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A Comparison of the Age and Growth of Yellow Perch, Perca flavescens (Mitchill) in Lake Audubon and Lake Sakakawea, North Dakota, 1978

Steven W. Kelsch

A COMPARISON OF THE AGE AND GROWTH OF YELLOW PERCH, *PERCA FLAVESCENS* (MITCHILL), IN LAKE AUDUBON AND LAKE SAKAKAWEA, NORTH DAKOTA, 1978

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This thesis submitted by Steven W. Kelsch in partial fulfillment of requirements for the Degree of Master of Science from the University orth Dakota is hereby approved by the Faculty Advisory Committee r whom the work has been done.

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e A comparison of the age and growth of yellow perch, *Perca flavescens* (Mitchill), in Lake Audubon and Lake Sakakawea, North Dakota, 1978.

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ABSTRACT

The age and growth of yellow perch, Perca flavescens (Mitchill), ere compared in two lakes which are part of a large Missouri River ainstem reservoir. Forty-five and one hundred and two perch were aptured from Lake Sakakawea and Lake Audubon, respectively, by using xperimental gill nets and frame fets. Longevity, condition, back-alculated annual growth, and length-weight relationships of the two erch populations were compared.

Studies of length-weight, annual growth, and condition revealed relatively slow growth rate, reduced longevity, and poor condition Lake Sakakawea; being on the order of a stunted population. Perch Lake Audubon lived longer, and had better condition than those in ake Sakakawea. A comparison with growth in other areas showed that akakawea perch had a growth rate that was somewhat below average hereas that of Audubon perch was well above average. Catch statistics ndicated that the perch population was also more dense in Lake Audubon.

Visibly apparent differences in water quality and relative amount f littoral area appear to be responsible for the observed differences n age and growth in the two lakes. Sakakawea, appearing less nutrient ich, and having a shortage of well established littoral zone, appears o have a weakness in its food web at the benthic level.

INTRODUCTION

Lake Sakakawea, the largest of the Missouri River mainstem reser-
rs, has a relatively small subimpoundment, Lake Audubon, which is
arated from the main reservoir by an embankment. The age and growth
yellow perch has been studied and found to be below normal in Lake
akawea (Hill 1969, Wahtola et al. 1971). No such studies have been
e in Lake Audubon. Superficially, it would seem unnecessary to
dy age and growth in both lakes due to their proximity and inter-
tent connections. Visible observation, however, reveals differences
water quality which might potentially have caused differences in age
growth of yellow perch.

Lake Audubon was built as a water storage and regulation reservoir
the Garrison Diversion irrigation project. If the project goes
operation, large quantities of water would be pumped from Lake
kawea into Lake Audubon, potentially causing changes in present
populations.

The purpose of this study was to compare the age and growth of
ow perch in Lake Audubon with that in Lake Sakakawea, and to suggest
ible reasons for any differences, should they exist. This study may
serve as a reference point with which to compare the Audubon perch
lations after the Garrison Diversion goes into operation.

LITERATURE REVIEW

The genus Perca contains two closely related species; the Eurasian perch (Perca fluviatilis) and the North American perch (P. flavescens). A tendency in recent literature has been to group these into a single species (P. fluviatilis) based on the work of Svetovidov and Dorofeeva (1963). These authors suggest that existing morphological differences in the perch are attributable to intraspecific variation which shows a longitudinal geographic cline from Europe eastward, the yellow perch being the easternmost form. If this were accepted, the Eurasian perch and the North American perch would be distinguished as subspecies, P. fluviatilis fluviatilis and P. f. flavescens (McPhail and Lindsey 1970). Many authors, however, feel that the current names should be retained until more conclusive evidence is presented (Bailey et al. 1970).

Thorpe (1977) provides excellent background information on both P. fluviatilis and P. flavescens. The North American perch is known by many names such as American perch, common perch, lake perch, perch, raccoon perch, red perch, ringed perch, river perch, striped perch, yellow ned, and yellow perch. The standard common name, however, is yellow perch (Thorpe 1977).

Distribution

The yellow perch is native to North America. It occupies lakes, impoundments, and slow reaches of rivers throughout its range. Due to its high fecundity and unspecialized spawning requirements, it is common and readily adapts to new areas (Thorpe 1977). The original range of the yellow perch encompassed the eastern to northcentral United

States, continuing into southeastern and central Canada (Scott and Crossman 1973). It has since been stocked in many areas outside of its original range and in many instances has become well established (Thorpe 1977). Successful introductions have been made into almost every state to the west and south of the original range, including Washington, Oregon, California, Utah, New Mexico, and Texas (Scott and Crossman 1973).

Yellow perch occur in every drainage basin in North Dakota and are one of the most common fish in the state (Russell 1975, Elsen 1977, Reigh 1978). They probably entered the Missouri River basin following Wisconsin glaciation about 10,000 years ago (McPhail and Lindsey 1970). Since that time, except for periods of extreme aridity, this species has occupied the basin and was present in Lake Sakakawea upon its impoundment. Perch from Lake Sakakawea became established in Lake Audubon in 1961 when Audubon was being filled (Henegar pers. comm.).

The adaptable yellow perch inhabits warm to cooler habitats throughout its range. Its northern extension appears to coincide with the 15.5° C (60° F) July isotherm (McPhail and Lindsey 1970) and the southern extension appears to coincide with the 31° C (87.8° F) summer isotherm (Weatherley 1963), suggesting that temperature is an important factor limiting distribution. Ferguson (1958) found perch in a natural lake to be most common in water temperatures of 19-21° C (66.2-69.8° F), but they selected temperatures of 21-24° C (69.8-77.0° F) under experimental conditions.

Perch are most abundant in areas with open water, moderate amounts of vegetation, and bottoms of muck, sand, or gravel. Increasing turbidity and decreasing vegetation tend to reduce abundance (Scott and Crossman 1973).

Perch are shallow water fish, rarely found below 9.1 m (30 ft), t individuals have been taken as deep as 45.7 m (150 ft) (Ferguson 58). Schools segregate by size, older and larger individuals generally cupying deeper water.

production

Males consistently become mature before females. Jobes (1952) und that 47% of the males he studied in Lake Erie were mature by age , whereas this percentage of females had not reached maturity until e three. In Lake Huron, El-Zarka (1959) found that all males and y 44% of the females were mature by age three. Time of maturity ries and seems to be more closely related to size than to age within kes (Ney 1978).

Perch spawn once a year in the spring, sometime between February July (Thorpe 1977). In North Dakota it usually occurs from 15 April early May (Scott and Crossman 1973). Water temperature is the main tor governing spawning but other factors such as photoperiod, may ally affect times of spawning (Thorpe 1977).

