1984

A Comparison of the Temporal Spawning Distributions and Growth Rates of Young-of-the-year Redear Sunfish (Lepomis microlophus) and Bluegill (Lepomis macrochirus) in Three Illinois Impoundments

Craig Douglas Schmittler
Eastern Illinois University

THESIS REPRODUCTION CERTIFICATE

TO: Graduate Degree Candidates who have written formal theses.

SUBJECT: Permission to reproduce theses.

The University Library is receiving a number of requests from other institutions asking permission to reproduce dissertations for inclusion in their library holdings. Although no copyright laws are involved, we feel that professional courtesy demands that permission be obtained from the author before we allow theses to be copied.

Please sign one of the following statements:

Booth Library of Eastern Illinois University has my permission to lend my thesis to a reputable college or university for the purpose of copying it for inclusion in that institution's library or research holdings.

October 12 - 1984

Date

I respectfully request Booth Library of Eastern Illinois University not allow my thesis be reproduced because ______________________________

____

____

______________________ ______________________

Date Author

m

A Comparison of the Temporal Spawning Distributions and Growth Rates of Young-of-the-year Redear Sunfish (*Lepomis microlophus*) and Bluegill (*Lepomis macrochirus*) in three Illinois Impoundments

(TITLE)

BY

Craig Douglas Schmittler

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Master of Science in Zoology

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

1984

YEAR

I HEREBY RECOMMEND THIS THESIS BE ACCEPTED AS FULFILLING
THIS PART OF THE GRADUATE DEGREE CITED ABOVE

12 Oct. 84

DATE

12 Oct 84

DATE

12 Oct 84

DATE

12 Oct 84

DATE

TABLE OF CONTENTS

ACKNOWLEDGMENTS

I would like to express thanks to the following people for their help with my thesis research. Bill Dimond and Ted Storck helped with the collection of the fish from the three impoundments sampled and Bob Davis assisted in shocking Lake Land Pond to determine the adult population densities for both species of interest. Steve Miller showed me how to mount and read the otoliths and he and Bill Dimond assisted in verifying my daily ring counts. Ted Storck and Dennis Newman helped with the statistical analysis of the data and Steve Miller and Ted Storck critically reviewed the drafts of this paper. Thanks also to my advisor, Dr. Leonard Durham, for all his assistance.

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The purpose of this study was to compare the temporal spawning distribution and growth rates of bluegill (*Lepomis macrochirus*) and redear sunfish (*Lepomis microlophus*) in Illinois impoundments. Otolith sagittae were used to age the fish and to determine the intervals of successful spawning for both species.

Readear sunfish initiated spawning slightly before or a the same time as bluegill; however, bluegill spawned for twice as long as redear sunfish in all study impoundments. The earliest spawned fish of both species showed the fastest growth and the earliest spawned redear sunfish grew faster than did the earliest spawned bluegill. Growth rates of both species declined constantly, decreasing for each day later in the summer that they were spawned. The length to age regressions were positively correlated showing that the growth rates of the fish declined constantly throughout the growing season. There was a direct relationship between otolith radius and fish length for both species, but the relationship seemed to be population specific and differed among impoundments sampled.

INTRODUCTION

Bluegill (*Lepomis macrochirus*), redear sunfish (*Lepomis microlophus*), and largemouth bass (*Micropterus salmoides*) are commonly stocked together in small impoundments. The bluegill populations are usually very successful while the redear sunfish frequently fail to sustain populations after the initial stocking. Reasons for the poor success of redear sunfish populations have not been determined. The purpose of this study was to examine aspects of the early life history stages of bluegill and redear sunfish in an effort to understand recruitment failure of redear sunfish.

The temporal spawning distributions and growth rates of the two species were contrasted to determine if these could contribute to differences in the success of either species. Comparisons between the species from the different lakes were also made to see if any differences in spawning intervals or growth rates could be attributed to the geographical location of the impoundment.

LITERATURE REVIEW

A common stocking combination used in small impoundments includes bluegill, redear sunfish, and largemouth bass. The bluegill and redear sunfish are introduced primarily as forage for the largemouth bass, but they also provide a panfish for the creel. Bluegill typically establish strong, multiple year-class populations, but redear sunfish are usually less successful (McCormick and Brigham 1979).

Redear sunfish are generally thought to spawn earlier and over a shorter interval than bluegill (Childers 1967). Poor reproductive success has been documented for redear sunfish (Gabelhouse 1978) and high turbidity (Buck 1956) and lack of vegetation (Gabelhouse 1978) are two factors that may limit their reproductive success. Climate may also be an important factor in the success of redear sunfish reproduction; McCormick and Brigham (1979) have shown that the success of redear sunfish populations decreases from south to north in Illinois. Overwinter mortality may also be greater for young-of-the-year redear sunfish than for bluegill (Gabelhouse 1978).

Growth rates may also be important in determining the success or failure of redear sunfish populations. Growth rates of young-of-the-year fish (mm/day) can be estimated from the length and age of the fish at capture. The age in days of young-of-the-year fish can be determined accurately using the sagittae of the otoliths (Pannella 1971, 1980). Taubert and Coble (1977) found daily rings in the otoliths (sagittae) of bluegill and two other species of Lepomis. Daily rings have also been found in the otoliths from young-of-the-year redear sunfish (Bill Dimond, Illinois Natural History Survey, personal communication). By counting these daily rings, the age of the fish in days after swim-up can be determined. The approximate date of spawning can then be determined by adding ten days to the age of the fish (Childers 1967). There is also evidence that otolith radius (mm) and fish length (TL) are correlated in largemouth bass (Miller and Storck 1982) and thus that increment thickness of the otolith directly reflects the growth of the fish. This study will examine this relationship to see if there is a similar correlation in redear sunfish and bluegill.

DESCRIPTION OF STUDY IMPOUNDMENTS

Three impoundments, chosen to cover a wide latitudinal range within Illinois (Figure 1), contained populations of bluegill and redear sunfish.

