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GROWTH RATES AND FOOD HABITS OF SMALLMOUTH BASS IN THE SNAKE, CLEARWATER AND SALMON RIVERS, IDAHO, 1965-1967

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GROWTH RATES AND FOOD HABITS OF SMALLMOUTH BASS

IN THE SNAKE, CLEARWATER AND SALMON RIVERS, IDAHO, 1965-1967

A Thesis

Presented in Partial Fulfillment of the Requirements for the

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JAMES F. KEATING, JR.

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ABSTRACT

In 1965-67 I investigated the growth rates and food habits of smallmouth bass in several major rivers of central Idaho to compare growth rates in local waters of dissimilar environmental characteristics and to establish the prospects for continued survival of these bass populations if proposed dams cause lowered summer water temperatures.

I and cooperators collected bass with electrofishing gear, on hook-and-line, by blasting, and with rotenone.

Back calculation of the length of bass at scale annuli provided estimates of growth increments. I compared the increments of growth of year classes of bass from each of three river sections and also compared the average growth increments with those of other smallmouth bass populations reported by other investigators throughout North America.

Smallmouth bass from the study sections of the Snake, Clearwater, and Salmon rivers grew slowly (approximately 85 mm the first year and 60 mm in the next two years) compared with other smallmouth bass populations reported in the literature.

Bass from the warmer, more fertile upper Snake River section grew slightly faster than those in the lower Snake River, the Clearwater River and the Salmon River in their first three years of life, but bass from the latter sections grew faster in older age classes and all populations reached nearly the same size, approximately 300 mm total length, by the end of their sixth year. Bass over six years old grew at reduced rates of 12 to 20 millimeters a year through age class nine. Crowded and indistinct annuli prevented me from accurately determining age from scales with more than 8 or 9 annuli; however, I estimated from 10 to 15 annuli on the few scales available from "lunker" bass 381 to 521 mm long.

Growth increments of bass did not vary with normal, minor fluctuations in the annual sums of degree days over 10 C in three growth-temperature comparisons made and I concluded that other environmental factors, such as inter- or intra-specific competition, overrode any benefits that occur in these river sections in warmer years.

Annual thermal sums of the Clearwater River approach minimum sums of waters listed by Coble, 1967, in his thorough review of smallmouth bass growth and temperature correlations in North America. A reduction of only 2 C in daily water temperature of the Clearwater River by dam regulation during four summer months would reduce the annual thermal sum from 1,000 to below 800 degree days and could adversely affect bass growth and survival. Coble does not list any bass populations in waters with less than 848 degree days.

Smallmouth bass in the Snake River feed predominately on crayfish while those in the Clearwater River and Salmon River rely heavily on fish and to a lesser degree on insects. The variation in food habits is due to food availability as crayfish are abundant in the Snake River and scarce in the Clearwater and Salmon rivers.

A study of ecological interrelationships is needed to explain why smallmouth bass in the 50 percent warmer, more fertile, all around "better" appearing bass habitat of the Snake River do not grow faster than bass in the "poor" habitat of the Clearwater River.

INTRODUCTION

Scope and Objectives

Smallmouth bass (Micropterous dolomieui) planted only 20 to 30 years ago in Idaho waters support major sport fisheries in the lower, warmer sections of the Snake, Clearwater and Salmon rivers. Anadromous species passed through these lower rivers but early settlers had to go to the tributaries to catch resident trout for the main stems had few game or food fishes other than white sturgeon (Acipenser transmontanus).

After an initial period of satisfaction with the success of the recently established smallmouth bass, local anglers noted "poorer" fishing and "decreased" catches of large bass. They blamed, in part, year-around seasons and the lack of size or bag limits.

Anglers continued to make good catches of smallmouth bass in remote reaches of the Snake River area but there was cause to investigate the status of the bass fisheries in the more heavily fished, roaded sections of the three rivers.

I undertook an age-growth and food habit study to obtain basic life history data needed to properly manage the smallmouth bass populations in these rivers. Gregory Munther undertook another study to ascertain the movement and distribution of smallmouth bass in the same waters, during the same period 1965-1966 (Munther, 1967).

My primary objectives were to:

1. Ascertain if bass in the warmer, more fertile waters of the Snake River grow faster than those in the Clearwater and Salmon rivers.

2. Measure annual variations in growth of bass and correlate these with annual fluctuations in thermal sums (degree days).

3. Compare the growth rates of local bass with those in other North American waters and correlate these growth rates to warm water.

4. Predict what might happen to growth of bass if river temperatures were

reduced by release of cold water from proposed dams.

Several authors, notably Fraser (1955), Doan (1940) and Latta (1963), have attempted to correlate warmer water with increased growth of smallmouth bass and the concensus opinion is that warmer water results in faster growth with exceptions caused by competition, disease and other factors.

Although smallmouth bass survive in regions with extreme winter conditions they do not feed actively below 10 C (Webster, 1954). Their preferred temperature range is much higher, 20.3 C to 21.3 C (Fry, 1947).

I theorized that bass in the Snake River grew faster than those in the Clearwater River since the former river was much warmer and appeared more fertile.

I collected samples of smallmouth bass, from subpopulations of the Snake River immediately above and below the mouth of the Salmon River, from the Salmon River below Riggins and from the Clearwater River below Orofino, Idaho from 1965 to 1967 to compare growth rates and food habits of bass from the four river sections. The areas are grossly dissimilar in physical conformation, water chemistry, temperature regimes, variety and abundance of indigenous and imported fish and invertebrate populations.

Distribution of Smallmouth Bass in Idaho

Lampman (1949) states that the game wardens of Oregon and Washington imported smallmouth bass into the northwest in 1921 - 1925, some 20 to 30 years after the importation of the more "desirable" species, carp (*Cyprinus carpio*), tench (*Tinca tinca*), catfish (*Ictalurus* sp), etc. Personnel of the Idaho Fish and Game Department first planted smallmouth bass in the Snake River in 1942 and in the Clearwater River in 1948.

Smallmouth bass became well established throughout the main stem of the Snake River, below Swan Falls Dam; in the Clearwater River, below

Kooskia; and in the Salmon River, below Riggins (Figure 1). Bass populations also support fisheries in the lower reaches of the Boise, Payette, and Weiser rivers and the Middle Fork of the Clearwater, Mel Reingold, Fisheries Biologist, (personal communication) reports recent catches of two smallmouth bass near Salmon, Idaho approximately 272 km above Riggins.

Most smallmouth bass catches consist of fish 254 to 356 mm long. " Lunkers", bass from 381 to 533 mm long, comprise a substantial portion of the catch. A sport caught 508 mm smallmouth bass weighing 2,66 kg holds the State weight record.

Description of the Study Areas

I collected smallmouth bass within four river sections:

(1) The "lower" Snake River includes the 77 km section from Lewiston, Idaho upstream to the Salmon River; (2) the "upper" Snake River includes the 68 km section from the Salmon River to Johnson Bar within Hells Canyon; (3) the lower 71 km of the Clearwater River below the North Fork; and (4) the lower. 132 km of the Salmon River below Riggins (Figure 1, Table 1).

The upper Snake River section and the Salmon River section have steep gradients, 4,3 and 4.8 m/km while the Clearwater and lower Snake River have more gentle gradients of 2,1 and 1.9 m/km respectively.

The upper Snake River and Salmon River flow through restricted V-shape canyons. Rough bedrock or broken rocks and rubble comprise a high percent of their streambeds. Deep pools and white-water rapids characterize these sections (Figure 2).

Typical pool-riffle structure interspersed with shallow "glides" characterize the streambeds of the Clearwater River and lower Snake River.