Males move to spawning grounds before females and remain longer, h individually and as a group. The spawning act begins as a female ibits the quick movements associated with egg release. At this cue, erous males rush in quickly behind the female, forming a line, each ing for the position closest to her vent. The males then release t as the female expels the tubular egg strand (Hergenrader 1969). wning takes place over submerged brush, fallen trees and occasionally vel onto which the eggs adhere (Scott and Crossman 1973). No nest lding or parental care has been observed in yellow perch (Hergen-er 1969, Thorpe 1977).

The fecundity of yellow perch shows a linear increase with weight Tsai and Gibson 1971), ranging from 10,000 eggs (82 g female) to 57,000 eggs (678 g female) in Lake Michigan (Brazo et al. 1975). High gg mortality often occurs due to wind (Caldy and Hutchinson 1975) and luctuating water levels (Thomas 1978).

ood Habits

Perch are opportunistic feeders selecting prey items which are ost abundant; there is, however, some selection for size (Ney 1978). erch exhibit a limnodromous movement (onshore at dusk and offshore at awn which appears to be mainly connected with feeding (Lagler et al. 962). Perch feed offshore in the sublittoral area primarily during he morning and evening (Scott and Crossman 1973).

Food preferences change as the perch grow (Forbes 1880). Young-f-the-year (YOY) perch feed mainly on copepods and cladocerans (Clady 974); as they grow the food emphasis shifts to larger zooplankters, enthic insect larvae (mainly chironomids and mayflies), amphipods, eeches and crayfish (Tharratt 1959). Larger perch also include small ish in their diet (Keast and Webb 1966, Scott and Crossman 1973). Al-hough Schneider (1972) found no abrupt changes in diet, he observed hree major size groups that had sufficiently different food preferences o that competition for food occurred only within groups and not among roups. Fish under 7.6 cm fed mainly on zooplankton, those from 7.6 to 6.5 cm fed on smaller sized benthos, and those larger than 16.5 cm fed n larger benthos and fish.

ge and Growth

Growth of yellow perch is highly variable depending on population size, abitat size, and productivity. It is normally most rapid during the irst or second year of life and gradually tapers off thereafter. Feales characteristically grow faster than males and achieve a larger ltimate size (Scott and Crossman 1973). Stunting, where the dominant ge group limits the growth of younger age groups and is itself limited n size and longevity due to competition within the group, is common in ellow perch populations (Eschmeyer 1937).

Yellow perch commonly reach seven years of age (Herman et al. 1959) nd live to nine or ten in northern populations (Scott and Crossman 973). The age and growth of yellow perch has been recorded throughout ts range. Much work has been done on the great lakes primarily due to ne value of yellow perch as a commercial species (Harkness 1922, Hile nd Jobes 1941, Jobes 1952, Joeris 1957, Brazo et al. 1975). Other tudies were conducted in Minnesota (Carlander 1950a), Wisconsin Hasler 1945, Schneberger 1935), Michigan (Eschmeyer 1937), Maryland Muncy 1962), South Dakota (Fogle 1963, Gasaway 1970, Nelson 1974, elson and Walburg 1977) and North Dakota (Hill 1969, Ragan 1970, Wahola et al. 1971, Farmer 1974). Studies in Canada have taken place in ova Scotia (Smith 1939), Manitoba (Lawler 1953) and Ontario (Sheri and ower 1969).

DESCRIPTION OF THE STUDY AREA

Lake Sakakawea and Lake Audubon (Fig. 1) were formed by the closure of Garrison Dam in April of 1953. The dam lies on the Missouri River, 123 km (75 mi) north of Bismarck, in west-central North Dakota. It was built by the U. S. Army Corps of Engineers primarily for flood control, navigation, power generation and irrigation.

Lake Sakakawea is 287 km (178 mi) long and averages 4.8 km (3 mi) in width. It has an average and maximum depth of 17.4 m and 64.9 m, respectively. At normal operating level, the lake has a storage capacity of 30 billion m^3 (24.62 million acre ft), a surface area of 156 thousand ha (386 thousand acres) and a shoreline length of 2580 km (1600 mi) (U. S. Army Corps of Engineers 1977, Benson 1968).

Lake Audubon was formed by the construction of a 6098 m (20 thousand ft), 26 m (85 ft) high embankment across the eastern extension of the reservoir. Audubon has approximately 4050 ha (10 thousand acres) of surface area with a maximum depth of 16.8 m (55 ft). It was built to store and regulate the flow of water used in the Garrison Diversion irrigation project (Duerre 1965).

The local climate is semi-arid with an annual precipitation of less than 40.6 cm (16 in), much of which falls as snow. Temperatures range from a maximum of 46.7° C (116° F) to a minimum of -45° C (-49° F) (U. S. Dept. of Interior 1974). Typically, the first frost occurs in late September and the reservoir is ice covered from late November to early April (Hieb 1968, U. S. Dept. of Interior 1952). The area normally receives a high number of sunny days, and winds are common, occasionally exceeding 80 km per hour (50 mph) (U. S. Dept. of Interior 1974). Winds