Washington County Lake (Table 1), located in southern Illinois, is a public fishing lake in the Washington County Conservation Area and is subject to heavy fishing pressure. The lake is owned and managed by the Illinois Department of Conservation. It has good shoreline development and an abundance of aquatic vegetation. Filamentous algae (Cladophora), brittle naiad (Najas minor), elodea (Elodea canadensis), coontail (Ceratophyllum demersum), sago pondweed (Potomogeton pectinatus), cattail (Typha sp.), American lotus (Nelumbo lutea), arrowhead (Sagittaria latifolia), and creeping waterprimrose (Jussiaea repens) are the most abundant plants present. American lotus is becoming a problem in the northern end of the lake, but none of the other plants occur at nuisance levels. Game and panfish species present include: bluegill, redear sunfish, largemouth bass, white crappie (Pomoxis annularis), black crappie (Pomoxis nigromaculatus), warmouth (Lepomis gulosus), green sunfish (Lepomis

Figure 1. Locations of the three study impoundments in Illinois; Washington County Lake (WCL), Lake Land Pond (LLP), and Dawson Lake (DL).

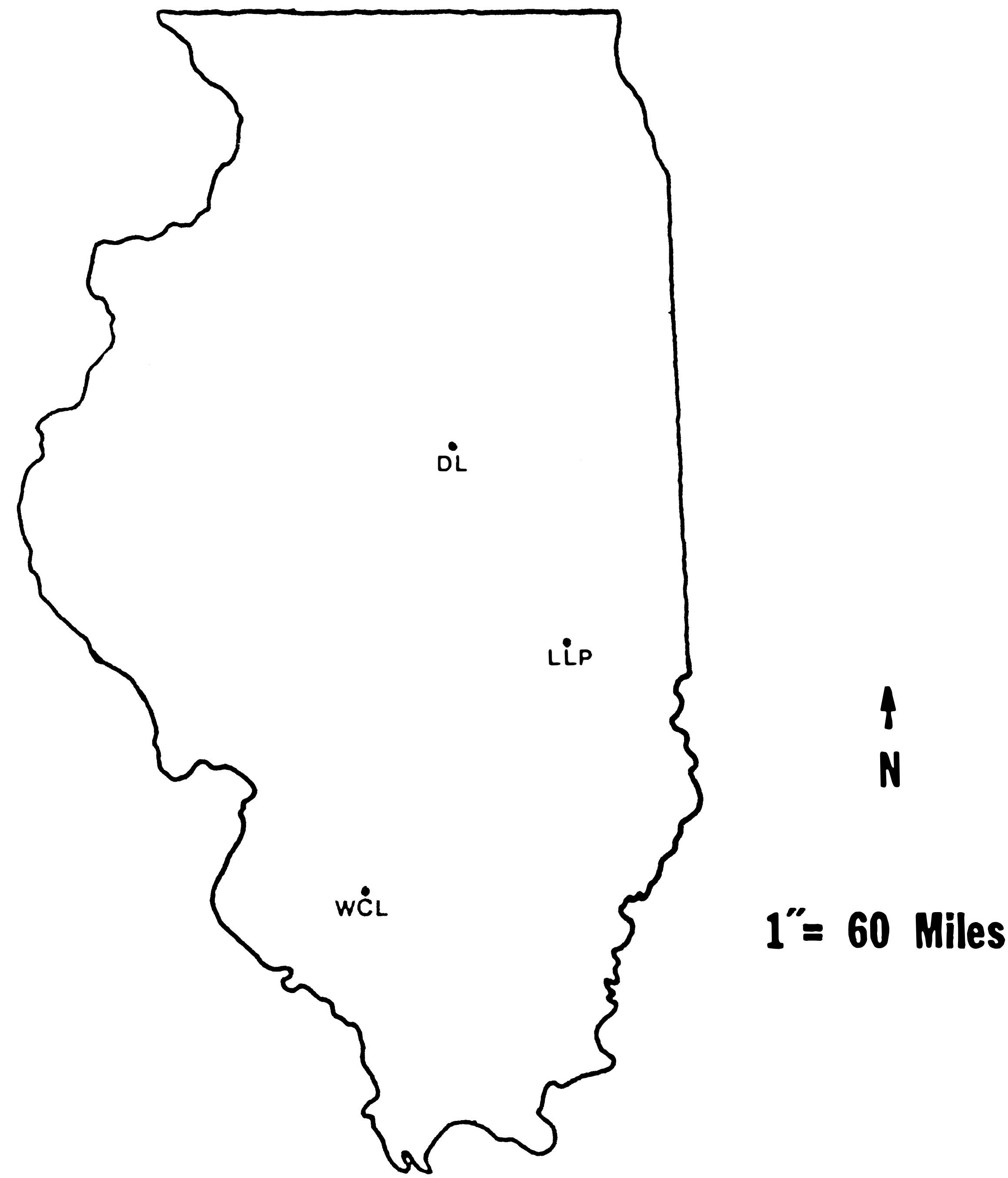

DL
LLP
WCL
N
1"= 60 Miles

Table 1. Description and locations of the three study impoundments.

	Washington County Lake	Lake Land Pond	Dawson Lake
Surface acres	248	3.2	158
Maximum depth (ft)	23.5	8.0	28.0
Mean depth (ft)	8.9	3.3	10.4
Miles of shoreline	12.4	1.7	5.4
Latitude	T3S, R2W, Sect. 18 5 mi S. of Nashville, Washington Co., IL	T11N, R7E, Sect. 11, 4 mi S. & 2 mi E. of Mattoon, Coles Co., IL	T23N, R4E, Sect. 26 & 35, 3 mi N. & 2 mi E. of LeRoy, McLean Co., IL

Table 2. The spawning intervals and mean spawning dates for redear sunfish and bluegill from all three impoundments.

	Washington County Lake	Lake Land Pond	Dawson Lake
Redear sunfish			
Spawning interval	19 May-22 June	29 May-7 June	31 May-27 June
Mean	5 June	2 June	13 June
Bluegill			
Spawning interval	23 May-1 August	20 May-28 July	10 June-13 August
Mean	26 June	24 June	11 July

cyanellus), and channel catfish (Ictalurus punctatus). Non-game fish species present include: carp (Cyprinus carpio), bigmouth buffalo, (Ictiobus cyprinellus), black bullhead (Ictalurus melas), yellow bullhead (Ictalurus natalis). Gizzard shad (Dorosoma cepedianum) and threadfin shad (Dorosoma petenense) are the major forage species present. This lake also contains an excellent population of freshwater prawns (Palaemonetes sp.) and too many minnow species to list. This lake was sampled on 10 September 1983 when the water temperature was 29.5 C.