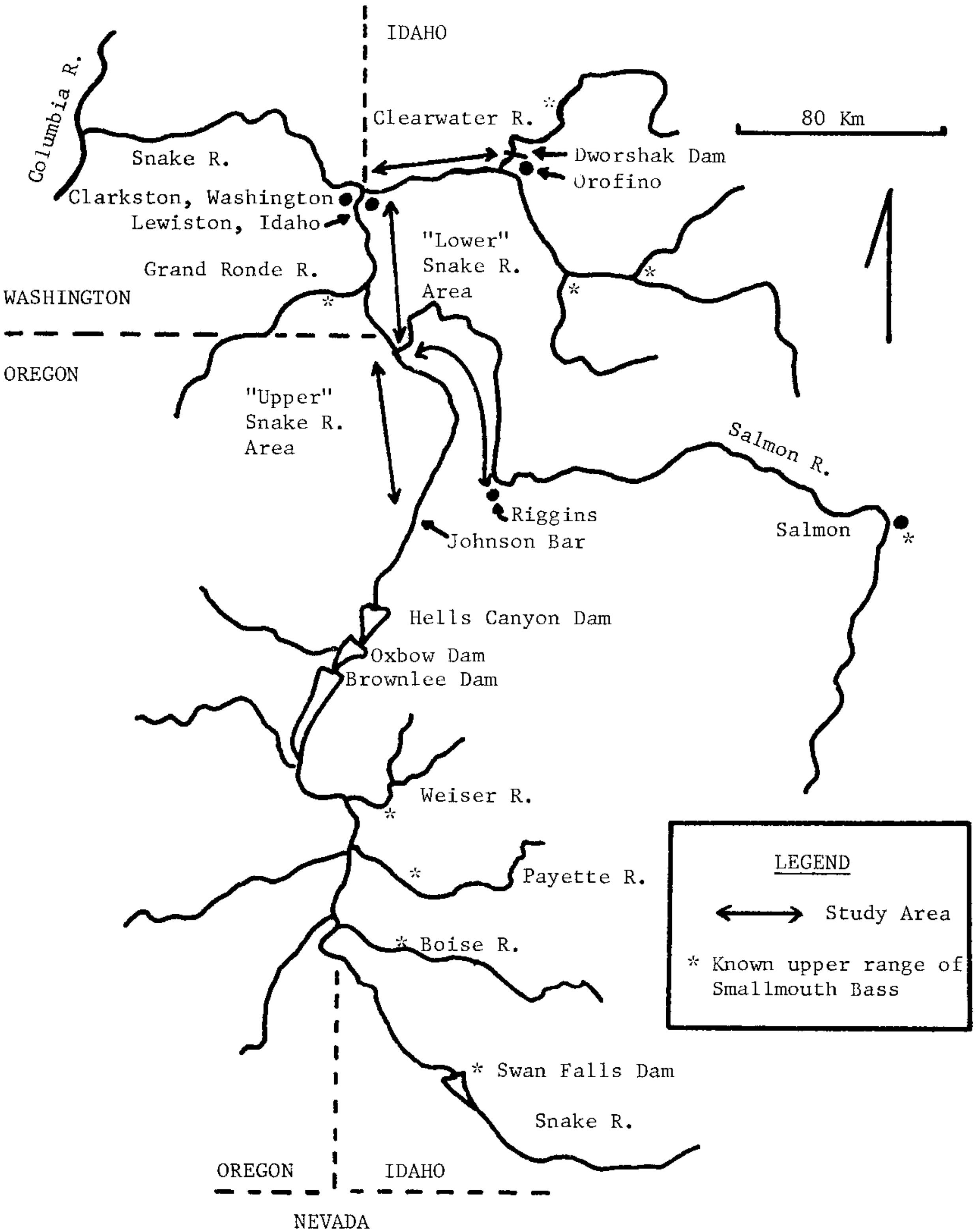

Figure 1. Snake River drainage in Idaho, Washington, and Oregon - showing the upper limits of smallmouth bass distribution and the study areas sampled in 1965-1967.

Table 1. Comparison of some physical and chemical characteristics of the study sections of the Snake, Clearwater and Salmon rivers.

Stream Section	Length (km)	Gradient (m/km)	Range of Summer Flows (m^3/ sec.)	Nutrient* Levels	Roughness** of Substrate	Access
Upper Snake R. (Above Salmon R.)	68	4.3	170-650	++++	++++	No roads
Lower Snake R. (Below Salmon R.)	77	1.9	283-849	+++	++	48 km of road
Clearwater R.	71	2.1	85-141	++	+	71 km of road
Salmon R.	132	4.8	113-170	+	+++	51 km of road

* Indicates relative abundance of total dissolved solids, hardness, conductivity, and bicarbonates for each section as indicated by U. S. Geological Survey water quality analysis.

** Indicates my gross estimate of the relative abundance of rough, broken rocks and angular bedrock material in each streambed.

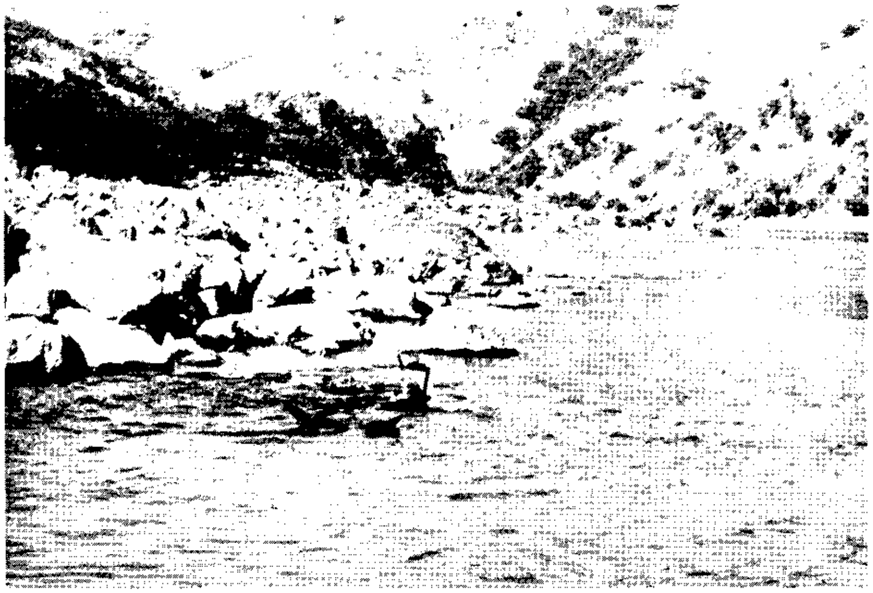

Figure 2. Rough, angular streambed material provides an abundance of refuge areas for smallmouth bass in the upper Snake River and Salmon River.

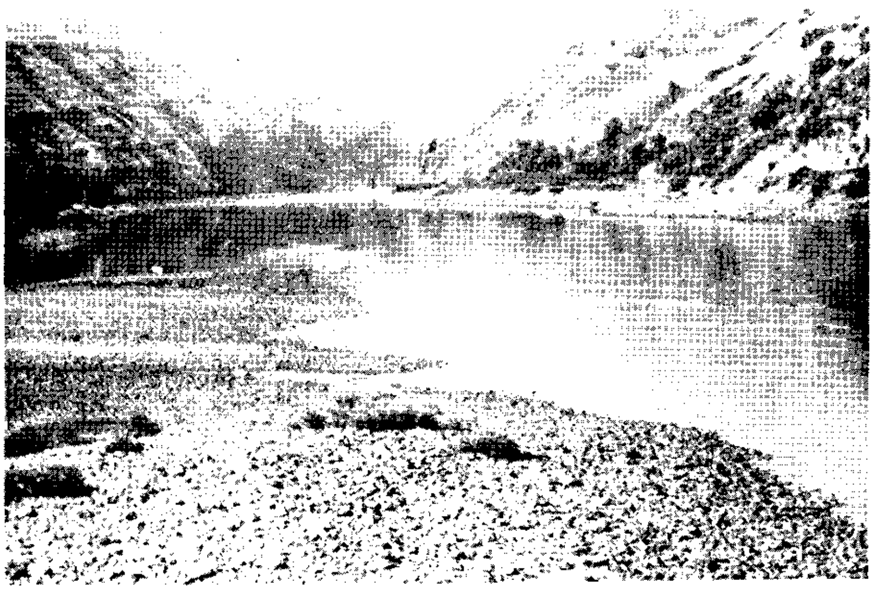

Figure 3. The Clearwater River, pictured here, and the lower Snake River have moderate gradients (1.9 to 2.1 m/km) and flow through wider valley floors than do the upper Snake River and Salmon River sections. Streambed material, water-worn rubble and sand, provides little cover for large bass.

The Clearwater River streambed, particularly, consists of predominately smooth, water-worn rubble set in a sand and gravel matrix (Figure 3). Road and railroad fills and some bedrock provide limited angular rock habitat for bass along the Clearwater River. Gravel extraction and dike construction create a number of small, isolated sloughs and pools at midsummer river levels (Figure 4) along the Clearwater River. The Washington Water Power Dam at Lewiston backs water over approximately 25 axes and forms a major subhabitat for smallmouth bass,

Smallmouth bass concentrate in the flooded estuaries of nine small, warm streams along the lower Clearwater from April to mid-June or July (Figure 5). Summer water flows in the Clearwater River and Salmon River vary between 85 to 141 and 113 to 170 m^3/sec. respectively and high flows in spring generally reach 707 to 1,415 m^3/ sec. (U.S. Geological Survey, 1964-1967).

