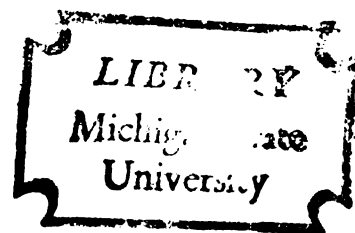


FECUNDITY, FOOD HABITS, AND CERTAIN
ALLOMETRIC FEATURES OF THE YELLOW PERCH,
PERCA FLAVESCENS (MITCHILL), BEFORE
OPERATION OF A PUMPED STORAGE PLANT ON
LAKE MICHIGAN

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
DAN C. BRAZO
1973



3 1293 10128 0018



LIBRARY
Michigan State
University



RETURNING MATERIALS:
Place in book drop to
remove this checkout from
your record. FINES will
be charged if book is
returned after the date
stamped below.

APR 02 1987

115 A 113

JUN 17 1987

~~APR 17 1987~~ KG

APR 20 1987
~~HI 847802~~

OCT 28 2001

ABSTRACT

FECUNDITY, FOOD HABITS, AND CERTAIN ALLOMETRIC FEATURES OF THE YELLOW PERCH, PERCA FLAVESCENS (MITCHILL), BEFORE OPERATION OF A PUMPED STORAGE PLANT ON LAKE MICHIGAN

By

Dan C. Brazo

Ecological research data were gathered before operation of a pumped storage plant on the eastern shore of Lake Michigan. Yellow perch were studied in depth because of their economic importance as a sport fish.

Perch were found to be most abundant in the area during the summer months. At this time they were in water of 6-12 meters of depth. In the spring and fall most perch were collected in waters deeper than 20 meters. Age III fish dominated the population. Length-weight studies of perch from Ludington revealed that these fish were longer and heavier than perch in other regions of the Great Lakes. Condition factors reflected this size disparity also. Greatest growth during the year was achieved from June to August. By the end of September growth had slowed to a minimum. Perch spawned from late May to the middle of June in 1972. Males dominated the spring samples in all

age classes, but during the summer and fall sampling periods males dominated only ages II and III. A fecundity index was developed by tracing the ratio of ovary weight to total body weight through the year. Just prior to spawning the ratio had a value of 20-25%. Four body features: length, body weight, ovary weight, and age were used as predictors of fecundity. The largest number of eggs produced by an individual was 157,699 by a VI year old female. Food and feeding habits of the perch were also studied. The major food items eaten were amphipods, fish, and crayfish. Differences in types and quantities of food eaten were observed for different sized fish and for different seasons of the year.

FECUNDITY, FOOD HABITS, AND CERTAIN ALLOMETRIC FEATURES
OF THE YELLOW PERCH, PERCA FLAVESCENS (MITCHILL),
BEFORE OPERATION OF A PUMPED STORAGE PLANT
ON LAKE MICHIGAN

By

Dan C. Brazo

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Fisheries and Wildlife

1973

ACKNOWLEDGMENTS

Consumer Power financed this research in its entirety. I wish to express my deep appreciation to Dr. Peter I. Tack who made this research a reality by securing the contract and financial aid. As my major professor his encouragement and suggestions were most helpful. I am also indebted to Drs. E. W. Roelfs and T. Wayne Porter who served on my graduate committee. Their useful suggestions and review of the manuscript is deeply appreciated.

Dr. Charles Liston, research coordinator on the Ludington project, contributed many valuable suggestions and was mainly responsible for and in collection of data. His views for interpretation of data were of great help. Of even greater value were our impromptu sessions, which helped ease the burden of research while in Ludington. Dr. John Gill is to be thanked for his helpful suggestions in statistical analysis of the data.

My gratitude is also extended to Messrs. Tom Chiotti and Greg Olson for their aid in collection of data. Special thanks goes to fellow graduate student John Armstrong whose friendship and help were greatly

valued. His continual suggestions and ideas further enhanced the probability of my research being a success.

Deepest and sincerest thanks should go to my dear wife, Susan. Her endurance and understanding were of immeasurable aid to my mental attitude and desire to achieve. It is with my greatest gratitude that I thank her for standing by me during these trying times.

TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS	ii
LIST OF TABLES	v
LIST OF FIGURES	vi
 INTRODUCTION	 1
AREA OF STUDY	6
METHODS AND MATERIALS	11
RESULTS AND DISCUSSION	14
Seasonal Variations	14
Fish Activity	14
Age Composition	20
Length-Weight Relationships	23
Condition Factor	33
Growth	34
Reproduction and Fecundity	38
Spawning Activity and Sex Ratios	38
Gonadal Development	43
Maturity and Fecundity	44
Food Habits	53
Seasonal and Size Differences	54
Food Selectivity	67
Summary	68
 LITERATURE CITED	 71

LIST OF TABLES

Table	Page
1. Age Composition of Perch Population by Season .	21
2. Comparison of Growth in Length of Yellow Perch From Five Regions of the Great Lakes	31
3. Comparison of Growth in Weight of Yellow Perch From Five Regions of the Great Lakes	31
4. Condition Factor (K_{S1}) by Age, Sex, and Season For Lake Michigan Perch	33
5. Frequency of Occurrence of Taxa Eaten by Different Sizes of Yellow Perch in Different Seasons of the Year	57

LIST OF FIGURES

Figure	Page
1. Map and Location of Sampling Stations Near the Consumer Power Pumped Storage Plant in Ludington, Michigan	7
2. Biomass and Numbers of Perch Taken at Each Station Throughout the Year, With Corresponding Temperatures at Time of Collection	15
3. Length-Weight Relationship for Spring Males and Females	24
4. Length-Weight Relationship for Summer Males and Females	26
5. Length-Weight Relationship for Fall Males and Females	29
6. Seasonal Growth by Length of Yellow Perch, Ages II-VI	36
7. Seasonal Sex Ratios of Different Age Classes of Yellow Perch From Lake Michigan	41
8. Development of Yellow Perch Ovaries Through the Year Expressed as a Ratio of Ovary Weight to Total Weight. Year Classes Were Not Kept Separate After June 5 Because of Proximity of Values	45
9. Relationship of Fecundity to Four Body Features as Predictors: Fish Length, Fish Weight, Ovary Weight, and Fish Age. Curves are Fitted by Inspection	49
10. Composition by Numbers and Volume of Spring Foods of Yellow Perch	55
11. Composition by Numbers and Volume of Summer Foods of Yellow Perch	60
12. Composition by Numbers and Volume of Fall Foods of Yellow Perch	64

INTRODUCTION

Development of electrical generating plants is becoming commonplace on the Great Lakes. The increasing affluence of our society and the alarming decrease of fossil fuels indicates increasing dependence on nuclear power. A study of the effects of such operations on the physical, chemical, and biological parameters of our fresh water seem necessary to protect our aquatic natural resources. Such is the case at Ludington, Michigan, where Consumers Power Company is erecting a pumped storage generating plant. This plant will act as a giant storage reservoir for electricity. During hours of low electrical demand, excess electricity in the Michigan area may be used by the Ludington plant for operation of one or more of six pump-turbines. With this excess electricity the pump-turbines will pump water from Lake Michigan to fill a man-made reservoir above the plant. Filling will be accomplished by the six pump-turbines handling approximately 11,000 cfs each. When full, the reservoir will hold 27 billion gallons of water and have a surface area of 830 acres. During hours of peak electrical demand the pump-turbines will be operated in the generating phase by release of stored water. The alternating pumping and

generating stages will create a current in the immediate vicinity of the plant not dissimilar to a large river flowing out of and into Lake Michigan.

Such currents coupled with the vast physical alteration of the area by addition of stone jetties, dredging, and construction activity may produce significant limnological modifications. For this reason, Michigan State University contracted to evaluate the potential ecological effects of operation of the plant upon the immediate area of the lake. Three phases of research were proposed. Phase I consists of a preoperational study to establish an ecological base line for the immediate area. Phases II and III, conducted concurrently, will involve a post-operational study on the affected area of Lake Michigan and a study of the reservoir, respectively.

This research involved an extensive study of some biological aspects of the yellow perch, Perca flavescens (Mitchill), as a portion of the larger preoperational evaluation of Lake Michigan near the plant site. Yellow perch were chosen because of their economic potential and importance as a sport fish. Sport fisherman used to come from considerable distances when the perch runs were on at the Ludington harbor and other harbors on Lake Michigan. However, recently perch populations are known to have declined in the Great Lakes (Michigan DNR, personal communication). One aspect of this paper is to evaluate the present perch population and its growth near Ludington.

Previous studies of this species have involved all biological aspects; however, very few studies have been conducted on perch from the Great Lakes. Hile and Jobes (1942) studied age and growth of yellow perch in northern Lake Michigan and Green Bay. They also studied age and growth of the yellow perch in Saginaw Bay of Lake Huron in 1941. El-Zarka (1959) published a follow-up study in Saginaw Bay on fluctuations in the population of yellow perch. This was the first real indication of decline in size and numbers of perch. Age and growth of yellow perch in Lake Erie were studied by Jobes (1952). Many age, growth, and life history studies have been done on the yellow perch in inland waters. These findings may not describe yellow perch from the Great Lakes but are useful for comparisons. Parsons (1950) found that perch in Clear Lake, Iowa grew very slowly. Muncy (1962) studied perch in an estuarine situation in Maryland and found high body weights at certain lengths of fish. Beckman (1948 and 1947) made observations on various allometric features of the perch in the inland waters of Michigan. Pearse and Achtenberg (1920) investigated perch habits in a Wisconsin lake. LeCren (1951 and 1958) examined growth and growth factors of the European counterpart (Perca fluviatilis) to our yellow perch.

Numerous papers have been published describing the feeding habits of this species in inland waters.

Previous mentioned papers on inland waters usually included a section on the feeding habits of these same waters. Also, Langford and Martin (1941) discussed some seasonal changes of food of perch in an Ontario lake and Ewers and Boesel (1935) studied the food habits of yellow perch in Buckeye Lake, Onio. Food habits of the European perch, Perca fluviatilis (Linneaus), were examined extensively by Allen (1935) in Windermere Lake. Rawson (1930) studied the food of large perch in an Ontario lake. However for the Great Lakes, this author could find only two papers. Tharatt (1959) investigated the fall foods of perch in Saginaw Bay. Food habits of the yellow perch in western Lake Erie were incidental in a report on the utilization of crustaceans as fish food by Ewers (1933).

Reproductive behavior, spawning time, and sex ratios have been researched extensively, but actual fecundity studies are rare for yellow perch. In fact, only Sheri and Power's (1968) work on Lake Ontario relates to the Great Lakes. Tsai and Gibson (1971) conducted a fecundity study on estuarine perch in Maryland. The previous two papers are apparently the only ones using different body features as predictors for egg numbers. Worth (1892) observed 90,000 eggs in one mass, and Herman et al. (1959) recorded up to 48,000 eggs being laid by one female perch with the average being around 23,000 eggs. Knowing the number of eggs produced may be of

value in predicting the reproductive potential of a fish population. Sheri and Power (1968) and Tsai and Gibson (1971) do not resolve the fecundity of yellow perch. The present study has been conducted with the hope of providing predictive data for fecundity of yellow perch in Lake Michigan.

AREA OF STUDY

Collections were made on Lake Michigan approximately three miles SSE of the Ludington harbor $86^{\circ} 27' 30''$ west longitude and $43^{\circ} 57' 10''$ north latitude. Six collection sites (stations) were used, five of these being in the immediate vicinity of the breakwater jetties of the power plant. The other station was approximately three miles further south to act as a control (Figure 1). A description of the physical and chemical characteristics of each station follows.

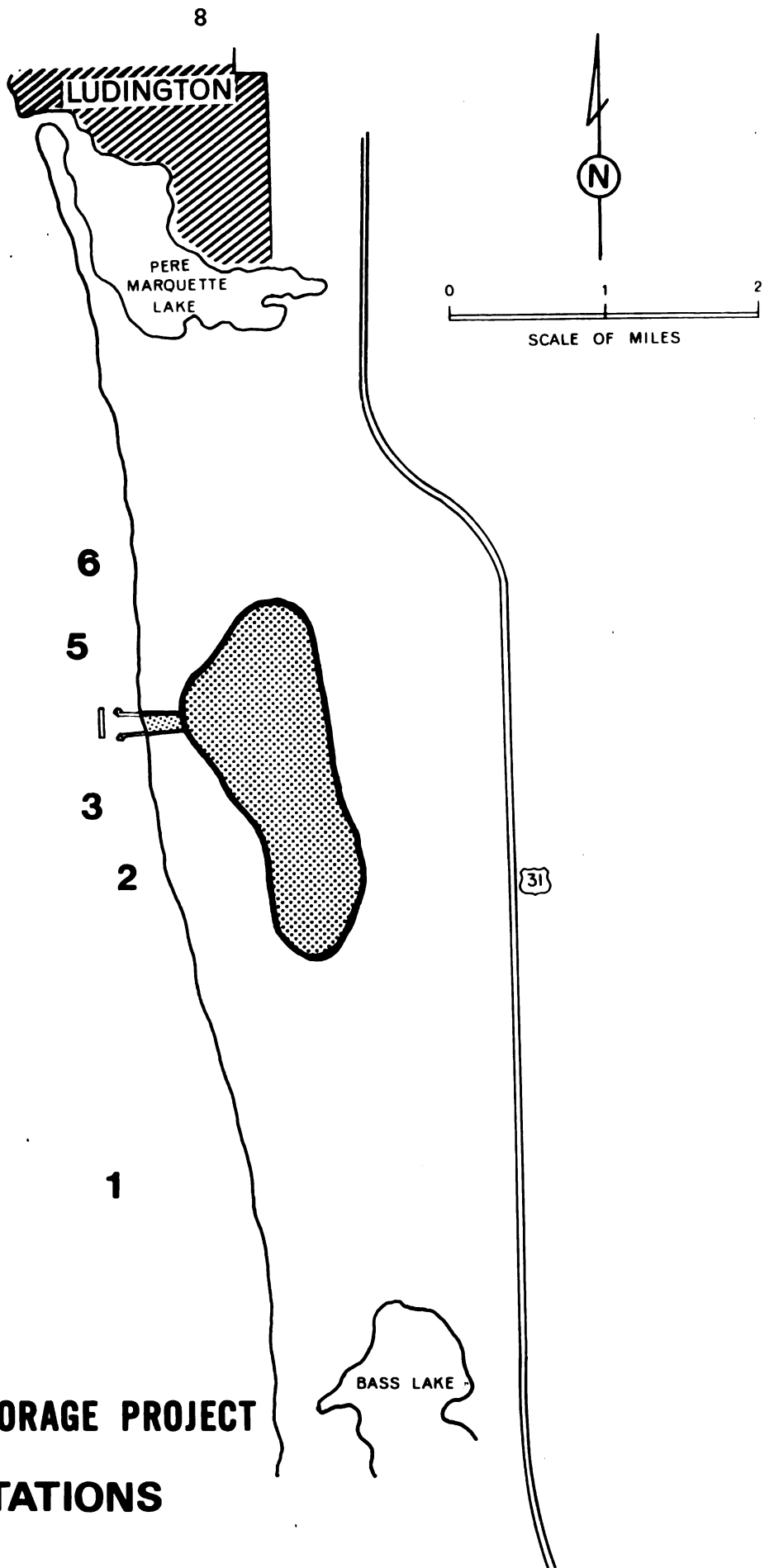
Station 1 ($86^{\circ} 27' 20''$ WLong, $43^{\circ} 51' 00''$ NLat) is the control station about three miles south of the Consumers Power plant, where the effects of the plant should be negligible. The bottom is mostly sand with some gravel. Water depth is 12 meters. Light penetration was intermediate here, in relation to other stations, averaging 3 m. Station 2 ($86^{\circ} 27' 50''$ WLong, $43^{\circ} 52' 45''$ NLat) is one mile south of the project in 8 m of water. The bottom is mostly sand interspersed with a few large rocks. Light penetration was relatively low, averaging approximately 2 m. Station 3 ($86^{\circ} 27' 20''$ WLong, $43^{\circ} 53' 5''$ NLat) is one half mile south of the project in 14 m of water. The bottom here is sandy with a few clay outcroppings. Light penetration

/

Figure 1.--Map and location of sampling stations near the
Consumer Power pumped storage plant in Ludington,
Michigan.