A small pond on the campus of Lake Land Community College, Lake Land Pond (Table 1), was the second body of water sampled for this study. It is located in Coles County in central Illinois, approximately 130 miles northeast of the Washington County Lake. This pond is subject to moderate fishing pressure. This pond is similar to small farm ponds in the area and is subject to moderate fishing pressure. Cattails and rushes (Scirpus sp.) surround the pond and thick growths of algae (Cladophora and Spirogyra) are found throughout the pond. Fish species present include: bluegill, redear sunfish, largemouth bass, green sunfish, and channel catfish. Fish in the lake were sampled on 8 September 1983 when the water temperature was 26 C.

Dawson Lake (Table 1), was the third impoundment used in this study. It is located in McLean County about 100 miles north of Lake Land Pond in Moraine View State Park. This lake is also a public fishing lake and is subject to heavy fishing pressure. The dominant aquatic plant species present here include: creeping waterprimrose, muskgrass (Chara sp.), cattails, sago pondweed, southern naiad (Najas guadalupensis), curlyleaf pondweed (Potomogeton crispus), and filamentous algae (Spirogyra). None of these plants are considered overabundant. Game and panfish species present here include: bluegill, redear sunfish, largemouth bass, black and white crappie, green sunfish, channel catfish and northern pike (Esox lucius), which were introduced as fry in the summer of 1983. Carp and black bullheads are present in low numbers. Additional forage is provided by gizzard shad, threadfin shad, and golden shiners (Notemigonus crysoleucas). This lake was sampled on 11 September 1983 when the water temperature was 25.5 C.

METHODS

Age 0 bluegill and redear sunfish were collected from each impoundment using a standard minnow seine (3.0 m x 1.2 m, 3.2-mm mesh). Hauls were taken at randomly chosen locations to assure a representative sample. All specimens from each of the first twenty seine hauls were identified and counted in order to estimate relative abundance of the two species. Supplementary hauls were made in each lake to better estimate the size-structure and to increase the number of redear sunfish available for otolith-age analysis. All fish were preserved in 70% ethyl alcohol to protect the otolith microstructure (William and Bedford 1974).

All specimens were positively identified to species in the laboratory using length and thickness of the gill rakers (Pflieger

1975). After the fish were identified and sorted they were measured to the nearest mm total length (TL) and assigned to 5-mm length groups. Ten fish were taken from each 5-mm length group and their otoliths were removed to age the fish.

Otoliths (sagittae) were used to age the fish because they are the only means available to determine the age of young-of-the-year fish (Pannella 1971, 1980). The otoliths were removed by making an incision posterior to the eyes, down through the dorsal part of the cranium. The front part of the fish's head was then bent forward to expose the two otoliths in the semicircular canals. The otoliths were removed, dried, and mounted on microscope slides using a small drop of thermoplastic cement. Each slide was numbered and labeled with the fish's length (TL). Using 600-grit carborandum sandpaper, the otoliths were ground in the sagittal plane until the nucleus was exposed. This was achieved by alternately grinding and viewing the otolith until the nucleus stood out clearly. The otolith was then placed in a solution of 1% HCl for 15-45 seconds to etch the otolith and define the daily rings so they were more easily distinguished. The daily rings were counted at 100x and a drop of immersion oil was added to increase the resolution. Otolith preparation and reading methods generally followed those of Miller and Storck (1982).

Ten fish were aged from each 5-mm length group, or as many as were available if less than 10. To estimate the population age structure, the remaining fish in each age group were assigned ages in proportion to the age composition of the subsample.

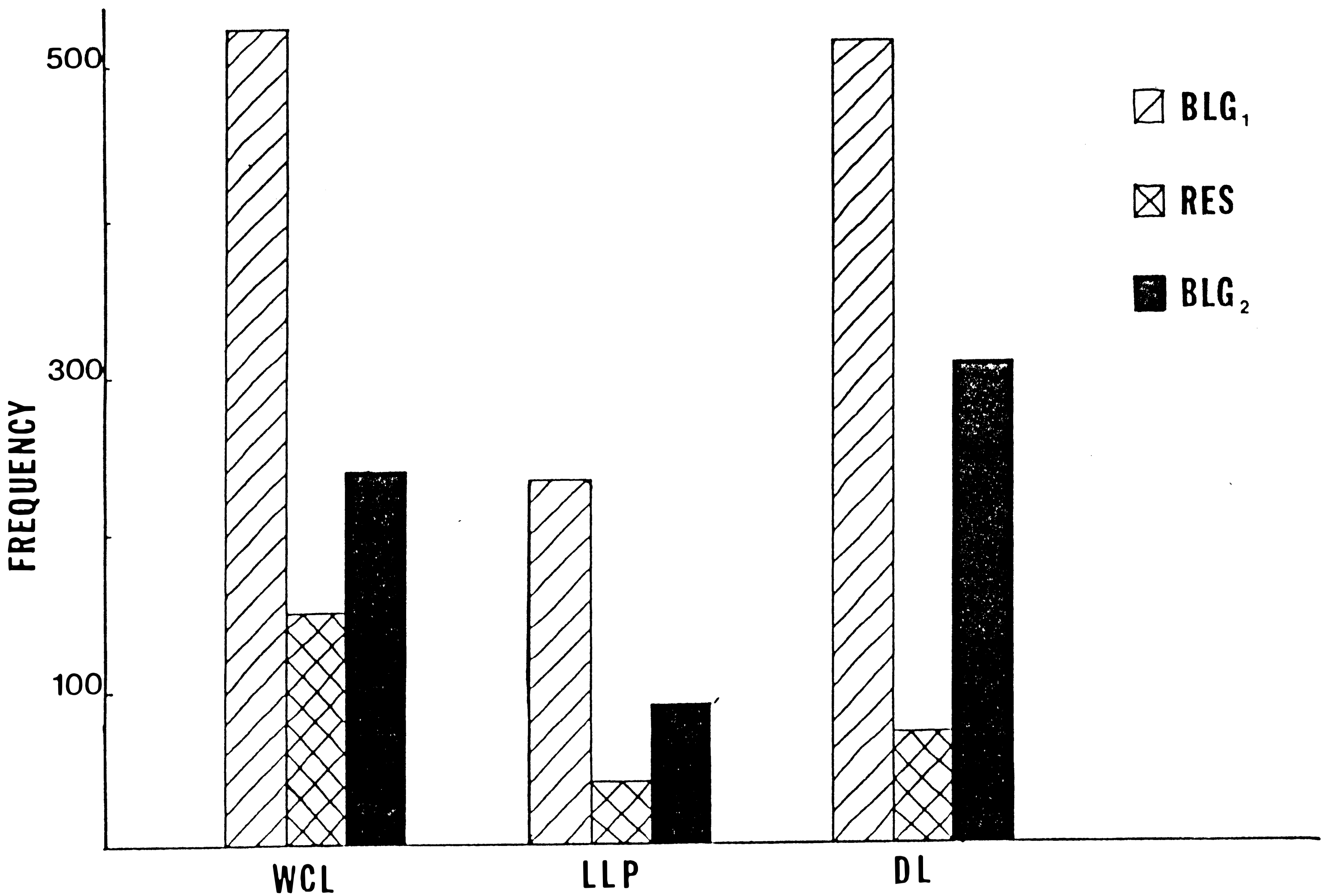
Each otolith was counted twice consecutively and averaged for the first count. A second and third count was made at a later date. The otoliths were counted randomly to prevent bias. The three counts of each otolith were checked for agreement of greater than 90% and averaged. If differences were found or if the original counts differed by more than 10%, the otolith was recounted. No otoliths were rejected because of disagreement. Otolith counts were checked and verified by Steve Miller and Bill Dimond of the Illinois Natural History Survey. The mean ring count of each otolith was used as the age of that fish in days after swim-up. An additional 10 days were added to the otolith age to approximate the interval from egg deposition to swim-up (Childers 1967).

