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Research and Development

Environmental Effects of Western Coal Surface Mining

Part V
Age and Growth of Walleyes and Saugers in the Tongue River Reservoir, Montana 1975-77

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ENVIRONMENTAL EFFECTS OF WESTERN COAL SURFACE MINING PART V - AGE AND GROWTH OF WALLEYES AND SAUGERS IN THE TONGUE RIVER RESERVOIR, MONTANA, 1975-77

by

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FOREWORD

As additional surface mining for coal in Western U.S. occurs, the potential disruption of surface waters or their degradation is of increasing importance. This study was completed to identify discernible impacts on walleye and sauger populations in southeastern Montana as a result of strip mining of coal.

No measurable impacts were found although the dilution volume into which the drainage emptied was relatively large. This study provides a background against which future evaluations can be assessed.

J. David Yount
Deputy Director

ABSTRACT

A study was conducted between 1975-1977 on the populations of walleye (*Stizostedion vitreum*) and sauger (*Stizostedion canadense*) in the Tongue River Reservoir, in southeastern Montana. The Tongue River Reservoir is the recipient of mine water effluents from the Decker Mine, the largest surface coal mine in the western United States. The objective of the study was to determine possible impacts of the mine on the walleye and sauger populations in the reservoir, and to provide data against which future comparisons can be made. These species were chosen because they are two of the most important game fishes in the reservoir.

The age and growth of 640 walleyes and 546 saugers were determined from collections made in gill nets, trap nets, and by electrofishing. The 1973 sauger year class and the 1972 walleye year class dominated the catches during the three years of the study. The movements of tagged fish in late March and early April 1977 strongly suggested that walleyes spawned in the Tongue River, upstream from the reservoir. The growth rates for both species were excellent for a northern latitude reservoir, indicating no noticeable effect by surface coal mine operations at the time of the study.

CONTENTS

		Page
Foreword		iii
Abstract		iv
Figures		vi
Tables		vii
Acknowledgments		ix
I	Introduction	1
II	Conclusions	4
III	Recommendations	5
IV	Description of Study Area	6
V	Materials and Methods	14
VI	Results and Discussion	16
	A. Sauger Population Characteristics	16
	B. Walleye Population Characteristics	26
	C. Movement of Tagged Walleyes	37
	D. Tag Loss	43
	E. Deviation from Lee's Phenomenon	43
VII	Potential Impacts of Surface Coal Mining	45
References		51

FIGURES

Number		Page
1	Map of Montana showing location of study area	2
2	Study area, showing locations of present and proposed surface coal mining areas	7
3	Discharge rates of the Tongue River near Decker, Montana	9
4	Water level elevations above sea level for the Tongue River Reservoir	10
5	Water storage history of the Tongue River Reservoir	11
6	Length-scale relation of saugers from the Tongue River Reservoir	18
7	Growth in length of saugers from the Tongue River Reservoir	21
8	Length-weight relation of saugers from the Tongue River Reservoir	23
9	Growth in weight of saugers from the Tongue River Reservoir	25
10	Length-scale relation of walleyes from the Tongue River Reservoir	28
11	Growth in length of walleyes from the Tongue River Reservoir	33
12	Growth curves for male and female walleyes collected in the Tongue River Reservoir and Tongue River study areas in 1977	34
13	Length-weight relation of walleyes from the Tongue River Reservoir	38
14	Growth in weight of walleyes from the Tongue River Reservoir	39
15	Tagging locations in the Tongue River Reservoir of five adult male walleyes recaptured in the Tongue River	41
16	Recapture locations in the Tongue River Reservoir of six adult male walleyes previously captured in the Tongue River	42

TABLES

Number		Page
1	Morphometric data of the Tongue River Reservoir at spillway elevation	8
2	Species of fishes present in the Tongue River Reservoir, 1975-1977	13
3	Lengths and weights of saugers from the Tongue River Reservoir in each age class at time of capture	17
4	Back calculated lengths of saugers from the Tongue River Reservoir, 1975-1977	19
5	Calculated lengths of saugers of different ages from various waters	22
6	Estimated weight-to-length relation for saugers from the Tongue River Reservoir	24
7	Lengths and weights of walleyes from the Tongue River Reservoir in each age class at time of capture	27
8	Back calculated lengths of walleyes from the Tongue River Reservoir, 1975-1977	29
9	Back calculated lengths of male and female walleyes collected from the Tongue River Reservoir, 1977	30
10	Back calculated lengths of male and female walleyes collected from the Tongue River, 1977	31
11	Lengths and weights of young-of-the-year walleyes from the Tongue River Reservoir, September 1976	35
12	Calculated lengths of walleyes of different ages from various waters	36
13	Estimated weight-to-length relation for walleyes from the Tongue River Reservoir	40
14	Averages and ranges of some chemical and physical parameters of the Tongue River Reservoir, November 1975 to November 1976	46

TABLES

Number | Page

15 Average values of selected parameters measured in the Decker Mine discharge water and in the Tongue River above and below the mine discharge, June 1975 to November 1976 48

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SECTION I

INTRODUCTION

The Tongue River watershed, including the Tongue River Reservoir, lies in the Fort Union Coal Basin, an area that encompasses a large portion of eastern Montana (Figure 1) as well as parts of northern Wyoming and western North Dakota. The Fort Union Basin, and other coal deposits in the northern Great Plains, contain nearly half of the nation's known coal reserves. To meet the nation's growing energy demands, surface coal mining in the Fort Union Basin is rapidly increasing.

The largest surface coal mine in the Tongue River area is the Decker Mine, located on the southwest shore of the Tongue River Reservoir in eastern Montana, just north of the Wyoming border. The Decker Mine began operation in 1972, and is currently being expanded to the southeastern shore of the Reservoir; permit application has been made for expansion northward along the western shore. As the mine expands, and production increases, the Decker Mine complex is projected to be the largest surface coal mine in the world. In addition to the Decker Mine, other mines are located in the Tongue River watershed, farther up river in Wyoming. Resource development plans also call for construction of mine-mouth coal-fired power plants in that same region.

Historically, water from the Tongue River has been used for agricultural purposes and the raising of livestock. In 1939 an earthfill dam was completed on the Tongue River, forming a reservoir for flood control and irrigation water storage. In recent years the reservoir has also become an important recreation area.

The potential impacts from coal mining and proposed coal combustion facilities on the Tongue River system are largely unknown. To provide a basis for measuring that impact, a variety of studies have been undertaken by the Montana Cooperative Fishery Research Unit, U.S. Fish and Wildlife Service, on the present status of the aquatic biota of the river and reservoir. The research reported here is the result of a study conducted between 1975 and 1977 on the populations of walleye (*Stizostedion vitreum*) and sauger (*S. canadense*) in the Tongue River Reservoir. These are two of the most important sport fishes in the reservoir, and are highly sought by fishermen because of their large size and the excellent quality and flavor of their flesh. The immediate objective of the present research was to study the populations, age and growth, and life histories of the walleyes and saugers in the Reservoir, and to see what discernable impact, if any, present coal mining operations might be having on these fishes. The longer

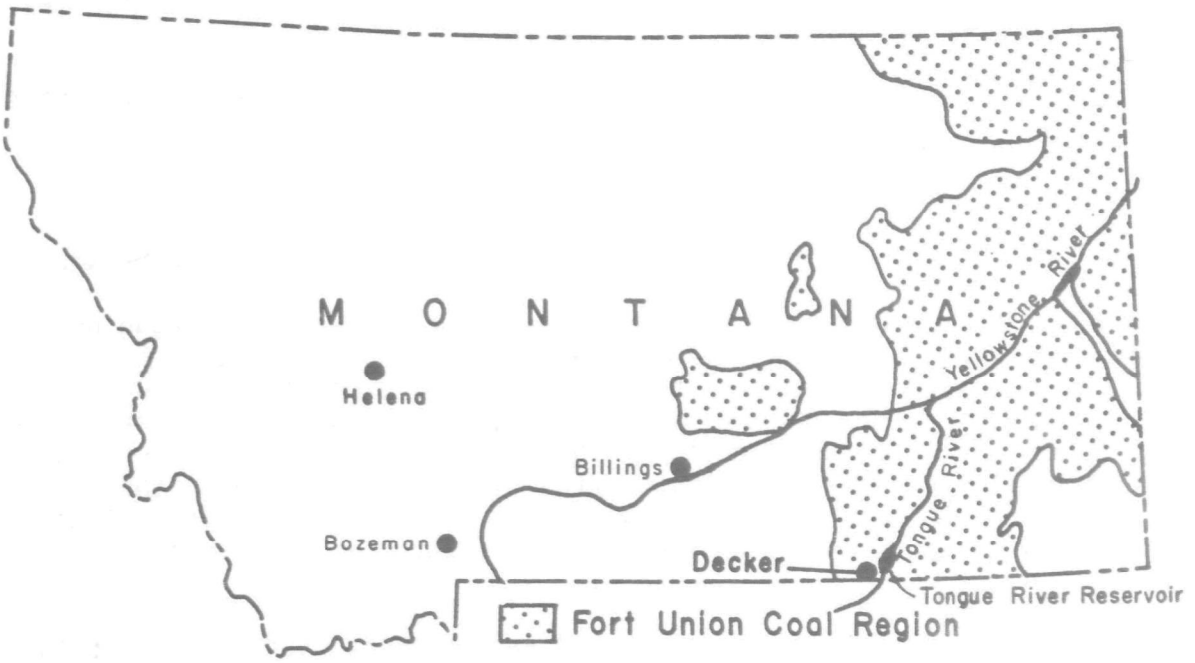

Figure 1. Map of Montana showing location of study area.

range objective is to provide information against which comparisons can be made in the future as mining operations in the Tongue River watershed increase.

Additional studies on the aquatic biota of the Tongue River and Reservoir will be reported separately. These include reports on the microbiological community within the Decker Mine settling pond (Turbak et al. In press), the limnology of the Tongue River Reservoir (Whalen 1979), and the distribution and behavior of smallmouth bass (*Micropterus dolomieui*) and largemouth bass (*M. salmoides*) in the reservoir (Penkal and Gregory, in press). Information from these and the present study will be of value in formulating recommendations for institution of appropriate safeguards to protect aquatic life as mining and combustion operations expand in this region of the country with relatively little water and a fragile environment.

SECTION II

CONCLUSIONS

1. Growth of both the walleye and sauger in the Tongue River Reservoir was excellent for a northern body of water. Characteristics of the populations were: (a) the greatest increment of growth in length for both species occurred during the first year of life and the greatest weight increment during the third year; (b) annulus formation of both species occurred primarily in June; (c) saugers collected were up to seven years old and walleyes up to 11 years; (d) female walleyes of all age groups collected were significantly larger than males; (e) the 1972 walleye year class and the 1973 sauger year class were predominant during the three years of this study, representing from 37 to 56 percent and 29 to 45 percent of the catch, respectively; the 1973 walleye year class was noticeably weak.

2. Tag and recapture studies demonstrated that some sexually mature walleyes migrate from the reservoir into the Tongue River in the spring, presumably to spawn. Male and female walleyes captured in the river were slightly larger than fish of the same age class collected in the reservoir. The tag and recapture studies did not yield sufficient data for comparable conclusions for saugers. The significance of the river as a spawning habitat and the resultant contribution to reservoir populations of walleyes and saugers has not been determined.

3. Based on the data collected, there is no apparent evidence that the presence of surface mining activities adjacent to the reservoir, or the addition of the mine discharge water after mixing with the Tongue River water source to the reservoir, is affecting the growth, reproduction, survival, or movements of walleyes or saugers within the reservoir.

SECTION III

RECOMMENDATIONS

Further monitoring of walleye and sauger populations in the Tongue River and Reservoir and concurrent water chemistry studies will be necessary to determine if increased mining activities and associated human population increases adversely affect these fish populations.

Information that will be critical for determining potential effects include: (a) the future trends in growth, abundance, distribution, and age structure of sport fishes; (b) the influence of human population increases on fishing pressure and sport fish harvest; (c) the importance of the Tongue River as a spawning area; (d) the food and habitat requirements of each species at various life stages; (e) water quality data, including nutrients, temperature, salinity, and concentrations of trace metals, on the mine discharges and the receiving waters; (f) data on trace metal accumulation in fish tissues.

SECTION IV

DESCRIPTION OF STUDY AREA

The Tongue River Reservoir (Figure 2) is located in Big Horn County in southeastern Montana, 23 km north of Sheridan, Wyoming. It is the only major impoundment on the Tongue River. The river originates on the eastern slopes of the Big Horn Mountains of Wyoming and flows in a northeast direction for 105 river kilometers until reaching the reservoir. The drainage area above the reservoir is 4584 km^2 [U.S. Geological Survey (USGS) 1976]. The river continues for 271 km beyond the reservoir to its confluence with the Yellowstone River at Miles City, Montana.

The reservoir was created for irrigation and flood control purposes, and the earthfill dam (27.7 m high) was completed in 1939. At spillway level (1043 m above sea level) the reservoir floods an area of about 1415 ha (USGS and Montana Department of State Lands 1977). At storage capacity the reservoir has a maximum length of 12.5 km, a maximum width of 1.4 km, and an average depth of 6.1 m (Garrison et al. 1975). The surface area is 1277 ha, the length of shoreline at spillway elevation is 60 km, and the shoreline development index is 4.74 (Penkal 1977). The shoreline development index is the ratio of the length of the shoreline to the length of the circumference of a circle having the same area as the lake (Hutchinson 1957). The initial storage capacity of the reservoir was estimated at about 8939 ha-m in May 1939 (Dendy and Champion 1973); by 1948, sedimentation had decreased the capacity to about 8557 ha-m. Assuming similar rates of sedimentation, the 1975 capacity was estimated to be about 7398 ha-m (USGS and Montana Department of State Lands 1977). Selected morphometric characteristics of the Tongue River Reservoir are listed in Table 1.