LAKE MICHIGAN

LUDINGTON PUMPED STORAGE PROJECT SAMPLING STATIONS



averaged from 3 to 4 m. Station 4 ($86^{\circ} 29' 00''$ WLong, $43^{\circ} 53' 30''$ NLat) is the deepest of all stations at 24 meters, and is located 1.5 miles due west of the project. The bottom here is totally sand. Light penetration was greatest at this station usually averaging 5-6 meters, but on occasions exceeding seven meters. Station 5 ($86^{\circ} 27' 10''$ WLong, $43^{\circ} 54' 5''$ NLat) is one half mile north of the project in twelve meters of water. The bottom at this station was the most diverse of all stations. Sand was interspersed with clay outcroppings, and strewn with huge rocks. Light penetration was similar to station 3. Station 6 ($86^{\circ} 27' 35''$ WLong, $43^{\circ} 54' 20''$ NLat) is the shallowest station with a depth of only 6 m and is located one mile north of the project. The bottom is sand with a few large rocks present. Of all stations, light penetration was poorest at station six. Secchi disc readings were usually from 1-3 meters, but occasionally fell below one meter.

Wind action caused extensive mixing in this locality. Physical and chemical parameters (temperature excepted) were almost homogeneous from station to station and from top to bottom throughout the year. Dissolved solids ranged from 170-190 ppm, alkalinity from 110-130 ppm, pH from 7.8-8.0, and dissolved oxygen normally ranged from 11-14 ppm. Except for a period in late May and early June, when two weeks of calm weather was experienced, there was little stratification.

Water temperatures ranged from a low of 2°C in early April to a high of 19°C in late August and early September. By November water temperatures had dropped to 7°C. No aquatic macrophytes were observed in the area. Diatoms were the most abundant group of phytoplankton with Synedra acus-nana being the most prevalent species. Zooplankton consisted of large numbers of copepods and a few cladocerans.

Dominant fish species collected in the area were: lake trout (Salvelinus namaycush), longnose sucker (Catostomus catostomus), white sucker (Catostomus commersoni), round whitefish (Prosopium cylindraceum), alewife (Alosa pseudoharengus), and spottail shiners (Notropis hudsonius).

METHODS AND MATERIALS

Perch were collected with experimental gill nets from April 10, 1972-November 16, 1972. These nets consisted of six 50-ft. panels of mesh sizes, 2, 2.5, 3, 4, 4.5, and 7-inch stretched mesh. On July 27 a seventh panel of one-inch stretched mesh was added. Nets were set at each of the six stations four times a month for a 24-hour period (weather permitting). Some collections spanned more than 24 hours and food analysis was discarded for these periods. Trawling was attempted sporadically with a Helgoland frame trawl but because of a rough bottom, this method proved inefficient for capturing perch.

All fish collected were placed on ice and returned to the laboratory as quickly as possible. Using a maximum of fifteen perch per station, total length (nearest mm), weight (nearest g), and sex of each fish were then determined. When the number of perch at a station exceeded fifteen, the extra fish were counted and their total biomass recorded. Ovaries from females and stomachs from representative samples of fish were removed each day trapped, wrapped in cheesecloth, and fixed in a 10% formalin solution. Scales were removed from each fish immediately below the lateral line in an area directly below the

spinous portion of the dorsal fin. Scale impressions were made later with a roller press on cellulose acetate. Subsequently all fish were aged.

Visual examination of stomachs were made, and if appeared empty were examined under a Bausch and Lomb dissecting scope at 30X to check for microscopic organisms. Early in the study, observations indicated that the size of organisms eaten could readily be seen by the naked eye. Thus further microscopic work was abandoned except for identification of food organisms. All food organisms were identified to the lowest possible taxonomic category, enumerated, and a volume (nearest cc) taken of each taxonomic group by water displacement as described by Lagler (1956).

Ovaries were likewise examined soon after fixation in formalin. Ovarian weights were recorded to the nearest .1gm with the use of a dial-a-gram balance. Division of the ovary weight by the total body weight of the female and subsequent multiplication by 100 yielded ovary weight as a percentage of total body weight. Thus gonadal development could be continued through the whole year and used as a fecundity index.

Fecundity studies were conducted on ninety-six females captured in April and May immediately prior to spawning since eggs were largest and easiest to count then. Total volume of the ovary was found by water displacement

methods (Tsai and Gibson, 1971). Ovarian tissue was separated from the eggs and the tissue volume recorded. The above procedure was used on 20 ovaries, after which it became apparent that 5-7% of the ovary volume was ovarian tissue. In future estimates, 6% of the ovary volume was deducted as ovarian tissue. Ten egg counts were made on a single ovary to check for reliability of the method. Egg counts were made of 0.5-ml aliquots taken randomly from each ovary. Two counts were made and the values averaged. By simple proportion the total number of eggs in an ovary could then be estimated. Regression analysis could then be made of fecundity versus length, body weight, ovary weight, and age of the fish. This was done to gain predictor equations for future reference.

RESULTS AND DISCUSSION

Seasonal Variations

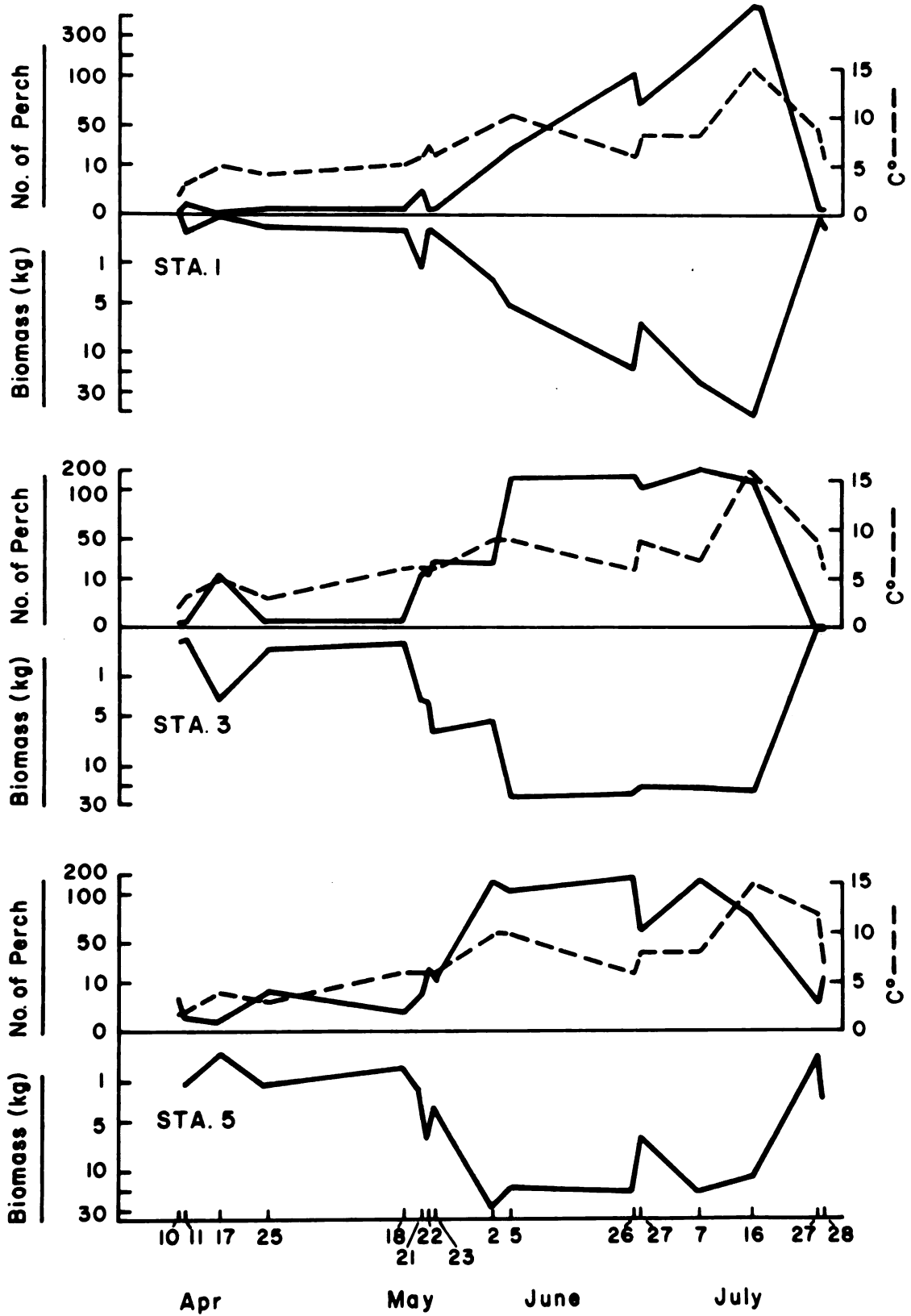
Fish Activity

In early April and May, 1972 most perch were collected in twenty-four meters of water at Station 4. By mid-May fish had started to move into shallower water at stations 3 and 5. On May 22 and 23, an influx of fish occurred at the shallowest stations (2 and 6) as indicated in Figure 2. This seems to be correlated with rising temperatures (Figure 2), which in turn may be eliciting spawning behavior. Perch continued to be taken in great numbers at shallower stations from June through August. However, the variability between stations was quite large. Generally, station 4 yielded fewer fish than the other stations. By late September the percentage of total perch in shallow water had decreased. The total number of perch caught at all stations combined was also decreasing. By October and November the perch had moved back into deeper water with 60% of the catch (by numbers) being taken at station 4 (Figure 2).

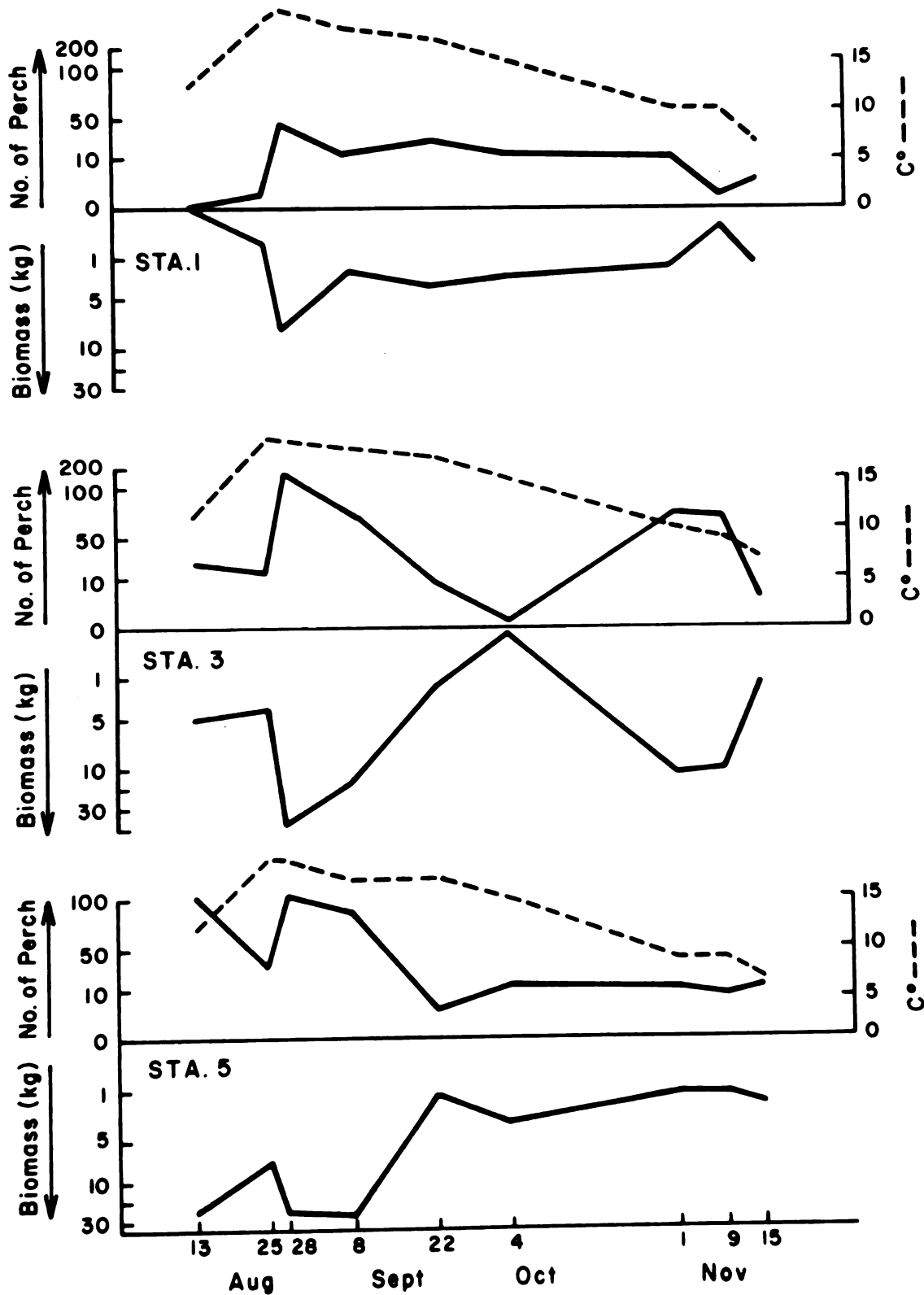
Seasonal migration patterns were also observed by Allen (1935) for European perch (P. fluviatilis) in Windermere Lake and by Wells (1968) in southeastern Lake

Figure 2.--Biomass and numbers of perch taken at each station throughout the year, with corresponding temperatures at time of collection.