Water flow in the upper Snake River is almost completely man-controlled by release between 170 to 650 m^3/ sec. from Brownlee, Oxbow, and Hells Canyon dams above the Salmon River. Flows fluctuate daily and weekly for power production and to provide water for navigation.

The controlled flows of the upper Snake River sections and the added, natural flows of the Imnaha, Salmon, and Grand Ronde rivers form the lower Snake River which flows 283 to 849 m^3/sec. in the summer.

Nutrients in the Snake River sections exceed those of the Clearwater and Salmon rivers by approximately 50 to 300 percent (Table 2).

Both the Clearwater and Salmon rivers freeze over every winter and ice jams frequently fill the channels. Reservoir releases temper the Snake River, which remains ice free.

Figure 4. Isolated pools and sloughs created by dikes and gravel extraction provide nursery areas for young smallmouth bass along the Clearwater River.

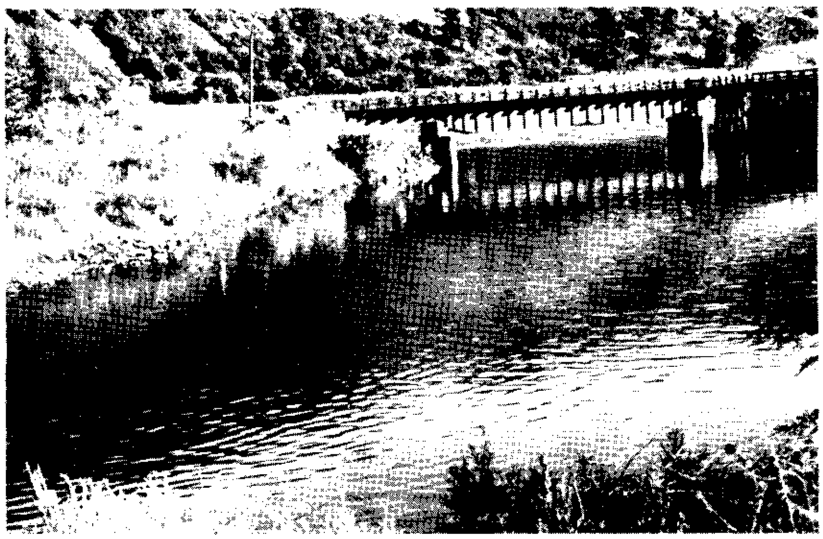

Figure 5. Smallmouth bass move into flooded estuaries of warm, lowland tributaries of the Clearwater River early in the spring and remain until the river level drops in late June or July.

Table 2. Water quality characteristics of the upper and lower Snake River sections; the Clearwater River; and the Salmon River - averages of available data collected in October, 1964-1967.*

River Section and Station	Parts per million of: Dissolved Solids	Bicarbonates (HCO_3)	Hardness ($CaCO_3$)	Conductivity as Micromhos/cm^3 (at 25 C)
Upper Snake R. (at Brownlee)	295	200	160	490
Lower Snake R. (at Clarkston)	265	170	140	430
Salmon River (at Whitebird)	115	95	70	180
Clearwater R. (at Spalding)	50	30	20	60

* From U. S. Geological Survey field records on file at the District Office at Boise, Idaho.

The study sections of all three rivers warm to above 22 C in mid-summer. The upper Snake section warms early and stays warm later than the other rivers, so the growth season (over 10 C) for bass extends 7 to 7½ months compared to only 5 to 6 months in the Salmon and Clearwater river (Figure 6).

Smallmouth bass, channel catfish (Ictalurus punctatus), white sturgeon (Acipenser transmontanus), northern squawfish (Ptychocheilus oregonensis), chiselmouth (Acrocheilus alutaceus), redside shiner (Richardsonius balteatus), and suckers (Catostomus sp) are the major species in flowing water in the two Snake River sections. Bullhead catfish (Ictalurus sp), black crappie (Pomoxis nigromaculatus) and carp are abundant in sloughs and pools.

Smallmouth bass, northern squawfish, chiselmouth, redside shiners, and suckers are the major Clearwater River fishes and the same complex predominates in all but the lower 16 to 32 km of the lower Salmon River where anglers take a few white sturgeon and channel catfish. Anglers catch only a few resident trout in all river sections, Sizable migrations of adult, and emigrations of smolt, chinook salmon (Oncorhyncus tshawytcha) and steelhead trout (Salmo gairdneri) pass through the river sections I studied.

Filamentous green algae becomes abundant for extended periods each year in the fertile Snake River, but not in the Clearwater and Salmon rivers.

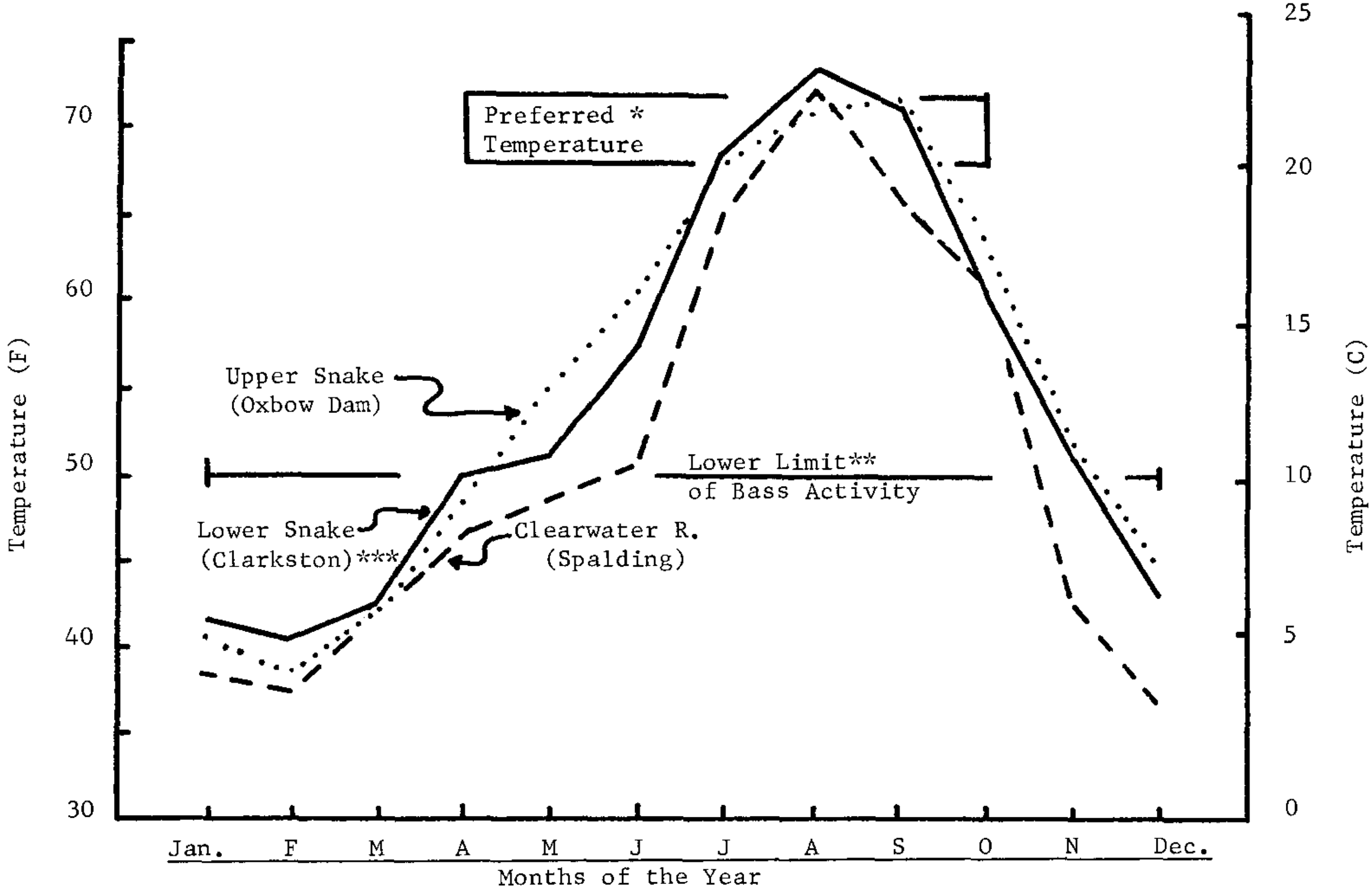

Figure 6. Comparison of mean monthly temperatures for the Snake River at Oxbow Dam and Clarkston, Washington and the Clearwater River at Spalding, Idaho--1967.