Peak runoff in the river usually occurs during late May and early June, but 1975 was an exceptional year; runoff persisted from early May to mid-July (Figure 3). The high runoff in 1975, coupled with an extensive late summer draw-down, resulted in a reservoir fluctuation of about 8 m (Figure 4). Water levels in 1976 and 1977, when fluctuations were 5 m and 6 m, were closer to normal. The greater water level fluctuation in 1975 is apparent from the water storage history of the reservoir (Figure 5). Annual water level fluctuations prevent the development of shoreline and emergent vegetation.

The river study section was approximately 3.1 river kilometers long and contained areas of gravel substrate which appeared suitable for walleye and sauger spawning. During the study period the ice cover broke up on April 23, 1975; April 3, 1976; and April 6, 1977.

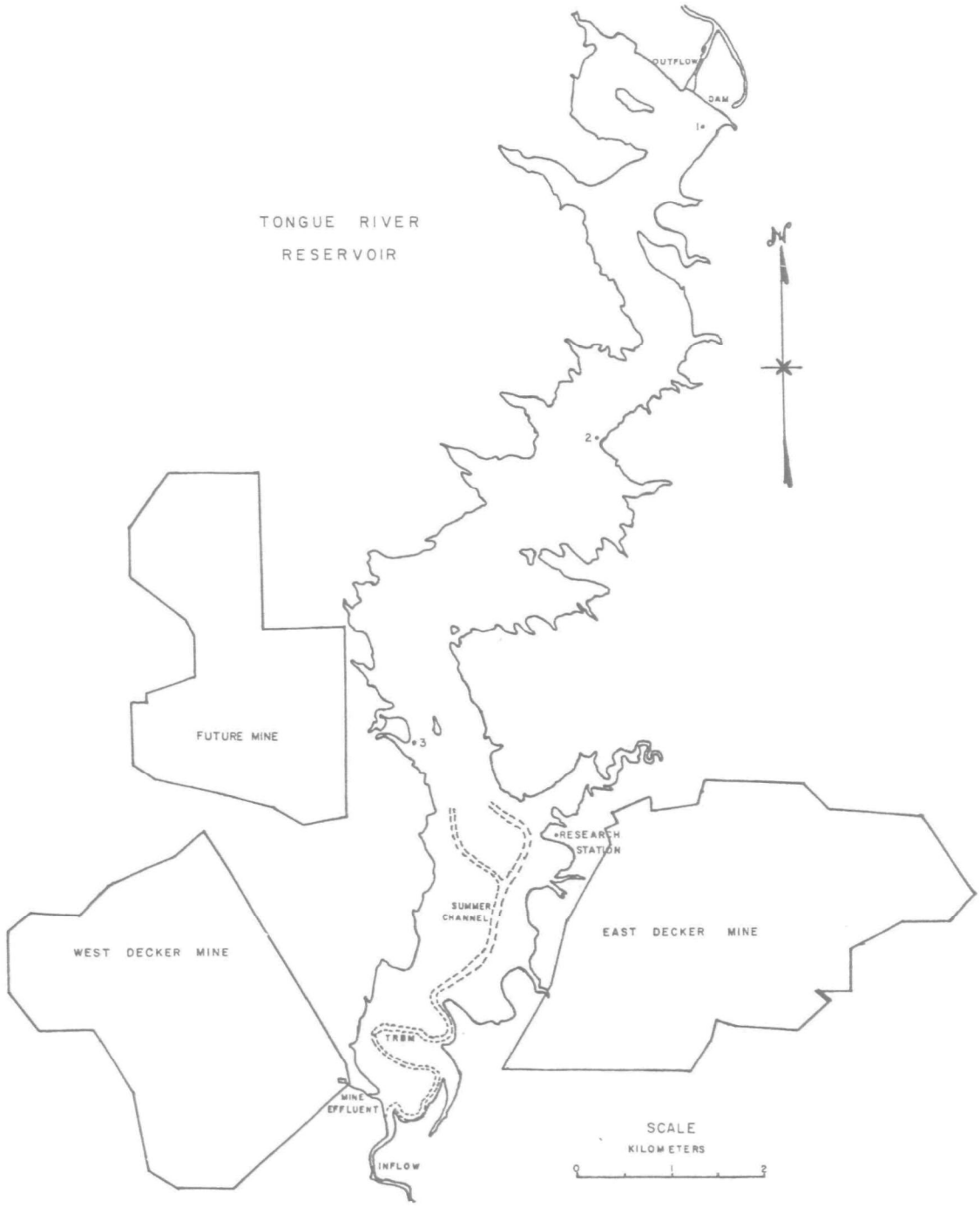

Figure 2. Study area, showing locations of present and proposed surface coal mining areas. [Numbers designate water sampling stations of Whalen (1979) discussed in section VII]

TABLE 1. MORPHOMETRIC DATA OF THE TONGUE RIVER RESERVOIR AT SPILLWAY ELEVATION (1043 m ABOVE SEA LEVEL).

Maximum depth (m)[a]	18.0
Mean depth (m)[a]	6.1
Depth of outlet (m)[b]	15.2
Maximum length (km)[c]	12.5
Maximum breadth (km)[a]	1.4
Mean breadth (km)[a]	1.1
Surface area (ha)[c]	1277
Volume (ha-m)[b]	7398
Length of shoreline (km)[c]	60
Index for shoreline development[c]	4.74

[a] Garrison *et al*. 1975.

[b] USGS and Montana Department of State Lands 1977.

[c] Penkal 1977.

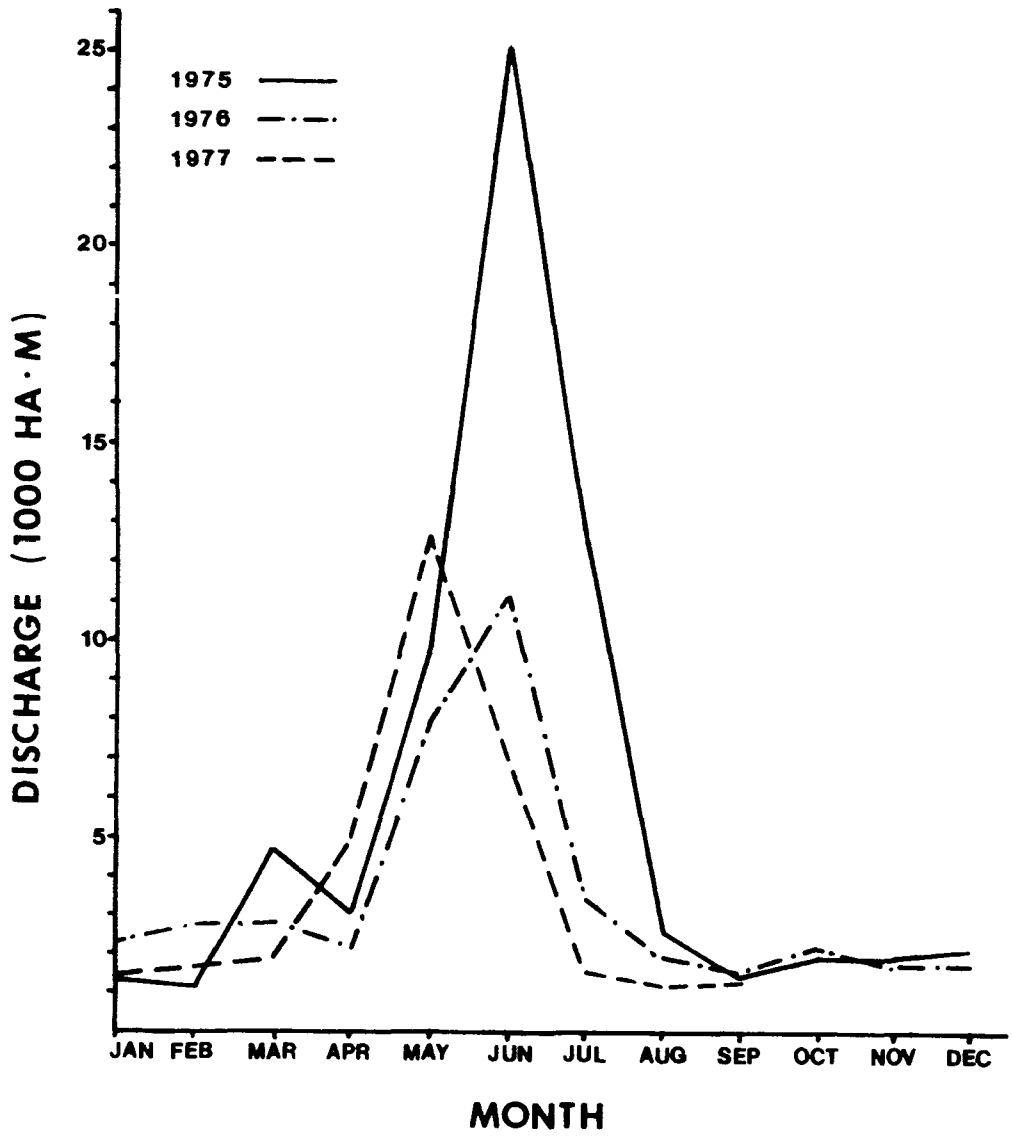

Figure 3. Discharge rates of the Tongue River near Decker, Montana (USGS 1976, 1977, and 1978).

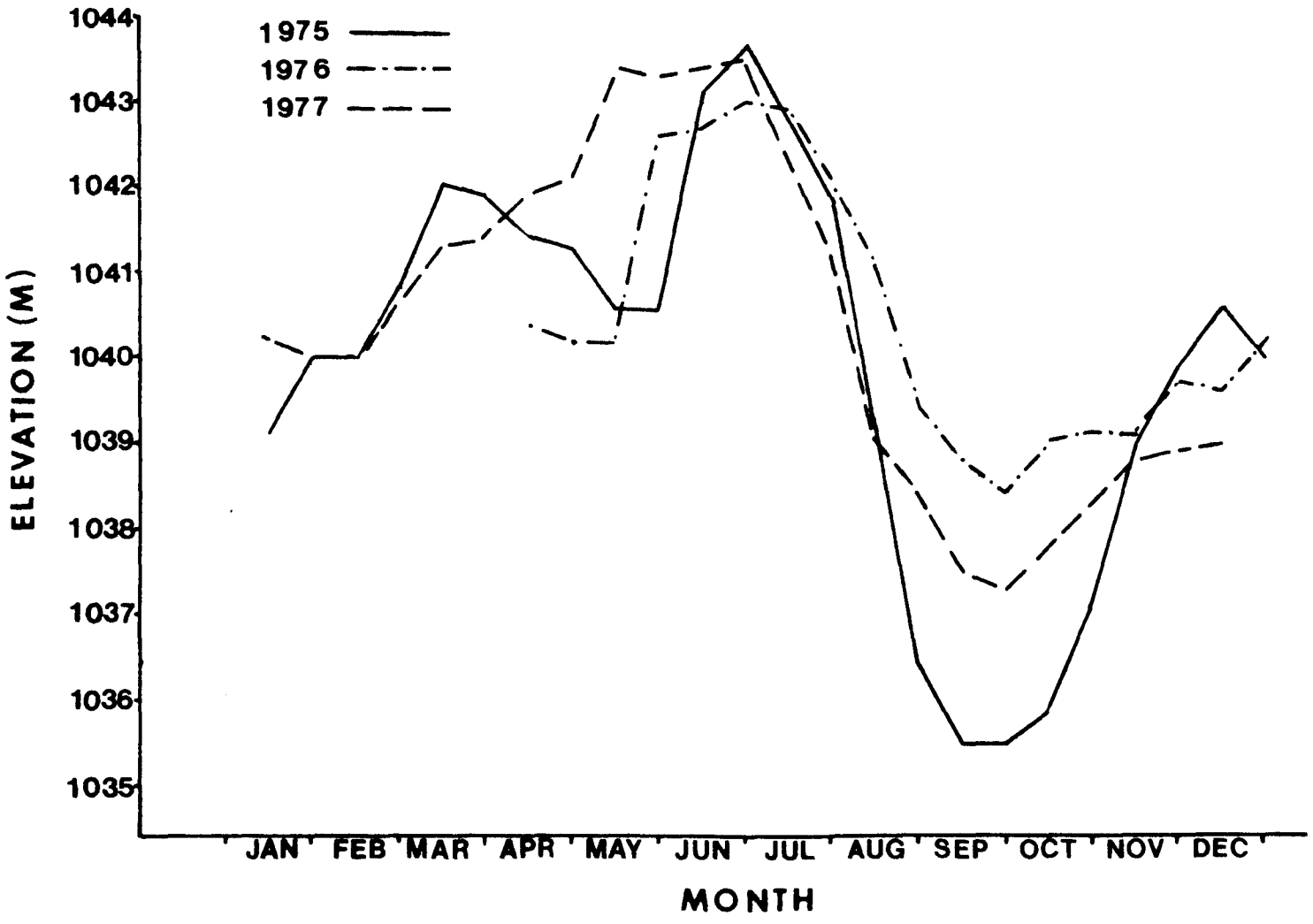

Figure 4. Water level elevations above sea level for the Tongue River Reservoir. (Montana Department of Natural Resources, unpublished data)