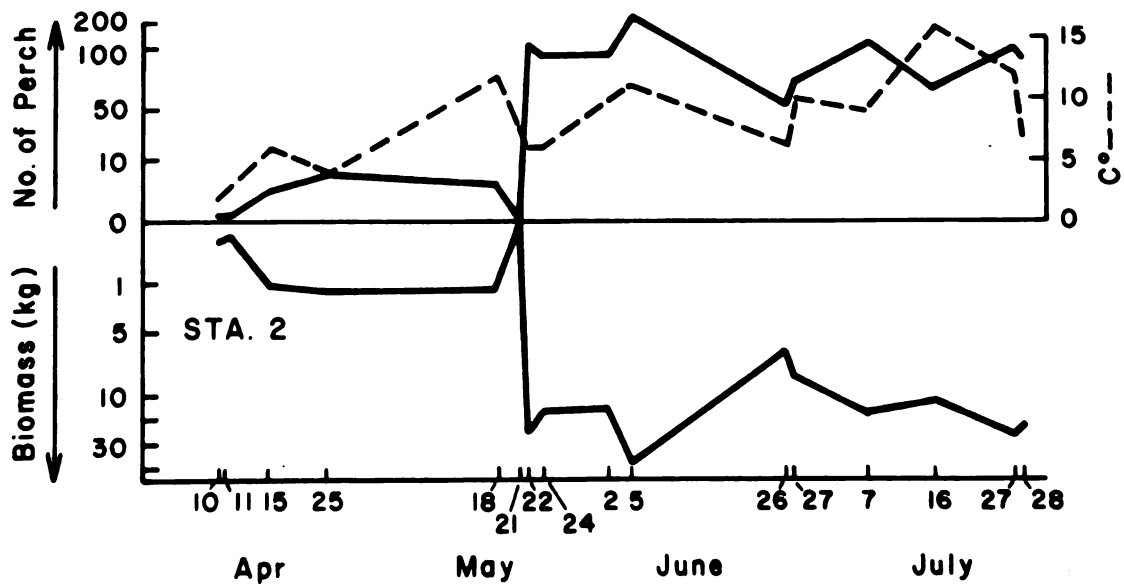
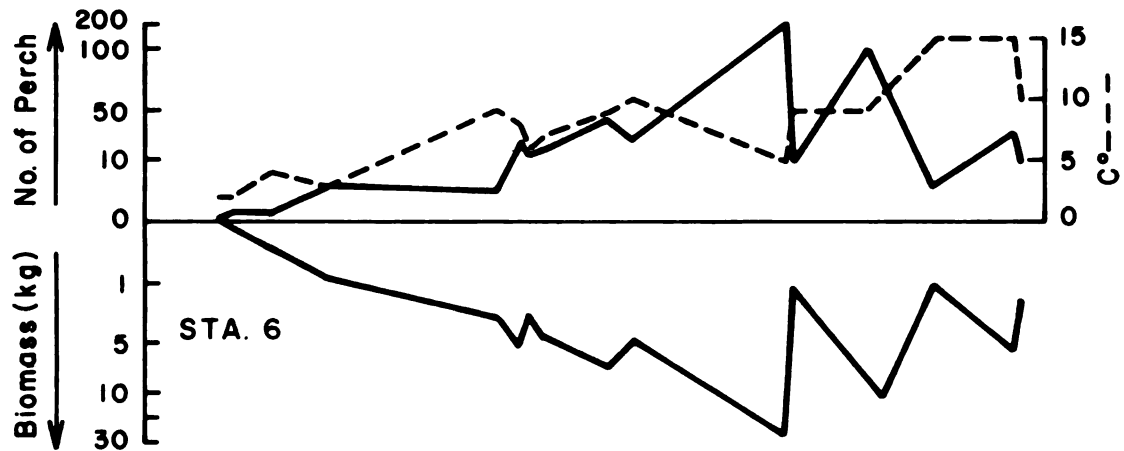
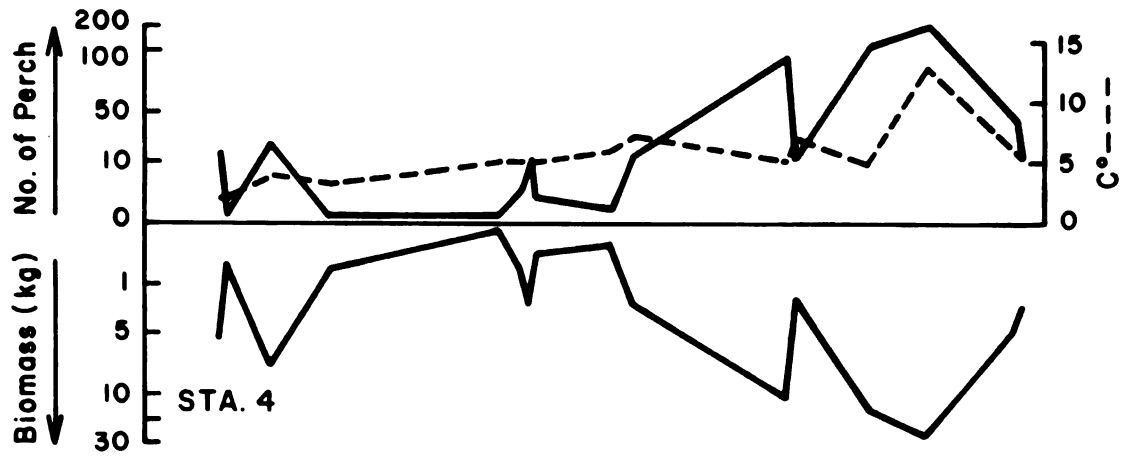
Stations 1, 3, 5 (April - July)



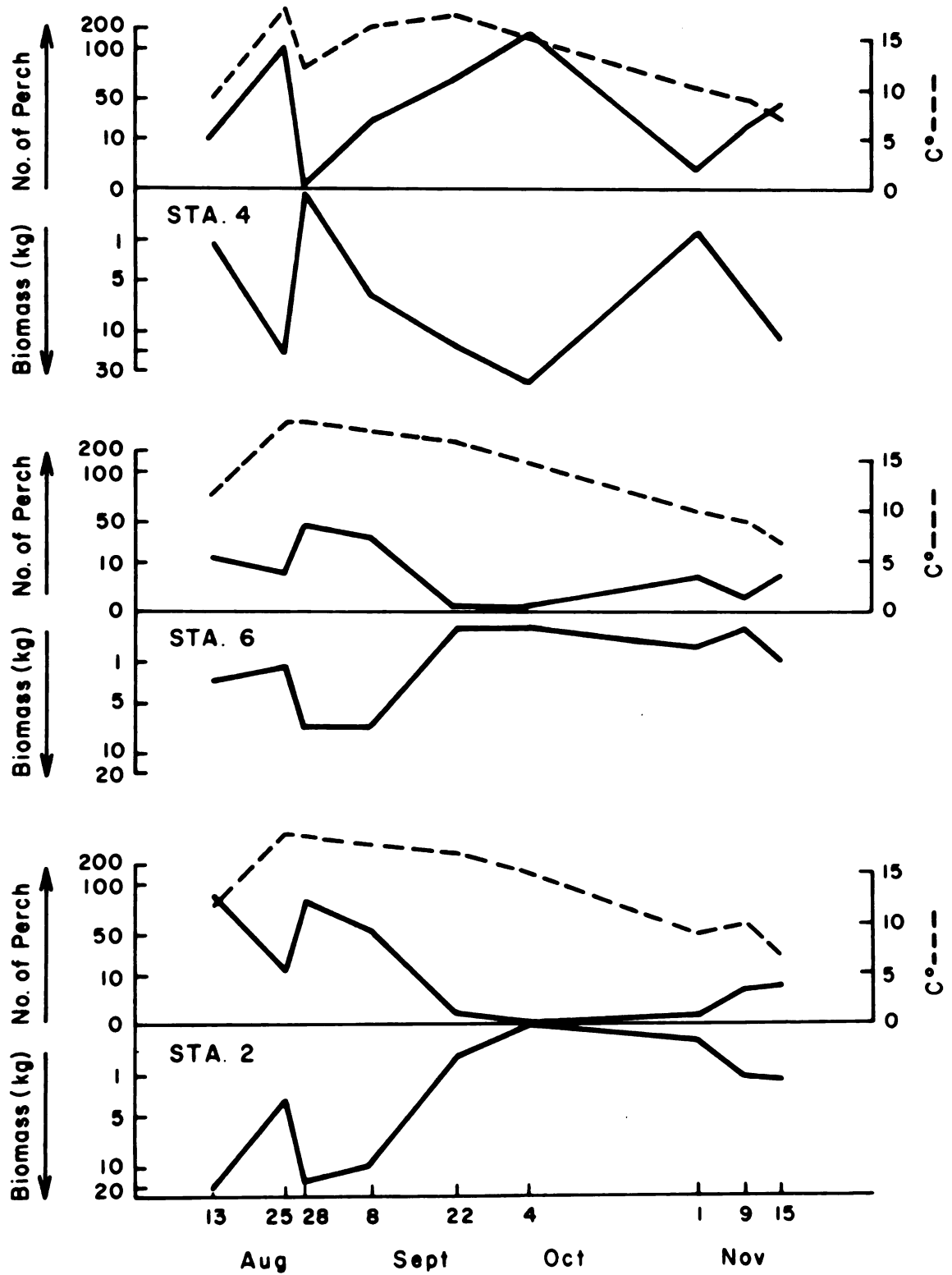
Stations 1, 3, 5 (August- November)



Stations 2,4,6 (April - July)



Stations 2, 4, 6 (August-November)



Michigan. They state that perch came in to the shallows to spawn in April and May. After spawning they spent the majority of the summer months in the littoral zone at approximately ten meters depth. By October very few perch were taken in less than 10 meters of water. Most of the fish had moved to deeper waters (18-27 meters) where they overwintered. Allen (1935) concluded that this may be a reaction to food abundance. Such a comparison was not made for Lake Michigan perch.

Age Composition

Dynamics of fish populations are quite involved and require much time with tagging and marking, recapture studies, and creel census. Time being a limiting factor in this research, only a superficial age composition of the population was established. Selectivity of gill nets makes any analysis of size or age composition difficult (Moyle, 1949 and Moyle and Lound, 1960). However the use of experimental nets with six mesh sizes may tend to minimize this error.

In the spring, 563 perch were collected and aged (Table 1). Age classes III, IV, and V contributed almost equally to the catch (Table 1). Age class VI accounted for another 15.5%, with the remainder being made up by age classes II, VII, and VIII. The sample of two-year-old fish may not be representative of the actual population as the catch of age II fish increased throughout the year as they

TABLE 1.--Age composition of perch population by season.

Season	Age								Total	Avg.
	I	II	III	IV	V	VI	VII	VIII		
Spring	-	5	144	169	145	86	12	2	563	4.4
Summer	9	23	327	142	90	46	6	-	642	3.7
Fall	3	37	148	112	37	6	1	-	341	3.5
Total	12	65	619	423	272	138	19	2	1546	3.9

attained a larger size. Six hundred forty-two specimens were aged for the summer period. The 1969 year class (age III) made up over half the catch (51.6% from Table 1). Age IV fish contributed 22.4% and age V perch added 14.2%. All other age classes comprised insignificant numbers to the total. This great preponderance of age III fish can be traced into the fall when this same age group contributed 43.4% of the catch (Table 1). Four-year-olds were second in abundance at 32.8%. Age classes II and V contributed equal numbers (10.8%), and ages I, VI, and VII made up insignificant numbers. Full recruitment can be realized for all age classes except I and II. The percentage of age II fish increased throughout the year. This indicates that all age II fish had not reached a catchable size. Age I fish collected were characterized by a relatively high coefficient of condition indicating that only the fastest growing fish were caught (see page 34).

An increased percentage of younger fish and a decreased percentage in older year classes resulted in lowering the average age of the perch population from 4.4 in the spring to 3.5 in the fall (Table 1). Heyderhahl and Smith (1971) observed a similar phenomenon for perch in Red Lakes, Minnesota. Such trends may be due to the increasing numbers of younger fish reaching a catchable size and the decrease of older fish due to fishing and natural mortality.

Totals for the entire year show that of 1546 fish, age III perch contributed 40.1% and age IV fish comprised 27.4% (Table 1). Relative strength of age I and age II perch could not be reliably determined due to gill net selectivity. In addition ages V-VII contributed only a minor portion to the population (Table 1). The tremendous number of age III and IV fish might be explained in the following manner. Alewife dieoffs in 1967 removed a major competitor with and a predator on larval yellow perch. Enrichment of the water and "blooms" of plankters may have resulted from the nutrients released to the water by the dead alewives. A time lag would occur but by 1968, the new potential for reproduction and survival would result in a large year class. These effects probably carried over to the following year (1969) and produced even a larger year class (age III fish now).

Length-Weight Relationships

Length-weight values were developed using Carlander's (1951) general equation $W=aL^n$. Changes in condition observed during the year may be attributed to gonadal changes or to variation in feeding habits. It has been shown for many species that differences occur between sexes and seasons (LeCren, 1951). Thus values were developed, by the least squares method, for each season of the year: spring, April 1-June 15; summer, June 16-August 31; and fall, September 1-November 15. Fish from each season were also analyzed by sex. Original values were derived with L =total length in millimeters. Subsequently, a relationship was developed between standard length and total length where $SL=.852TL$. Original length-weight regressions were then transformed to new equations where L =standard length.

The empirical relationship of spring fish can be seen in Figure 3. For the spring, females ($\log W=-5.18+3.40 \log L$) had a steeper (but not significantly so) slope than males ($\log W=-5.25+3.37 \log L$). The slightly steeper slope for females is probably due to the larger percentage of body weight made up by the enlarged ovaries compared to the relatively smaller percentage of body weight of males made up by testes. Summer females, $\log W=-5.07+3.30 \log L$, and summer males, $\log W=-5.12+3.30 \log L$, had identical slopes (Figure 4). This is probably due to the discharge of sexual products prior to this time. However, it can be observed that females had a higher intercept value.

Figure 3.--Length-weight relationship for spring males and females.