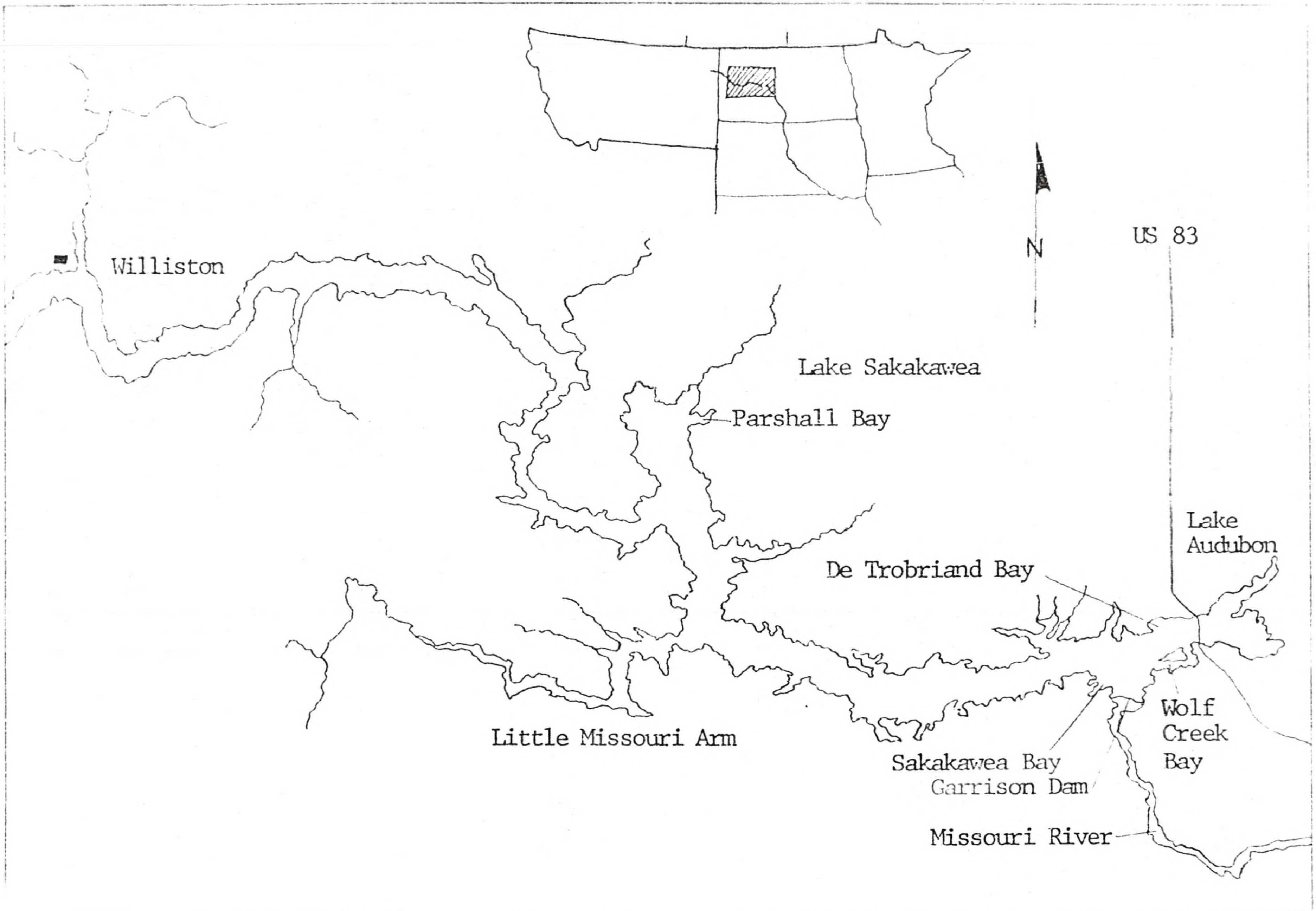

Figure 1. Map of Garrison Reservoir showing study area.

have a significant effect on the reservoir by preventing severe oxygen depletion, causing locally high turbidity, and by not allowing seasonal thermal stratification (Benson 1968).

Garrison Reservoir is generally long and narrow with an extremely irregular shoreline. As is normal for man-made lakes, the shoreline development (ratio of shoreline length of the reservoir to the circumference of a circle encompassing the same area as the reservoir) of Garrison Reservoir is high (16.3), indicating that a relatively high percentage of protected shoreline area exists. The productive potential of this area is partially offset by fluctuating water levels caused during normal operation of the reservoir (Benson 1968).

Even though Lakes Sakakawea and Audubon are part of the same reservoir and are subject to similar climatic conditions, a number of differences exist between them. A large waterfowl refuge on Lake Audubon affords the lake a much higher nutrient concentration potential. Waterfowl increase nutrient quantities in refuges where they concentrate by depositing nitrogenous excretory material and by stirring up sediment layers (Hooper 1969, Jorde 1978). Visibly, water qualities of the two lakes appear different. Blue-green algae blooms and relatively high concentrations of green algae suggest that Lake Audubon does have a higher nutrient concentration than Lake Sakakawea. In addition to the effect of the waterfowl refuge, Lake Audubon's smaller size and present lack of an outlet may act to concentrate nutrients.

The lakes also differ in morphometry. Exact data measuring the differences are not available but some differences such as shoreline slope are evident. This slope, or degree of dropoff of the lake substrate, is important in determining the width of the littoral zone.

Lying mainly within the original river basin, Lake Sakakawea has banks that are the remains of steep riverside bluffs. This original steep topography has produced many sharp dropoffs and shoreline cliffs in the study area. Lake Audubon, being farther from the original river channel, has more gently sloping shorelines and numerous islands; hence, a higher percentage of shoreline and littoral zone than Lake Sakakawea.

MATERIALS AND METHODS

Yellow perch were captured at various locations along the north shore of Lake Audubon and from Wolf Creek Bay, De Trobriand Bay, Sakakawea Bay and Parshall Bay in Lake Sakakawea during the summer of 1978. Both experimental gill nets and frame nets were used to reduce the effects of gear selectivity (Schneberger 1935). Nets were set daily for periods lasting approximately 24 hr. Four types of gill nets were used: 1) a 76.2 m (250 ft) long by 3.6 m (12 ft) high net with five 15.2 m (50 ft) panels having bar mesh sizes of 1.9, 2.5, 3.8, 4.4, and 5.1 cm; 2) a 76.2 m long by 1.8 m (6 ft) high net with five panels similar to the preceding; 3) a 38.1 m (125 ft) long by 1.8 m high net with five 7.6 m (25 ft) panels having bar mesh sizes of 1.3, 1.9, 2.5, 3.8, and 5.1 cm; 4) a 91.5 m (300 ft) long by 1.8 m high net with three 30.5 m (100 ft) sections having bar mesh sizes of 7.6, 10.2, and 12.7 cm. Two sizes of frame nets were used: 1) a 0.9 m (3 ft) high by 1.2 m (4 ft) wide net with 0.6 cm mesh, 2) a 1.2 m high by 1.8 m wide net with 1.2 cm mesh.

Total fishing effort in terms of net hours was kept approximately equal for the two lakes. Periodic alternation of fishing effort between the two lakes was designed to reduce sampling bias but the frequency of alternation was compromised by feasibility. Fishing began on 24 May on Lake Audubon where it continued for about a month before it was shifted to Lake Sakakawea for approximately three weeks. Following this, each lake was again fished for about a week after which fishing was terminated.

Captured specimens were weighed to the nearest 1.0 g on a dietetic scale and the total length was measured to the nearest 1.0 mm. The perch were not separated according to sex. Scale samples from below the lateral line and posterior to the left pectoral fin were taken. Scales were cleaned and imprinted on acetate slides using a roller press (Smith 1954). The imprinted scales were magnified using a Bausch and Lomb microprojector. The center (focus), the edge of the scale, and the annuli (year marks) were marked on a paper strip aligned from the focus to the anterior edge of the scale. This was done for the purpose of aging the fish and back-calculating its length at each previous annulus.