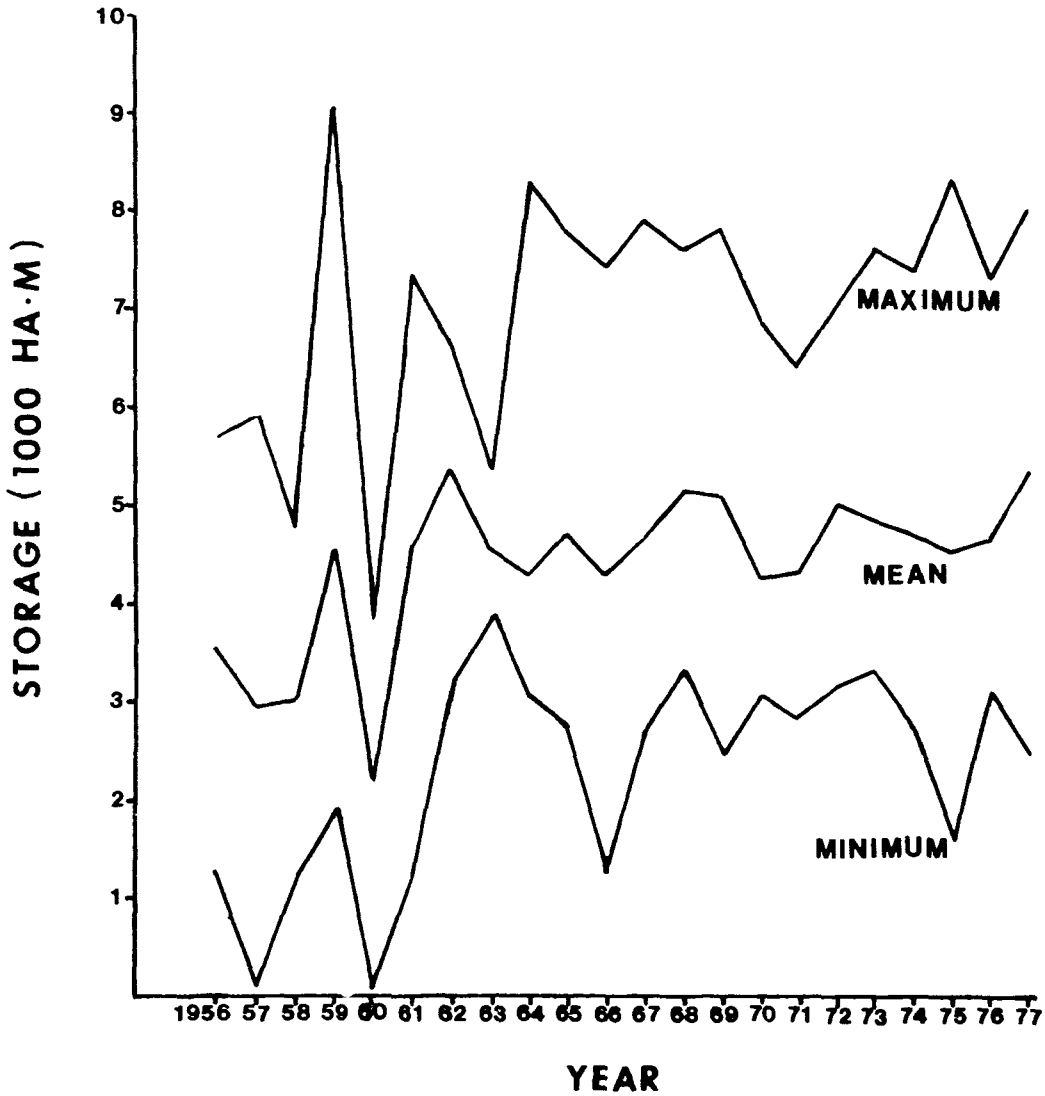

Figure 5. Water storage history of the Tongue River Reservoir. (Montana Department of Natural Resources, unpublished data).

A warmwater fisheries program was implemented at the reservoir in 1963. Prior to this time, rainbow trout (Salmo gairdneri) had been planted, but their numbers remained low, and populations of rough fish, remaining from a rehabilitation project in 1957, increased. The warmwater species planted included northern pike (Esox lucius), channel catfish (Ictalurus punctatus), largemouth bass (Micropterus salmoides) and walleye. White crappie (Pomoxis annularis) and black crappie (Pomoxis nigromaculatus) were present prior to the 1957 rehabilitation and were abundant at the time of our study (Penkal 1977). Smallmouth bass (Micropterus dolomieui) first appeared in 1972 and are believed to have entered the reservoir as a result of overflow from stripmine ponds near Sheridan, Wyoming (Elser 1975). Saugers first appeared in the reservoir in 1973 and are believed to stem from a planting by the Wyoming Game and Fish Department in the Tongue River near the Montana-Wyoming border in 1967 (Elser et al. 1977). Walleye fry were planted as follows: 1965--750,000; 1966--100,000; 1967--197,700; 1968--601,200; and 1969--92,500. Of the warmwater fishes present in the reservoir, only northern pike are not self-sustaining. A list of the species present is given in Table 2.

TABLE 2. SPECIES OF FISHES PRESENT IN THE TONGUE RIVER RESERVOIR, 1975-1977

Common name	Scientific name
Trouts	Salmonidae
Rainbow trout	*Salmo gairdneri*
Brown trout	*S. trutta*
Minnows and carps	Cyprinidae
Carp	*Cyprinus carpio*
Goldfish	*Carassius auratus*
Golden shiner	*Notemigonus crysoleucas*
Flathead chub	*Hybopsis gracilis*
Suckers	Catostomidae
River carpsucker	*Carpiodes carpio*
Shorthead redhorse	*Moxostoma macrolepidotum*
Longnose sucker	*Catostomus catostomus*
White sucker	*C. commersoni*
Catfishes	Ictaluridae
Black bullhead	*Ictalurus melas*
Yellow bullhead	*I. natalis*
Channel catfish	*I. punctatus*
Stonecat	*Noturus flavus*
Sunfishes	Centrarchidae
Rock bass	*Ambloplites rupestris*
Green sunfish	*Lepomis cyanellus*
Pumpkinseed	*L. gibbosus*
Smallmouth bass	*Micropterus dolomieui*
Largemouth bass	*M. salmoides*
White crappie	*Pomoxis annularis*
Black crappie	*P. nigromaculatus*
Pikes	Esocidae
Northern pike	*Esox lucius*
Perches	Percidae
Yellow perch	*Perca flavescens*
Sauger	*Stizostedion canadense*
Walleye	*S. vitreum*

SECTION V

MATERIALS AND METHODS

Walleyes and saugers were captured at numerous locations throughout the reservoir with trap nets and gill nets in 1975, 1976, and 1977. The fishes were widely distributed, and at any location on any given occasion no more than 20 individuals were captured; most frequently the numbers were five or less. During September 1976 electrofishing proved successful for collecting young-of-the-year walleyes and 2- and 3-year-old saugers. In addition, fishes were sampled in the river study section during spring 1977 by electrofishing. Electrofishing was conducted in the reservoir at night and in the river during the day. Direct current was used in both waters. The shocking gear consisted of a modified Smith Root Model VI electrofishing boat (Penkal 1977), a model VP-10 Coffelt variable voltage pulsator, and a 230-volt, 4000-watt, AC generator. Total lengths were measured to the nearest millimeter and weights to the nearest 10 grams. Fish were tagged with Floy FD-67 anchor tags in 1975 and 1976, and Floy FD-68B anchor tags in 1977. A right pelvic clip was used in 1976 and a left pelvic clip in 1977 as a precaution in the event of tag loss. Sex was determined by manually expressing eggs or milt from ripe fish or by dissection.

Scale samples for age and growth determination were taken from the fish's left side, just posterior to the pectoral fin. Cellulose acetate impressions were examined with a scale projector at a magnification of 66X. Total scale radius and radius at each annulus were measured from the center of the focus to the median anterior margin. The anterior edge of the scale was considered the annulua for the period January 1 until the beginning of spring growth.

The length-scale radius relations for walleyes and saugers in the Tongue River Reservoir is curvilinear. The equation best describing this relation is:

$$L = aS^b$$

or

$$\log L = \log a + b \log S$$

where L = length, S = scale radius, and a and b are constants determined by linear regression, using logarithms of the length and scale radius values. The method of back calculation is that described by Hile (1941).

Weights were estimated by using the relation described by the equation of Ricker (1975):

$$W = aL^b$$

or

$$\log W = \log a + b \log L$$

where W = weight, L = length, and a and b are constants determined by linear regression based on logarithms of the length and weight values.

A modified Schnabel population estimate (formula 3.17 in Ricker 1975) was computed for walleyes in the river study section for spring 1977.

A comparison of the ratio of tagged fish to untagged fin-clipped fish in the population at the time of capture to the same ratio at the time of recapture was used to determine tag loss. Statistical analyses were conducted according to procedures described in Snedecor and Cochran (1967). Linear regressions were derived using the method of least squares.

SECTION VI

RESULTS AND DISCUSSION

A. SAUGER POPULATION CHARACTERISTICS

Age and growth

The growth rate of saugers varied considerably (Table 3). In some age groups certain individuals were over 50% longer and 200% heavier than others. Some fish reached 457 mm at age 3, while others not until age 7.

The 1973 sauger year class was dominant in the three collection years, making up 29.1% of the catch in 1975, 27.4% in 1976, and 43.8% in 1977. The ages of saugers collected ranged from one to seven; only two age 7 fish were taken. The largest sauger taken was 591 mm long and weighed 2660 g. The largest sauger ever reported from the Tongue River Reservoir weighed 3266 g; it was taken by an angler in 1975 and was still the state record in 1977.

Annulus formation

Annulus formation occurred during June in 1975 and 1976. In 1975 it was 67% complete by June 19 and complete by July 11. In 1976 it was 80% complete on June 29 and complete by July 5. Nelson (1969) reported that in saugers 3 years old and older in Lewis and Clark Lake, South Dakota, annuli began forming in mid-June and were complete by early July; Carlander (1950) reported May and early-June as the time of annulus formation in saugers from Lake of the Woods, Minnesota.

Growth in length

The relation between body length and scale radius (Figure 6) was based on 546 saugers, 141 to 631 mm long. The assumption was made that no significant differences existed in the relation from one year to the next, and therefore the data for all three years were combined.

The average back calculated lengths at each age increased when calculations were made from progressively older fish (Table 4). This observation is unlike Lee's phenomenon, where the average calculated length at each age class usually decreases when the calculations are made from progressively older fish.

TABLE 3. LENGTHS AND WEIGHTS OF SAUGERS FROM THE TONGUE RIVER RESERVOIR IN EACH AGE CLASS AT TIME OF CAPTURE

Age class	Total length (mm)			Weight (g)		
	Number	Mean	Range	Number	Mean	Range
			1975			
1	6	215	141-265	5	88	60- 120
2	23	315	265-404	15	277	140- 560
3	17	423	362-464	15	677	400- 870
4	12	481	420-540	8	915	600-1150
5	21	537	458-631	12	1352	1020-1750
			1976			
1	6	258	197-293	6	135	60- 180
2	101	305	216-365	100	216	50- 440
3	107	387	293-578	107	473	170-1870
4	76	462	347-530	76	860	350-1350
5	65	501	427-591	65	1163	720-2660
6	37	547	465-595	37	1497	862-2210
7	1	613		1	2100	
			1977			
1	0	--	--	0	--	--
2	0	--	--	0	--	--
3	4	378	327-425	4	435	300- 530
4	32	453	394-562	32	797	394-1040
5	26	495	404-527	26	1104	840-1240
6	10	536	449-587	10	1443	740-1900
7	1	587		1	1610	

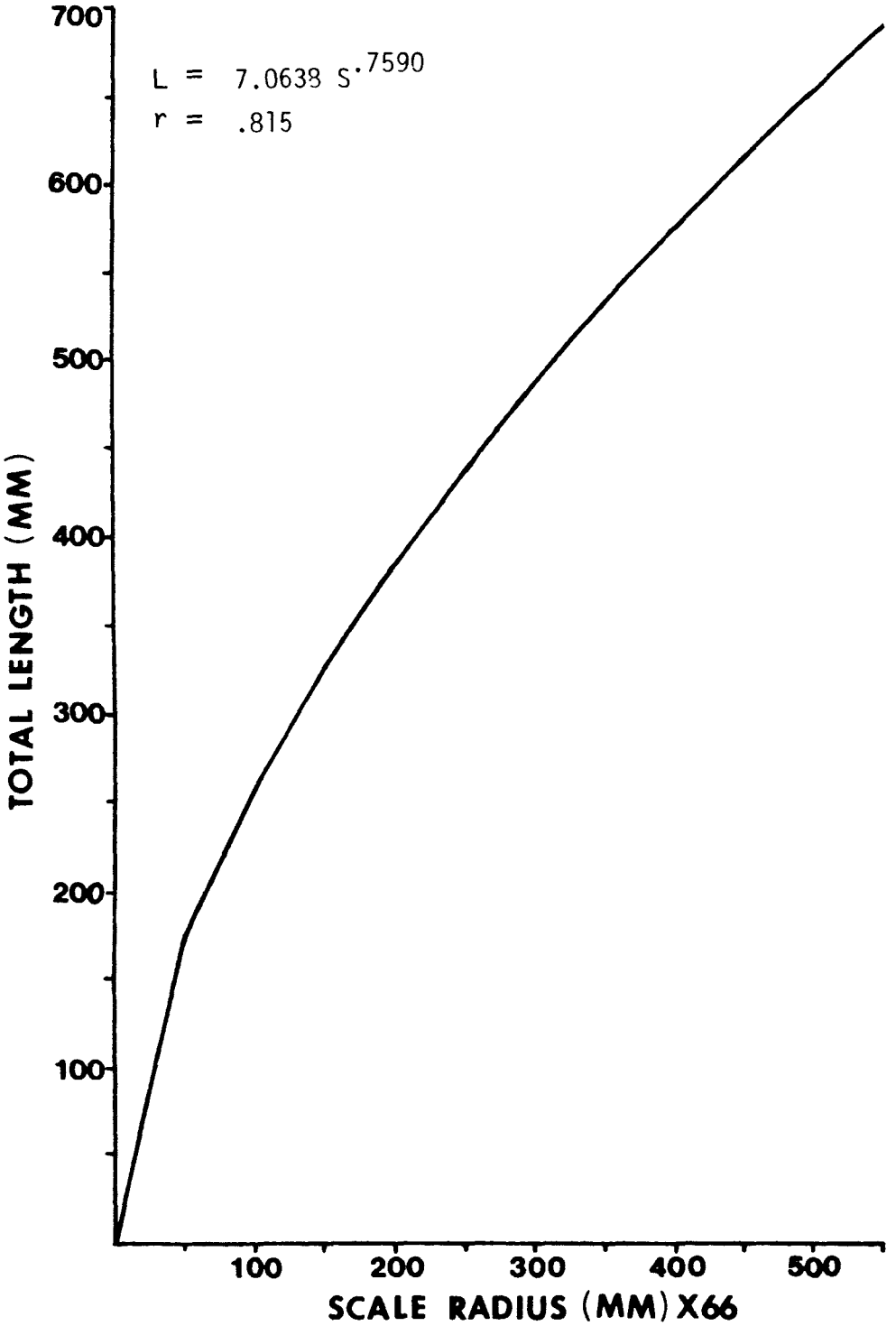

Figure 6. Length-scale relation of saugers from the Tongue River Reservoir.