Otolith radius was measured from the center of the nucleus to the edge of the posterior field. This measurement was regressed against the fish's length (TL) to determine if a predictive relationship existed.

RESULTS

Age 0 bluegill were more abundant than age 0 redear sunfish in all three impoundments (Figure 2). The ratio of bluegill to redear sunfish in the twenty seine hauls from each lake differed significantly among impoundments (X^2 test, $\underline{p} \leq 0.05$), increasing from south to north. The ratio of bluegill to redear sunfish increased from 3.5:1 in Washington County Lake, to 5.2:1 in Lake Land Pond, and to 7.9:1 in Dawson Lake.

Figure 2. Relative abundance of age 0 bluegill (BLG_1) and age 0 redear sunfish (RES) in the three study impoundments; (BLG_2) represents the bluegill that were spawned in the interval overlapping the redear sunfish spawning.


FREQUENCY
500
300
100
WCL
LLP
DL
BLG1
RES
BLG2

Successful spawning was initiated only slightly earlier for redear sunfish than for bluegill in Washington County Lake (WCL) and Dawson Lake (DL) (Figure 3). In Lake Land Pond (LLP) (Figure 3), both species began spawning on approximately the same date. Both redear sunfish and bluegill initiated spawning earlier in the southern and central impoundments (mid-May) than they did in the northern-most lake (early June).

The interval of successful spawning was shorter for redear sunfish than for bluegill in all three impoundments (Figures 3 and 4). Redear sunfish spawned from mid-May through late June in WCL and for almost the entire month of June in DL. In contrast, the spawning interval in LLP lasted for only 11 days, from late May to early June. Bluegill spawned from mid-May until early August in both WCL and LLP, while in DL they spawned from mid-June until mid-August. Thus, the interval of successful spawning for bluegill was at least twice that of redear sunfish in all three impoundments.

The mean spawning date was earlier for redear sunfish than for bluegill in each of the three impoundments (Table 2). The mean spawning dates of redear sunfish were similar at WCL and LLP, but was 10 days later in DL. In contrast, the mean spawning dates of bluegill were similar in WCL and LLP, but occurred 17 days later in DL.

In the three study impoundments, 40 to 60% of the successful bluegill spawning occurred after redear sunfish spawning had ended (Figure 4). Nonetheless, assuming that seine samples provided

Figure 3. Initial spawning dates and frequency of occurrence of young-of-the-year fish at 5-day intervals.