Criteria used to validate annuli were relative compression of the spacing of the circuli (growth rings) in the anterior field and crossing over of circuli in the lateral fields (Bennett 1970, Jobes 1952). Scales were read twice or more until readings were in agreement.

The validity of the annulus as a year mark has long been assumed for yellow perch (Harkness 1922, Jobes 1933, Hile and Jobes 1941 and 1942); Jobes (1952) and Joeris (1957) specifically found evidence to support the dependability of these scale readings.

In addition to determination of age from a scale, the length of the fish at the time of formation of each annulus was determined by back-calculation, assuming directly proportionate growth between body length and scale length. A correlation analysis was run to test the validity of this assumption among these data. This body-scale relationship was determined by the Lee method which assumes that the mathematical relation between the body length and scale length is linear and is expressed by the equation, $S = a + bL$, where L is the total length of the fish, S is the total scale length, b is the slope and a is the Y intercept of the regression line. The constant "a" accounts for the fish being a certain length when the scale forms and is used as a correction factor in back-calculating fish lengths at each previous annulus. The above equation, determined with the aid of a hand calculator by the method of least squares, provided the value for a, the correction factor. The length of a fish at any previous annulus was then determined by using the following equation: $Lx = Sx(Ly - a)/Sy + a$, where Lx is the length of a fish at any annulus, Sx is the distance from the focus of the scale to that annulus, Ly is the length of the fish at capture and Sy is the distance from the focus of the scale to its margin (Lagler 1952).

The length-weight relationship and condition factor approach the relationship of a fish's weight (W) to its length (L) differently. If body form and density remained constant throughout life for all individuals of a population, it would be useless to use both approaches. Since this is not the case, both approaches become individually useful in comparing fish growth and have been calculated for use in this study (Lagler 1952).

The condition factor (K) is a coefficient calculated individually for all fish from the cube relationship, $K = L^3(100,000)/W$. This factor is commonly calculated in age and growth studies and is a measure of the relative suitability of the environment for a particular species (Lagler 1952). The condition factor varies with age, sex, and season (Lagler 1952) but is not affected by the presence of food in the stomach (Schneberger 1935). Condition factors were determined individually, by age group, and for total catches from each lake.

The length-weight relationship is a single equation determined for the population as a whole. The relation, $\log W = \log a + \log L$, was determined for all fish captured by performing a regression of the empirical data using the method of least squares. The resulting equations were used to calculate the growth curves for each lake (length vs. weight).

RESULTS

Lake Sakakawea

Total fishing effort on Lake Sakakawea consisted of the following: 1188 hr of 38.1 m by 1.8 m experimental gill nets (76.2 m by 3.6 m and 76.2 m by 1.8 m experimental gill nets were multiplied by 4 and 2, respectively, and given in terms of 38.1 m by 1.8 m nets to help standardize the effort), 65 hr of 91.5 m by 1.8 m experimental gill nets, 119 hr of small frame nets, and 68 hr of large frame nets.

Of the 45 yellow perch taken from Lake Sakakawea, 32 could be aged with confidence and were used in age and growth calculations. These ranged in age from three to five years old, three and four-year-olds being dominant.

No yellow perch, other than young-of-the-year (YOY), were taken in frame nets in either lake. Approximately 3850 YOY were caught in Parshall Bay but none were taken in Wolf Creek Bay, De Trobriand Bay, or Sakakawea Bay. These YOY were not included in age and growth studies.

The correlation analysis, used to test the assumption of linear proportionality between body length and scale length, produced a coefficient (r) of 0.838 which is highly significantly correlated at a probability of 0.01. In other words, body length and scale length of Sakakawea perch are sufficiently correlated to meet the above assumption which is commonly made in age and growth studies of perch (Lagler 1952, Jobes 1952).

The correction factor "a", determined empirically from the data by the method of least squares, was 8.3 mm. This was used as a constant in back-calculating total length at each previous annulus (Table 1). Average annual growth peaked during the second year and gradually

Table 1. Average back-calculated lengths (mm) at each annulus for yellow perch in Lake Sakakawea.

Year Class	Age Group	No. of Fish	Length at Capture	Annulus I	II	III	IV	V
1978	0	0	-					
1977	I	0	-	-				
1976	II	0	-	-	-			
1975	III	21	179	56	124	162		
1974	IV	10	207	46	131	176	194	
1973	V	1	205	38	92	139	183	196
Average Length				52	125	166	193	196
Average Growth Increment				52	73	41	27	3

tapered off thereafter.

The condition factors (K) of all 45 perch ranged from 0.92 to 1.53. The K(TL) (condition determined using total length) averaged for all fish was 1.22, the K(TL) of 21 three-year-olds was 1.28, 10 four-year-olds 1.14, and 1 five-year-old 1.25.

The equation of the best fit line, determined empirically from the data for the length-weight relationship of 32 yellow perch, was log W = -4.1669 + 2.6724 log L. This equation was used to calculate the growth curve (Figure 2). A point corresponding to the average length and weight of each age group was plotted along the curve for the comparison of the empirical data with the calculated curve.

Lake Audubon

Standardized 38.1 m by 1.8 m experimental gill nets were fished for 1079 hr in Lake Audubon (76.2 m by 3.6 m and 76.2 m by 1.8 m experimental gill nets were multiplied by 4 and 2, respectively, as for Lake Sakakawea). Small frame nets were fished for a total of 292 hr and a 91.5 m by 1.8 m experimental gill net was fished for 32.5 hr. A total of 102 yellow perch were caught.

Age and growth calculations involved 89 perch which could be aged with accuracy. These range in age from one to eight years, the third year class being dominant. No perch, including YOY were taken in frame nets in Lake Audubon.