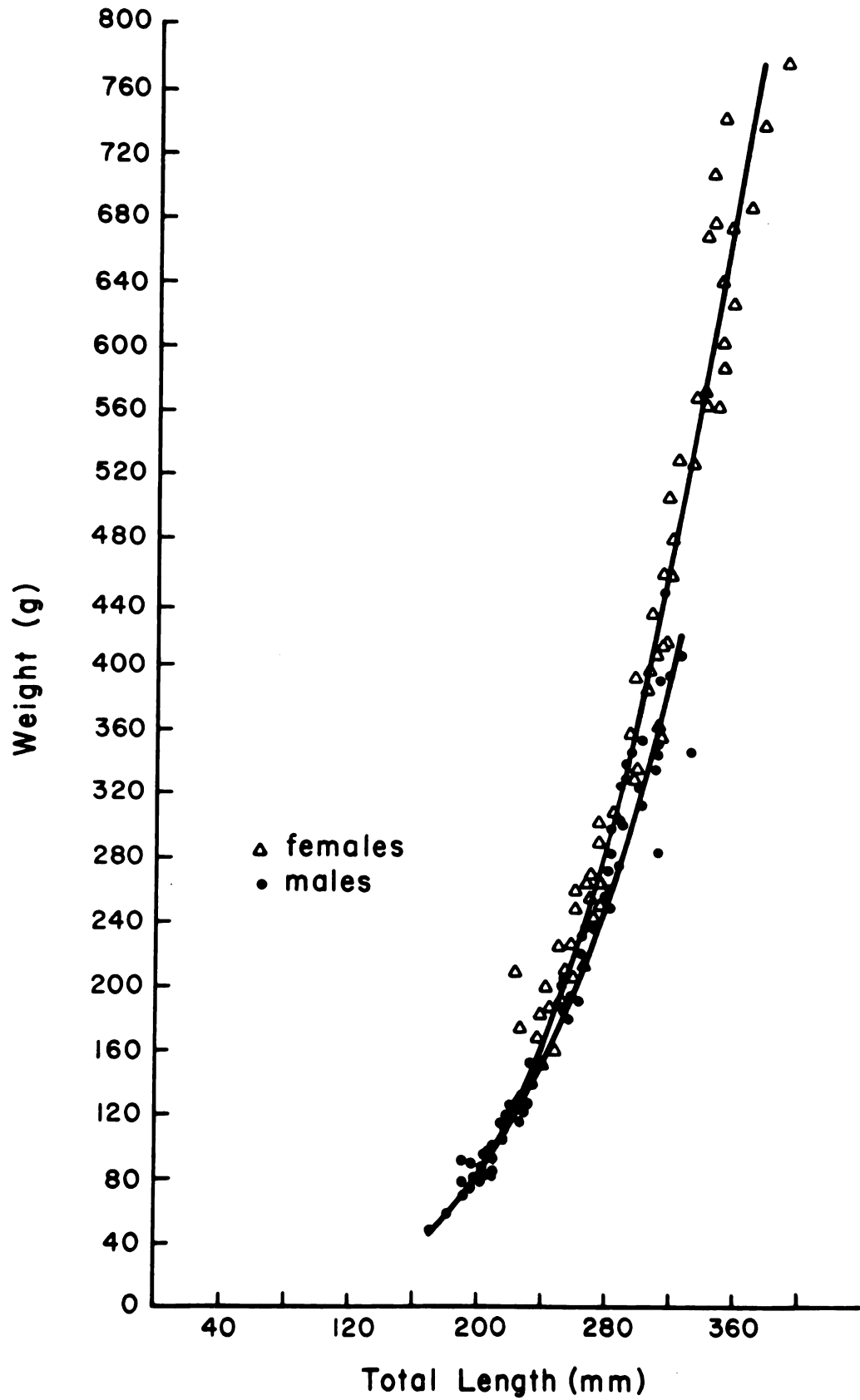
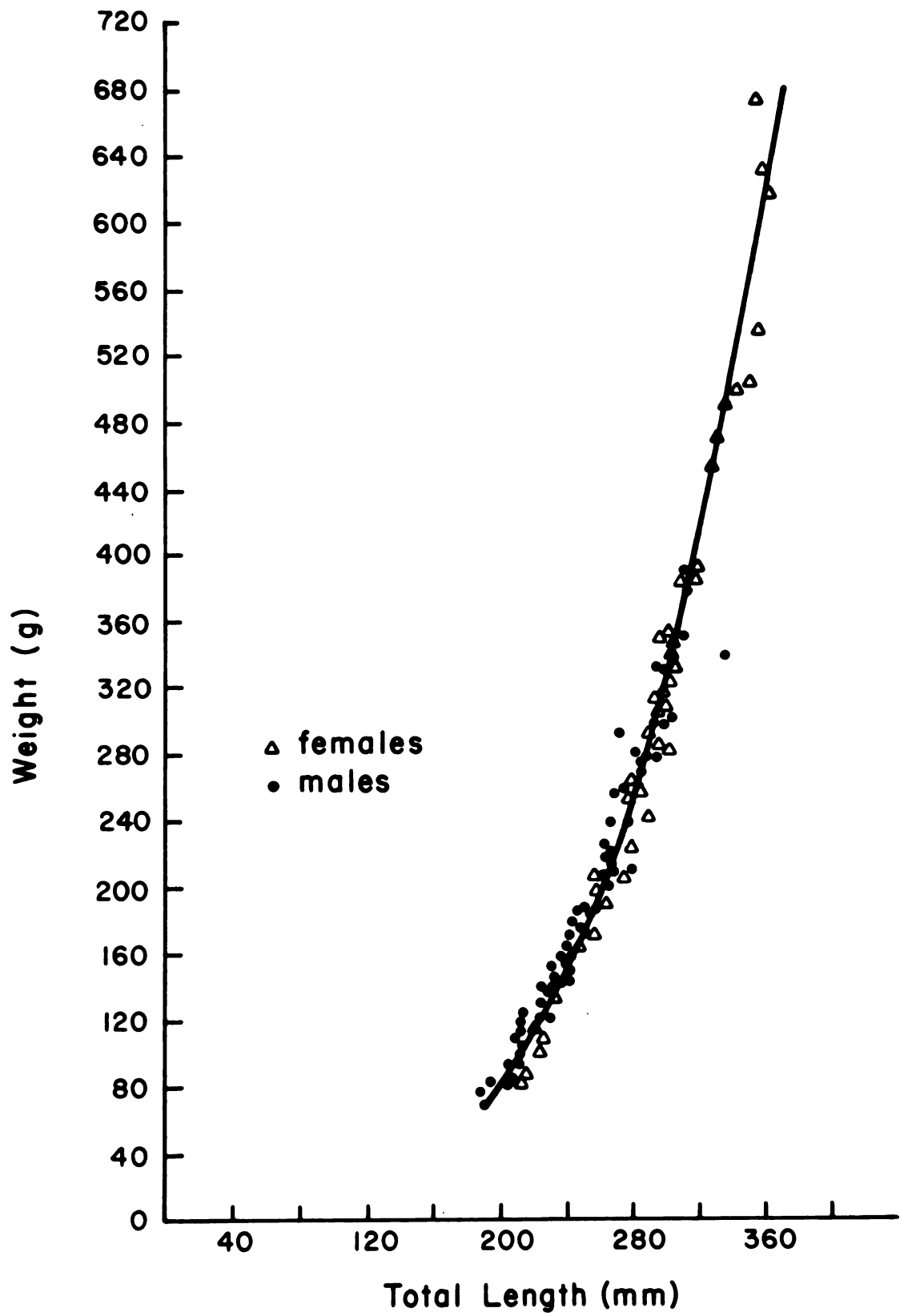


Figure 4.--Length-weight relationship for summer males and females.



Females from fall collections, $\log W = -5.12 + 3.34 \log L$, again exhibited a steeper slope than fall males, $\log W = -5.18 + 3.31 \log L$ (Figure 5). In all comparisons it was observed that female and male growth were similar in early life. As females got older they became much heavier for their length than males.

By season, spring fish (both males and females) had significantly higher slopes than either summer fish or fall fish ($\alpha = .1$ and $.15$ for males, $\alpha = .2$ and $.4$ for females). This appears to reflect size of gonads. For males, summer and fall fish exhibited almost identical equations. Summer females had a lower slope than fall females. No attempt was made to analyze separate regression lines by age as done by LeCren (1951), who found that larval European perch and immature perch (ages I and II) had significantly different slopes than older mature fish. In all age classes, females had significantly greater lengths and weights than their male counterparts when tested by Student's *t* test for difference between means.

Comparison of perch from Ludington with other populations was difficult because of differences in collection methods, times of collection, and selectivity of gill nets. However, Hile and Jobes (1942) have compiled comparison tables of average lengths and weights of yellow perch in different regions of the Great Lakes (Tables 2 and 3). Data from the present study on lengths and weights

Figure 5.--Length-weight relationship for fall males and females.

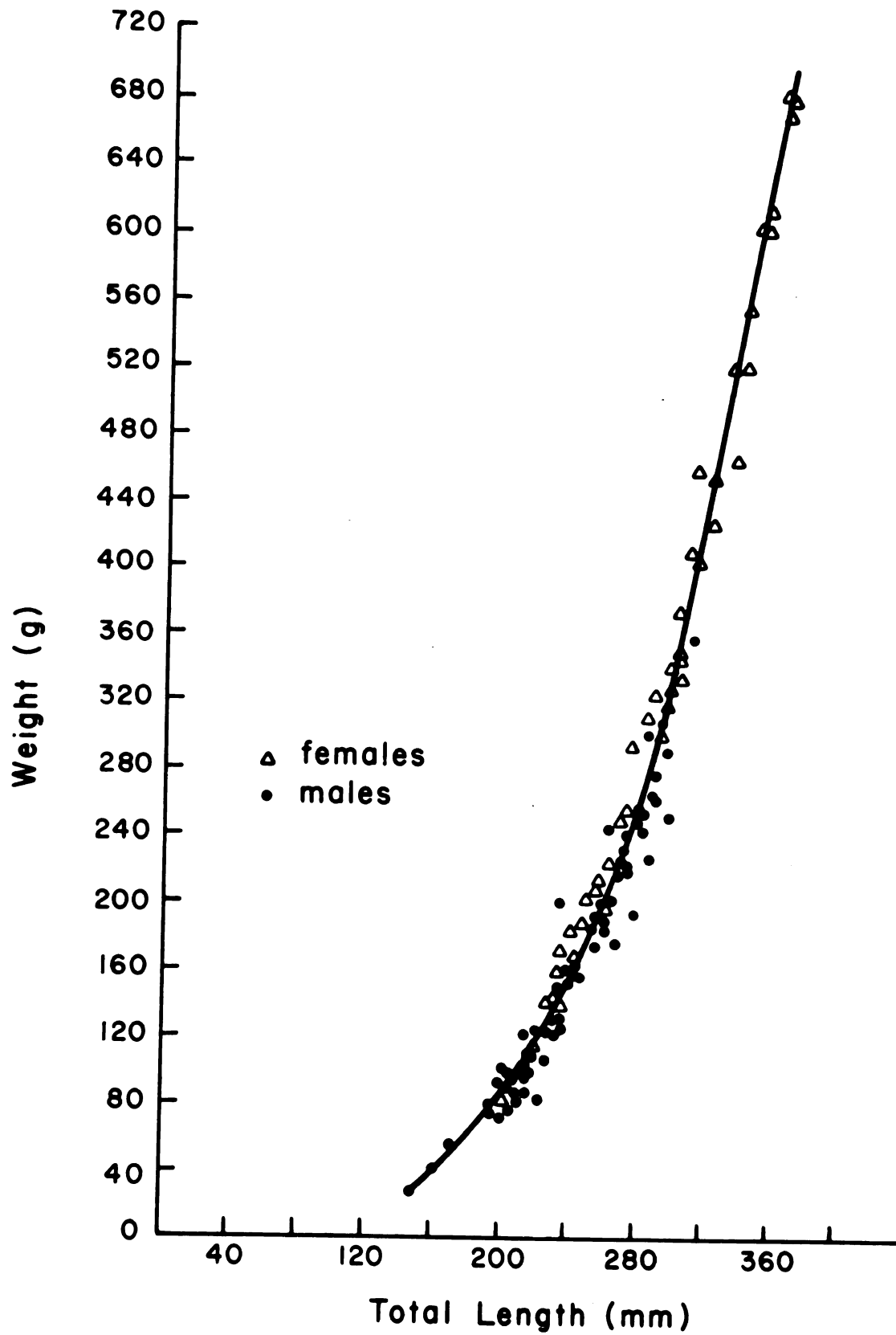


TABLE 2.--Comparison of growth in length of yellow perch from five regions of the Great Lakes.

Locality	Sex	Standard Length in Millimeters at End of Year of Life					
		2	3	4	5	6	7
Lake Michigan	M	159	182	215	235	247	252
near Ludington	F	162	206	225	252	291	313
Green Bay	M	99	130	159	185	211	227
	F	99	137	173	197	228	251
Lake Erie	M	143	181	203	220	-	-
	F	146	187	215	234	251	-
Saginaw Bay	M	114	166	204	232	259	275
	F	116	174	211	236	270	293
Northwestern Lake Michigan	both	96	128	154	183	212	-

TABLE 3.--Comparison of growth in weight of yellow perch from five regions of the Great Lakes.

Locality	Sex	Weight in Grams at End of Year of Life					
		2	3	4	5	6	7
Lake Michigan	M	71	108	177	254	297	306
near Ludington	F	79	208	253	382	538	703
Green Bay	M	17	39	73	118	178	224
	F	17	46	96	144	224	307
Lake Erie	M	56	113	160	204	-	-
	F	59	125	190	246	303	-
Saginaw Bay	M	25	82	156	233	328	395
	F	27	95	173	245	373	482
Northwestern Lake Michigan	both	22	49	83	134	203	-

of early spring fish were added to Tables 2 and 3. Comparisons could then be made between perch from the Ludington area to perch from different areas of the Great Lakes. These comparisons (Tables 2 and 3 above) indicate that perch taken near Ludington are generally longer and heavier than perch from other regions of the Great Lakes. This information and the steeper slope of the length-weight relationship than perch taken in other fresh-water regions indicates that perch from Lake Michigan near Ludington grow faster and bigger than their counterparts in other geographical areas.

This excellent growth may be accounted for by two possibilities. First, larval perch in years of high alewife populations had to compete with larval and adult alewives for zooplankton. Also, larval perch are a major food item of adult alewives (Stanford H. Smith, personal communication). A sharp reduction in the perch population after the alewife gained prominence in the Great Lakes resulted. LeCren (1958) observed how major reductions in an European perch population led to increased growth in succeeding years. The second factor leading to increased growth could be the great alewife dieoff in Lake Michigan in 1967. Competition was removed and an influx of nutrients from decomposing alewives could have occurred. This would lead to an increase of fish food organisms that perch utilized.

Condition Factor

Condition factors are considered as the "plumpness" of a fish or the suitability of the environment to the fish. However, this measure of plumpness has frequently been misused in the past and is very difficult to compare owing to the many variables affecting it. No attempt was made to compare the condition of perch from Lake Michigan to fish from other areas.

The condition factor, K, can be calculated by use of the general equation $K = W/L^3$. This was done for individual age classes, by sex, and by season for Lake Michigan perch (Table 4). First calculations were made using total length. A weighted mean K was determined. This was transformed to K for standard length by the formula $K_{sl} = r^3 K_{tl}$, where $r = \text{total length} / \text{standard length}$.

TABLE 4.--Condition factor (K_{sl}) by age, sex, and season for Lake Michigan perch.

Season	Sex	Condition Factor at Age						
		I	II	III	IV	V	VI	VII
Spring	M	-	1.65	1.71	1.84	1.92	1.92	2.01
	F	-	1.84	2.22	2.09	2.19	2.38	2.37
Summer	M	1.77	1.67	1.67	1.78	1.80	1.84	1.90
	F	(Im)	1.97	1.96	2.02	2.16	2.16	2.17
Fall	M	-	1.67	1.73	1.86	1.85	1.74	-
	F	-	1.59	1.88	1.95	2.02	2.08	2.21

As expected, K increased rather smoothly with age from a low of 1.59 for age II fall females to 2.37 for age VII spring females. For all seasons females had a consistently higher condition factor than males (Table 4). This reflected a greater body weight for a given length in females than males, and may be interpreted as sexual dimorphism. Generally, spring males and females had higher condition factors than fish of other seasons. This was undoubtedly due to the enlarged gonads prior to spawning. Fall males had a higher K value than summer males. On the other hand fall females generally exhibited a lower K value than summer females. Age I fish had a higher than expected K value. In most instances it was higher than the K for II year old fish and higher than some age III perch. This could be an aberration produced by gill net selectivity for larger, faster growing one-year-olds.

In comparisons with other bodies of water perch from Ludington have a higher condition factor. Beckman (1948) reported that for inland lakes of Michigan perch had a coefficient of condition from 1.81-1.86. These higher condition factors for perch from Lake Michigan add to the evidence that perch in this area of Lake Michigan are growing remarkably well.