* (Fry, 1947) ** (Webster, 1954) *** Station above the Clearwater River

MATERIALS AND METHODS

Field Collections

I obtained most scale samples from smallmouth bass captured by hook and line angling or from Gregory Munther who captured bass with electrofishing gear on the Snake River for a study of bass movements in 1965 and 1966. I made scheduled collection trips and also obtained bass scales and bass stomachs from anglers and local personnel of the Idaho Fish and Game Department.

Attempts to collect bass from the Clearwater and Salmon rivers with both AC and DC electrofishing gear failed because soft water prevented effective operation. Gillnets and seines failed to collect significant numbers of smallmouth bass.

Detonating fuse exploded in confined pools and sloughs killed many fish other, than bass, and turbid water caused by the explosions prevented the collection of bass. Liquid rotenone proved to be the best means of collecting young-of-the-year bass in isolated pools and other quiet water areas.

Munther and I measured the total length of bass in millimeters and weighed whole fish in grams on a spring-activated dietary scale or triple beam balance.

I preserved individual stomach contents from some of the bass collected, and weighed the sorted, blotted contents (wet weight to the nearest one-tenth gram) on an electronic scale. Sometimes cooperators examined bass stomachs in the field and only listed the frequency of occurrence of major food items.

I noted many freshly-caught fish in the mouths and stomachs of bass taken with rotenone and therefore did not use rotenone-sampled bass for stomach analysis. I recorded the maturity of all smallmouth bass cut open and recorded the dates when I saw bass nests, sac fry or black fry.

Munther and I removed two scales from each bass midway between the lateral line and the ventral line at the tip of the extended pectoral fin. We mounted these on gummed, coded collection cards in the field and made plastic impressions on a heated press at the University of Idaho fisheries laboratory. Cooperators put bass scales in standard collection envelopes and I later mounted these scales on glass slides in glycerine or in agar medium. I tried to use clear plastic adhesive tape to mount scales on slides in the field but many of these scales were optically distorted and unreadable under the tape.

Scale Analysis

I read scales on a ground glass projector at a magnification of X 75, and found that 79 percent of the scales collected were readable, the rest were regenerated. I tabulated the total fish length and length of anterior scale radius (X 75) of individual bass by scale size classes for fingerling, medium sized and large bass respectively, to estimate the average total length : scale radius length ratio. I plotted the size class averages on graph paper and drew a smooth line through the points by inspection. I made a table from X-Y coordinates along the plotted line which listed the estimated, average total length of fish for any given scale annuli measurement (at X 75) by one millimeter increments.

I then read the scales, recording the annuli measurements across tabular paper for each fish, and estimated the total length of bass at each annulus by reference to my scale margin : total length conversion table.

Source of Temperature and Water Quality Data

Unpublished summaries of the U. S. Fish and Wildlife Service and U S. Geological Service annual reports provided records of temperature from the Snake River at Oxbow, Oregon; Clarkston, Washington; and the Clearwater River at Spalding, Idaho. I obtained water quality data from annual reports of the U. S. Geological Service.

RESULTS

Spawning Time and First Year Growth

I found nests occupied by smallmouth bass from May 26 to July 10 in the Snake, Clearwater and Salmon rivers (Figures 7 and 8). Bass spawned early in warm, isolated sloughs and at the mouths of lowland streams which were low and warm (over 15.5 C) by June. Bass spawned in warm sloughs along the Clearwater and Salmon rivers over the same range of dates as did bass in the Snake River even though the water temperature of the Snake River warmed to 15.5 C (60 F) by June 1 in most years while the Clearwater and Salmon rivers did not reach 15.5 C until mid- or late June. Most of the bass spawned in all three rivers between June 15 and July 1. I found black fry in nests through July.

Smallmouth bass young-of-the-year (fingerlings) grew to lengths ranging from 55 to 120 millimeters by the end of the growth season (Figure 9).

Bass Size Range

The sample of smallmouth bass over 100 millimeters total length included 80 percent bass between 200 and 349 mm, 12 percent over 350 mm, and 8 percent less than 200 mm (Table 3). "Lunkers", 400 mm to 525 mm comprised only three percent of the bass collected.

Size at Maturity

I found only immature smallmouth bass in the size classes under 200 mm total length and only mature bass in those over 250 mm in length. Scales from immature male bass 210 to 230 mm long had three annuli while those of immature females between 220 and 260 mm long had four annuli (Table 4).

Back Calculations

When possible, I back calculated the total length of 20 or more smallmouth bass from each year-class in the sample from each river section. I did not

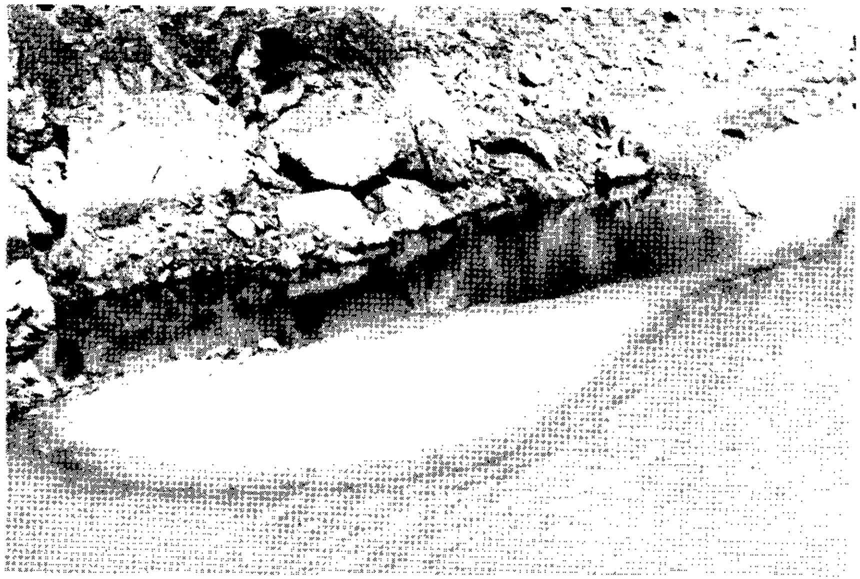

Figure 7. Smallmouth bass spawned in nests constructed in quiet-water eddys similar to the one shown. Reduced river flows exposed this nest site on the upper Snake River.

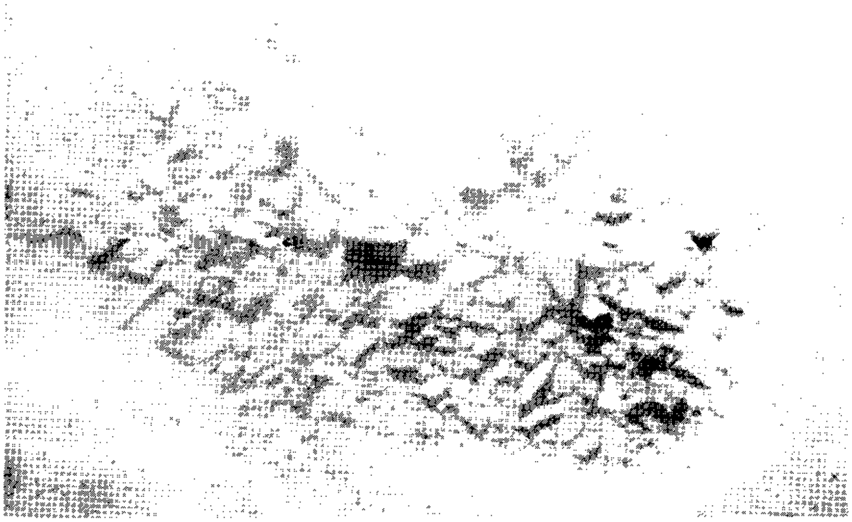

Figure 8. Smallmouth bass often swept away large quantities of sand to expose clean gravel for their nests.