A coefficient (r) of 0.924 was obtained from the correlation analysis which was run to test the assumption of linear proportionality between body length and scale length. This coefficient is highly significantly correlated at a probability of 0.01 indicating that this assumption has ble 2. Average back-calculated lengths (mm) at each annulus for yellow perch in Lake Audubon.

ear lass	Age Group	No. of Fish	Length at Capture	Annulus							
				I	II	III	IV	V	VI	VII	VIII
978	0	0	-								
977	I	1	105	48							
976	II	10	175	67	141						
975	III	55	221	65	161	206					
974	IV	15	245	62	158	210	234				
973	V	3	275	57	137	200	250	267			
972	VI	3	289	61	150	211	249	268	281		
971	VII	0	-	-	-	-	-	-	-	-	
970	VIII	2	282	68	137	190	224	238	252	264	275
verage Length				64	156	206	237	260	269	264	275
verage Growth Increment				64	92	50	31	23	9	-	-

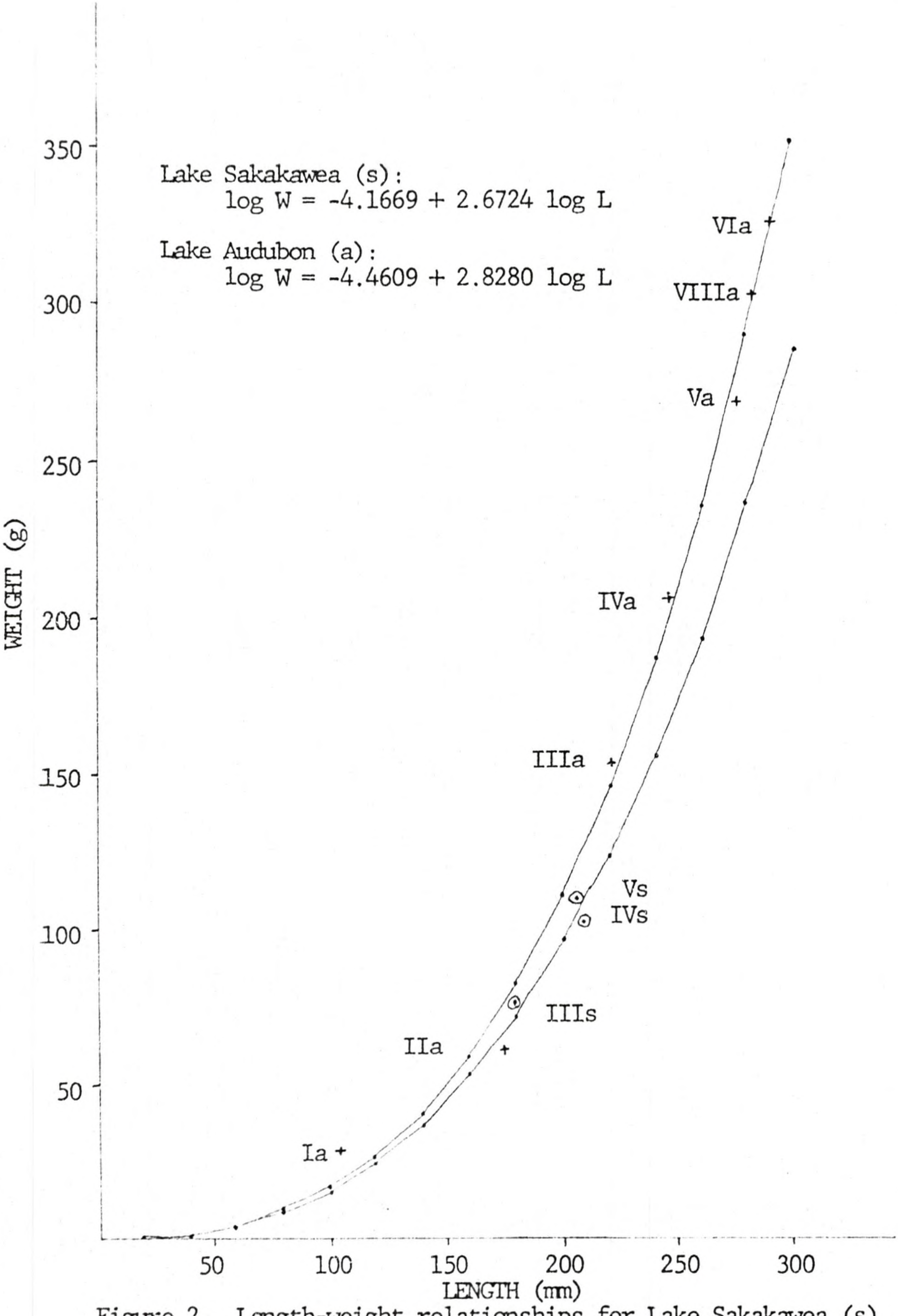

Figure 2. Length-weight relationships for Lake Sakakawea (s) and Lake Audubon (a). Points indicate observed average lengths and weights for each age class in Lake Sakakawea (⊙) and Lake Audubon (+).

been adequately met.

The correction factor "a", determined empirically by a regression of length and weight, was 2.2 mm. This was used as a constant in back-calculating total length at each annulus (Table 2). Like Sakakawea, annual growth peaked during the second year and gradually tapered off thereafter.

The overall condition factor, determined for all 102 perch from Lake Audubon was 1.38 (range 1.10 - 2.42). The breakdown of conditions was as follows: 1 one-year-old, 2.42; 10 two-year-olds, 1.28; 55 three-year-olds, 1.37; 15 four-year-olds, 1 37; 3 five-year-olds, 1.28; 3 six-year-olds, 1.35; and 2 eight-year-olds, 1.34.

The equation of the best fit line as determined empirically from the data for the length-weight relationship of 102 perch was $\log W = -4.4609 + 2.8280 \log L$. This equation was used to calculate the growth curve of length versus weight (Figure 2). Points corresponding to the average length and weight of each age group were plotted along the curve to give an idea of the fit of the data.

DISCUSSION

Yellow perch in Lake Sakakawea have a much shorter life span than those in Lake Audubon. Only three age groups, III, IV, and V (one individual), were collected from Lake Sakakawea (Table 1). The lack of younger age groups (I and II) might be the result of poor reproduction, but due to the small sample size and selectivity of the fishing gear, I do not feel confident in identifying these age groups as missing. My findings of a maximum age of five is consistent with that found in other studies in Sakakawea (Hill 1969, Wahtola et al. 1971) and likely represents the maximum age achieved in the lake. Seven age groups were collected in Lake Audubon ranging in age from I to VIII (VII's were missing) (Table 2). The longevity of Lake Audubon perch is consistent with that found in other waters. Carlander (1950b) reported that perch commonly exceed seven years of age, suggesting that longevity is inhibited in Lake Sakakawea rather than being enhanced in Lake Audubon.

The average back-calculated lengths for each age group have themselves been averaged among all year classes and given in terms of mean total lengths at the time of formation of each annulus (Tables 1 and 2). A collection of age and growth data in this form has been compiled for perch in areas throughout its range for comparative purposes (Table 3). These data have been averaged over all of the studies listed in Table 3 and graphed with the mean lengths at each age of Lake Audubon and Lake Sakakawea perch for comparison (Figure 3). Data from these studies were averaged only to simplify presentation by making it easier to see how growth in these lakes compares to growth of perch in other areas; the resulting curve should not be considered a representation of a true average population.