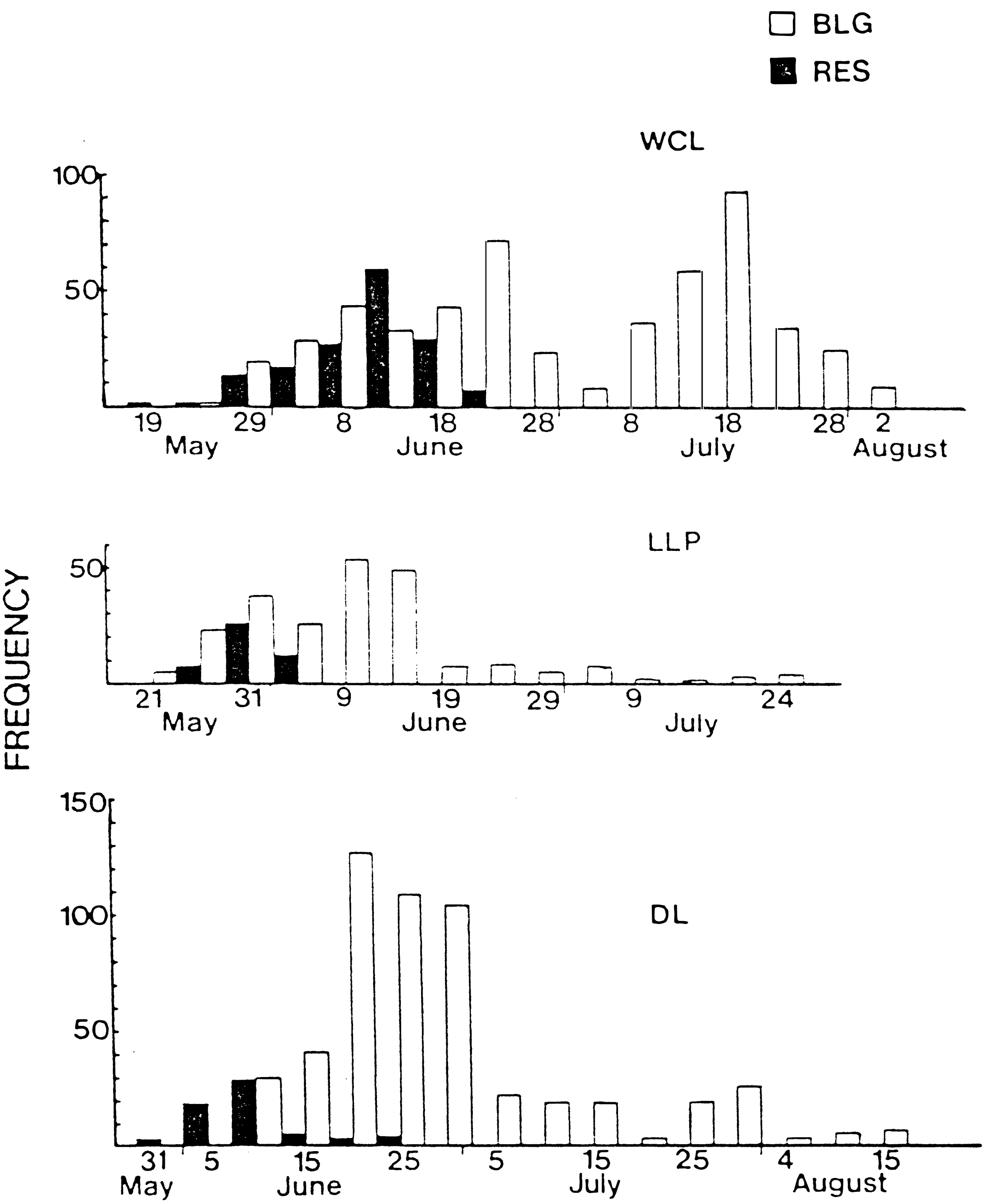
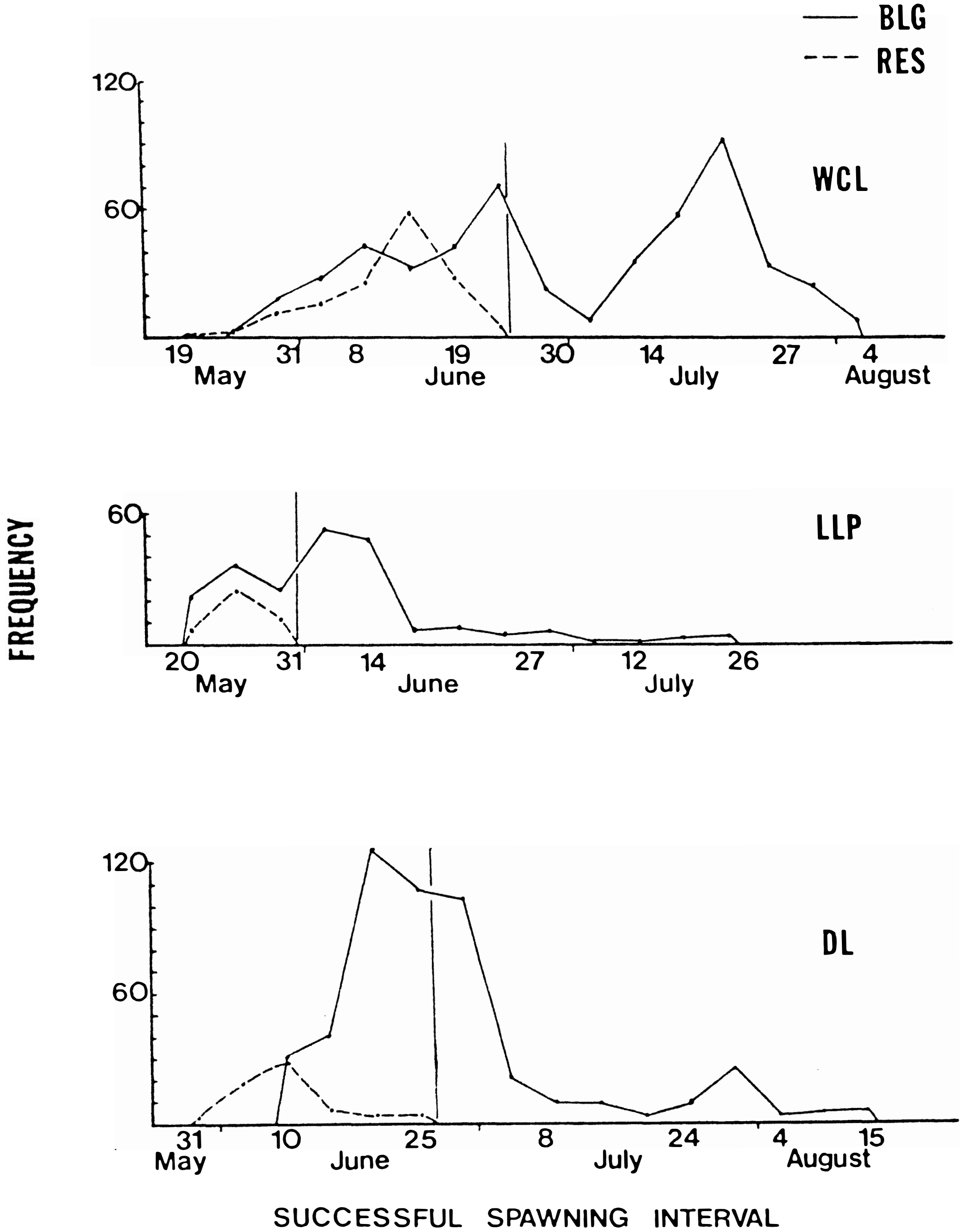

BLG
RES
WCL
100
50
19
May
29
8
18
June
28
8
18
July
28
2
August
LLP
50
21
May
31
9
19
June
29
9
July
24
FREQUENCY
150
100
50
DL
31
May
5
15
June
25
5
15
July
25
4
15
August

Figure 4. A comparison of the successful spawning intervals of bluegill and redear sunfish showing peaks in spawning.



BLG
RES
WCL
120
60
19
May
31
8
19
June
30
14
July
27
4
August
FREQUENCY
LLP
60
20
May
31
14
June
27
12
July
26
DL
120
60
31
May
10
June
25
8
July
24
4
August
15
SUCCESSFUL SPAWNING INTERVAL

unbiased estimates of the relative abundances of respective age groups of the two species, more surviving bluegill than redear sunfish were produced during the overlapping spawning interval. The ratio of bluegill to redear sunfish produced in the common spawning interval increased from south to north from 1.6:1 in WCL, to 2.1:1 in LLP, and to 4.7:1 in DL.