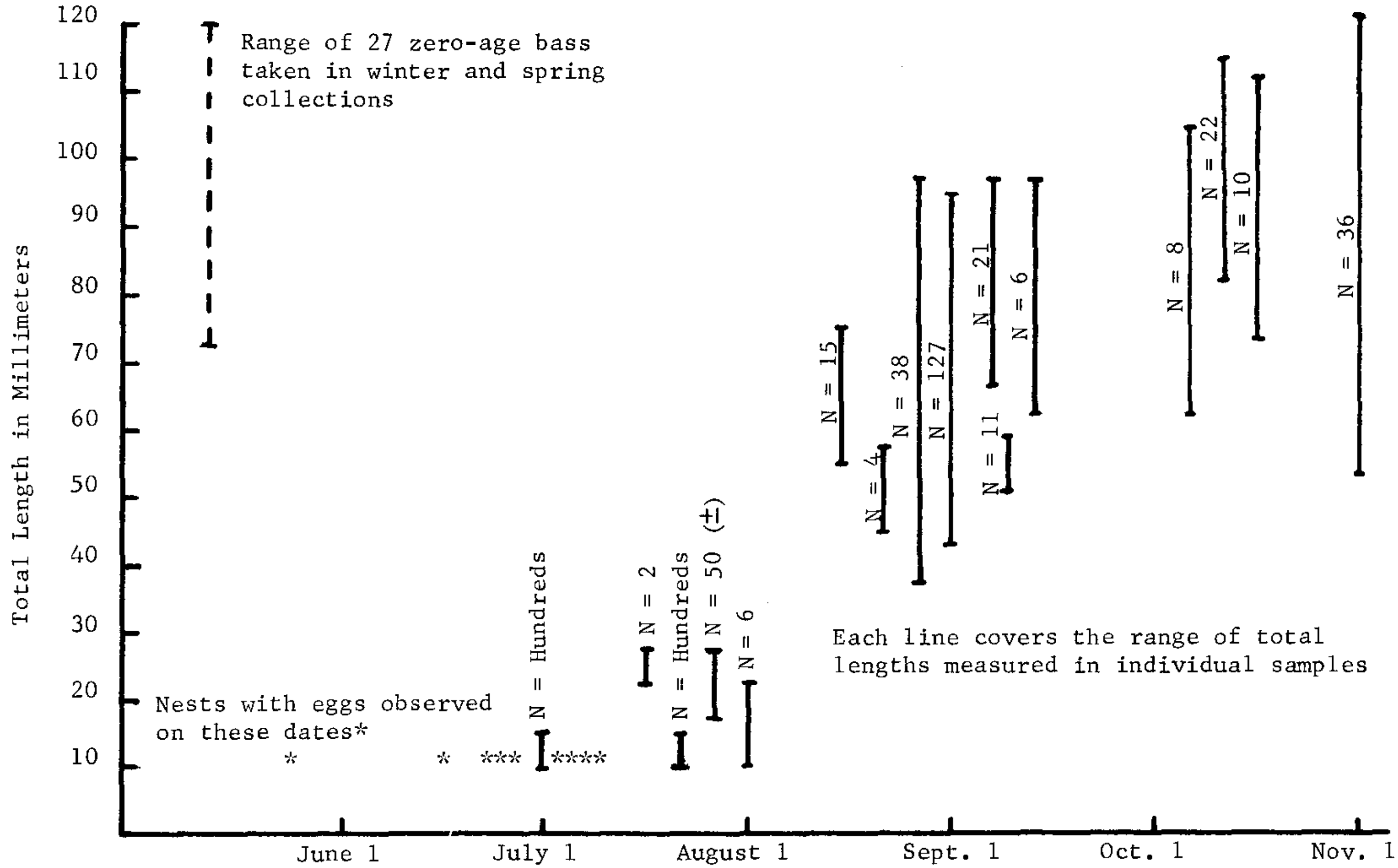

Figure 9. A graphic description of the approximate dates when bass nests with eggs were noted and the range of size of zero-age bass collected, by dates, from all study areas of the Snake, Clearwater and Salmon rivers, 1965-1967.

Table 3. Comparison of the length frequency of occurrence of age class I and older smallmouth bass from the two Snake River sections, the Clearwater River and the Salmon River, 1965-1967.

Total Lengths (50 mm groups)	1965* Upper** Snake R. No.	%	1965* Lower Snake R. No.	%	1966 Upper** Snake R. No.	%	1966 Lower Snake R. No.	%	1965, 1966, 1967 ***Clearwater R. No.	%	1966, 1967 Salmon R. No.	%
100-149	5	2	0		1	1	0		31	18	4	10
150-199	30	10	3	4	4	2	6	3	29	16	9	21
200-249	57	18	8	11	27	14	17	9	31	18	6	14
250-299	108	35	28	40	63	33	94	50	38	22	12	29
300-349	102	33	21	29	86	45	45	24	29	16	6	14
350-399	4	1	8	10	10	5	15	8	14	8	4	10
400-449	0		4	6	0		8	4	3	2	0	
450-500	2	1	0		1	1	2	2	0		1	2
+ 500	0		0		0		0		1	1	0	
Total	308	100	72	100	192	100	187	100	176	100	42	100

* "Upper" Snake River is that section above the Salmon River.
"Lower" Snake River is that section below the Salmon River.

** We collected 73 percent of the bass taken in 1965 from the Snake River sections with hook and line and only 27 percent with electrofishing gear and explosives. Munther collected all of the 1966 Snake River bass with electrofishing gear.

*** I obtained most bass in the Clearwater and Salmon River by hook and line angling.

Table 4. Total length and maturity of smallmouth bass from the Snake, Clearwater and Salmon Rivers, Idaho - for overlapping immature-mature range only.

Total Length (10 mm Groups)	Immature			Mature	
	Unknown	Male	Female	Male	Female
200-209	3	2	3	--	--
210-	--	1	--	1	--
220-	1	--	2	3	1
230-		2	--	--	--
240-		2	1	2	--
250-		1	2	4	1
260-			1	8	1
270-				2	--
280-				11	6
290-300				8	14

collect 20 fish for the young and old year-classes of bass in the Snake River (two sections) and Clearwater River or for any Salmon River year-classes (Table 5).

The ratio of the length of the anterior scale radius to the total length of bass declined as the size of fish increased. The scale radius length (X 75) : total fish length ratio was 1:2.63 for bass approximately 31 millimeters long (Table 6); however, scales grew proportionately faster than the total length of small bass and at 40 mm and 78 mm the total ratios dropped to 1:1.85 and 1:1.46 respectively. The ratio continued to decrease rapidly to 1:1.20 at 134 mm and flattened out to 1:1.10 at 147 mm total length. The ratio decreased gradually to 1:0.85 for large bass over 300 mm total length.

I calculated 95 percent confidence intervals of scale radius : total length ratios for all size group samples that contained 10 bass. Only two of the group ratios had confidence interval limits as wide as 10 percent of the mean and the rest were less than 5 percent; therefore, I concluded that for each size group the scale margin : total length ratio was a reliable estimate for back calculations of length at annuli.

Growth Rates

Back calculated length increments of smallmouth bass from all three rivers ranged, on the average, from 82 to 87 millimeters in the first year; 55 to 64 mm in the second; 43 to 61 mm in the third; and 35 to 48 mm in the fourth. Growth decreased markedly to 24 to 28 mm in the fifth year and 12 to 25 mm for older age groups (Table 5),

Smallmouth bass in the first, second, and third year of life from the upper Snake River section grew faster than did bass of the same year-class in 13 of 21 comparisons with lower Snake River bass and 20 of 21 comparisons

Table 5. Calculated annual growth increments and average total lengths at the end of each year of life of smallmouth bass collected from two Snake River areas, the Clearwater River, and the Salmon River, Idaho, 1965-1967.