Table 3. Average calculated total lengths (mm) at each annulus for yellow perch in various areas throughout its range. (Adapted from other authors.)

Author and Location	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Present study (1978),												
Lake Sakakawea	52	125	166	193	196							
Lake Audubon	64	156	206	237	260	269	264	275				
Harkness (1922), Lake Erie	-	168	196	216	251	274	279					
Hile and Jobes (1941),												
Lake Erie	88	167	212	240	260							
Lake Michigan (Saginaw Bay)	75	133	196	238	268	304	325					
Lake Michigan (Green Bay)	71	115	155	192	220	252	274					
Northwestern Lake Michigan	71	111	148	178	211	243						
Jobes (1952), Lake Erie	94	170	216	241	264	279						
Joeris (1957),												
Fayette	125	161	211	216	224							
Suamico	128	163	183	183								
Brazo et al. (1975),												
Lake Michigan	-	185	224	252	279	308	324					
Carlander (1950a), Minnesota												
Lake of the Woods	97	137	178	204	230	251	262	278	280	273	303	
Hasler (1945), Wisconsin												
Lake Mendota	140	199	230	241								
Schneberger (1935), Wisconsin												
Nebish Lake	144	181	200	240	281							
Weber Lake	-	151	182	201	220							
Silver Lake	-	126	139	168	200							
Eschmeyer (1937), Michigan												
South Twin Lake	101	100	137	150	195							
Muncy (1962), Maryland												
Severn River	108	166	202	230	253	271	283	293	301	306	316	284

Continued

Table 3 continued.

Author and Location	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Fogle (1963), South Dakota												
Lake Oahe	81	140	180	208								
Gasaway (1970), South Dakota												
Lake Francis Case	84	148	190	216								
Nelson (1974), South Dakota												
Oahe	76	126	163	185	206	225	237					
Nelson and Walburg (1977), S.D.												
Lake Sharpe	62	149	167	184	200							
Hill (1969), North Dakota												
Lake Sakakawea (1968)	64	109	147	183	208							
Lake Sakakawea (1967)	64	109	147	180	201							
Lake Sakakawea (1966)	66	112	145	175								
Lake Sakakawea (1965)	58	102	140	178								
Lake Sakakawea (1964)	46	97	137	165	206							
Ragan (1970), N.D.												
Lake Ashtabula	60	112	147	174	194	207						
Wahtola et al. (1971), N.D.												
Lake Sakakawea	81	126	155	181								
Farmer (1974), N.D.												
Lake Ashtabula	55	116	161	197	247	265	263					
Smith (1939), Nova Scotia												
Lake Jesse	80	96	112	130								
Lawler (1953), Manitoba												
Heming Lake	74	90	129	148	176	219	238	266	311			
Sheri and Power (1969),												
Bay of Quinte (Lake Ontario)	-	164	178	188	208	222	215	264				

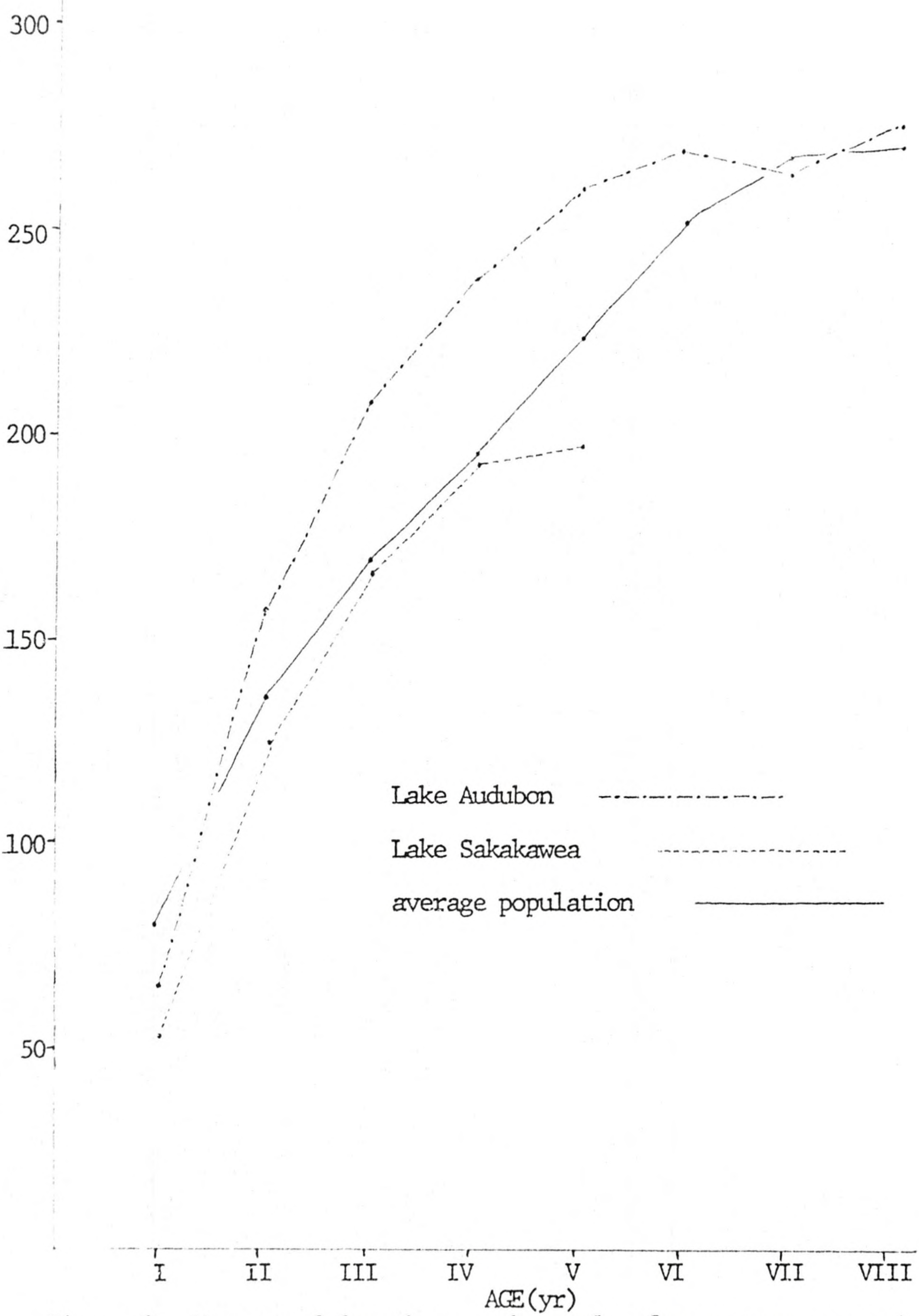

Figure 3. Mean total length at each annulus for an average perch population (averaged from the studies listed in table 3) compared with mean length at each annulus in Lake Sakakawea and Lake Audubon.