Growth

Seasonal growth rate was based on weighted mean lengths for each year class (sexes combined) for the last

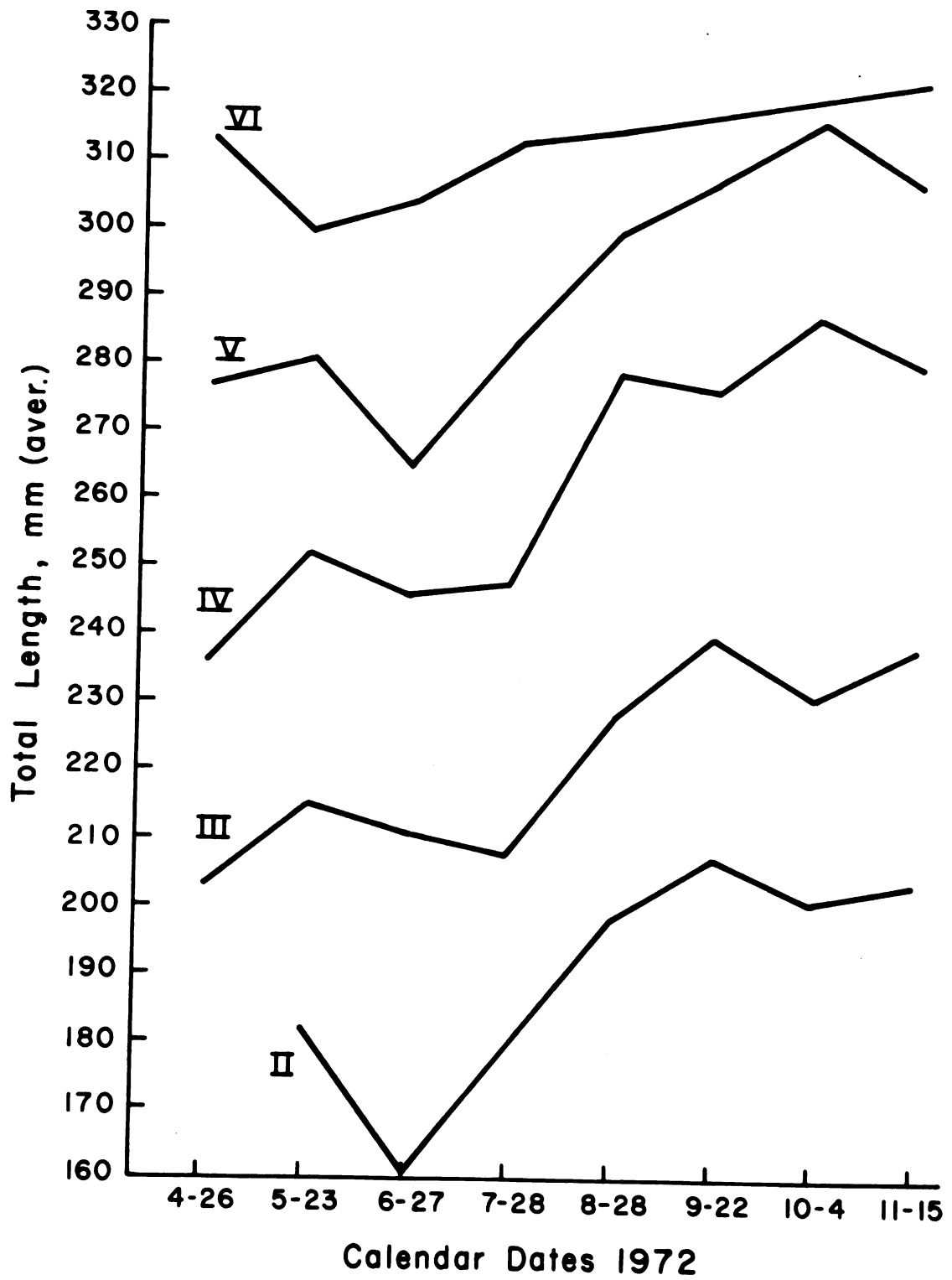
collection date of each month. These mean lengths were then plotted versus the time of year (Figure 6).

Greatest growth was achieved from the end of June until the middle of September (Figure 6). This period also corresponds to the period of greatest feeding activity for the perch (see page 50). By the end of September the growth rate had declined. Parkhurst (1971) reported similar results in western Lake Erie for the summer of 1970.

A decline in the average lengths of each age group from May-June (Figure 6) appeared unusual. This may be a result of females comprising almost half of the catch in April, but during the spawning period from May through June, males comprised 80% of the collection. It has already been established that for a given age, males are significantly shorter than females (Table 2). Thus by using weighted means, a larger number of males relative to females would reduce the average length for a given age group.

Observed growth rates for perch from Lake Michigan are not as great in older year classes as in younger year classes. Although no young-of-the-year perch were captured, Parkhurst (1971) reported that perch from Lake Erie grew fastest in their first year of life. He also observed declining growth rates with increasing age in Lake Erie perch.

Figure 6.--Seasonal growth by length of yellow perch,
ages II-VI.



Reproduction and Fecundity

Spawning Activity and Sex Ratios

First catches of perch in April were small in number with most fish in deep water (24 m). These catches contained approximately equal numbers of males and females. Gonads were still green at this time. Temperatures increased from 2°C to 4°C and a slight shoreward movement of fish occurred. The first ripe male was taken on April 26, 1972. By May 18, all males taken had readily running milt, but the few females taken were not ready for spawning. Successive catches on May 21, 22, and 23 indicated a tremendous influx of perch into the shallow water stations. Water temperatures were uniform from surface to bottom and were around 6-7°C. Of the 213 fish studied in these three days, only 16 or 7.5% were females (of which 75% were now ripe). The low percentage of females continued for the spring season.

By June 2, 1972 a number of partly spent males were taken. The number of partly spent males increased on June 6. Water temperatures were now 11°C at the bottom. The first spent female was taken on June 26, 1972. Of all females collected on this day only 25% had not yet spawned. By July 7, 1972, 100% of the females collected were spent. Thus, the spawning period for this year could be considered to occur from the middle of May through the end of June. A questionnaire developed by Van Oosten (1934)

for commercial fisherman indicated that the median spawning time of yellow perch in Lake Michigan was May 1-June 1 and the range of modes varied from May 1-June 15.

Of the 563 fish sexed during the spring spawning period, 86.9% were males. Segregation by age groups had no effect as the ratio ran about 8 males:1 female for all age classes. Using a Chi-square test these differences were highly significant for all age groups ($p=.005$). This sex ratio difference could be due to two circumstances. First the behavior of females during spawning prevented them from being caught in any great numbers. Harrington (1947) observed 20-25 males following an individual female. This would heighten the possibilities of males being caught in our nets. Secondly, it is quite probable that actual spawning occurred in areas different than those where our nets were set (i.e. rock piles closer to the breakwater jetties where strands of eggs could be strewn). Tsai and Gibson (1971) reported very dissimilar results on the Patuxent River in Maryland. They stated that the height of the spawning period the sex ratio of perch was 1:1. Discrepancies could be caused by gear differences as they were using trap nets.

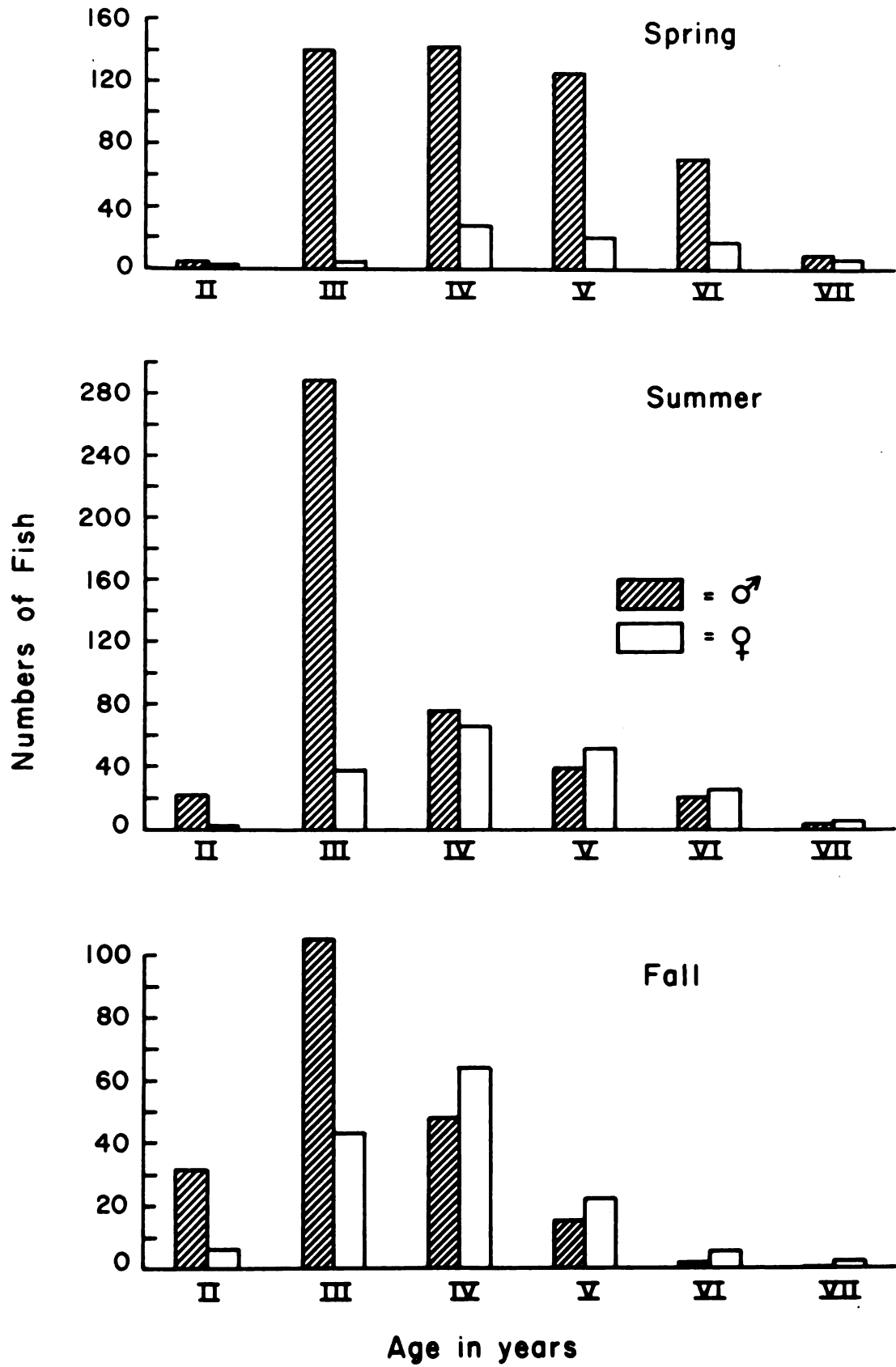
Partly spent males continued to be taken long after the last ripe female was caught. Phenomena of this sort were also reported by Tsai and Gibson (1971) and Muncy (1962). They observed that males came into the spawning

area of the Severn and Patuxent Rivers of Maryland several days before the females, and males remained there long after the females had left. El-Zarka (1959) claimed similar results for perch in Saginaw Bay.

Males comprised 69.5% of the summer catch by numbers. Again this sex ratio was highly significant ($p=.01$) when using a Chi-square test. A test of age groups to detect where the variation lay revealed that age groups IV-VII had no significant difference between the number of males and females. In fact females were slightly more abundant (Figure 7). Significant differences were detected in age groups II and III. Females comprised only 11.6% of age III fish and only 4.3% of age II perch. Reasons for this are not clear. Some possibilities may be suggested. First, males may mature earlier than females and the males would then demonstrate different behavior patterns. This aspect was discussed earlier indicating how males are especially more active during the spawning season. Secondly, different growth rates may play an important role. Females in this population have been shown to grow faster than males. By cropping off early developed females, the sex ratio would be shifted toward males at a later date when males reach a larger size.

The fall collection period exemplified the same sex ratio features as summer. Results for all ages combined were not significant. All age groups combined revealed

Figure 7.--Seasonal sex ratios of different age classes of yellow perch from Lake Michigan.



57.8% males by numbers. Again, age classes IV-VII exhibited no significant differences (in fact, slightly more females than males were taken in each age group). Three-year-old fish were composed of 29.2% females, while females comprised only 16.2% of age group II (Figure 7). Factors responsible for sex ratio discrepancies in the summer may be influencing the fall ratio as well.

Beckman (1949) reported similar sex ratios by age class in the inland waters of Michigan. He stated that males become scarcer in older year classes and are more prevalent in younger age groups.

Gonadal Development

Development of the ovaries was traced throughout the year to yield a spawning or fecundity index. Ovary development was measured as a ratio of ovary weight to total body weight. Weighted means for each age class were plotted versus collection time as seen in Figure 8. This procedure was used because individual ovary weights varied widely within an age group. Ovary weight as a percentage of body weight generally increased smoothly for all age classes from April to May and reached 20-25% immediately prior to spawning. This agrees quite well with LeCren's (1951) data for European perch. However, he stated that the ovary weight-body weight ratio does not differ with different age fish. Observations in this study indicated

that older and larger fish tend to have higher ovary weight-body weight ratios (Figure 8) than younger and smaller females.

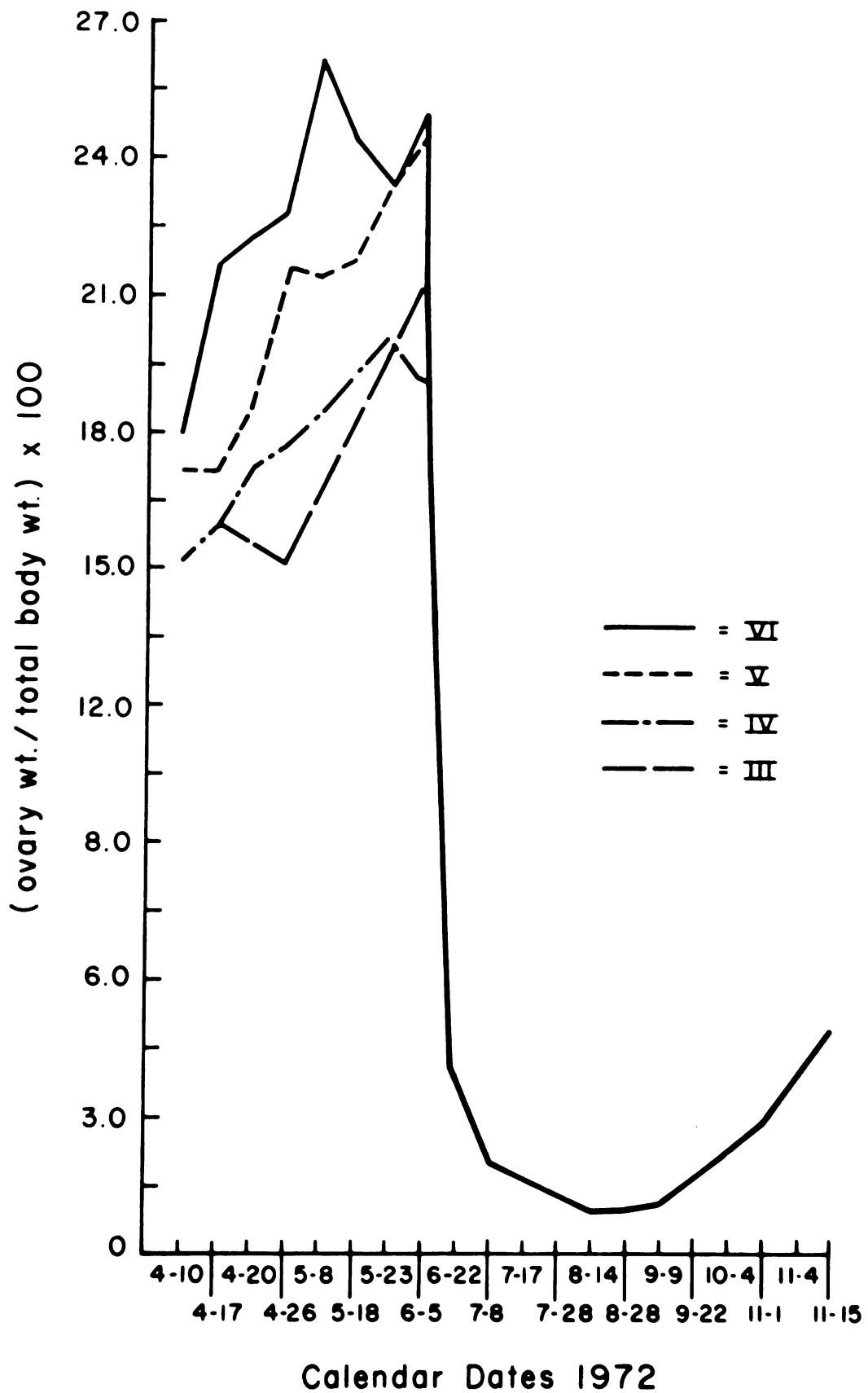
After reaching their peak percentage, the ovary weight-body weight ratios declined sharply after spawning (Figure 8). Values were approximately 2% for all age classes by July 8. The ovaries continued to shrink to approximately .8% of the body weight for all age classes and remained at that level for the remainder of the summer. This could be termed the spent condition in females and was characterized by the complete absence of individual ova visible to the naked eye.