Section and Year Class	Number of Fish	Mean Annual Calculated Growth in Millimeters at Each Annulus								
		1	2	3	4	5	6	7	8	9
Upper Snake River										
1958	16	93	55	48	37	32	25	18	16	--
1959	21	78	70	45	43	21	26	11	--	--
1960	25	88	68	59	35	24	18	--	--	--
1961	26	85	63	66	42	21	--	--	--	--
1962	17	90	70	79	30	--	--	--	--	--
1963	21	84	67	68	--	--	--	--	--	--
1964	31	94	53	--	--	--	--	--	--	--
1965	5	85	--	--	--	--	--	--	--	--
Unweighted mean increment		87	64	61	37	24	23	14	16	--
Mean annual total length		87	151	212	249	273	296	310	326	--
Lower Snake River										
1958	19	87	57	45	42	35	21	22	15	--
1959	26	78	61	52	42	24	24	15	--	--
1960	31	82	71	58	35	25	27	--	--	--
1961	25	84	59	66	34	24	--	--	--	--
1962	25	85	75	61	20	--	--	--	--	--
1963	10	85	54	78	--	--	--	--	--	--
1964	13	98	40	--	--	--	--	--	--	--
1965	6	83	--	--	--	--	--	--	--	--
Unweighted mean increment		85	60	60	35	27	24	18	15	--
Mean annual total length		85	145	205	240	267	291	309	324	--
Clearwater River										
1958	8	79	54	47	62	32	27	29	11	12
1959	11	73	60	36	62	27	28	13	14	--
1960	20	83	62	40	48	33	15	18	--	--
1961	14	74	59	57	39	15	30	--	--	--
1962	20	83	56	46	29	33	--	--	--	--
1963	23	74	60	56	46	--	--	--	--	--
1964	31	93	56	75	--	--	--	--	--	--
1965	20	90	73	--	--	--	--	--	--	--
1966	19	87	--	--	--	--	--	--	--	--
Unweighted mean increment		82	60	51	48	28	25	20	12	12
Mean annual total length		82	142	193	241	269	294	314	326	338
Salmon River										
1959	1	69	59	40	22	30	16	20	18	--
1960	3	87	48	46	37	27	24	20	--	--
1961	5	88	47	37	52	25	16	--	--	--
1962	2	84	55	57	40	32	--	--	--	--
1963	9	85	47	36	56	--	--	--	--	--
(no 1964's taken)										
1965	2	88	75	--	--	--	--	--	--	--
1966	2	94	--	--	--	--	--	--	--	--
Unweighted mean increment		82	55	43	41	28	19	20	18	--
Mean annual total length		82	137	180	221	249	268	288	306	--

Table 6. Summary of mean lengths of the scale radii by 5, 10, and 50 millimeter groups, and corresponding mean total lengths of each group of smallmouth bass from the Snake, Salmon and Clearwater rivers, Idaho, 1965-1967.

Anterior Scale Radius Group Range (mm)	Anterior Scale Radius Length (mm)	Mean Total Bass Length (mm)	T. L. Mean ÷ by Mean Scale Radius	Number of Bass
10-14	11.8	31.0	2.63	5
15-20	19.0	36.7	1.93	3
20-29	21.7	40.0	1.85	3
30-39	38.0	58.0	1.52	2
40-49	44.3	64.3	1.45	10
50-59	53.4	78.1	1.46	10
60-69	64.0	86.1	1.34	10
70-79	72.6	92.8	1.28	10
80-89	84.8	106.0	1.25	5
90-99	90.2	109.0	1.21	5
100-109	103.0	134.0	1.20	3
110-119	113.0	137.9	1.22	10
120-129	124.5	138.0	1.09	4
130-139	133.8	147.5	1.10	4
140-149	144.1	156.2	1.08	10
150-159	157.0	168.0	1.07	1
160-169	164.5	170.5	1.03	7
170-179	--	--	--	--
180-189	184.0	179.0	.98	2
190-199	195.0	200.0	1.02	1
200-209	205.0	208.0	1.01	1
210-219	213.0	239.0	1.14	2
220-229	224.5	236.0	1.05	4
230-239	234.9	229.8	.98	10
240-249	243.8	241.4	1.00	10
250-299	271.8	262.9	.97	10
300-349	325.6	298.3	.92	10
350-399	375.6	337.5	.90	10
400-+	443.8	376.6	.85	10
				172

with Clearwater River bass. However, this growth trend was reversed in bass 4 or more years old. The average total length by ages 6, 7 or 8 was similar for Clearwater, Snake, and Salmon river bass samples.

Crowded annuli and indistinct annuli on scales of bass over 8 years old prevented accurate age determination. I often read individual scales 3 or 4 times and could not read the same number of annuli consistently. I counted from 10 to 15 annuli on scales from "lunker" size bass 457 to 521 mm long.

Bass from the Salmon River appeared to grow more slowly than those et all other sections; however, the sample sizes were too small to give reliable estimates.

Growth as a Function of Water Temperature

Annual sums of degree days (over 10 C) for the upper Snake River section exceeded those of the lower Snake River section and the Clearwater River in all years between 1960 and 1967 by averages cf 17 and 53 percent respectively (Table 7).

Pooled growth increments for bass of age-classes 1 and 2 reared in warmer water exceed those of the same age-classes in colder water in 15 of 18 comparisons (Table 8); however, pooled growth increments for bass of age-classes 3 and 4 from the warmer sections exceeded growth of the same age-classes in the colder sections in only 4 of 12 comparisons.

Annual sums of degree days of the upper and lower Snake River sections did not vary more than 10 percent above or below their respective means during the years 1960 .to 1967. Growth increments for pooled age-classes 1 and 2 and age-classes 3 and 4 from the two Snake River sections also did not vary greatly about their respective means. Where comparisons are possible, the two annual growth increments did not vary with changes in the annual thermal sums (Tables 7, and 8)..

Table 7. Comparison of the annual sums of degree days above 10 C for the upper Snake River (above the Salmon River), lower Snake River (below the Salmon River) and the Clearwater River, Idaho, 1960 to 1967.

Calendar Year	Upper Snake R. Total	Upper Snake R. % of Mean	Lower Snake R. Total Units	Lower Snake R. % of Mean	Clearwater R. Total Units	Clearwater R. % of Mean
1960	1,553	100	1,333	100	1,121	111
1961	1,655	106	1,467	110	1,166	115
1962	1,555	100	1,233	93	1,066	105
1963	1,650	106	1,375	103	no records	
1964	1,450	93	1,233	93	750	74
1965	1,458	94	1,192	90	992	98
1966	1,566	101	1,392	105	1,075	106
1967	1,541	99	1,416	106	933	92
Mean	1,554	100	1,330	100	1,014	100

Note: I computed the annual sum of degree days over 10 C from temperature records of 24-hour recording thermographs at Oxbow, Oregon (upper Snake River); Clarkston, Washington (lower Snake River); and Spaulding, Idaho (Clearwater River). U. S. Geological Survey and U. S. Forest Service thermographs

Table 8. Comparisons of the pooled increments of growth for age-classes 1 and 2 and age-classes 3 and 4 for the years 1960 to 1965 of smallmouth bass collected from the upper Snake River, lower Snake River, Clearwater River and Salmon River, Idaho.

River	Upper Snake R.		Lower Snake R.		Clearwater R.		Salmon R.	
Year of Growth	Fraction of mean	Increment (mm)	Fraction of mean	Increment (mm)	Fraction of mean	Increment (mm)	Fraction of mean	Increment (mm)
Pooled Increments of Growth for Age-Classes 1 and 2								
1960	.94	118	.88	106	1.01	107	--	--
1961	.90	113	1.02	123	.92	98	.94	88
1962	.97	122	.98	117	.94	99	.99	93
1963	1.08	136	1.18	141	1.07	113	.98	92
1964	1.16	146	.96	115	1.00	106	1.11	104
1965	.96	121	.98	118	1.06	112	--	--
Mean Increments Pooled (2 Years)	1.00	126	1.00	120	1.00	106	1.00	94
Pooled Increments of Growth for Age-Classes 3 and 4								
1962	1.21	75	1.28	77	1.34	94	--	--
1963	.90	56	.98	59	1.07	75	.92	67
1964	1.06	66	.98	59	.99	72	.99	72
1965	.82	51	.73	44	.63	44	.89	65
Mean Increments Pooled (2 Years)	1.00	62	1.00	60	1.00	71	1.00	73

Comparison With Growth of Bass in Other Waters

Bass in the Snake, Clearwater, and Salmon rivers grew slowly compared with almost all major populations of smallmouth bass reported on in the literature (Table 9). Bass from the Snake and Clearwater rivers grew 81 to 89 mm in their first year which was comparable with first year growth of most other smallmouth bass. Bass from the Des Moines River (Reynolds, 1965) and other Iowa streams (Tate, 1949) had unusually large (119 and 142 mm) first year growth (Table 10). Annual growth of bass in the Clearwater and Snake River dropped to approximately 51 mm in the second, third, and fourth years while most of the other bass grew approximately 76 mm in each of the same years.