TABLE 4. BACK CALCULATED LENGTHS OF SAUGERS FROM THE TONGUE RIVER RESERVOIR, 1975-1977

Age group	Number of fish	Total length at the end of each year						
		1	2	3	4	5	6	7
1	12	146						
2	124	164	270					
3	129	175	310	372				
4	120	186	324	400	445			
5	112	194	330	409	460	496		
6	47	195	337	421	479	518	541	
7	2	156	340	429	495	546	573	591
Grand average calculated length		180	311	396	457	503	543	591
Grand average incremental length		180	130	73	50	37	23	18
Sum of grand average increments		180	310	383	433	470	493	511

Growth curves for saugers, based on the grand average calculated lengths and on the sums of the grand average increments of length, differed (Figure 7); this difference can be attributed to the greater calculated lengths of the older fish. The summation of the grand average increments is probably the most representative of the growth of saugers because it avoids the irregularities caused by the successive elimination of fish of the older age groups. This curve should represent the average growth that saugers might have if the opposite effect of Lee's phenomenon were not present. The rationale for this data treatment is discussed in a later section. The greatest average annual increment for saugers occurred during the first year of life and decreased steadily thereafter.

The back calculated lengths of the saugers from the Tongue River Reservoir are greater than those reported for other Montana waters (Table 5). The only exception is the 1948 Fort Peck Reservoir study (Peters 1964) in which average lengths equaled those at age 6, and surpassed those at age 7 in the present study. Saugers grew faster in the Tongue River Reservoir than in the Garrison Reservoir, North Dakota, Lake Winnebago, Wisconsin, and Lake of the Woods, Minnesota, except that the length of saugers at age 6 in the Garrison Reservoir surpassed that of saugers in all other studies. The lengths of saugers from Lewis and Clark Lake were greater than those in the present study, and the lengths of saugers from Lake Oahe were greater at all ages except age 1.

Growth in weight

A length-weight relationship (Figure 8) was derived from the measurement of 521 saugers captured from 1975 through 1977. In the length-weight relationship formula ($W = aL^b$), the constant b equals 3.0 if growth is isometric (Ricker 1975). When b is greater or less than 3.0, growth is allometric. Values greater than 3.0 indicate weight increasing faster than the length and values less than 3.0 indicate length increasing faster than weight. In a normal fish population b usually ranges between 2.5 and 4.0 (LeCren 1951). The value of b for the Tongue River Reservoir sauger ($b = 3.23$) falls within this range, and indicates allometric growth.

The predicted weights of fish at ages 1 through 7 were obtained by applying the length-weight equation to the summed grand average increments at successive annuli (Table 6, Figure 9). Although the greatest annual length increment occurred during the first year of life, the greatest annual weight increment did not occur until age 3. The average weight increment was nearly constant for ages 2 through 5 but declined at ages 6 and 7.

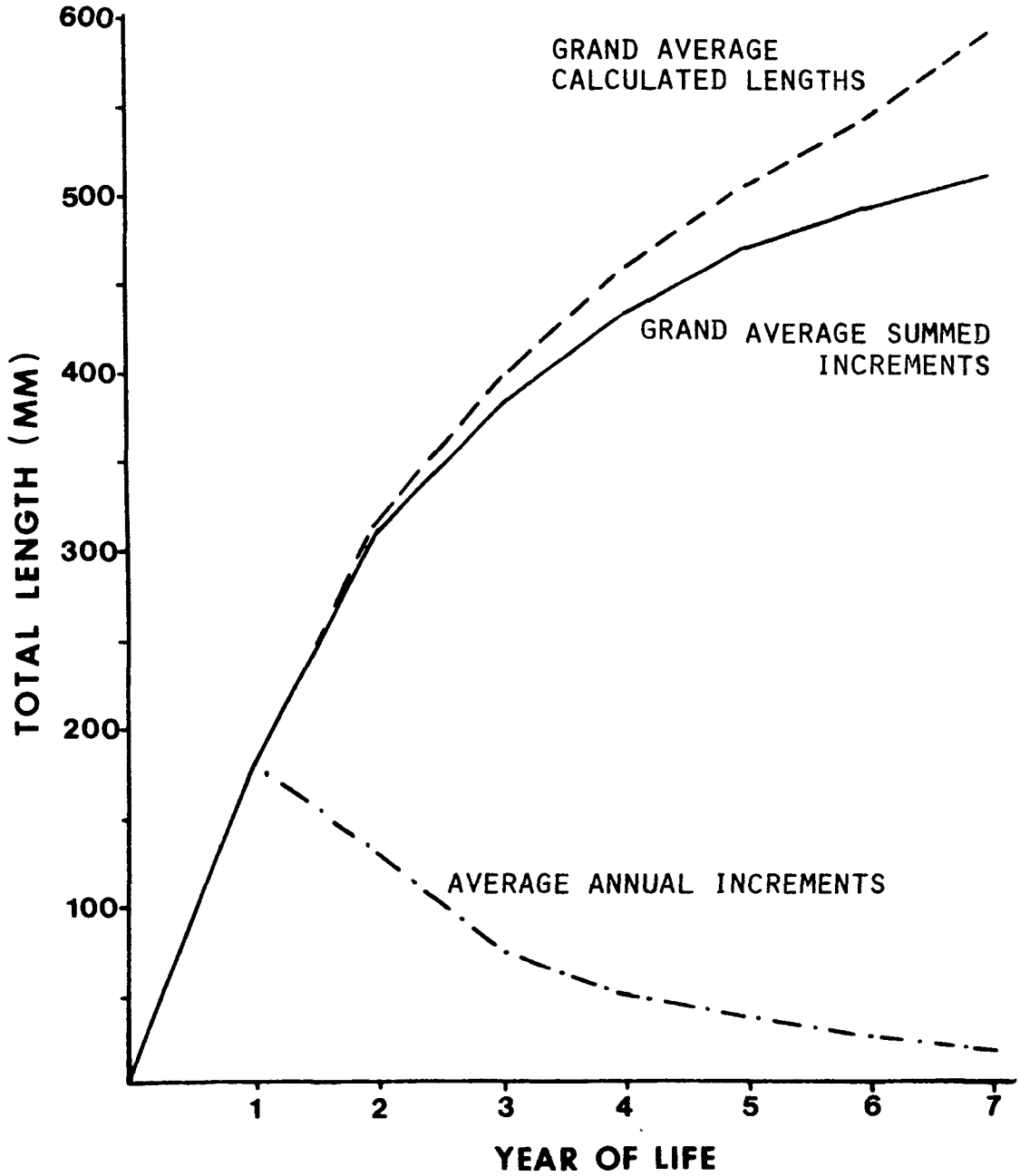

Figure 7. Growth in length of saugers from the Tongue River Reservoir.

TABLE 5. CALCULATED LENGTHS OF SAUGERS OF DIFFERENT AGES FROM VARIOUS WATERS

Locality	Number of fish	Average calculated total lengths at end of year (mm)									
		1	2	3	4	5	6	7	8	9	10
Tongue River Reserv. (present study)	546	180	310	383	433	470	493	511			
Ft. Peck Reserv., MT 1948 (Peters 1964)[a]	124	130	224	297	363	429	493	521			
Ft. Peck Reserv., MT 1949 (Peters 1964)[a]	134	122	244	325	389	371	488				
Marias River, MT 1961 (Peters 1964)[a]	16	112	203	282	335	384	465				
Garrison Reserv., ND	96 m[b]	122	216	292	358	447					
(Carufel 1963)[a]	222 f[b]	127	224	318	399	467	587				
Lake Winnebago, WI	784 m	125	241	307	335	356	376	389	401		
(Priegal 1969)[a]	957 f	135	252	310	338	358	378	391	401		
Lake of the Woods, MN (Carlander 1950)[c]	883	126	185	235	276	313	337	362	359	385	383
Lewis and Clark Lake (Nelson 1969)	1112	188	324	404	466	514	560	596	626		
Lake Oahe, ND, SD (Nelson 1974)	506	158	311	401	464	517	551	589	594	612	

[a] Total length in inches converted to total length in mm.

[b] m = male, f = female.

[c] Standard length in inches converted to total length in mm (Total length - Standard length ratio of 1.159 derived by Carlander 1950).

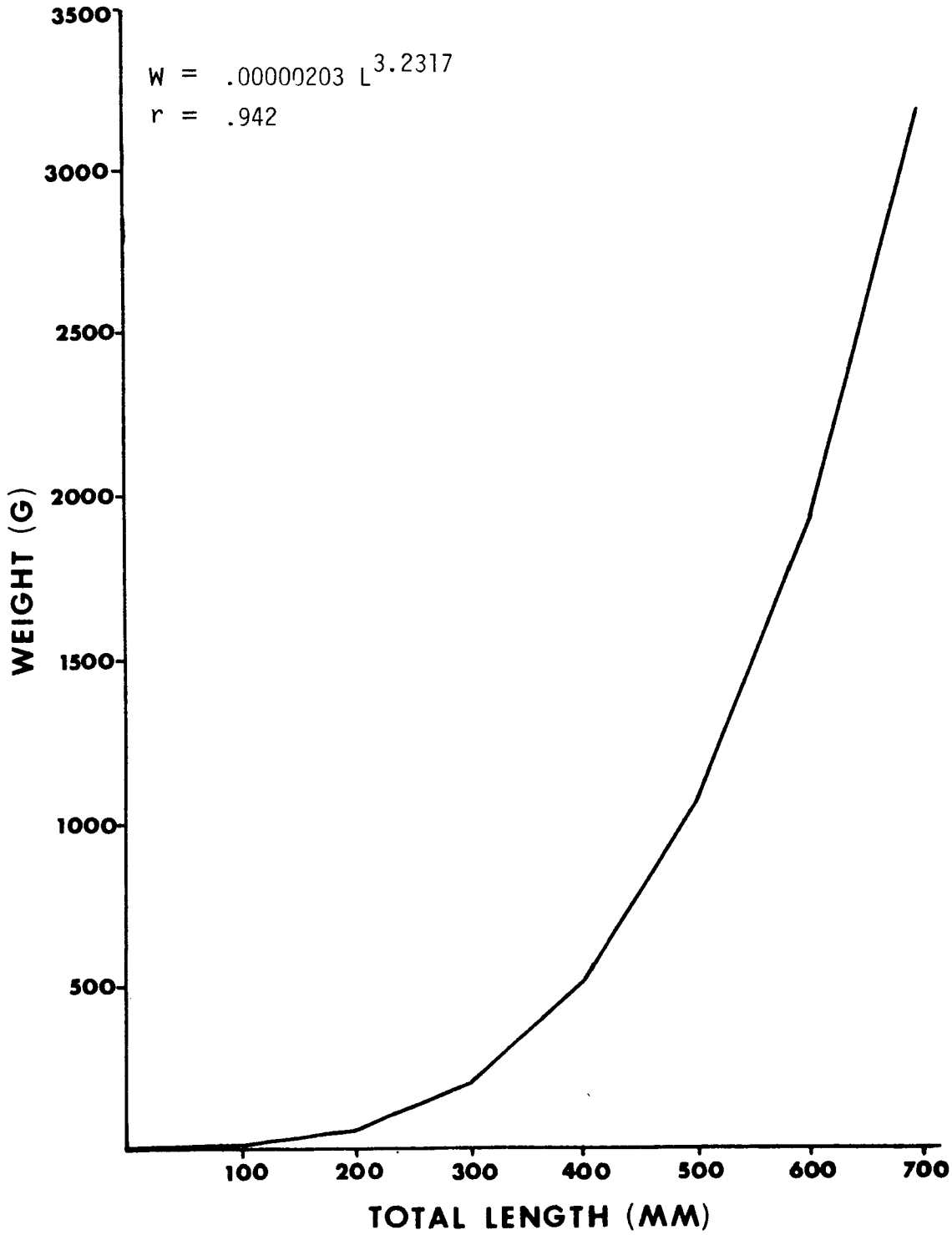

Figure 8. Length-weight relation of saugers from the Tongue River Reservoir.