Figure 3 shows that annual increase in length of Sakakawea perch is not far below that for the "average population" during the first few years. Later, the growth tapers off and the fish die, where the perch in the so called "average population" continue to grow at the same rate. The annual length increase of Lake Audubon perch rises at a faster rate than that of the "average population" but as growth slows down in later years the "average population" catches up.

Figure 4 shows mean annual increase in length of perch populations in three Missouri River mainstem reservoirs. Perch in Lake Audubon not only have a faster growth rate than in Sakakawea but faster than that in Lake Francis Case, Lake Oahe, and Lake Sharpe (Gasaway 1970, Nelson 1974, Nelson and Walburg 1977). It seems that growth of perch in Lake Audubon may be somewhat above what is normal for reservoirs in the upper Missouri Basin.

Relative density of the perch populations in Lake Sakakawea and Lake Audubon was determined by comparing total catch per total effort in each lake. Frame net hours were kept fairly constant but no perch other than young-of-the-year (YOY) were taken in them. The lack of success in catching older perch with frame nets is likely due to low fishing effort and should not be considered a reflection on the effectiveness of frame nets since others have had success with them in Lake Sakakawea (Hill 1969). The differences in catch of YOY, 3850 in Lake Sakakawea compared to 0 in Lake Audubon, can probably be explained by reasons other than hatching success. All of the YOY taken in Lake Sakakawea came from Parshall Bay where conditions for yellow perch reproduction probably were very good. The lack of success in catching YOY in other areas is probably again due to a lack of frame net effort

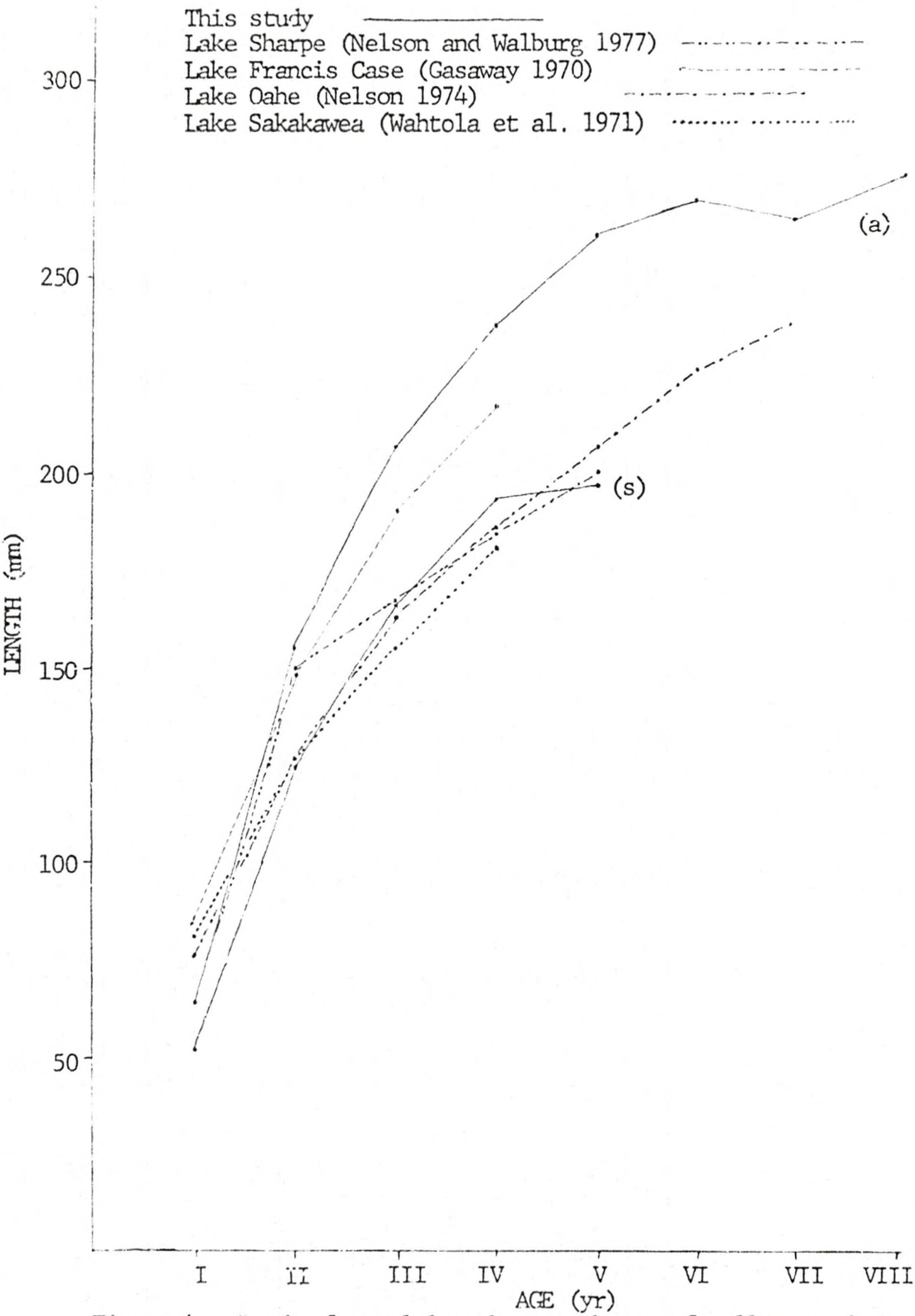

Figure 4. Graph of total length at each age of yellow perch in Lake Sakakawea (s) and Lake Audubon (a), compared with other Missouri River Reservoirs.

which was not intense since these individuals were not the main object of the study.

Total gill net hours in terms of standardized 38.1 m by 1.8 m experimental gill nets were 1079.5 and 1188 for Lake Audubon and Lake Sakakawea, respectively. It is with these nets that all of the perch were caught. The 91.5 m by 1.8 m gill nets had bar mesh sizes of 7.6, 10.1, and 12.7 cm; probably too large for the successful capture of perch. The total number of fish caught was 102 and 45 for Lake Audubon and Lake Sakakawea. More than twice as many perch were caught in Audubon than in Sakakawea with actually less fishing effort. Although other factors such as daily movements and net locations might be partly responsible for the relatively large catch in Lake Audubon, it appears that Lake Audubon has a more dense perch population than Lake Sakakawea.

