	Miles C.	8/05/76								1
		TOTALS		143	6	6	4	6	3	11	1

TABLE F-2. Numbers of major identifiable food items in burbot stomachs collected in January 1976 near Miles City.

Total Length (mm)	Weight (g)	Ephemeroptera	Plecoptera	Trichoptera	Carp	Flathead Chub	Sturgeon Chub	*Hybognathus* sp.	Fathead Minnow	*Catostomus* sp.	Stonecat
340	290	3									
365	227				2					1	
365	236		13								
385	295			4							
388	254					1					
405	236	1		5				1			
423	318							1			
430	363					9	1	3	1		2
438	408					1					4
465	463							1			
480	508							2			2
TOTALS		4	13	9	2	11	1	8	1	1	8

TABLE F-3. Numbers of major identifiable food items in stomachs of goldeye.

Total Length (mm)	Weight (g)	Location	Date	Ephemeroptera	Plecoptera	Trichoptera	Diptera	Misc. Aquatic Species	Terrestrial Insects
288	159	Miles C.	8/05/76						3
290	191	Miles C.	8/05/76						1
290	263	Miles C.	8/05/76				1	1	1
293	218	Miles C.	8/05/76	2		8			2
300	200	Miles C.	8/18/75	9		2			
303	218	Miles C.	8/05/76	1		1			1
303	249	Miles C.	8/05/76						1
305	200	Miles C.	8/18/75	1	1	14			
310	318	Miles C.	8/05/76						1
310	354	Miles C.	8/27/75	581			9	1	74
313	249	?	?	8			3	1	
315	245	Miles C.	8/05/76	4		1			1
315	272	Miles C.	8/05/76						1
318	272	?	?	5				4	
325	318	?	?	2			2	3	
325	318	?	?	21	2		21		
330	354	Miles C.	8/27/75			1	1		1
		TOTALS		634	3	27	37	10	87

TABLE F-4. Numbers of major identifiable food items in stomachs of channel catfish.

Total Length (mm)	Weight (g)	Location	Date	Ephemeroptera	Plecoptera	Trichoptera	Diptera	Terrestrial Insects	Fish
233	109	Intake	8/21/75	19		18		24	
303	204	Miles C.	8/27/75	149		2		81	
323	245	Intake	7/22/76			2		8	
338	299	Miles C.	8/27/75	1					
338	372	Miles C.	8/27/76	1				1	
350	?	Miles C.	6/08/76	1	4	63	3	1	
393	454	Intake	7/22/76			1		35	
405	608	Miles C.	8/17/76	536		4			
425	644	Miles C.	8/27/75			11		49	
433	789	Miles C.	9/10/75	6		1	105		
455	962	Miles C.	8/05/76	1993			7		
458	1016	Intake	7/22/76			2		11	
490	1361	Intake	7/22/76			1		66	
500	1297	Miles C.	8/27/75	3		1	1	202	
525	1624	Intake	9/12/75	2205			7		
565	1588	Intake	7/22/76	1				4	1[a]
578	2014	Intake	9/12/75	915		5		5	
741	4425	Tongue R.	8/27/76						1[b]
		TOTALS		5830	4	111	123	487	2

[a] Stonecat

[b] Shorthead redhorse

TABLE F-5. Numbers of major identifiable food items in stomachs of shovelnose sturgeon collected in May and June, 1975 and 1976.

Total Length (mm)	Fork Length (mm)	Weight (g)	Location	Date	Ephemeroptera	Plecoptera	Trichoptera	Diptera	Terrestrial Insects
343	308	132	Intake	5/15/75	6	1	2	55	
355	325	145	Intake	5/15/75	7	2	5	9	
363	330	141	Intake	5/15/75	1	2	3	16	
388	350	181	Intake	5/15/75	1	3	1	34	
400	390	209	Intake	5/15/75	8	8	30	269	
428	390	218	Intake	5/15/75	38	31	104	67	
438	398	218	Intake	5/15/75		1	1		
450	410	240	Intake	5/15/75	46	9	20	11	
450	435	272	Intake	5/15/75	11	31	62	11	
478	435	318	Intake	5/15/75	18	92	78	82	
480	438	331	Intake	5/15/75		3	20	1	1
540	485	499	Intake	5/15/75	47	42	192	49	
548	495	508	Intake	5/15/75	21	63	82	28	
615	573	807	Intake	5/15/75	3	8	22	2	
738	668	1216	Intake	5/15/75	30	299	333	18	
775	705	1851	Terry	6/16/76	2	5	140	1	
785	725	2064	Miles C.	6/02/76	51	16	21	2	
850	785	?	Miles C.	6/08/76		1	16	1	
875	813	?	Miles C.	6/08/76	5	8	31	2	
875	813	3334	Miles C.	6/16/76	140	75	359	15	
			TOTALS		435	700	1522	673	1

TABLE F-6. Numbers of major food items in stomachs of shovelnose sturgeon collected July through September 1975 and 1976.

Total Length (mm)	Fork Length (mm)	Weight (g)	Location	Date	Ephemeroptera	Plecoptera	Trichoptera	Diptera	Terrestrial Insects
325	300	100	Intake	8/20/75	43		2	8	
343	310	118	Intake	8/20/75	28		1	2	
350	313	118	Intake	8/20/75	33		2	61	
378	355	240	Intake	8/07/76	13		6	1183	1
378	348	249	Intake	8/07/76	36		1	2	
380	350	136	Intake	8/21/75	40		3	536	1
380	343	154	Intake	8/20/75	47			4	
430	385	227	Intake	8/20/75	93		4	23	
453	403	426	Intake	8/07/76	127		8	3	
480	450	336	Intake	8/20/75	118	2	6	57	
485	440	299	Intake	8/20/75	93	1	4	23	
513	475	404	Sidney	8/30/76	16			4	
520	470	390	Intake	8/20/75	151	2	6	71	
550	500	735	Intake	7/26/76	44	1	5		
553	493	567	Intake	7/26/76	99		1	2	
565	513	517	Intake	8/30/76	17	2	30	6	
565	513	517	Intake	8/30/76	11		9	164	
588	530	762	Intake	8/07/76	113	4	13	16	
623	590	907	Intake	9/12/75	69		5	45	1
733	673	1243	Intake	9/12/75	246	5	15	171	
843	770	2268	Intake	8/20/75	1428		4	9	4
			TOTALS		2865	17	125	2390	7

Appendix G

YELLOWSTONE BASIN FORAGE FISH REPORTED BY BROWN (1971)

Scientific Name	Common Name
Family Cyprinidae	
Notemigonus crysoleucas	Golden shiner
Semotilus margarita	Pearl dace
Semotilus atromaculatus	Creek chub
*Phoxinus neogaeus**	Finescale dace*
*Hybopsis gracilis**	Flathead chub*
*Hybopsis gelida**	Sturgeon chub*
*Covesius plumbeus**	Lake chub*
*Notropis atherinoides**	Emerald shiner*
*Notropis stramineus**	Sand shiner*
*Hybognathus hankinsoni**	Brassy minnow*
*Hybognathus placitus**	Plains minnow*
*Hybognathus nuchalus**	Silvery minnow*
*Pimephales promelus**	Fathead minnow*
*Rhinichthys cataractae**	Longnose dace*
Family Catostomidae	
*Catostomus platyrhynchus**	Mountain sucker*
Family Ictaluridae	
Noturus flavus	Stonecat

* These species were collected during this study.

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