TABLE 6. ESTIMATED WEIGHT-TO-LENGTH RELATION FOR SAUGERS FROM THE TONGUE RIVER RESERVOIR (LENGTH IN MILLIMETERS, WEIGHT IN GRAMS)

Length	Weight	Length	Weight	Length	Weight	Length	Weight	Length	Weight
5	0.0	145	19.6	285	174	425	634	565	1590
10	0.0	150	21.9	290	184	430	658	570	1640
15	0.0	155	24.3	295	195	435	683	575	1680
20	0.0	160	27.0	300	206	440	709	580	1730
25	0.1	165	29.8	305	217	445	735	585	1780
30	0.1	170	32.8	310	229	450	762	590	1830
35	0.2	175	36.0	315	241	455	790	595	1880
40	0.3	180	39.4	320	253	460	818	600	1930
45	0.4	185	43.1	325	266	465	847	605	1980
50	0.6	190	47.0	330	280	470	877	610	2040
55	0.9	195	51.1	335	294	475	908	615	2090
60	1.1	200	55.4	340	308	480	939	620	2150
65	1.5	205	60.0	345	323	485	971	625	2200
70	1.9	210	64.9	350	338	490	1000	630	2260
75	2.3	215	70.0	355	354	495	1040	635	2320
80	2.9	220	75.4	360	371	500	1070	640	2380
85	3.5	225	81.1	365	387	505	1110	645	2440
90	4.2	230	87.1	370	405	510	1140	650	2500
95	5.0	235	93.4	375	423	515	1180	655	2560
100	5.9	240	99.9	380	441	520	1220	660	2630
105	6.9	245	107	385	460	525	1250	665	2690
110	8.0	250	114	390	471	530	1290	670	2760
115	9.3	255	122	395	500	535	1330	675	2830
120	10.6	260	129	400	521	540	1370	680	2890
125	12.1	265	138	405	542	545	1420	685	2960
130	13.8	270	146	410	564	550	1460	690	3030
135	15.6	275	115	415	587	555	1500	695	3110
140	17.5	280	165	420	610	560	1550	700	3180

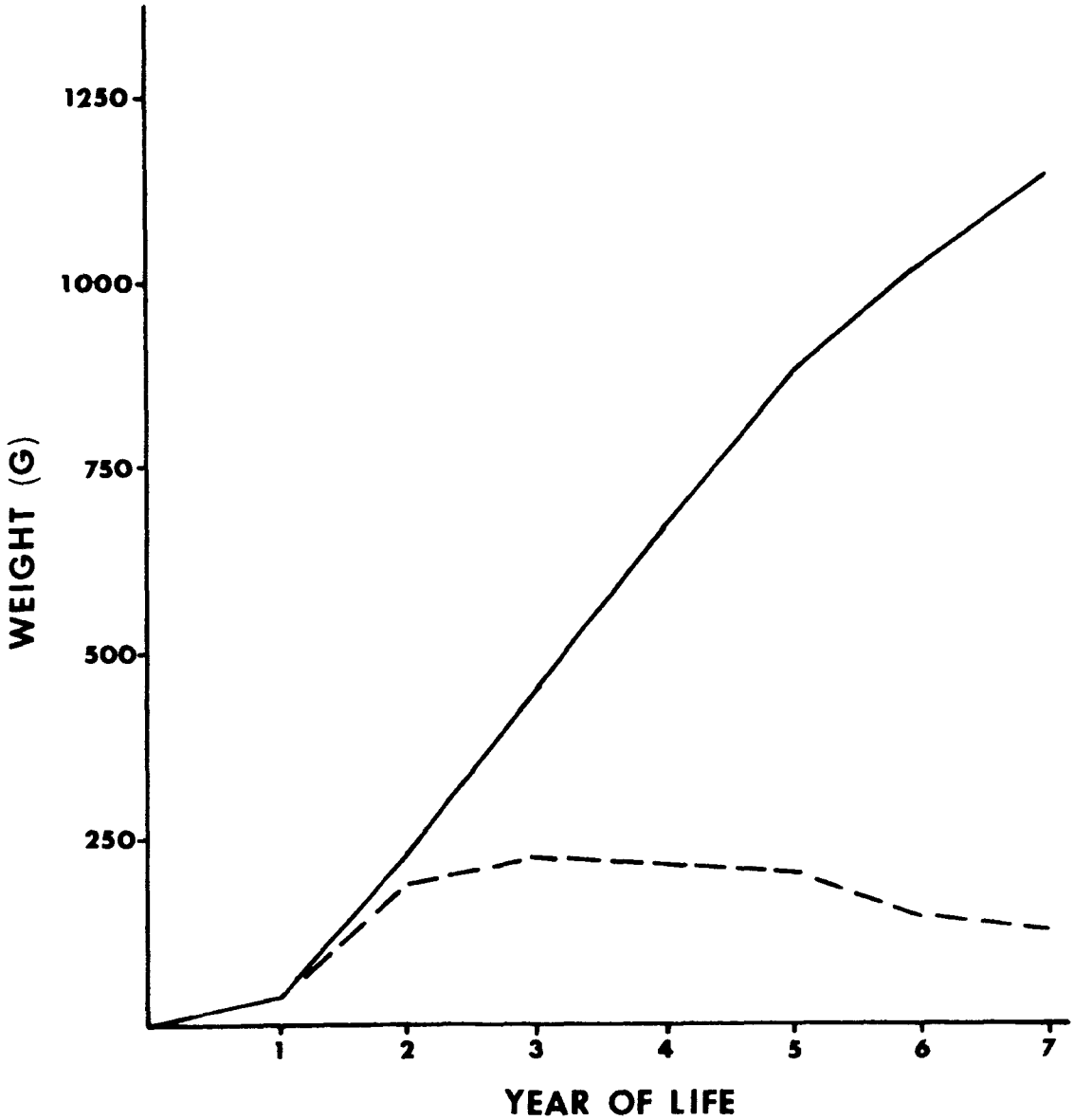

Figure 9. Growth in weight of saugers from the Tongue River Reservoir. (Dashed line represents average annual weight increments).

B. WALLEYE POPULATION CHARACTERISTICS

Age and growth

The growth rates of individual walleyes varied considerably (Table 7). For example, certain individuals in the 1973 age-3 group were over 100% longer and 280% heavier than others of the same group. Some individuals reached 457 mm during their third year of life and others not until their fifth year.

The 1972 walleye year class dominated the catch in the three years of the study; it constituted 56% of the catch in the reservoir in 1975, 37% in 1976, and 52% in 1977. Of the walleyes captured in the river study area during the spring spawning migration of 1977, the 1972 year class was also dominant (37% of the catch). The 1973 year class was noticeably weak; its greatest contribution was in 1976 when it represented 11% of the reservoir catch. It contributed only 5% to the reservoir catch in 1975 and 2% in 1977, and none were collected in the river in 1977.

During the study age-0 to -11 walleyes were collected, but age groups 7-11 were poorly represented. No walleyes under age 3 were collected in 1977. The largest walleye captured was 787 mm in length and weighed 5556 g.

Annulus formation

Annulus formation in 1976 was 22% complete by June 9 and complete by June 20. Too few walleyes were collected in May and June of 1975 to determine time of annulus formation, and no fish were collected after May in 1977.

Growth in length

Measurements of 640 walleyes 173 to 787 mm long were used to derive the length scale relationship (Figure 10). This relation was applied to the combined data for the years 1975, 1976, and 1977, and to the reservoir male-female groups and the river male-female groups for 1977.

The tendency for greater average calculated lengths at younger ages when calculated from older fish is evident in the back calculated lengths from the combined walleye data (Table 8). This trend breaks down with the inclusion of the 10- and 11-year-old fish; however, each of these age groups are represented by only one individual. The presence or absence of the trend is difficult to determine when considering the back calculated lengths for the reservoir and river male-female data (Tables 9 and 10). The age groups 1-4 are either poorly represented or not represented at all in the 1977 male and female samples, and it is in these age classes where the trend was most evident.

TABLE 7. LENGTHS AND WEIGHTS OF WALLEYES FROM THE TONGUE RIVER RESERVOIR IN EACH AGE CLASS AT TIME OF CAPTURE

Age class	Total length (mm)			Weight (g)		
	Number	Mean	Range	Number	Mean	Range
			1975			
1	20	267	231-317	19	173	90- 300
2	7	355	300-430	7	396	300- 600
3	84	431	317-500	70	783	340-1260
4	31	485	422-629	27	1147	700-2980
5	7	572	542-601	7	1919	1580-2410
6	5	584	502-665	5	2050	1360-3280
7	4	646	612-709	4	2709	1542-3760
			1976			
0	64	190	159-216	64	59	30- 90
1	9	215	173-313	9	101	40- 300
2	60	327	194-412	60	320	130- 500
3	27	443	386-507	25	817	400-1380
4	93	490	411-578	90	1139	550-2080
5	36	539	445-615	35	1508	880-2630
6	12	589	531-635	12	2051	1360-3050
7	6	632	582-704	5	2306	1640-3100
8	4	682	604-891	4	2645	2240-3720
9	4	735	700-762	4	4608	3690-5556
10	--	--	--	--	--	--
11	1	787	--	1	5556	--
			1977-Reservoir			
1	--	--	--	--	--	--
2	--	--	--	--	--	--
3	25	408	362-440	25	724	420-1740
4	3	479	475-484	3	1010	930-1130
5	80	525	398-595	80	1433	680-2080
6	30	555	477-621	30	1730	1070-2600
7	5	616	593-657	5	2306	2090-2790
8	7	658	590-699	7	2687	1890-3290
9	4	704	661-751	4	3928	2480-5330
			1977-River			
1	--	--	--	--	--	--
2	--	--	--	--	--	--
3	5	385	319-415	5	682	490- 720
4	--	--	--	--	--	--
5	28	510	415-575	28	1286	840-2070
6	9	569	530-604	9	1707	1350-2020
7	18	589	560-632	18	1969	1570-2750
8	9	625	595-675	9	2442	2170-3100
9	6	669	610-755	6	3058	2360-4090
10	1	640	--	1	2680	--

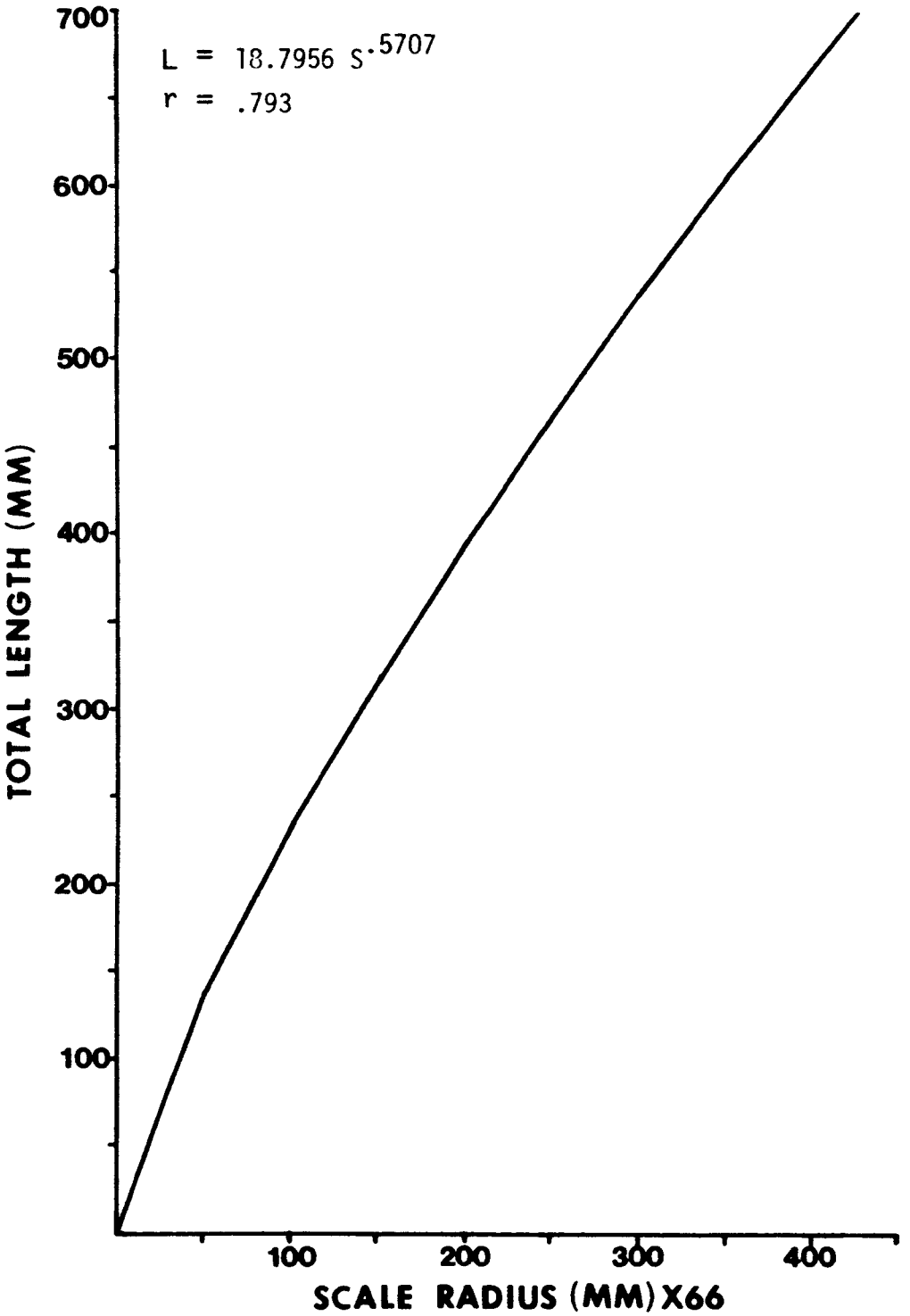

Figure 10. Length-scale relation of walleyes from the Tongue River Reservoir.