In September, ovarian weights began to increase again and had reached 4-5% of the body weight by mid-November (Figure 8). The state of the ovary was termed green during this period and was characterized by individual ova visible to the naked eye. The low percentages in the middle of November indicated that some development of the ovary must occur through the winter to attain the 15-18% level by April of the following year.

Maturity and Fecundity

All fish taken older than age I were mature, while all age I perch were immature. Two age II females taken in the summer were of questionable maturity. It was difficult to discern if they had spawned in the spring

Figure 8.--Development of yellow perch ovaries through the year expressed as a ratio of ovary weight to total weight. Year classes were not kept separate after June 5 because of proximity of values.



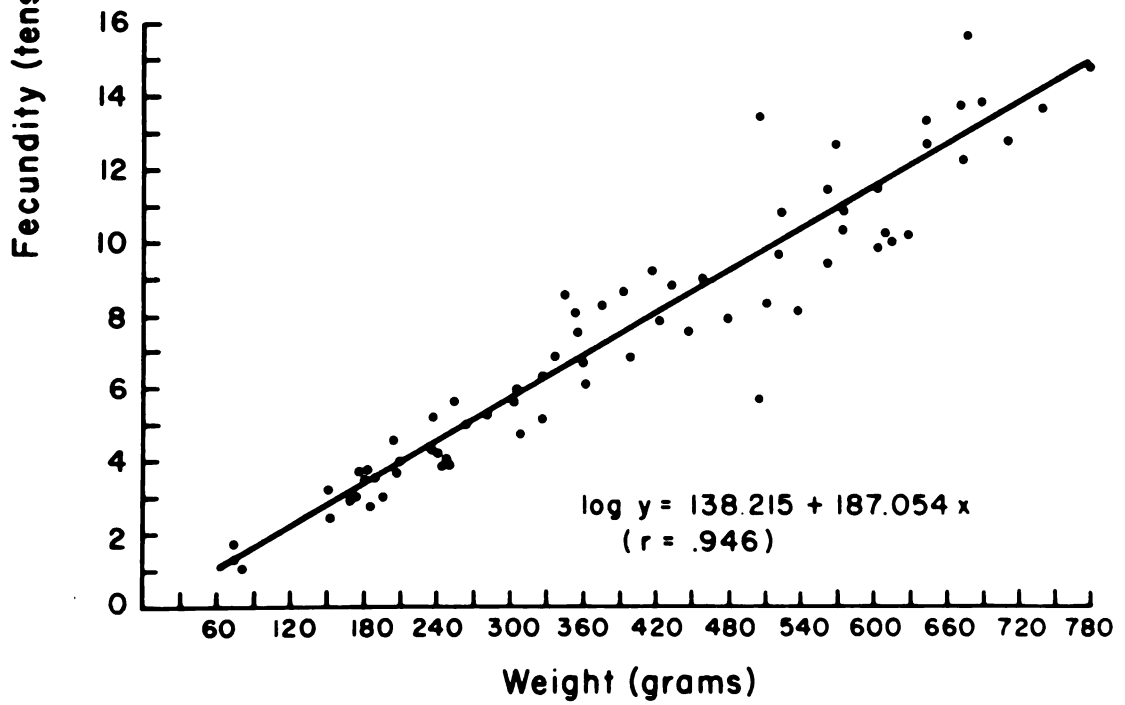
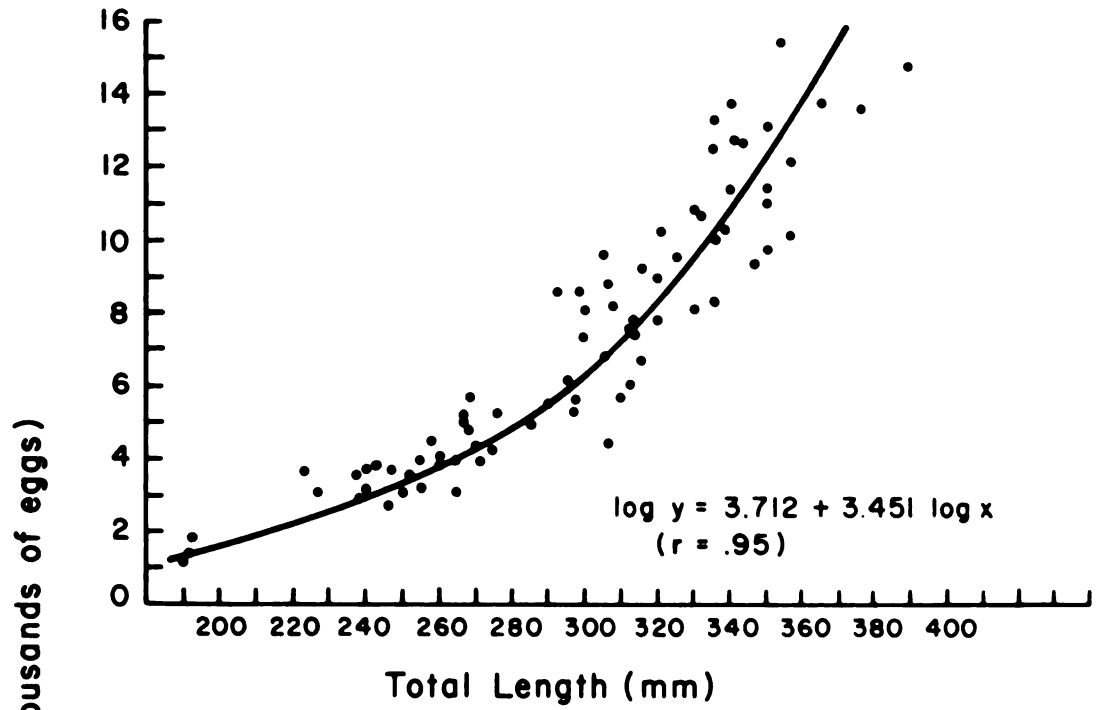
and were now spent, or if the ovary was just maturing for spawning the following spring. All age II males collected were mature. LeCren (1958) and Muncy (1962) both stated that 100% of the females are not mature until the third year and that males are usually mature by the second year. Differences in age of maturity of females among these studies may be attributed to gill net selectivity in that only the larger, faster growing age II females were collected by our study.

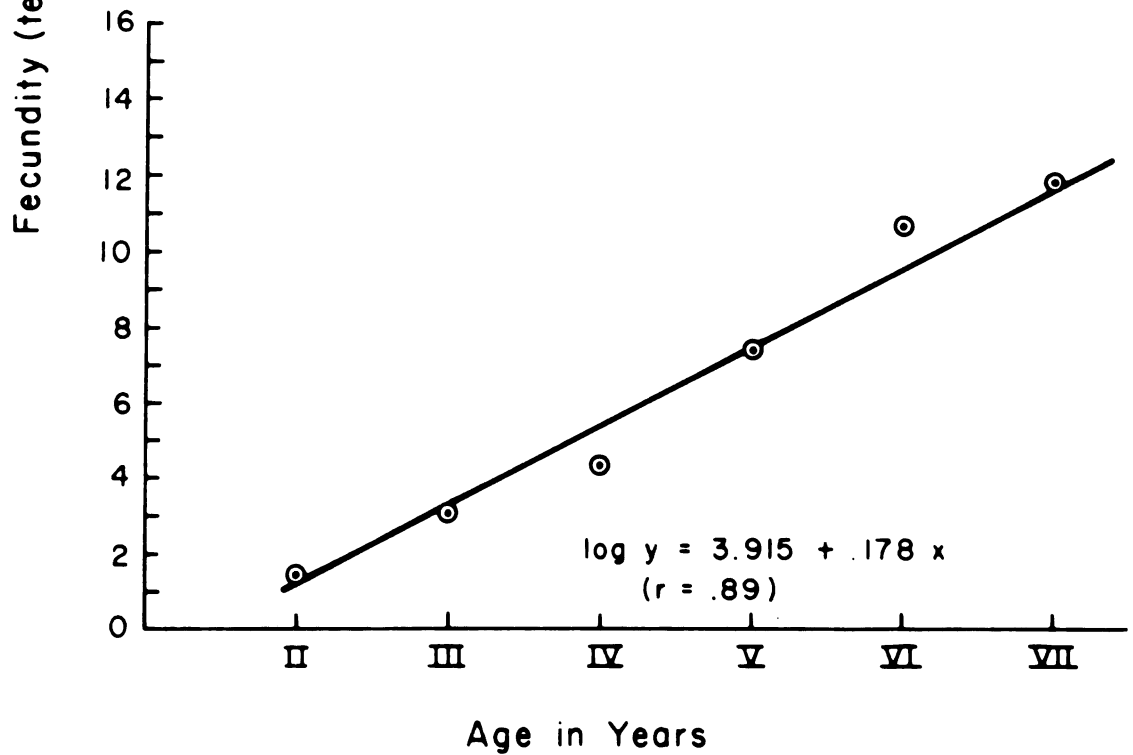
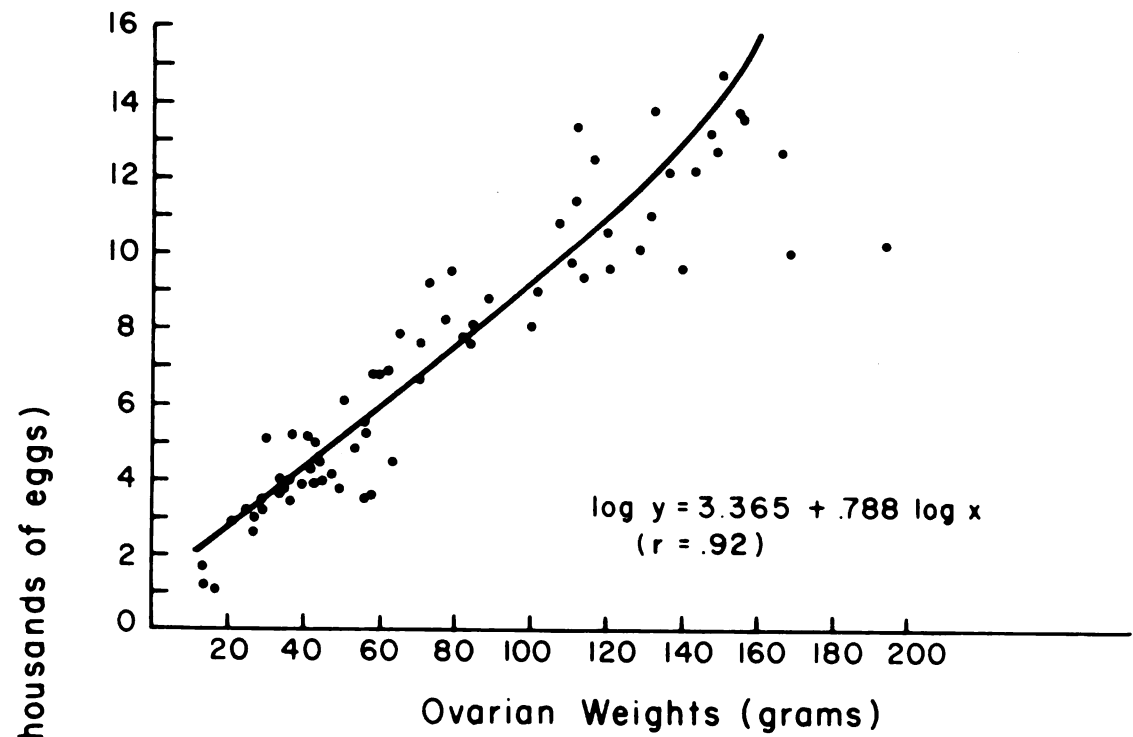
Ninety-six female perch were used for fecundity studies. Regression analysis by the least squares method was used because of its predictive value. Fecundity was compared to four different body features: length, weight, ovary weight, and age. A two-year-old female (190mm length, 82g weight) produced the fewest eggs (10,654), while 157,599 eggs were produced by an age VI fish that was 354mm total length and weighed 678g. Overall fecundity of perch from Lake Michigan was much higher than Tsai and Gibson (1971) reported for an estuarine situation in Maryland. Sheri and Power (1968) also observed lower values in perch from Lake Ontario. Fecundity for perch from Maryland ranged from 5,266 eggs in the smallest fish to 75,715 eggs in the largest fish (Tsai and Gibson, 1971). Perch from Lake Ontario ranged from 3,035 individual ova in the smallest fish to 61,465 ova in the largest fish. Sheri and Power's (1968) work may not be comparable as they classified the

eggs into three groups: ripe, atretic, and immature, and then counted only the ripe eggs. From observations on perch in the Ludington area it appeared that no such distinction among eggs could be made and all ova were counted. The major portion of the differences in fecundity estimates may be attributed to differences in size of fish. Lake Michigan perch were by far the largest fish of the three populations.

Fecundity plotted against total length (Figure 9) produced a curved line indicating exponential relationship. A logarithmic equation was then developed: $\log y = -3.712 + 3.451 \log x$, where y =number of eggs and x =total length in millimeters. The correlation was significant ($r=.95$). This slope was much steeper than the slope for Lake Ontario fish, but slightly lower than the slope for Patuxent River fish. Number of eggs produced ranged from 10,654 ova for a female 175mm fork length to 148,287 ova in a fish that was 358mm fork length. Egg production of small fish from Ludington and small fish from Lake Ontario (Sheri and Power, 1968) are comparable, but large fish from Ludington produced almost twice as many eggs as the largest perch from either Lake Ontario or the Patuxent River. However, the largest perch from these populations were only 257mm fork length and 290mm fork length, respectively. Since an exponential relation exists between fecundity and length, any small increase in length would produce an even more pronounced increase in egg production.

Figure 9.--Relationship of fecundity to four body features as predictors: fish length, fish weight, ovary weight, and fish age. Curves are fitted by inspection.





MacGregor (1968) observed fecundity is proportional to body weight, and this is substantiated by Tsai and Gibson (1971). Data for perch from Lake Michigan add evidence to support this conclusion. Fecundity was regressed against body weight both linearly and logarithmically. Resulting correlation coefficients were almost identical ($r=.946$ and $.957$, respectively). The derived equation was $y=138.215 + 187.054x$, where x =the body weight of the perch. Tsai and Gibson (1971) seem to have misinterpreted their regression analysis as they reported a negative intercept value, yet their actual plot indicates a positive value as is the case for my study. For all females observed, fecundity ranged from 13,579 ova for female weighing 79 grams to 148,287 eggs for a female weighing 780 grams. These weights are much heavier than perch observed in Lake Ontario (308.4g largest fish) or in the Patuxent River, Maryland (411g largest fish).