Comparison of Length-Weight Relationships

Comparison of the average total length-weight ratios of smallmouth bass caught in the fall from the two Snake River sections and the Clearwater River by length groups show that bass from the warmer, more fertile upper Snake River section did not weigh more than bass from the other two areas (Table 11). Bass from all three sections had almost identical length-weight ratios for the three groups berween 200 and 274 mm. Bass both from the lower Snake River and Clearwater River were slightly heavier than bass from the upper Snake River in length groups exceeding 275 millimeters.

Length-weight ratios for individual bass within each length group varied widely and "t" tests at the 5 percent level of significance failed to indicate a measurable difference in the means of comparable samples.

Food Habits of Fingerling Bass

I examined the stomach contents of 68 fingerling smallmouth bass taken from isolated pools and sloughs along the Snake, Salmon and Clearwater rivers and found aquatic insects in 84 percent; terrestial and flying aquatic insects in 36 percent; plankters (clodocerans and

Table 9. Summary of the average total lengths of smallmouth bass from the Snake and Clearwater rivers and those of other smallmouth bass reported in the literature.

Water	Average Total Length in Millimeters at Each Annulus										
	1	2	3	4	5	6	7	8	9	10	11
Clearwater R.	81	142	193	241	269	295	315	325	338	--	--
Upper Snake R.	86	150	211	249	272	297	310	325	--	--	--
Lower Snake R.	84	145	206	239	267	292	310	322	--	--	--
Missouri Streams Ave. (Purkett, 1958)	89	170	244	290	343	371	--	--	--	--	--
Potomac R. (Sanderson, 1958)	99	193	244	284	335	373	--	--	--	--	--
Des Moines R., Iowa (Reynolds, 1965)	119	229	297	340	389	411	--	--	--	--	--
Quabbin Res., Massachusetts (McCaig & Mullan, 1960)	89	170	259	328	373	409	424	434	439	444	--
Big Lake, Maine (Watson, 1955)	76	147	218	279	330	376	409	434	--	--	--
Cayuga Lake, N. Y. (Webster, 1954)	64	162	213	262	307	348	373	396	424	432	457
Waugoshance Pt. L. Michigan (Latta, 1963)	99	160	206	246	292	335	371	401	428	442	455
Oneida Lake, N. Y. (Forney, 1961)	99	175	249	312	343	373	399	416	424	434	--
Lake Ontario, St. Lawrence R. (Stone, etal, 1954)	--	--	--	262	277	301	318	348	--	--	--
Iowa Streams (Tate, 1949)	142	206	264	272	297	--	358	419	--	--	--
Jordan Cr., Illinois (Durham, 1955)	84	160	241	290	325	352	--	--	--	--	--
Wisconsin Waters (Bennett, 1938)	61	134	208	269	318	358	389	424	--	--	--

Table 10. Comparison of the first seven annual growth increments of smallmouth bass from the Snake and Clearwater rivers and of smallmouth bass from other waters reported in the literature.

Water	Growth Increments (mm) for Each Year of Life						
	1	2	3	4	5	6	7
Clearwater R.	81	61	51	48	28	26	20
Upper Snake R.	86	64	61	38	23	25	13
Lower Snake R.	84	61	61	33	28	25	18
Missouri Streams Ave. (Purkett, 1958)	89	81	74	46	53	28	--
Potomac R. (Sanderson, 1958)	99	94	51	40	51	38	--
Des Moines R., Iowa (Reynolds, 1965)	119	110	61	43	49	22	--
Quabbin Res., Mass. (McCaig & Mullan, 1960)	89	81	89	69	45	36	25
Big Lake, Maine (Watson, 1955)	76	71	71	61	51	46	33
Cayuga Lake, N. Y. (Webster, 1954)	64	98	51	49	45	41	25
Waugoshance Pt. L. Mich. (latta, 1963)	99	61	46	40	46	41	36
Oneida Lake, N. Y. (Forney, 1961)	99	76	74	63	31	30	26
Ontario, St. Lawrence R. (Stone, etal, 1954)	--	--	--	--	15	24	17
Iowa Streams (Tate, 1949)	142	64	58	8	25	--	--
Jordan Cr., Ill. (Durham, 1955)	84	76	81	49	35	27	--
Wisconsin Waters (Bennett, 1938)	61	73	74	61	49	40	31

Table 11. Comparison of the length-weight relationship of smallmouth bass taken in the fall months from the upper and lower Snake River and Clearwater River.

Length	Upper Snake R.		Lower Snake R.		Clearwater R.	
Groups (mm)	No. Fish	T.L.÷Wt.*	No. Fish	T.L.÷Wt.	No. Fish	T.L.÷Wt.
100-124	--	--	--	--	8	0.17
125-149	--	--	--	--	13	0.25
150-174	--	--	--	--	12	0.34
175-199	11	0.47	--	--	--	
200-224	15	0.58	2	0.55	8	0.61
225-249	14	0.78	--	--	19	0.78
250-274	16	0.86	16	0.85	15	0.90
275-299	14	0.93	14	1.04	3	1.20
300-324	19	1.12	14	1.18	15	1.36
325-349	11	1.34	10	1.40	8	1.45
350-399	6	1.65	6	1.80	3	1.65
Total Sample	106		63		104	

* Total length ÷ weight is the quotient obtained by dividing the average total length (mm) by the average weight (gm) of each length group.

copepods) in 26 percent; nematodes and fish each in 6 percent; and hydrachnids in 2 percent of 51. stomachs which contained food. Chironomid and mayfly naiads each comprised approximately 50 percent of the aquatic invertebrate forms noted while ants, adult mayflies, and grasshoppers comprised almost. equal. portions of the terrestial and flying aquatic insect category.

Food Habits of Large Bass

Crayfish comprised 86 percent of the total weight (112.7 g) of food items found in stomachs of 72 bass over 100 mm in length from the Snake River. Fish, aquatic insects, and terrestial (-including all flying insects) comprised 1.1, 2 and 1 percent, respectively, of the total weight (Table 1.2).

Stomachs of 45 bass from the Clearwater River contained 84 percent fish, 7 percent aquatic insects, 7 percent terrestial insects and only 2 percent crayfish, by weight.

Comparison of the frequency of occurrence of various food items in 95 Snake Rivet, 63 Clearwater River, and 32 Salmon River bass stomachs also indicated that crayfish were the staple food of bass from the Snake River, as approximately 58 percent of the stomachs examined contained crayfish. I found fish, aquatic insects, and flying insects in 26 and 46 percent of bass stomachs from the Clearwater and Salmon rivers while only 2 percent of bass from the Clearwater River and no bass from the Salmon River contained crayfish (Table 13).

Bass stomachs contained only seven fingerling smallmouth bass and no salmonids or other game fish among 31 identifiable fish. Five of the seven fingerlings came from one stomach. Dace, shiners, and small suckers comprised the remainder of the identifiable fish found in stomachs.

Four bass stomachs contained from 20 to 50 emerging mayflies; five other stomachs contained 1 to 6 plecoptera or caddis naiads; 2 stomachs contained

Table 12. Percentage, by weight, of food organisms comprising samples collected from age-class I, and older, smallmouth bass stomachs - Snake and Clearwater rivers, Idaho, 1965-1967.

River	Number of Stomachs	Total Wet Weight of Contents (grams)	Percent of Total Weight of:			
					Insects	
			Crayfish	Fish	Aquatic	Terrestial*
Snake	72	112.7	86	11	2	1
Clearwater	45	72.1	2	84	7	7

Table 13. Percentage occurrence of food organisms in stomachs from age-class I, and older, smallmouth bass collected from the Snake, Salmon and Clearwater rivers, Idaho, 1965-1967.

River	Number of Stomachs		Percentage of occurrence of:			
					Insects	
	Empty	With Food	Crayfish	Fish	Aquatic	Terrestial*
Snake	26	95	58	13	16	21
Clearwater	18	63	2	46	32	35
Salmon	11	32	--	39	48	26

* Terrestial category includes adult, flying aquatic insects.

single dragonfly nymphs and one stomach held one adult aquatic beetle.

Smallmouth bass stomachs containing 8, 21, and 35 adult caddis flies; 9 adult mayflies; and 6 and 11 flying ants indicated that large bass fed heavily on terrestial or flying adult aquatic insects when available. Usually bass stomachs contained only individual grasshoppers (in 5 bass) and an infrequent ant or beetle.