TABLE 8. BACK CALCULATED LENGTHS OF WALLEYES FROM THE TONGUE RIVER RESERVOIR, 1975-1977

Age class	Number of fish	Total length at the end of each year										
		1	2	3	4	5	6	7	8	9	10	11
1	29	213										
2	67	231	304									
3	141	242	336	406								
4	127	246	352	430	479							
5	151	256	366	445	493	525						
6	56	257	376	457	509	542	558					
7	33	263	393	476	534	566	598	606				
8	20	258	391	484	540	583	604	631	647			
9	14	259	399	482	557	603	637	662	679	694		
10	1	219	346	434	497	534	578	599	622	628	640	
11	1	260	378	453	530	587	641	673	706	733	754	771
Grand average calculated length		247	353	437	499	542	583	625	661	692	697	771
Grand average incremental length		247	102	77	51	34	24	17	18	15	17	16
Sum of grand average increments		247	349	426	477	511	535	552	570	585	602	618

TABLE 9. BACK CALCULATED LENGTHS OF MALE AND FEMALE WALLEYES COLLECTED FROM THE TONGUE RIVER RESERVOIR, 1977

Age class	Number of fish	Sex	Total length at the end of each year (mm)								
			1	2	3	4	5	6	7	8	9
1	0	M	--								
	0	F	--								
2	0	M	--								
	0	F	--								
3	5	M	247	329	329						
	4	F	267	347	413						
4	3	M	249	375	440	479					
	0	F	--	--	--	--					
5	35	M	252	355	433	479	505				
	27	F	266	378	461	514	553				
6	17	M	260	363	440	490	520	542			
	8	F	257	375	453	507	543	565			
7	3	M	268	397	480	529	566	594	609		
	1	F	263	399	493	556	597	627	657		
8	2	M	239	382	463	520	551	527	601	615	
	1	F	310	441	549	610	651	671	688	699	
9	2	M	237	375	444	515	569	606	631	651	665
	2	F	263	405	494	581	631	680	707	725	743
Grand average calculated length		M	253	359	435	487	516	553	613	633	665
		F	266	378	459	520	559	598	690	717	743
Grand average incremental length		M	253	106	76	49	29	24	20	17	13
		F	266	112	82	56	39	27	26	16	17
Sum of grand average increments		M	253	359	435	484	513	537	557	574	587
		F	266	378	459	515	554	581	606	622	639

TABLE 10. BACK CALCULATED LENGTHS OF MALE AND FEMALE WALLEYES COLLECTED FROM THE TONGUE RIVER, 1977

Age class	Number of fish	Sex	Total length at the end of each year (mm)									
			1	2	3	4	5	6	7	8	9	10
1	0	M	--									
	0	F	--									
2	0	M	--	--								
	0	F	--	--								
3	5	M	250	323	385							
	0	F	--	--	--							
4	0	M	--	--	--							
	0	F	--	--	--							
5	25	M	251	358	440	480	504					
	3	F	256	380	454	521	558					
6	9	M	268	393	476	520	550	569				
	0	F	--	--	--	--	--	--				
7	17	M	269	391	471	524	550	571	585			
	1	F	270	406	498	551	582	609	629			
8	8	M	260	394	477	517	565	586	606	621		
	1	F	272	405	521	579	609	633	648	660		
9	4	M	242	396	465	525	562	593	613	633	644	
	2	F	279	409	501	574	637	665	686	702	714	
10	1	M	219	346	434	497	642	578	599	622	628	640
	0	F	--	--	--	--	--	--	--	--	--	--
Grand average calculated length		M	258	374	454	505	535	576	595	625	641	640
		F	267	396	483	549	591	643	662	688	714	--
Grand average incremental length		M	258	117	80	46	29	22	17	17	10	12
		F	267	129	88	66	43	27	19	15	12	--
Sum of grand average increments		M	258	374	454	500	529	551	568	585	595	607
		F	267	396	483	549	591	618	638	652	664	--

The general growth curve for walleyes derived from the grand average calculated lengths differs greatly from that derived from the summed increments of length (Figure 11). The summed increments of length are believed to be more representative of the growth of walleyes because of the occurrence of a reverse Lee's phenomenon in the back calculated lengths. The greatest annual length increments occurred at age 1 and then decreased to a nearly constant level at ages 7 through 11.

Separate growth curves based on the summed increments of length for male and female walleyes collected in the reservoir and river in 1977 (Figure 12) showed the growth of females to be faster than that of males at all ages. This relation has been reported by others (Mraz 1968; Stroud 1949; and Tucker and Taub 1970), but some investigators have shown the opposite trend for 1- and 2-year-old walleyes (Lewis 1970, Nelson 1974, and Wolfert 1977). At the end of the first year of life, females captured in the reservoir had a 12-mm advantage over the males and by age 9 this advantage had increased to 52 mm. For the river sample, the females had a 9-mm advantage at age 1 which increased to 68 mm at age 9. The curve for females from the river is based on only nine fish and may not be representative of the females that spawn in the river.

The calculated lengths of walleyes of both sexes captured in the river were greater than those captured in the reservoir. This difference never exceeded 19 mm for males at any given age, or 38 mm for females.

Young-of-the-year

A total of 64 young-of-the-year walleyes were collected between September 1 and September 16, 1976 (Table 11). These fish averaged 190 mm in length and ranged from 159 to 216 mm. Priegal (1970) reported lengths of young-of-the-year walleyes on September 1 for the years 1959 through 1967 to range from 83 to 148 mm in Lake Winnebago, Wisconsin. Young-of-the-year walleyes from Oneida Lake, New York, ranged from 111 to 156 mm on September 1 for the years 1956 through 1961 (Forney 1966). Wolfert (1977) reported average lengths of 185 mm at the end of August and 230 mm by the end of September for young-of-the-year walleyes in western Lake Erie.

Lengths of walleyes from the Tongue River Reservoir were greater than those reported for other Montana reservoirs with two exceptions: Hauser Lake, in which lengths were greater at ages 3 and 4, and Nelson Reservoir, in which lengths were greater at age 6 (Table 12). Walleyes from the Tongue River Reservoir grow faster than walleyes from Lake of the Woods, Minnesota, and Lake Gogebic, Michigan, but slower than walleyes from Norris Reservoir, Tennessee, and Canton Reservoir, Oklahoma. Walleyes from Clear Lake, Iowa, showed slower growth rates than walleyes from the Tongue River Reservoir at ages 1 through 6, but faster at ages 7 through 11. Walleyes from Lake Oahe were longer at all ages except age 1. An earlier spawning season and a longer growing season are factors contributing to the better growth in the Tennessee and Oklahoma reservoirs.

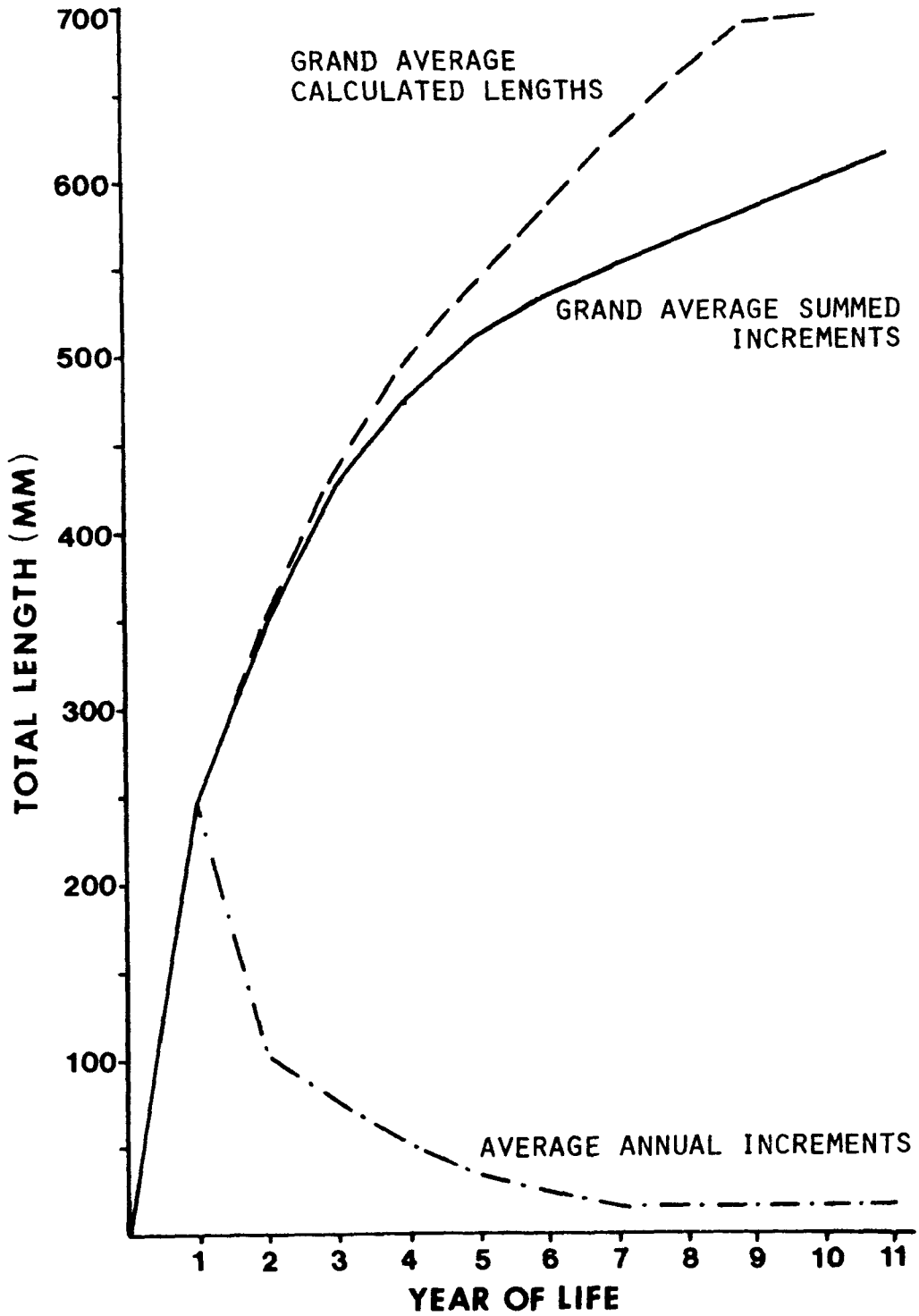

Figure 11. Growth in length of walleyes from the Tongue River Reservoir.

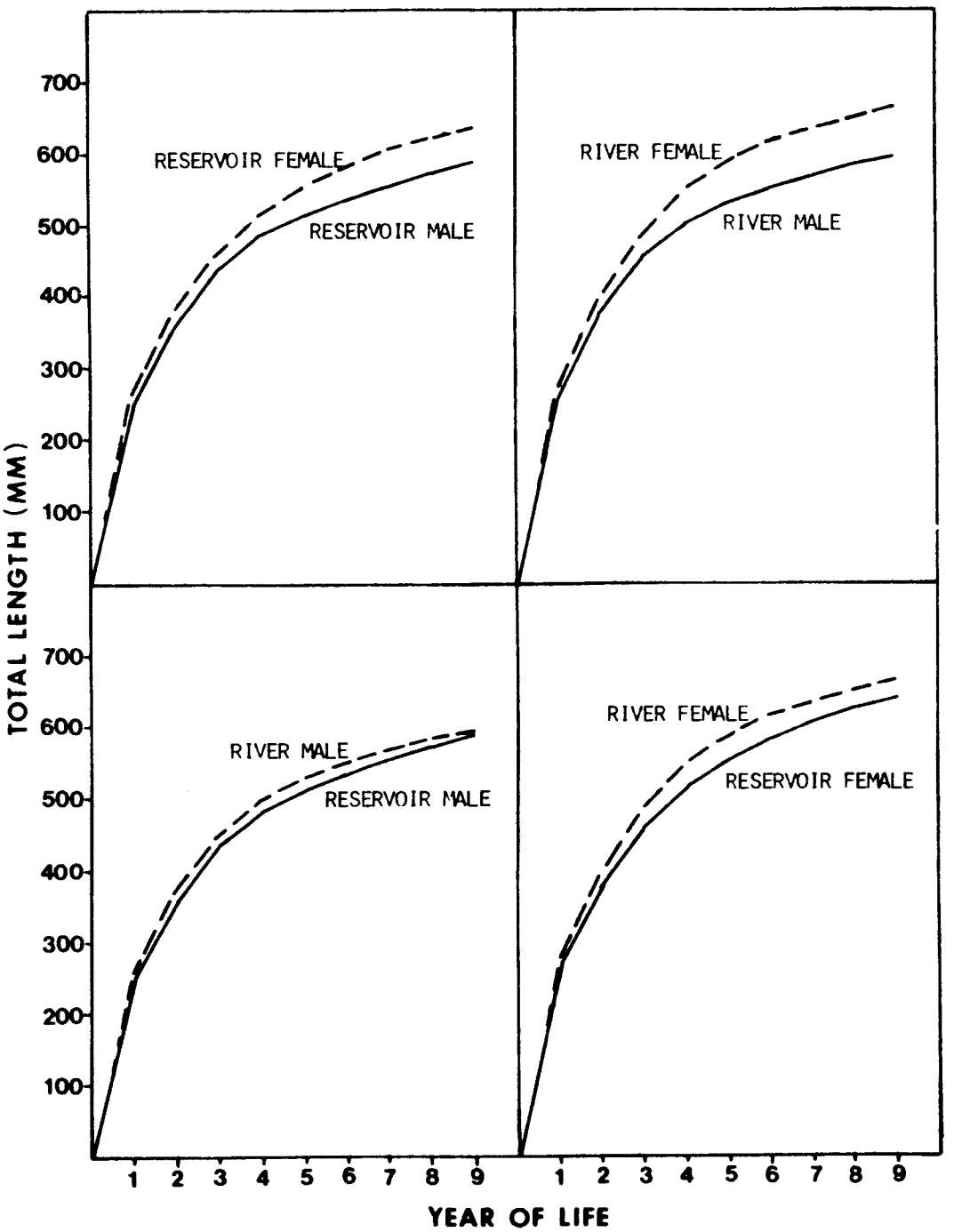

Figure 12. Growth curves for male and female walleyes collected in the Tongue River Reservoir and Tongue River study areas in 1977.