Ovarian weight was also plotted against fecundity. Sheri and Power (1968) found a semi-logarithmic function with a correlation of $.84$. However, when running a log-log regression analysis a much higher correlation ($r=.92$) between the two variables was obtained for perch from Lake Michigan. The equation that best fits this relationship is: $\log y=3.365 + .788 \log x$, where x =the weight of the ovary in grams. Perch ovarian weights ranged from 3.4g to 111.5g for Lake Ontario fish (Sheri and Power, 1968).

On the other hand perch from Lake Michigan had ovarian weights from 12.2g-198.2g. Observations also revealed that perch from Lake Michigan averaged approximately 1,000 eggs per gram of ovary weight. The upper limit for Lake Ontario fish was 1,073 eggs per gram of ovary weight. Implications are that perch in the Ludington area of Lake Michigan are much more fecund than perch from other areas. This high reproductive potential may be a reflection of the present environmental conditions.

Fecundity generally increased with age in a semi-logarithmic fashion. But variation within an age group was quite large and the number of eggs produced by a single female could fit into two or possibly three different age groups. Therefore, the mean number of eggs produced for each age class was plotted as a single point versus that age class (Figure 9). The relationship was described by the equation $\log y = 3.915 + .178x$ ($r = .89$), where x = the age of the fish. The number of eggs produced ranged from 10,266 for an age II fish to 148,287 ova for a seven-year-old fish.

Food Habits

For the best analysis possible food categories were described in three ways: per cent frequency of occurrence (%FO), per cent of the total volume (%TV), and per cent of the total organisms eaten (%TO). This procedure was used because a food item such as a crayfish or fish may have a

large volume but contributes a relatively smaller amount to the total number of organisms eaten. The opposite situation may be true when evaluating small food organisms as the amphipod Pontoporeia affinis. Perch were grouped into three size classes: fish smaller than 135mm total length, fish from 135-235mm, and fish larger than 235mm total length. These ranges were established to correspond to age 0 and I fish, age II and III fish, and fish older than III, respectively. Hopefully, differences could be detected in feeding habits with increasing size.

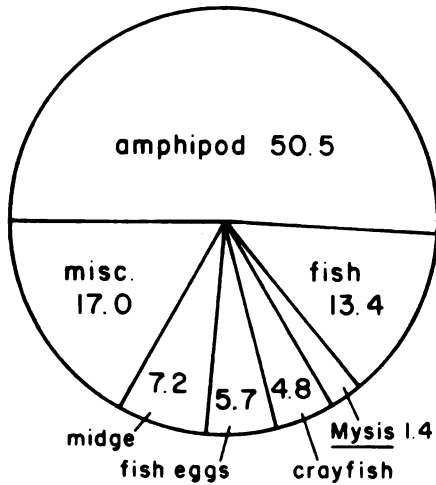
Seasonal and Size Differences

No fish of the smallest size class were taken in the spring. Of the 89 fish in the middle size class, 60.7% had empty stomachs. Stomachs of 205 large fish were examined and of these, 60.5% were empty. This large percentage of empty stomachs may have been due to cessation of feeding at spawning time. A Chi-square test indicated that there was no significant difference between the sexes relative to empty stomachs.

Amphipods (Pontoporeia) were the most significant food item eaten by middle size class perch. Pontoporeia predominated in all categories: %FO, %TV, and %TO (Table 5 and Figure 10). Miscellaneous material (including unidentified organic material, one stonefly, and one mayfly) was equal in occurrence with chironomid larva at 28.6% FO. However, midge larva only contributed 7.2% and 3.2% to the

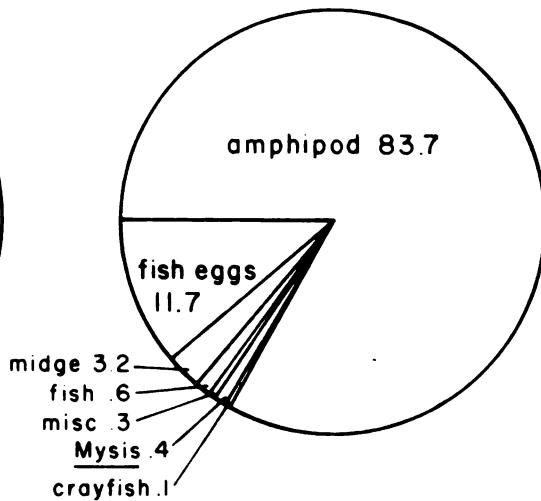
Figure 10.--Composition by numbers and volume of spring foods of yellow perch.

135-235 mm



% T.V.

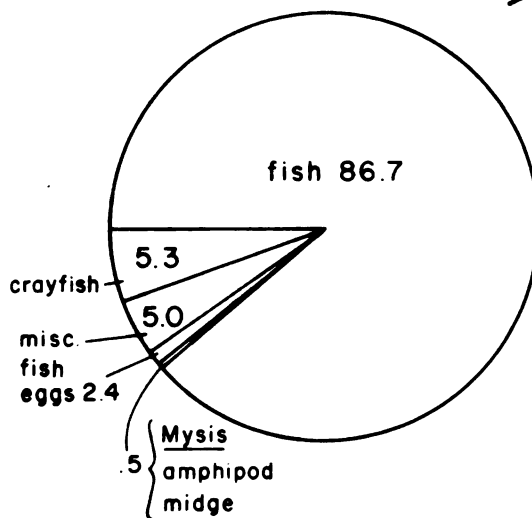
Average vol. (cc) .3



% T.O.

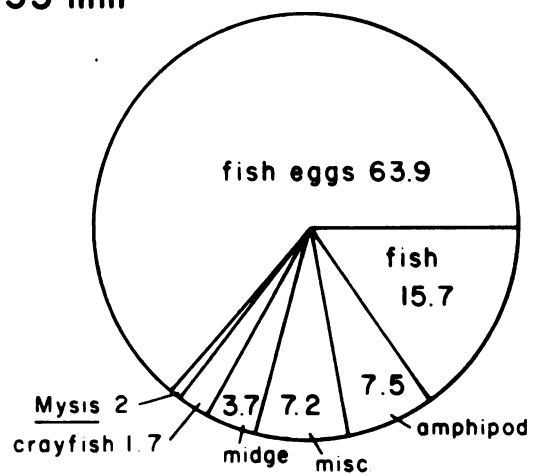
Average number org. 19.8

> 235 mm



% T.V.

Average vol. (cc) 1.8



% T.O.

Average number org. 4.8

TABLE 5.--Frequency of occurrence of taxa eaten by different sizes of yellow perch in different seasons of the year.

%FO by Season										
Size of Fish (mm)	Spring			Summer			Fall			
	<135	Intm	>235	<135	Intm	>235	<135	Intm	>235	
Number Examined	0	89	205	8	174	149	7	81	168	
Number Empty	0	54	122	1	62	53	0	48	68	
<u>Food Items</u>										
<u>Cladocera</u>	-	-	-	85.7	tr.	-	42.8	6.1	-	
<u>Amphipod</u>	-	40.0	4.8	28.5	25.0	2.1	-	48.5	21.0	
<u>Mysis</u>	-	5.7	1.4	14.3	16.9	-	-	3.5	4.0	
<u>Midge Larva</u>	-	28.6	9.6	57.1	24.9	-	14.3	15.1	2.0	
<u>Fish Eggs</u>	-	2.9	4.8	-	15.2	1.0	-	-	1.0	
<u>Crayfish</u>	-	2.9	7.2	-	11.6	30.2	14.3	3.5	27.0	
<u>Fish</u>	-	11.4	71.0	14.3	26.8	85.4	85.7	30.3	55.0	
<u>Miscellaneous</u>	-	28.6	9.6	14.3	13.4	2.1	-	27.3	13.0	

total volume and total organisms eaten, respectively, by this size class in the spring. Fish were fourth in occurrence at 11.4%. Their contribution to the total volume was high, but very few fish were eaten. Fish eggs, crayfish, and the opossum shrimp (Mysis) all comprised minor portions of the diet of middle sized fish in the spring. Fish eggs were second only to amphipods in numbers eaten, but this was due to ingestion of large amounts of eggs by a few fish.

Fish were dominant in the diet of perch larger than 235mm in the spring. Sculpins (Cottus) and unidentified fish remains comprised 79% of the total volume eaten. Other fish species (Pungitius pungitius, nine-spine stickleback; and Etheostoma nigrum, johnny darter) contributed only minor portions (Figure 10). All other food categories occurred only 1.5-9.5% of the time and added very little to the total volume. Fish eggs added the most to total organisms eaten but were very low in %FO. Again this is a reflection of a few fish ingesting large numbers of eggs. One perch contained 26 large leeches in its stomach.

Feeding activity was at its peak in the summer. This was probably the result of higher temperatures causing increased activity. Fish from the smallest size class to the largest exhibited 12.3%, 35.6%, and 35.6% empty stomachs, respectively. Testing by Chi-square revealed females in the upper two size classes had significantly fewer empty stomachs than did males ($p=.005$).

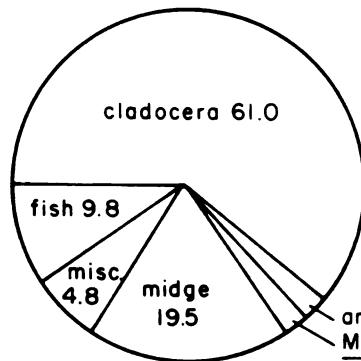
Small size fish in the summer fed chiefly on cladocerans (85.7% FO, 92.3% TO). Midges and amphipods were also taken frequently, but contributed little to the total volume or total number of organisms eaten. Other minor food items eaten were Hydracrina (water mites), Mysis, and fish (Cottus).

In the intermediate size class in the summer, no food item occurred less than 10% of the time and no food item occurred more than 27% of the time. Pontoporeia, midge larva, and fish were the major food items eaten, all occurring about 25% of the time (Table 5). Fish contributed over 50% of the total volume eaten but comprised only 1% of the total numbers of food organisms eaten (Figure 11), indicating that some other food item was eaten in great quantities. Figure 11 indicates that amphipods (Pontoporeia) were eaten in great numbers. Fish eggs as a food item reached its peak in the summer. This is probably because many forage fish species had come into the area to spawn and perch themselves had recently spawned. Eggs are not always eaten immediately after spawning as evidenced by the number of "eyed" eggs found in perch stomachs. Insignificant amounts of pelecypods (Sphaerium), gastropods (Helisoma), Hirudinea (leeches), and cladocerans were also eaten occasionally.

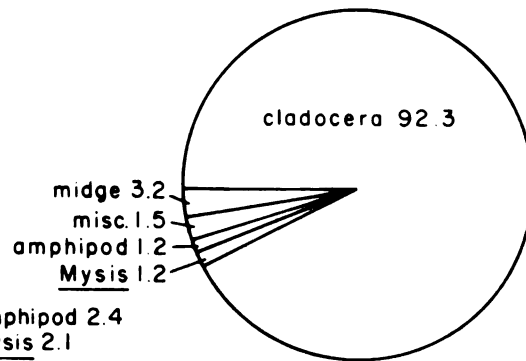
Fish were again the major food items consumed by large perch in the summer. However, there was a major shift

Figure 11.--Composition by numbers and volume of summer foods of yellow perch.

< 135 mm

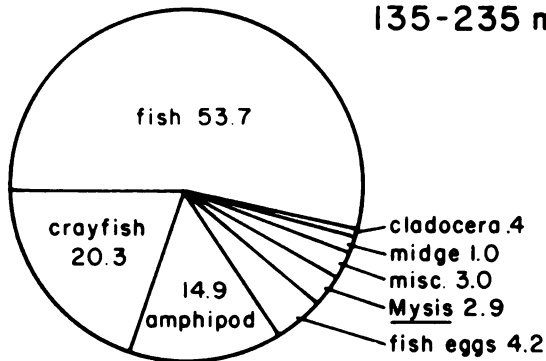


% T.V.
Average vol.(cc) .4

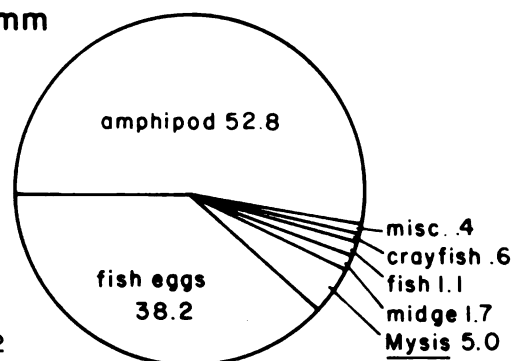


% T.O.
Average number org. 32.7

135-235 mm

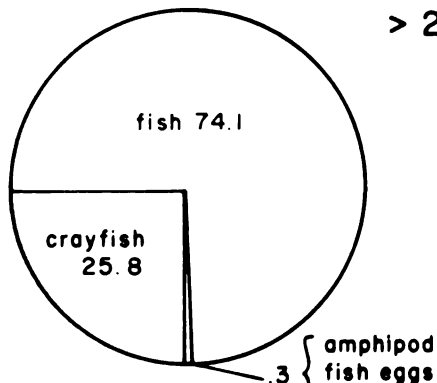


% T.V.
Average vol. (cc) .7

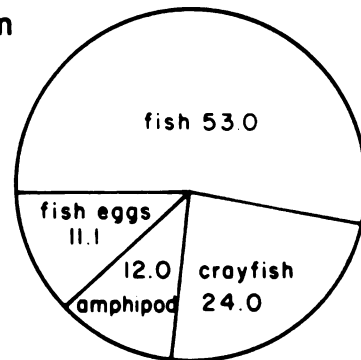


% T.O.
Average number org. 24.3

> 235 mm



% T.V.
Average vol. (cc) 3.9



% T.O.
Average number org. 2.3

in fish species eaten. In the spring sculpins comprised the bulk of prey fish, but in the summer sculpins constituted only 6.2% of the total volume eaten. Unidentified fish remains occurred most frequently. This was probably due to increased digestion rate in the summer. By species, the nine-spined stickleback and the alewife contributed 25.4% and 27.9% to the total volume, respectively. The large volume of alewives was contributed by only a few individuals indicating that one alewife may be worth more to the perch per unit of capture effort. A few johnny darters were also eaten. Crayfish were the second most important food item, occurring in 30.2% of the stomachs. In fact, crayfish and fish combined composed 99.6% of the total volume eaten in the summer (Figure 11). Crayfish were all of the genus Orconectes. Only trace amounts of amphipods and fish eggs were found. No Mysis, midge larva, or other invertebrates were consumed.

Fall feeding habits were similar to spring habits. Of the seven perch taken in the smallest size class all contained some food. Perch in the middle size range had 59.3% empty stomachs. Observations on fish in the largest size class revealed 40.5% with empty stomachs. Chi-square analysis of the latter two size groups disclosed significantly fewer empty stomachs in females than in males ($p=.005$).

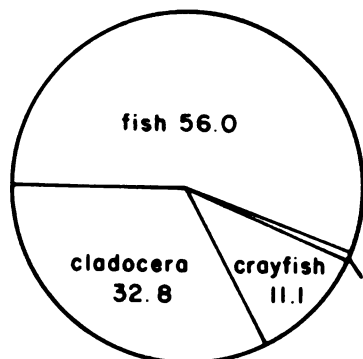
Even small perch were piscivorous in the fall period. Fish constituted 56.0% of the total volume of food eaten, and were present in 85.7% of the stomachs of fall fish for this size class (Table 5, Figure 12). Cladocerans were the only other food item present in significant amounts. One fish had eaten approximately 580 cladocerans, therefore yielding a very high %TO for this food item. Actual %FO was only 42.8% for cladocerans. Minor amounts of midges were also ingested.