Parasites

A nematode, (Contracaecum p.) heavily infested most of the Snake River bass (and channel catfish) mesenteries that I examined but not those of Clearwater River or Salmon River bass,

Fingerling bass in several shallow pools along the Clearwater River appeared to be infected with (Ichthyophthirius sp.) and, in three cases, fingerlings brought into the laboratory developed typical "Ich" symptoms. Tapeworms apparently were not a serious problem. to bass in the rivers studied as I found only 10 tapeworms in the stomachs examined.

DISCUSSION

My original hypothesis smallmouth bass in the warmer, more fertile upper Snake River section grow at a faster rate than those in the lower Snake River, Clearwater River, and Salmon River, held true only for the first three years of life. Smallmouth bass from the Clearwater River and lower Snake River grew faster than those of the upper Snake River in years four to six and overcame the early 10 mm a year advantage; therefore, bass from all river sections studied were approximately 290 mm long by the end of their sixth year. Growth of bass beyond six years of age slowed to approximately 10 to 15 mm per year and the oldest bass taken (10-15 years old) were 457 to 521 mm long.

I can only speculate that the warmer water, longer growing season, rougher streambed, and more fertile habitat of the upper Snake River results in relatively rapid growth and high survival of young bass. Eventually these bass grow too large for the shallow, rough edges of the river channel and join the older, larger bass in deep water and become involved in a more competitive ecosystem.

Bass in the Snake River must compete not only with an abundance of their own kind but with substantial populations of channel catfish (which also feed heavily on crayfish) as well as black crappie, northern squawfish and chiselmouth. We often caught from 10 to 30 smallmouth bass and several large channel catfish and northern squawfish from one pool or eddy in the isolated upper Snake River. Munther (1967) reported seeing as many as 100 bass in one pool of the Snake River.

The physical, thermal, and biological characteristics of the Clearwater River are strikingly dissimilar from those of the upper Snake River as I noted earlier. Over a period of seven years, I have fished for bass, censused bass anglers, and observed smallmouth bass from the shore and underwater, throughout the length of the Clearwater River. Fingerling bass are always abundant in isolated pools, sloughs, and shallow stiliwater areas along the banks. Small bass 25 to 100 mm long find refuge shelters under rubble even in shallow water. Large bass find far fewer areas of cover along the Clearwater River than do those in the Snake River since most of the streambed consists of smooth, water-worn rubble and sand.

I think it very likely that the lack of "rough" cover, angular bedrock crevices and deep pools severely limits the survival of large bass in the Clearwater.

Webster (1954), indicates that smallmouth bass hibernate in the winter in fissures in bedrock at Cayuga Lake. Hubbs and Bailey (1998), relate several instances of winter hibernation by smallmouth bass, including one case where workmen found "hundreds" of bass packed together in crevices and fissures of a streambed during a channel improvement project., In other cases they recorded that "dormant" bass congregate in hollow logs in streams and hibernate in rock ledges and reefs at Lake Erie.

Possibly the combination of severe ice conditions and periodic winter flooding on the Clearwater and the observed lack of "hibernation" cover drastically limits survival of bass. I contrast. these conditions with those of the Snake River with its rough substrate and controlled, ice-free winter flows. The Salmon River probably falls somewhere between the Snake and Clearwater rivers in amount of suitable habitat for winter survival.

I speculate one step further and picture an environment in the Clearwater River where large bass dominate fish populations in the relatively few areas with deep water or holding cover. Winter conditions restrict bass numbers and an intensive fishery in the few areas of bass concentration further reduces numbers of older bass. Only a few squawfish provide competition for food in contrast to the abundance of channel catfish, etc., in the Snake River. Drifting insects, from the expanse of shallow riffle areas, and small fish (dace, shiners, small squawfish and suckers) quite possibly provide a relatively abundant food source for the sparse population of large bass, Individual bass, possibly have relatively more food available and less competition than bass in the Snake River and, therefore, grow as fast or faster than Snake River bass in the "better" habitat,

Coble (1967) established a positive correlation between high temperatures and faster growth of smallmouth bass of pooled age-classes 3 and 4 in South Bay, Lake Huron, between years, and between South Bay and 18 other waters, He points out that parasitism and relative abundance of food may cause noted exceptions to the correlations.

As stated above, I did not find a positive relationship between warm water and fast growth for 3 and 4 year-eld bass from the warmer Snake River and the colder Clearwater River My comparison of the growth increments cf 3- and 4-year-old bass with those listed by Coble also indicates that there are many exceptions to the rule (Table 14)

Fraser (1955), Cleary (1956), and Latta (1963), report that survival of year-classes of smallmouth bass varies greatly with climatic variations in the first *year* of life of the fish. Possibly ineraspeeiftc competition intensifies with high survival of two or more successive year-classes in relatively restricted stream environments.

Additional conjecture on the factors which restrict bass growth in the Clearwater, Snake, and Salmon rivers is not warranted without a better understanding of the effects of competition, predation, disease, and climatic

Table 14. Comparison of annual thermal sums, expressed as degree-days over 10 C, and the average annual growth increment for pooled year-classes expressed in inches, - from waters compared by Coble, 1967, the Snake River sections, and the Clearwater River, Idaho.

	Annual Thermal Sums of Degree-Days (over 10 C)	Mean Annual Growth Increment of Pooled Age Classes - in inches		
		Age Classes 3 and 4		Age Classes 1 and 2
		Lakes	Rivers	
Eastern Georgian Bay, Ontario	886	0.57		
Columbia River, Washington	848		0.84	
Waugoshance Point, Lake Michigan	869	1.36		
Clearwater River	1,014		1.40*	2.01
South Bay, Lake Huron	1,046	1.21		
Lake Opeongo, Ontario	1,081	1.03		
Lower Snake River	1,330		1.20*	2.36
Upper Snake River	1,554		1.22*	2.48
Western Lake Erie	1,572	1.71		
Lake St. Clair	1,769	1.45		
Delaware River, New York	1,794		0.38	
Capapon River, West Virginia	1,958		1.15	
South Branch Potomac River, W. V.	2,036		1.29	
Black River, Missouri	2,279		2.58	
Potomac River, Maryland	2,380		1.80	
Shenandoah River, Virginia	2,545		1.84	
Clearwater Reservoir, Missouri	2,800	2.55		
Norris Reservoir, Tennessee	3,100	2.02		

* Data from my study. Unmarked waters listed by Coble, 1967.

variables in these waters.

I am sure, from my literature review and that of Coble (1967) that the CLearwater River falls in the low range of suitable smallmouth bass waters (compared by total thermal sums of degree days over 10 C), Any significant cooling of the summer temperature of the Clearwater River by controlled dam releases at Dworshak Dam (under construction) could drop the annual thermal sum to a level well below that of any major population of smallmouth bass on the North American continent.

Smallmouth bass do not feed actively at temperatures below 10 C (50 F) as has been widely reported (Webster, 1954). Fry (1947) gives the preferred temperature range as 20.3 C (68 F) to 21.3 C (70 F),

Several proposals to lower the maximum summer water temperatures of the Snake and Clearwater rivers some 5.5 C (10 F) to improve conditions for salmon and steelhead received favorable attention several years ago. Richards (personal communication, 1967) states that water released from Appaloosa Dam (on the Snake River) at 15.5 C (60 F) would provide a "cooler" flow of 21 C (70 F) at Ice Harbor Dam. I calculated that the Snake River annual thermal sum (degree-days over 10 C) would fall from 1,500 to approximately 1,000 with this change.

A similar reduction in summer water temperature (to 15.5 C) on the Clearwater River would drop its thermal sum from 1,000 to approximately 600 degree-days, approximately 200 units less than the coldest habitat for smallmouth bass listed by Coble. A reduction in water temperature of only 2 C daily over the 120 warmest days totals 240 degree days, a reduction to 750 degree days, still 100 degrees below Coble's coldest listing.

The abundance of crayfish in the diet of smallmouth bass in the Snake River reflects their abundance in the river I found few crayfish in bass from the Clearwater River, Crayfish, fish and insects comprise the major food of smallmouth bass in other waters (Doan, 1940; Webster, 1954; Cady, 1945; Watson, 1955). Availability apparently dictates which foods support individual bass populations.

Steeper, upriver sections of the Clearwater River and many tributaries sup port abundant crayfish populations. Rough substrate in the steeper sections and vegetation and debris in low-gradient tributaries provide cover for crayfish. Since crayfish do exist in the lower Clearwater River in the few areas of coarse substrate and since they are abundant both above and below the lower river I am sure that their relative scarcity is due the poor habitat cover and ncr unsuitable temperatures, lack of nutrients, or other limiting factors.

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