TABLE 11. LENGTHS AND WEIGHTS OF YOUNG-OF-THE-YEAR WALLEYES FROM THE TONGUE RIVER RESERVOIR, SEPTEMBER 1976

Date	Number of fish	Average length	Range of lengths (mm)	Average weight (g)	Range of weights
1	4	171	159-184	35	30-50
2	18	178	168-190	56	30-70
4	3	177	169-189	40	30-50
10	2	196	193-199	55	50-60
12	3	198	196-201	70	60-70
13	2	202	199-204	70	60-80
14	8	198	179-216	65	50-90
15	7	195	189-201	63	60-70
16	17	198	180-209	66	60-80
Totals	64	190	159-216	59	30-90

TABLE 12. CALCULATED LENGTHS OF WALLEYES OF DIFFERENT AGES FROM VARIOUS WATERS

Locality	Number of fish	Average calculated total lengths at end of year (mm)										
		1	2	3	4	5	6	7	8	9	10	11
Tongue River Res. (present study)	640	247	349	426	477	511	535	552	570	585	602	618
Nelson Res., MT 1959 (Peters 1964)[a]	71	94	193	269	345	470	650					
Lake Oahe, ND, SD (Nelson 1974)	757	213	351	445	522	569	603	633	678			
Clear Lake, IA (Carlander and Whitney 1961)[a]	3079	178	287	373	434	480	526	559	605	643	686	699
Lake of the Woods, MN (Carlander 1945)[b]	2898	163	235	293	342	378	424	464	507	549	577	607
Norris Res., TN (Stroud 1949)[a]	1146	262	417	475	506	528	533	561	633			
Lake Gogebic, MI (Eschmeyer 1950)[a]	519	117	239	307	361	401	437	457	478	495	508	
Canton Res., OK (Lewis 1970)[a]	870	310	427	495	554	607	650	704				
Killen Res., MT 1960 (Peters 1964)[a]	18	79	170	305	406	447						
Frenchman Res., MR 1958 (Peters 1964)[a]	34	185	338	401	460	450						
Hauser Lake, MT 1961 (Peters 1964)[a]	9	168	325	429	526							

[a] Total length in inches converted to total length in millimeters.

[b] Standard length in inches converted to total length in millimeters, (Total length-standard length ratio of 1.159 derived by Carlander 1945).

Growth in weight

The walleye length-weight relation (Figure 13) is based on a combined sample of 616 fish. The value of the constant b, from the length-weight formula, is 3.16. This value indicates allometric growth, where the increase in weight occurs faster than the increase in length and falls within the range of normal values established by LeCren (1951).

The predicted weight at ages 1 through 11 were obtained by applying the length-weight equation to the summed grand average increments of length at annulus (Figure 14). The yearly weight increments increased until age 3, declined steadily until age 7, and remained fairly constant thereafter.

The predicted weights for walleyes for each 5 mm length interval are listed in Table 13.

Population estimate in the Tongue River

A population estimate of male walleyes in the river study section was made in spring 1977. Electrofishing in the river was conducted on March 26, 28, and 31, and April 1 and 4, 1977 to determine if walleyes and saugers were spawning in the river. Increased river discharge and the accompanying increase in turbidity made electrofishing impossible beyond April 4 and no direct evidence of spawning could be obtained. On the five dates of electrofishing two saugers and 86 walleyes were captured. Of the 86 walleyes, 80 were ripe males, 30 of which (38%) were recaptured during the sampling period. This resulted in a male recapture rate of 37.5%. Using the Chapman method of population estimation (Ricker 1975) it was determined that 129 male walleyes (95% confidence limits: 86-251) were present in or passing through the river study section from March 26 to April 4. None of the six females was recaptured.

C. MOVEMENT OF TAGGED WALLEYES

Movement data were obtained for 11 walleyes, all of which were males. Four of these (No. 1-4 in Figure 15) captured in the reservoir in fall 1976 were recaptured in the river study area in spring 1977, 8.5 to 15 km from the points of release. Another walleye (No. 5 in Figure 15) was captured in the summer channel of the river in spring 1976 and recaptured in the river study section in spring 1977.

Of the 80 male walleyes tagged in the river study area during spring 1977, six were later recaptured in the reservoir (Figure 16). Of these six, three were recaptured twice and their movements from the first point of recapture to the second point of recapture are indicated by arrows in the figure.

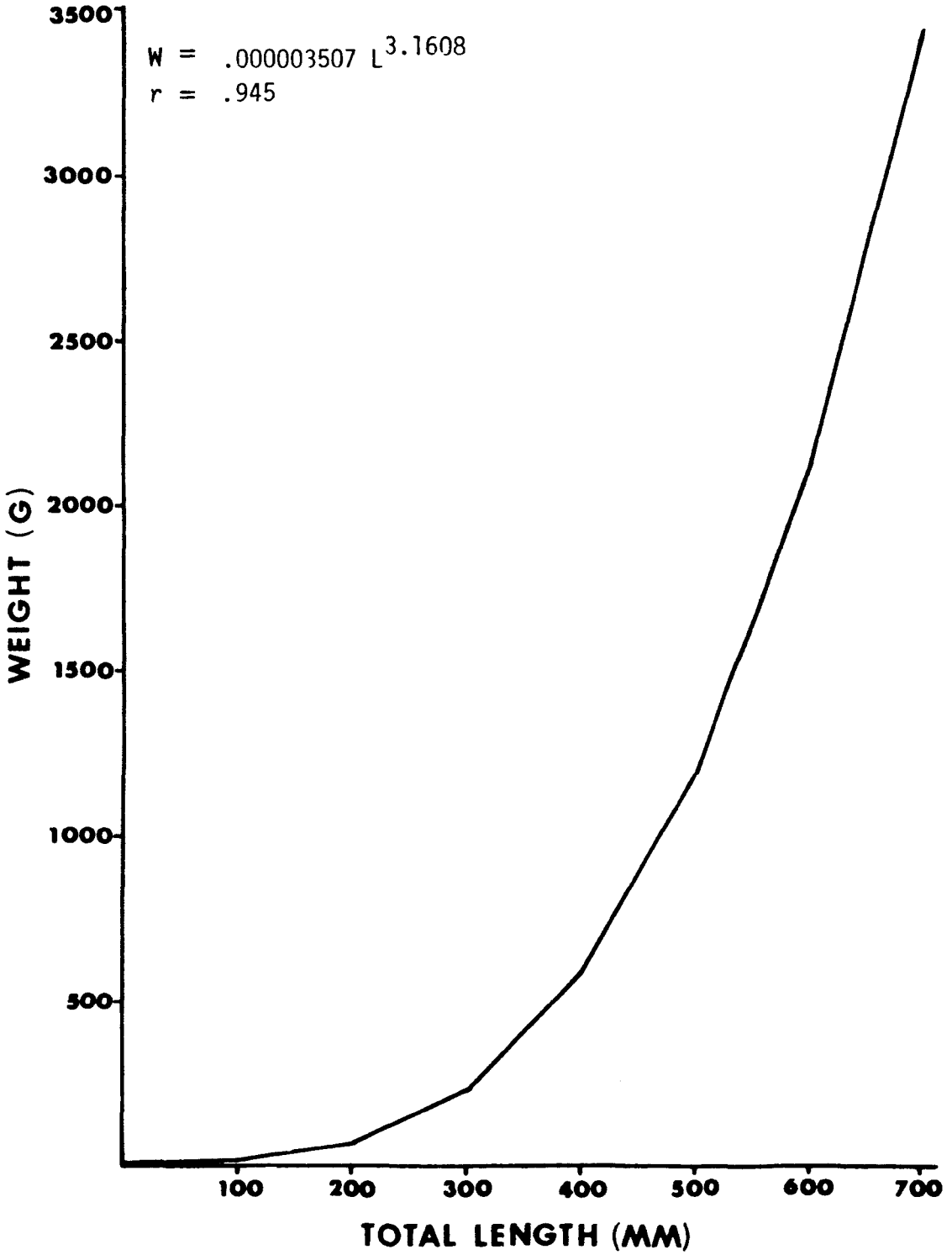

Figure 13. Length-weight relation of walleyes from the Tongue River Reservoir.

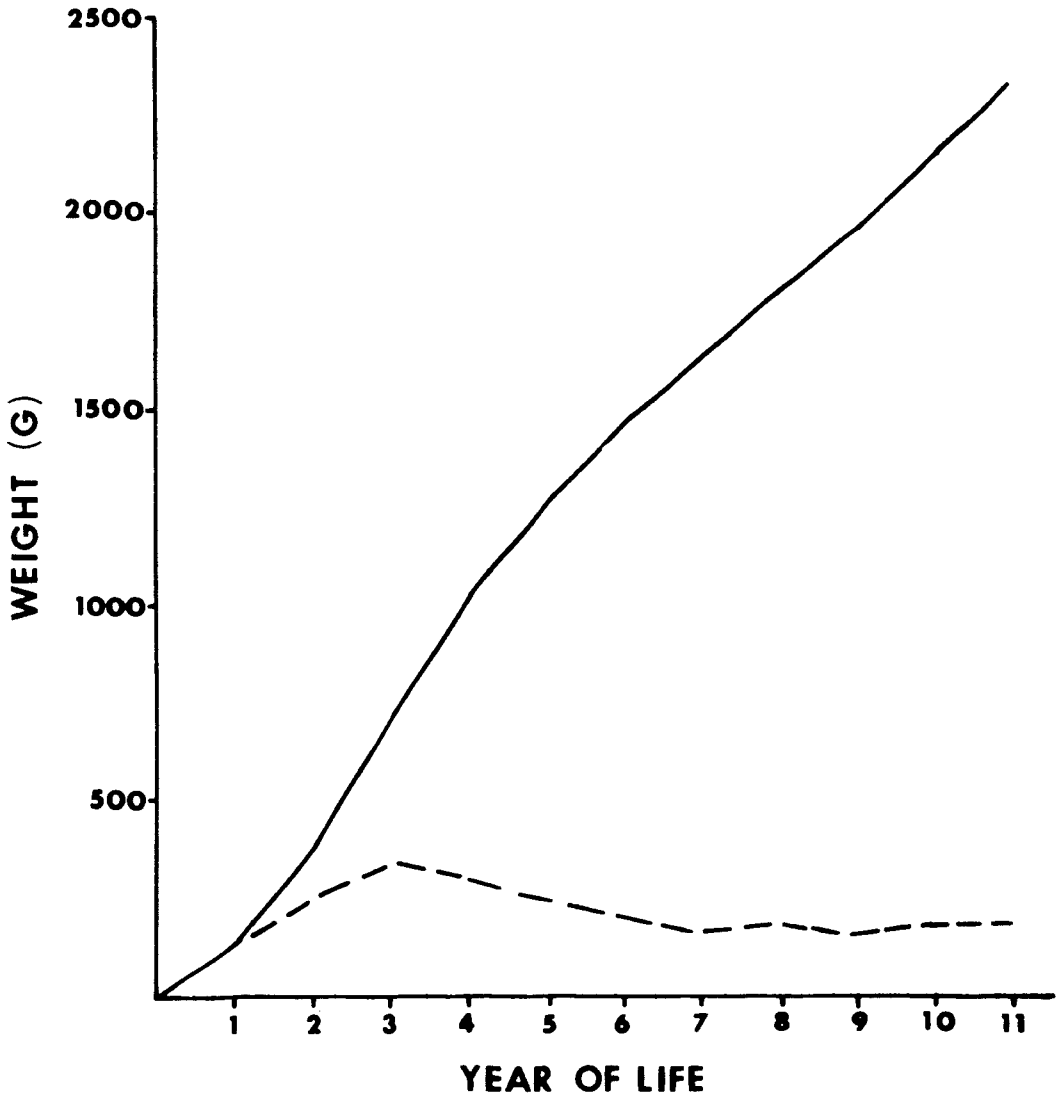

Figure 14. Growth in weight of walleyes from the Tongue River Reservoir. (Dashed line represents average annual weight increments.)

TABLE 13. ESTIMATED WEIGHT-TO-LENGTH RELATION FOR WALLEYES FROM THE TONGUE RIVER RESERVOIR (LENGTH IN MILLIMETERS, WEIGHT IN GRAMS)

Length	Weight	Length	Weight	Length	Weight	Length	Weight	Length	Weight
5	0.0	145	23.8	285	202	425	712	565	1750
10	0.0	150	26.5	290	213	430	739	570	1800
15	0.0	155	29.4	295	225	435	767	575	1850
20	0.0	160	32.5	300	237	440	795	580	1900
25	0.1	165	35.8	305	250	445	824	585	1960
30	0.2	170	39.3	310	263	450	854	590	2010
35	0.3	175	43.1	315	276	455	884	595	2060
40	0.4	180	47.1	320	291	460	915	600	2120
45	0.6	185	51.4	325	305	465	947	605	2180
50	0.8	190	55.9	330	320	470	979	610	2230
55	1.1	195	50.7	335	336	475	1010	615	2290
60	1.5	200	65.8	340	352	480	1050	620	2350
65	1.9	205	71.1	345	369	485	1080	625	2410
70	2.4	210	76.7	350	386	490	1120	630	2470
75	3.0	215	82.7	355	403	495	1150	635	2530
80	3.6	220	88.9	360	422	500	1190	640	2600
85	4.4	225	95.4	365	440	505	1230	645	2660
90	5.3	230	102	370	460	510	1270	650	2730
95	6.3	235	110	375	480	515	1310	655	2800
100	7.4	240	117	380	500	520	1350	660	2860
105	8.6	245	125	385	521	525	1390	665	2930
110	9.9	250	133	390	543	530	1430	670	3000
115	11.4	255	142	395	565	535	1470	675	3070
120	13.1	260	151	400	588	540	1520	680	3150
125	14.9	265	160	405	612	545	1560	685	3220
130	16.9	270	170	410	636	550	1610	690	3300
135	19.0	275	180	415	661	555	1660	695	3370
140	21.3	280	191	420	686	560	1700	700	3450

Fish No.	Date Tagged (1976)	Date Recaptured (1977)
1	10/21	3/28
2	11/5	3/28
3	11/6	4/1
4	10/28	4/4
5	4/10	4/4

Figure 15. Tagging locations in the Tongue River Reservoir of five adult male walleyes recaptured in the Tongue River.