Amphipods were again the major food item in the diet of intermediate size perch, 48.5% FO, constituting 47.7% of the total volume, and composing 91.1% of the total organisms. Miscellaneous items (snails, Helisoma and Physa; clams, Pisidium; and unidentified organic material) and fish occurred in almost equal amounts, 27.3% and 30.3%, respectively. However, fish added 44.4% to the total volume. Cladocerans, Mysis, fish eggs, and crayfish were eaten with some consistency but comprised only small portions of the total volume and total organisms eaten.

Diets of the largest size perch were predominantly fish. Of the 100 fish containing food, 55% had eaten some species of fish. Unidentified fish remains made up the largest percentage, but sculpins were a close second. In fact, sculpins constituted the bulk of the total volume of fish eaten. Nine-spine sticklebacks were completely absent and only a few johnny darters and alewives had been consumed.

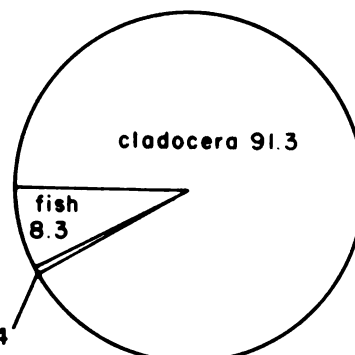
Figure 12.--Composition by numbers and volume of fall foods
of yellow perch.

< 135 mm



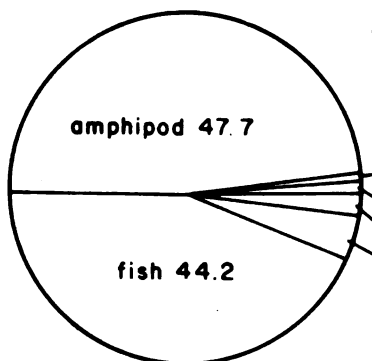
% T.V.
Average vol. (cc) .3

midge .1
midge
crayfish } .4



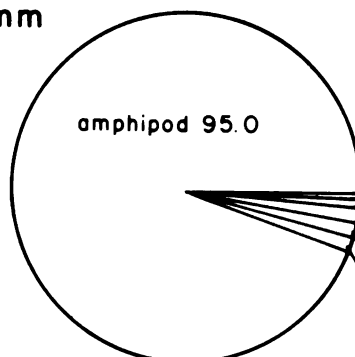
% T.O.
Average number org. 34.1

135-235 mm



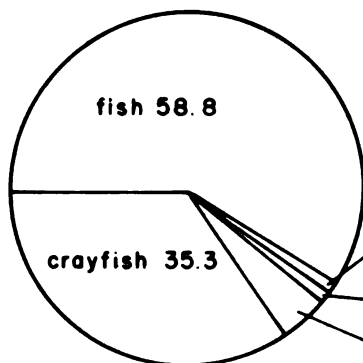
% T.V.
Average vol. (cc) .4

Mysis .3
midge .9
crayfish 2.1
misc. 4.6



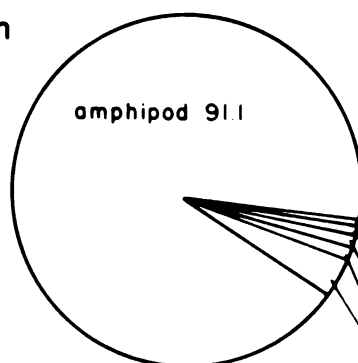
% T.O.
Average number org. 25.1

> 235 mm



% T.V.
Average vol. (cc) 3.1

fish eggs .5
Mysis, midge, misc. .5
amphipod 4.8



% T.O.
Average number org. 18.7

{ midge .7
misc .7
fish eggs 1.0
Mysis 1.2
crayfish 2.3
fish 3.7

Crayfish appeared in 27% of the stomachs and added 35.3% to the total volume. Ninety-four per cent of the total volume of food eaten consisted of crayfish and fish combined. However, amphipods contributed 91.1% of the total number of organisms ingested, while occurring in 21.0% of the stomachs (Table 5). This indicated that the fish which did eat amphipods consumed them in great numbers. Miscellaneous food items as snails, clams, and unidentified material occurred 13.0% of the time but added negligible amounts to the total volume. Other food categories were rarely found in the fall and contributed insignificant numbers and volumes to the total.

For this perch population the size of the fish had a definite bearing on what it ate. Another interesting trend was the average volume and average number of organisms eaten per fish in each size class. These values were based only on perch stomachs that contained food. For all seasons, apparently the average volume eaten per fish increased with fish size, but the average number of organisms eaten decreases with size (Figures 10, 11, and 12). This appears to follow fish physiology and energy flow theories quite well. It takes less effort to capture one large food item than many small ones. Thus, the efficiency of food assimilation is greater when a few large items are captured.

Food Selectivity

As are most fish, perch appear to be opportunistic feeders rather than selective feeders. Sampling techniques for fish food organisms were rather poor, thus it is quite difficult to make firm statements about selectivity by these perch. Generally, amphipods were the most abundant bottom organisms present and likewise were the commonest invertebrate food item in the stomachs. Fish species eaten may show slight selectivity. Sculpins were eaten quite readily in the spring and fall. However, this is practically the only forage species present at these times. In the summer an influx of spawning nine-spine sticklebacks, johnny darters, alewives, and spottail shiners occurred. Sculpins were still present as indicated by sporadic trawling efforts (personal data). But few sculpins were eaten in the summer. This may be due to the larger number of other forage fish available. Spottail shiners were neglected completely, even though they were present in large numbers during the summer.

Previously this research indicated that female perch were significantly longer and heavier than their male counterparts at given ages. After closely scrutinizing the food data, two possible causes for this phenomenon may be evaluated. One possible explanation is differences in the diet of older fish. During the summer and fall periods, nineteen perch were collected that had eaten alewives. Of

these 19, 17 or 90% were females. A simple Chi-square test with one degree of freedom revealed that this difference was highly significant ($p=.005$). The size of females eating alewives ranged from 235-345mm total length. The two males fell in the upper third of this range, indicating that this is not a simple size difference as females much smaller than the males were eating alewives.

A second possible explanation is that females eat more often or more constantly than males. This would be reflected in higher numbers of females having food in their stomachs. Such was the case during the summer and fall periods (pp. 60 and 64). Females for all size classes consistently had significantly fewer empty stomachs than did males. These two previous hypotheses attempt only to explain the size difference between males and females. In reality many other factors may also be involved.

Summary

1. Ecological studies were made on Lake Michigan in the immediate vicinity of Ludington to check the effect of operation of a giant pumped storage plant in the area.

2. Perch were chosen owing to their importance as a sport fish.

3. Various methods and materials were used to gather all necessary data. The research area was described.

4. Perch exhibited definite seasonal patterns in activity and abundance.

5. Three-year-old fish, year class 1969, dominated the catch throughout the year. Age IV and age V were also well represented.

6. Length-weight relationships of perch from Lake Michigan near Ludington indicated these perch were longer and heavier than perch from other waters in the Great Lakes area. Reasons for such phenomena were discussed.

7. Perch from Lake Michigan were likewise in better condition.

8. Growth progressed through the year much as described for other perch populations.

9. Spawning activity was similar to other areas. Peak spawning time was from the middle of May to the third week in June. Temperature at this time was around 10°C.

10. Sex ratios were aberrant for all age classes in the spring, but were aberrant for only age II and III fish during the rest of the year. Reasons for these occurrences were evaluated.

11. Ovarian development peaked just prior to spawning and then dropped off drastically. In September the ovary began enlarging again.

12. Fecundity relationships indicated that perch from Lake Michigan produced more eggs than perch from Lake Ontario or from the Patuxent River. This may be due to the larger size of perch from Lake Michigan.

13. Amphipods were the major food item for perch from 135-235mm total length throughout the year. The diet of fish larger than 235mm consisted mainly of fish and crayfish. However, forage fish species shifted through the year.

14. Food selectivity was difficult to establish. Feeding differences may account for female perch being larger than males.

LITERATURE CITED

LITERATURE CITED

1. Allen, K. R. 1935 The food and migration of the perch (Perca fluviatilis) in Windermere. J. Animal Ecol. 4: 264-273.
2. Beckman, William C. 1948. The length-weight relationship, factors for conversions between standard and total lengths, and coefficient of condition for seven Michigan fishes. Trans. Amer. Fish. Soc. 75: 237-256.
3. Beckman, W. C. 1949. The rate of growth and sex ratio for seven Michigan fishes. Trans. Amer. Fish. Soc. 76: 65-70.
4. Coots, M. 1956. The yellow perch, Perca flavescens (Mitchill) in the Klamath River. Calif. fish and game. 42: 219-228.
5. El-Zarka, S. E. 1959. Fluctuations in the populations of yellow perch in Saginaw Bay, Lake Huron. U. S. Fish. Wild. Serv. Fish. Bull. 59: 365-415.
6. Ewers, Lela. 1933. Summary report of crustacea used as food by the fishes of the western end of Lake Erie. Trans. Amer. Fish. Soc. 63: 378-390.
7. Ewers, Lela A. and M. W. Boesel. 1935. The food of some Buckeye Lake fishes. Trans. Amer. Fish. Soc. 65: 57-69.
8. Forney, John L. 1971. Development of dominant year classes in a yellow perch population. Trans. Amer. Fish. Soc. 100(4): 739-749.
9. Gibbons, J. Whitfield and David H. Bennett. 1972. Food of largemouth bass (Micropterus salmoides) from a South Carolina reservoir receiving heated effluent. Trans. Amer. Fish. Soc. 101(4): 650-654.
10. Harrington, R. W. 1947. Observations on the breeding habits of the yellow perch, Perca flavescens (Mitchill). Copeia 1937: 199-200.

11. Hergenrader, G. L. 1969. Spawning behavior of Perca flavescens in aquaria. Copeia 1969: 839-841.
12. Hergenrader, G. L. and Arthur Hasler. 1968. Influence of changing seasons on schooling behavior of yellow perch. J. Fish. Res. Bd. Can. 25: 711-716.
13. Herman, E., W. Wisby, L. Wigbert, and M. Burdick. 1959. The yellow perch, its life history, ecology, and management. Wisc. Cons. Dept. Madison Publ. (228): 1-14.
14. Heyerdahl, E. G. and Lloyd Smith, Jr. 1971. Annual catch of yellow perch from Red Lakes, Minnesota, in relation to growth rate and fishing effort. Agri. Exp. Stat. Univ. Minn. Tech. Bull. 285.
15. Hile, R. and F. W. Jobes. 1941. Age, growth, and production of the yellow perch, Perca flavescens (Mitchill), of Saginaw Bay. Trans. Amer. Fish. Soc. 70: 102-122.
16. Hile, Ralph and F. W. Jobes. 1942. Age and growth of the yellow perch, Perca flavescens (Mitchill), in Wisconsin waters of Green Bay and northern Lake Michigan. Papers Mich. Acad. Sci., Arts and Letters. 27: 241-266.
17. Jobes, F. W. 1952. Age, growth, and production of yellow perch in Lake Erie. U. S. Fish. & Wild. Serv. Fish. Bull. 52: 205-266.
18. Joeris, L. S. 1957. Structure and growth of scales of yellow perch of Green Bay. Trans. Amer. Fish. Soc. 86: 169-194.
19. Kilambi, R. V. and R. E. Baglin, Jr. 1969. Fecundity of the gizzard shad, Dorosoma cepedianum (LeSuer) in Beaver and Bull Shoals Reservoirs. Amer. Mid. Nat. 82: 444-449.
20. Langford, R. R., and W. R. Martin. 1941. Seasonal variations in stomach contents and rate of growth in a population of yellow perch. Trans. Amer. Fish. Soc. 70: 436-440.
21. LeCren, E. D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). J. Animal Ecol. 20: 201-219.

22. LeCren, E. D. 1958. Observations on the growth of perch (Perca fluviatilis L.) over twenty-two years with special reference to the effects of temperature and changes in population density. J. Animal Ecol. 27: 287-336.
23. Liston, Charles R. and Peter I. Tack. 1972. A study of the effects of installing and operating a large pumped storage project on the shores of Lake Michigan near Ludington, Michigan. Mich. State Univ. Fifth Quarterly Report to Consumer Power. 35 pp.
24. MacGregor, J. S. 1968. Fecundity of the northern anchovy, Engraulis mordax Girard. Calif. Fish and Game 54: 281-288.
25. Mansueti, Alice J. 1964. Early development of the yellow perch, Perca flavescens (Mitchill). Chesp. Sci. 5: 46-66.
26. Minckley, W. L. and Willard E. Barber. 1971. Summer foods of the cyprinid fish Semotilus atromaculatus. Trans. Amer. Fish. Soc. 100(2): 283-289.
27. Mraz, D. 1952. Movements of yellow perch marked in southern Green Bay, Lake Michigan, in 1950. Trans. Amer. Fish. Soc. 81: 150-161.
28. Muncy, R. J. 1962. Life history of the yellow perch, Perca flavescens, in estuarine waters of Severn River, a tributary of Chesapeake Bay, Maryland. Chesp. Sci. 3: 143-159.
29. Parkhurst, Benjamin R. 1971. The distribution and growth of the fish populations along the western shore of Lake Erie at Monroe, Michigan during 1970. Inst. Water Res. Mich. State Univ. Tech. Rep. 17. 71 pp.
30. Parsons, J. W. 1930. Life history of the yellow perch, Perca flavescens (Mitchill) of Clear Lake, Iowa. Iowa State Col. J. Sci. 25: 83-97.
31. Pearse, A. S. and Henrietta Achtenberg. 1920. Habits of yellow perch in Wisconsin Lakes. Bull. U. S. Bur. Fish. (1917-1918). 36: 293-266.
32. Pycha, R. L. and L. L. Smith, Jr. 1955. Early life history of the yellow perch, Perca flavescens

- (Mitchill), in the Red Lakes, Minnesota. Trans. Amer. Fish. Soc. 84: 249-260.
33. Rawson, D. R. 1930. The bottom fauna of Lake Simcoe and its role in the ecology of the lakes. Univ. Toronto Stud. Publ. 34. Ontario Fish. Res. Lab. No. 40.
 34. Scott, D. E. Activity patterns of perch, Perca flavescens (Mitchell), in Rondeau Bay of Lake Erie. Ecology 36: 320-327.
 35. Sheri, A. N. and G. Power. 1969. Fecundity of the yellow perch, Perca flavescens (Mitchill), in the Bay of Quinte, Lake Ontario. Canad. J. Zool. 47: 55-58.
 36. Tharatt, R. C. 1959. Food of yellow perch, Perca flavescens (Mitchill) in Saginaw Bay, Lake Huron. Trans. Amer. Fish. Soc. 88(4): 330-331.
 37. Tsai, Chu-fa and George R. Gibson, Jr. 1971. Fecundity of the yellow perch, Perca flavescens (Mitchill), in the Patuxent River, Maryland. Ches. Sci. 12: 270-284.
 38. Turner, C. L. 1919. The seasonal cycle in the spermary of the perch. J. Morph. 32: 681-711.
 39. Van Oosten, J. 1934. The value of questionnaires in commercial fisheries regulations and surveys. Trans. Amer. Fish. Soc. 64: 107-117.
 40. Wagner, Wilbert C. 1972. Utilization of alewives by inshore piscivorous fishes in Lake Michigan. Trans. Amer. Fish. Soc. 101(1): 55-63.
 41. Wells, LaRue. 1968. Seasonal depth distribution of fish in southeastern Lake Michigan. U. S. Fish. and Wild. Serv., Fish. Bull. 67: 1-15.

MICHIGAN STATE UNIV. LIBRARIES



31293101280018