Linear regressions relating length at capture (mm TL) to age (post-swim-up) in September were computed for both species in all three impoundments. In WCL, approximately 97% and 96% of the variation in lengths of redear sunfish and bluegill, respectively, was explained by the age of the fish (Figure 5). In LLP, 92% of the variation in lengths of bluegill, but only 35% of the variation in lengths of redear sunfish was explained by age (Figure 6), probably because the spawning interval for redear sunfish was so short. In DL, age explained 86% and 76% of the variation in lengths attained by bluegill and redear sunfish, respectively (Figure 7). The slopes of these regressions differed from zero (F test, $p \leq 0.05$) for both species in all three impoundments. With the exception of the redear sunfish in LLP, a large fraction of the variation in length was explained by age for both species, indicating that the initial length advantage associated with an earlier spawning date was maintained into September. However, the coefficients of determination (R^2) for both species in DL and the bluegill in LLP were improved by using an exponential or polynomial regression model, indicating that the length-age relationship was not linear (Table 3). At WCL, in

Figure 5. Linear regressions (y = a + bx) plotting age (days after swim-up) against length (mm/day) for the redear sunfish and bluegill from Washington County Lake.

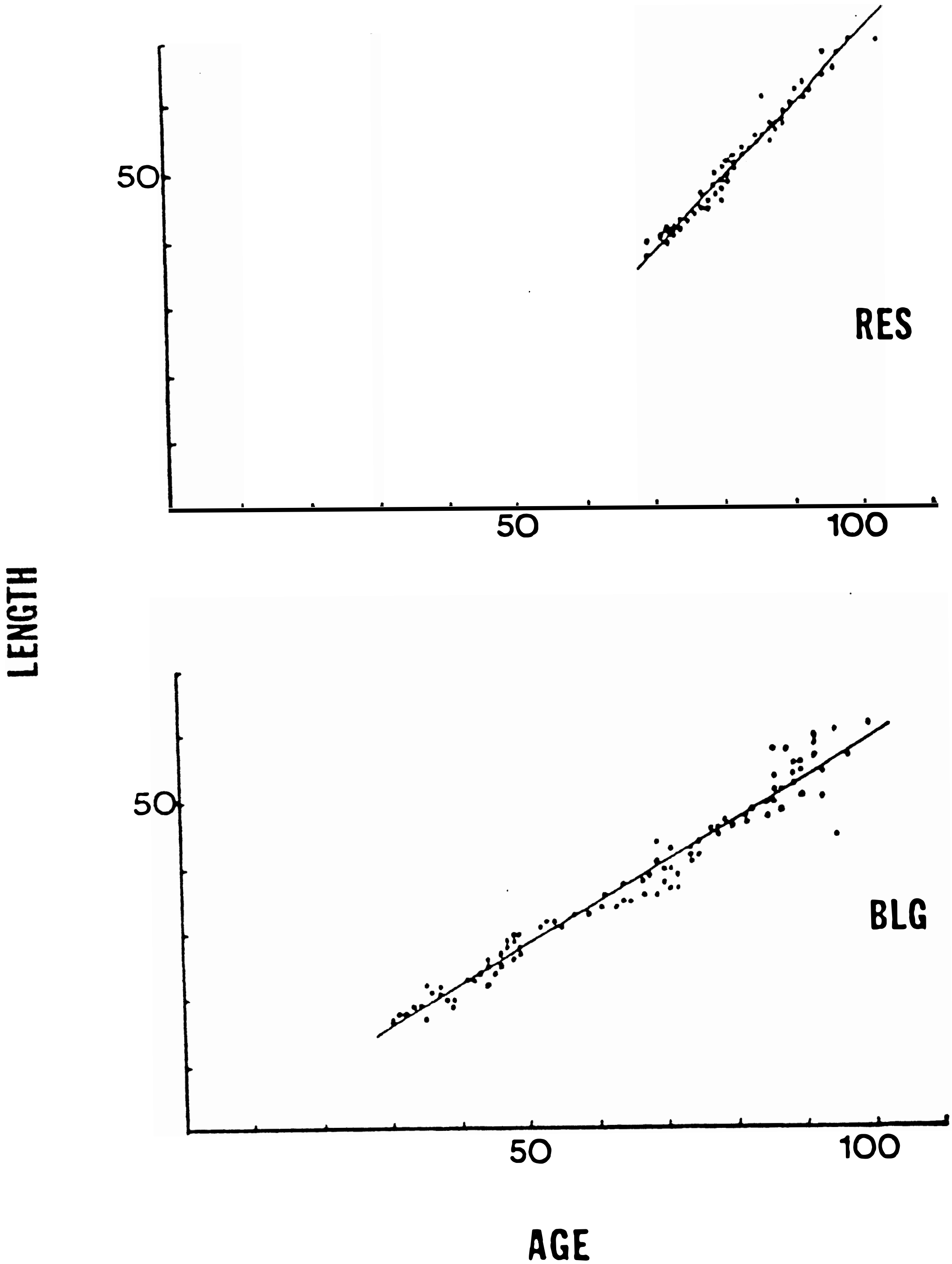
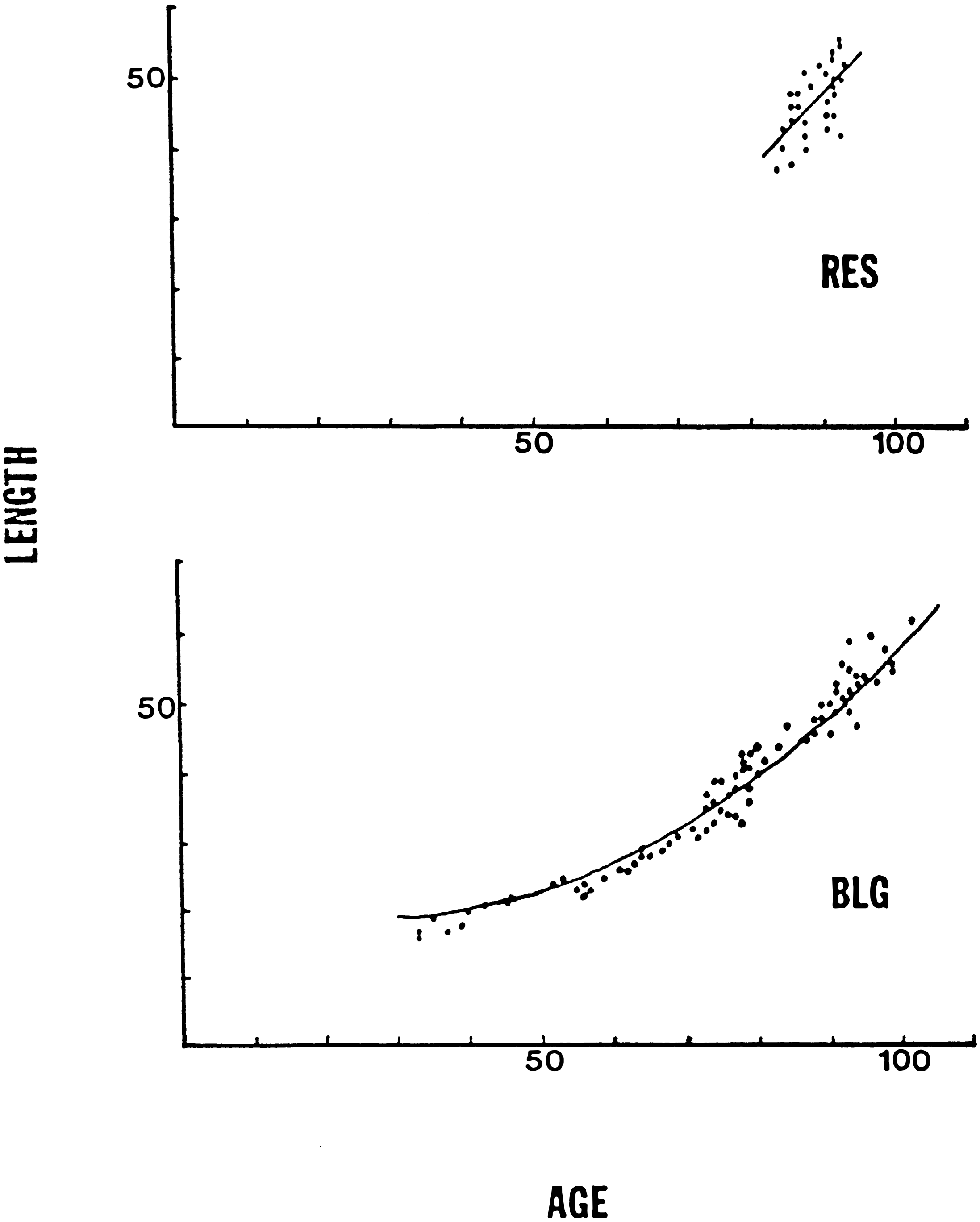
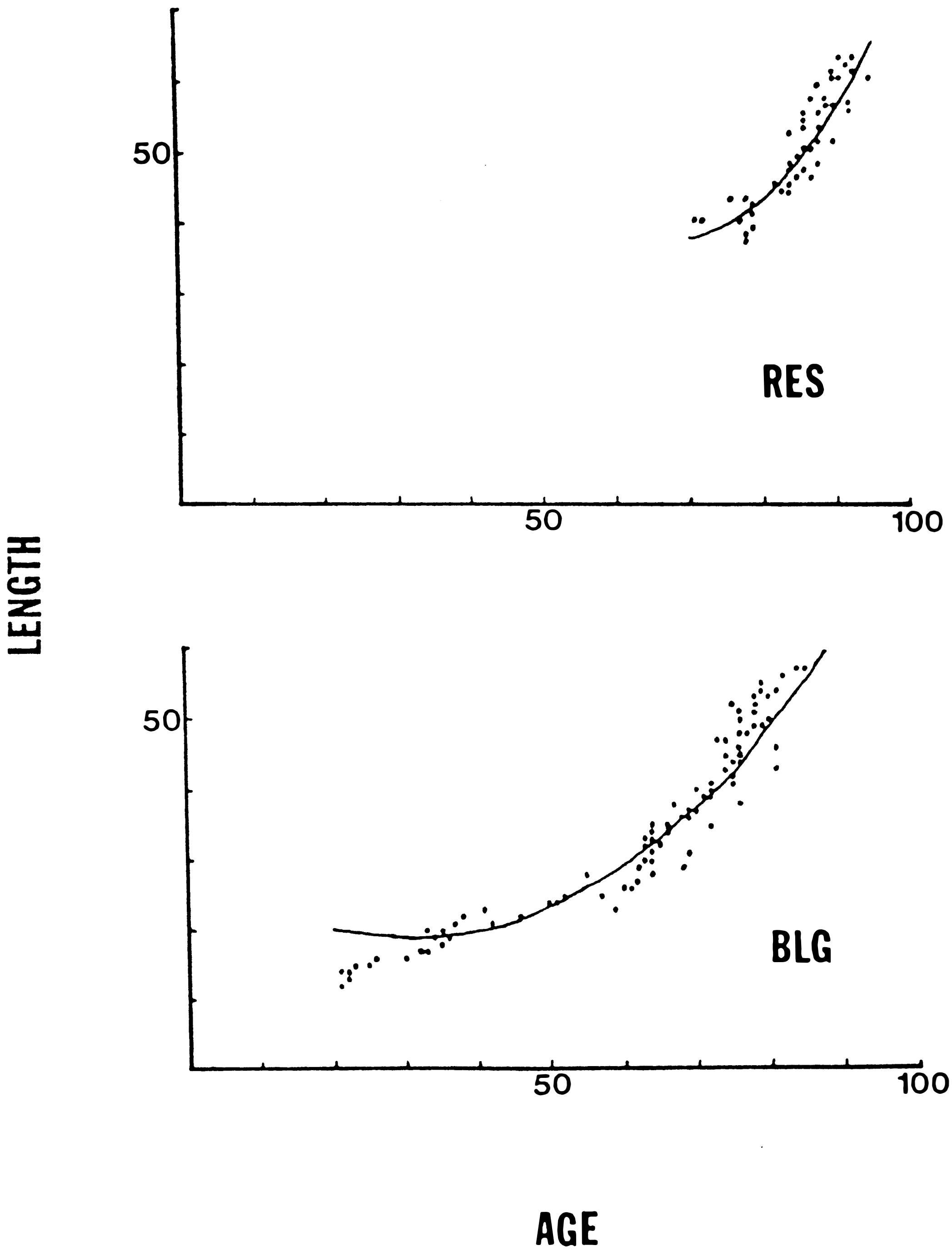

50
RES
50
100
LENGTH
50
BLG
50
100
AGE

Figure 6. A linear regressions ($y = a + bx$) plotting age (days after swim-up) against length (mm/day) for the redear sunfish and a second-degree polynomial regression ($y = a + bx + cx^2$) for the bluegill from Lake Land Pond.



LENGTH
50
50
100
RES
50
50
100
BLG
AGE

Figure 7. Second-degree polynomial regressions ($y = a + bx + cx^2$) plotting age (days after swim-up) against length (mm/day) for the redear sunfish and the bluegill from Dawson Lake.