Fish No.	Date Tagged (1977)	Date Recaptured (1977)
1	3/28	4/8, 4/13
2	3/28	4/13, 4/17
3	3/28	4/23
4	4/3	4/25, 4/29
5	3/28	4/26
6	3/28	4/26

Figure 16. Recapture locations in the Tongue River Reservoir of six adult male walleyes previously captured in the Tongue River. (Arrows indicate movement of fish recaptured twice.)

The tag return data suggest that walleyes in the reservoir may use the Tongue River for spawning. However, the portion of the reservoir population that uses the river and the extent of their upstream migration can be determined only through further research.

Whether saugers in the reservoir use the river for spawning has yet to be determined. Since only ripe males and spent females were collected it appears that most saugers had spawned before the start of sampling on March 23, 1977.

D. TAG LOSS

During summer 1976, 168 saugers and 76 walleyes were tagged and fin-clipped to measure the extent of tag loss. During spring 1977, 46 saugers and 184 walleyes were similarly marked. Floy FD-67 anchor tags were used in 1976 and Floy FD-68B anchor tags in 1977. Tags in both years were placed behind the spiny dorsal fin.

Tags were lost from one of four (25%) saugers recaptured during the summer of 1976. No tag loss occurred for the six saugers tagged in summer 1976 and recaptured in spring 1977, nor for the two saugers recaptured in spring 1977.

Only one fin-clipped walleye was recaptured during 1976 and it had retained its tag. However, of six walleyes recaptured in spring 1977, four (67%) had lost tags. During spring 1977 only one of 55 walleyes recaptured had lost its tag.

Much of the tag loss was attributable to the vinyl tubing slipping off of the anchor portion of the tag. Use of the Floy FD-68B tag, which incorporates a plastic bulb on the end of the anchor, reduced this kind of tag loss.

E. DEVIATION FROM LEE'S PHENOMENON

The greater calculated lengths at younger ages, when successively older fish were used in making growth calculations, is evident for both walleyes and saugers in the Tongue River Reservoir. The presence of this phenomenon could be caused by some naturally occurring factor, or by sampling bias. If non-random sampling were the problem, one of two conditions existed: (1) a sampling technique which would have a tendency towards capturing the smaller fish in the younger age classes, or (2) a tendency towards capturing the larger fish of the older age classes. Because of the variety of sampling techniques used (gill nets, trap nets, and electrofishing), non-random sampling is not a likely explanation. When Carlander and Whitney (1961) reported a similar occurrence in the back calculated lengths for walleyes in Clear Lake, Iowa, they felt that missed annuli on a few of the older fish may

have been responsible. It is possible that missed annuli contributed to the occurrence of the phenomenon in walleyes and saugers in the Tongue River Reservoir.

Selective mortality, bearing more heavily on the smaller fish of each age class, thus leaving the larger fish of each successive age class to be sampled for age and growth, would also explain the apparent decrease in growth rates observed. Predation has been shown to be selective toward slower-growing walleyes during the first year (Chevalier 1973), but such predation before the first annuli formed would have no effect on the back calculated lengths. The continuation of such size selective predation into the second and later years of life may be possible (Ricker 1975), but it probably does not continue throughout all of the age groups. When the phenomenon was observed in the calculated lengths for walleyes in Canton Reservoir, Oklahoma, Lewis (1970) believed that the growth reduction may have reflected the stabilization of an increasing walleye population to the pre-existing forage fish population. The oldest walleyes taken during the Tongue River Reservoir study were age 11 and the oldest saugers were age 7. Because the ages of these fishes date back to the earliest known existence of the two species in the reservoir, the apparent decrease in growth rates may have been a result of an increase in numbers of these two species, thereby increasing inter- and intra-specific competition. If so, later monitoring of these populations in the reservoir will be required for verification.

SECTION VII

POTENTIAL IMPACTS OF SURFACE COAL MINING

Surface run-off water in the immediate vicinity of the Decker mine, and subsurface water resulting from disturbing the aquifer, are collected within the Mine in a sedimentation pond system. The sedimentation pond water is reused for dust control and for irrigation onto reclaimed mine spoils; excess water is pumped onto the flood plain of the Tongue River at the upper end of the Reservoir.

Turbak et al. (In Press) have studied the quality of the settling pond water, including the heavy metals arsenic, cadmium, lead, mercury, and selenium, and data are reported for the mine effluent water for five dates from July 1976 to April 1977. Concentrations ranged from 1.1 to 1.9 μg/liter for arsenic and <1 to <5 for cadmium, both of these below the criteria published by EPA (1977). Reported concentrations for lead were <0.01 to <0.1 mg/liter and for selenium were <0.3 to 0.5 μg/liter. No specific numerical criteria for these two metals have been provided by EPA (1977), although it is recommended that acceptable concentrations be based on 96-hr LC50 values for sensitive resident aquatic species. The reported concentrations for mercury, 0.11 to 0.87 μg/liter, are in excess of the EPA (1977) criterion of 0.05 μg/liter, however these criteria are for receiving waters, not the discharge itself.

Additional data on mercury concentrations in the mine effluent between October 1975 and August 1976 have been reported by Phillips (1978); based on reported analyses performed by the Montana Department of Health and Environmental Sciences, mercury concentrations ranged between 1.2 and 335 μg/liter. Phillips also reported concentrations of mercury in the Tongue River below the mine effluent at this same time as ranging from <0.2 to 2.3 μg/liter.

The most extensive data available on the water chemistry of the Tongue River in the region of the Decker Mine have been reported by Whalen (1979), who studied the chemical limnology of the reservoir. Whalen has considered the potential impact on the river and reservoir of the mine discharge, and has extrapolated from his data to consider also the impact from the proposed expanded mine areas. Water chemistry from Whalen are presented in Tables 14 and 15. Whalen has calculated the average annual discharge of the mine to be less than 0.1 percent of the Tongue River flow at point of receipt. On the basis of the values obtained from the chemical parameters measured both in the receiving water and present mine discharge, Whalen has concluded that the impact of the mine water discharge on the Tongue River is and will be negligible for those parameters measured, with the caveat that an unusually

Table 14. Averages and ranges (in parenthesis) of some chemical and physical parameters of the Tongue River Reservoir, November 1975 to November 1976.[a]

Parameter	Station 1[b] Reservoir Above Dam	Station 2 Mid-Reservoir	Station 3 Reservoir Upper region
Ca^{++} (meq/ℓ)	2.86 (1.26-3.80)	2.79 (1.30-4.31)	2.81 (1.09-3.63)
Mg^{++} (meq/ℓ)	2.99 (0.96-4.29)	2.91 (0.84-4.59)	2.99 (0.79-3.81)
Na^{++} (meq/ℓ)	1.25 (0.34-1.92)	1.23 (0.29-22.7)	1.26 (0.28-2.02)
K^{+} (meq/ℓ)	0.10 (0.04-0.16)	0.10 (0.04-0.16)	0.10 (0.03-0.13)
Total alkalinity (meq/ℓ $CaCO_3$)	3.70 (1.92-4.70)	3.59 (1.68-5.62)	3.69 (1.56-4.71)
$SO_4^{=}$ (meq/ℓ)	3.44 (0.81-5.18)	3.35 (0.66-6.24)	3.37 (0.54-5.27)
Cl^{-} (meq/ℓ)	0.08 (0.03-0.12)	0.08 (0.03-0.13)	0.08 (0.03-0.12)
SiO_2 (mg/ℓ)	5.6 (1.4-11.8)	5.7 (1.1-10.0)	6.8 (2.5-13.0)
NH_3-N (μg/ℓ)	24 (0-236)	18 (0-142)	21 (0-220)
NO_3-N (μg/ℓ)	27 (0-204)	26 (0-187)	27 (0-47)
NO_2-N (μg/ℓ)	3 (0-20)	3 (0-10)	3 (0-10)
PO_4-P (μg/ℓ)	10 (0-100)	8 (0-77)	12 (0-27)
Total-P (μg/ℓ)	40 (16-144)	41 (10-109)	71 (37-260)

Table 14. Continued.

Parameter	Station 1[b] Reservoir Above Dam	Station 2 Mid-Reservoir	Station 3 Reservoir Upper region
Spec. cond. (μmhos/cm @25 C)	660 (246-929)	645 (221-1032)	654 (197-948)
pH	8.4 (7.5-8.9)	8.5 (7.5-9.0)	8.4 (7.9-9.0)
Turbidity (JTU)	7.3 (1.9-24)	8.6 (1.3-32)	20.3 (5.5-62)
Temperature (C)	10.6 (1.2-23.5)	10.9 (1.2-23.8)	11.4 (1.2-23.9)
Dissolved Oxygen (mg/ℓ)	8.5 (0.2-13.4)	9.3 (0.8-19.6)	10.1 (2.5-17.6)

[a] From Whalen (1979).

[b] Station locations shown in Figure 2.

Table 15. Average values of selected parameters measured in the Decker Mine discharge water and in the Tongue River above and below the mine discharge, June 1975 to November 1976.[a] (All parameters expressed as mg/liter unless otherwise noted.)

Parameter	Tongue River above mine	Mine discharge	Tongue River below mine
pH	8.6	8.5	8.4
Dissolved oxygen	10.1	9.8	9.8
Spec. Cond. (μmhos/cm @ 25 C)	693	1498	696
Turbidity (JTU)	15	18	14
Temperature (C)	14.7	14.9	14.7
Organic carbon	4.9	5.2	5.0
CO_3	4	12	4
HCO_3	238	597	240
Total alkalinity (as $CaCO_3$)	202	509	203
SiO_2	7.4	13.0	7.4
Fe	0.028	0.021	0.024
Cl	2.8	6.8	2.7
F	0.33	1.22	0.33
SO_4	166.4	295.1	166.4
Ca	61.2	33.1	61.0
Mg	37.8	42.4	37.8
Na	30.5	253.3	30.4
K	3.9	7.7	3.9
NO_2-N (μg/ℓ)	3	37	3
NO_3-N (μg/ℓ)	31	287	30

Table 15. Continued.

Parameter	Tongue River above mine	Mine discharge	Tongue River below mine
NH_3-N (μg/ℓ)	16	282	16
Total Kjehldahl nitrogen (μg/ℓ)	326	674	333
PO_4-P (μg/ℓ)	20	6	18
Total-P (μg/ℓ)	62	38	60
Sodium absorption ration (SAR)	0.78	6.88	0.78

[a] From Whalen (1979).

dry water year could alter his prediction. It should be noted that Whalen did not report concentrations of heavy metals.

The present study has concerned itself with the movement, age and growth, and life histories of walleyes and saugers in the Tongue River Reservoir. Any effect on these fishes as a result of altered water chemistry within the reservoir is not apparent from the results of the study. Fishes from the reservoir do move into the river above the reservoir, but the extent of this movement and whether this movement is affected by the mine discharge is not known, and warrants further study. With the intensification of coal mining planned for this area, we believe that additional information is needed to plan for adequate safeguards to protect the aquatic biota of the Tongue River drainage system. Information is now available which will provide baseline data against which data from future studies may be compared.

It is of particular concern, in our judgment, to assess the importance of the Tongue River above the reservoir relative to use by walleye and sauger for spawning migrations. If reproduction by these species makes a substantial annual contribution to reservoir populations, any alterations in water quality and spring flow regimes could significantly affect the standing crop available to sport fishermen. Such alterations could include abnormal spring temperatures, reduced flow volumes, dewatering, increased salinity, and heavy metal loading. Any of these factors, singly or in combination, could reduce recruitment of walleye and sauger in the Tongue River Reservoir downstream due to loss of migratory cues, improper conditions for egg deposition and incubation, and downstream transport of larval fishes.

An incremental increase in recreational use of the river and reservoir will undoubtedly result from expanded mining or coal conversion operations. These waters are currently subject to light fishing pressure but a human population influx could alter use patterns and fishing intensity.

In summary, we believe the following aspects should be studied in some detail in the near future:

1. Changes in water quality of the river and reservoir (salinity, temperature, nutrient loading, heavy metal loading).

2. Changes in water quantity (dewatering for offstream storage and use, and resultant reductions in reservoir storage levels).

3. Changes in fishing pressure and recreational use (including conflicts among various user types).

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

A study was conducted between 1975-1977 on the populations of walleye (Stizostedion vitreum) and sauger (Stizostedion canadense) in the Tongue River Reservoir, in southeastern Montana. The Tongue River Reservoir is the recipient of mine water effluents from the Decker Mine, the largest surface coal mine in the western United States. The objective of the study was to determine possible impacts of the mine on the walleye and sauger populations in the reservoir, and to provide data against which future comparisons can be made. These species were chosen because they are two of the most important game fishes in the reservoir. The age and growth of 640 walleyes and 546 saugers were determined from collections made in gill nets, trap nets, and by electrofishing. The 1973 sauger year class and the 1972 walleye year class dominated the catches during the three years of the study. The movements of tagged fish in late March and early April 1977 strongly suggested that walleyes spawned in the Tongue River, upstream from the reservoir. The growth rates for both species were excellent for a northern latitude reservoir, indicating no noticeable effect by surface coal mine operations at the time of the study.

17. KEY WORDS AND DOCUMENT ANALYSIS

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