The condition factor (K) is a distinctly different approach to the relation of a fish's length to its weight than is the "length-weight relationship" (Hile 1936). The equation for the condition factor is based on the cubic relationship of length to weight; therefore, the value of the condition factor varies with the relative plumpness of each fish and reflects the suitability of the environment for an individual (Lagler 1952).

The mean condition factor K(TL) (condition factor determined using total length) found in Lake Sakakawea, 1.22, was consistent with that found by others in Lake Sakakawea (Wahtola et al. 1971) in being below the average for perch in the United States of 1.3 (Carlander 1950b). With a mean K (TL) of 1.38, Audubon is a more suitable environment for yellow perch than Lake Sakakawea. No significant trends were noticed among year classes in either lake.

The length-weight relationship, log W = log a + n log L, was determined empirically from the data from each lake by the method of least squares. The equation that best describes this relationship in Lake Sakakawea is log W = -4.1669 + 2.6724 log L and that for Lake Audubon is log W = -4.4609 + 2.8280 log L. An n value of three indicates that the weight increases at the cube of the length. Lake Audubon has a higher n value than Lake Sakakawea which is an indicator of superior growth.

The length-weight equations for each lake were used to calculate growth curves (Figure 2). The curves are drawn together for comparative purposes. The growth curve of Audubon perch rises more sharply than that of Sakakawea perch and the points corresponding to average lengths and weights of each age group closely follow the curve. The points corresponding to the average length and weight of Sakakawea perch indicate the small amount of data from which the curve was calculated. In spite of the potential for unreliability of this curve due to limited data, the position of the curve is consistent with the findings of the other comparisons conducted in this study and may well be representative.

In summary, Lake Audubon perch have better growth than perch in Lake Sakakawea as is evidenced by the better growth curve (Figure 2) and the faster annual increase in length (Figures 3 and 4). Audubon perch live longer, have better conditions factors and have a higher population density than Lake Sakakawea perch. It appears that growth in Lake Audubon is well above what might be considered the average found for yellow perch throughout its range and the growth of Sakakawea perch is below this average.

Perch in Lake Sakakawea have many of the characteristics of a stunted population as described by Eschmeyer (1937); slow growth, poor condition, reduced longevity, and a cycling dominant year class which never reaches a suitable size for angling. Other workers (Wahtola et al. 1971) have also concluded that the Sakakawea perch population is in a stunted condition.

No specific study was made to determine what factor or factors amid all of the similarities between these two lakes might be responsible for the differences in growth, longevity and condition. Of all of the factors that might affect the growth of a fish, none affect it as powerfully as does its food supply. Even growth-related factors such as water quality and temperature affect an organism more through its food supply that by their direct action (Forbes 1880). Food is also probably the major factor causing stunting (Alm 1946). Growth of Sakakawea perch is most likely inhibited by some food related factor that Lake Audubon does not share.

One potential cause is the difference in water quality. Although there are no supporting data, levels of algae growth in Audubon indicate a higher nutrient concentration which may enhance the food web for yellow perch.

Relative amounts of littoral area in each lake may also be a factor responsible for the strengths or weaknesses in the food web. Lake Audubon inundated more gently sloping terrain than did Lake Sakakawea. Numerous islands along with this more gradually sloping substrate would appear to give Audubon a greater percentage of the productive littoral area per area of lake than in Sakakawea which inundated steep riverside bluffs. Evinhuis (1970) noted the lack of well established littoral zone in Sakakawea and discussed the effect of this lack with respect to goldeye.

Another factor, average depth of a lake, is inversely related to fish production. The large area of littoral zone in shallower lakes with its associated high plankton and bottom fauna production, was suggested as one of the principal reasons for the relation of fish production to average depth (Larkin 1964). The average depth of Lake Sakakawea is 17.4 m (57.1 ft) (Benson 1968), deeper than the maximum depth of Audubon of 16.8 m (55 ft) (Duerre 1965); a possible factor responsible for observed differences in growth.

Goldeye (Hiodon alosoides) are the most abundant fish in Lake Sakakawea (Wahtola et al. 1971) but are much less common in Audubon (Hall unpubl. data). Since goldeye and yellow perch eat similar food organisms (Hieb 1968, Forbes 1880), competition between them might be another factor influencing the differences in growth of yellow perch in Lake Audubon and Lake Sakakawea. Owen and Wahtola (unpubl. data), however, found that direct competition for food was not a major factor due to spacial and temporal separation of feeding.

Goldeye have been extensively studied in Lake Sakakawea. Hieb (1968) found that the goldeye population had poor growth. Like yellow perch, goldeye progress in food preferences from zooplankton (mainly microcrustaceans) to benthos (mainly aquatic insects and their larvae) and small fish (Kennedy and Sprules 1967). Food habit studies of goldeye in Lake Sakakawea indicate a lack of benthos which forces larger goldeye to rely more heavily on zooplankton which limits their growth (Evinhuis 1970). Evinhuis postulated that this lack of benthic food organisms was due to low amounts of well established littoral area. Since yellow perch feed on these same organisms, it is possible they are also being affected by this weak link in the food web at the benthic level.

Perch progress in food preferences with size from zooplankton to small benthos to large benthos and fish (Schneider 1972). Schneider found that there was very little competition for food between these groups. Because of this, in a situation where the productivity of plankton exceeded the productivity of benthos, more perch survived than could be supported by the environment at the benthic level. This situation may be occurring in Lake Sakakawea. High plankton productivity allows more perch to survive than can be supported by the environment as they reach the benthos level and explains their near normal growth through the first few years. As the perch grow they begin to require larger food organisms, but since there is not sufficient productivity at the benthic level to support the upcomming population, they are forced to continue to feed on zooplankton, thus suffering from poor growth, poor condition, and reduced longevity.

It would appear that a higher nutrient concentration, greater percentage of littoral zone and shallower depth are acting singly or in some combination to supplement the productivity at the benthic level in Lake Audubon. This allows perch to progress through their food preference sequence and grow normally.

Further studies, including that of food habits, is needed to actually determine if the growth of Lake Sakakawea's perch is being inhibited by this break in the food web at the benthos level.

An effort is being made to establish freshwater shrimp (*Mysis relicta*) in Lake Sakakawea primarily to supplement the food web for salmonids (Berard 1979). If there is suitable primary productivity and conditions in general are adequate for these organisms to become established, perhaps the Sakakawea perch population will also benefit.

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