50
50
100
RES
LENGTH
50
50
100
BLG
AGE

Table 3. Predictive regression formulas and R^2 values for age of fish (days after swim-up) to fish length (TL). L = length in mm TL, A = post-swim-up age, Exp. Log = exponential log, 2nd Poly. = second degree polynomial. RES = redear sunfish and BLG = bluegill.

	Species	Model	Equation	R^2
Washington County Lake	BLG	Linear	$L = -2.802 + 0.623A$	0.96
	RES	Linear	$L = -37.004 + 1.068A$	0.97
Lake Land Pond	BLG	Linear	$L = -11.869 + 0.670A$	0.92
		Exp. Log	$L = 2.125 + 0.0196A$	0.96
		2nd Poly.	$L = 21.114 - 0.364A + 0.007A^2$	0.96
	RES	Linear	$L = -44.933 + 1.026A$	0.35
Dawson Lake	BLG	Linear	$L = -5.281 + 0.653A$	0.85
		Exp. Log	$L = 2.114 + 0.022A$	0.94
		2nd Poly.	$L = 25.937 - 0.713A + 0.012A^2$	0.94
	RES	Linear	$L = -36.078 + 1.021A$	0.76
		Exp. Log	$L = 2.135 + 0.0209A$	0.80
		2nd Poly.	$L = 215.340 - 5.197A + 0.038A^2$	0.83

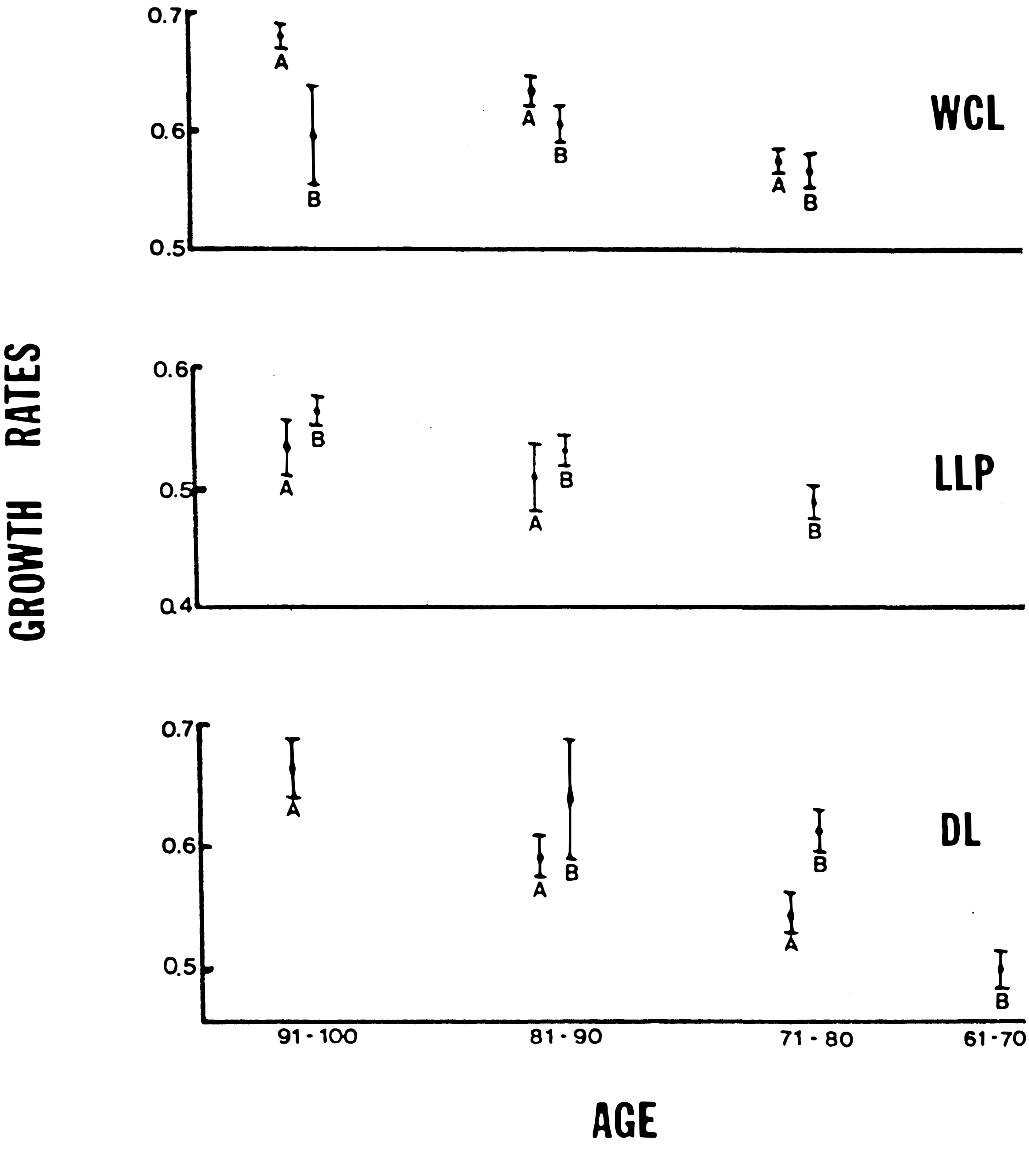
contrast, curvilinear models did not improve the fit of the data for either species, indicating that the advantage of an earlier spawning date was constant across the range of ages examined.

Using the otolith-derived ages of fry collected by seine in September, mean daily growth rates were calculated for fry of both species from three consecutive 10-day age intervals (Figure 8). The growth rates of young-of-the-year fish of both species were greatest for those individuals produced earliest in the season. Fish of similar ages were compared statistically using 95% confidence intervals. The growth rates were considered significantly different if the mean of one group was not included in the 95% confidence interval of the other group (Figure 8).

In WCL, the two earliest spawned groups of redear sunfish (91-100 days and 81-90 days) grew significantly faster (t test, $\underline{p} \leq 0.05$) than similar-aged bluegill (Table 4). The youngest age group for which comparisons were possible (71-80 days) showed no differences. At LLP, the bluegill aged 91-100 days old grew significantly faster than same aged redear sunfish. The growth rates for 81-90 day old fish from this lake were similar. There were no bluegill aged 91-100 days in DL and the fish aged 81-90 days old grew at similar rates. The bluegill aged 71-80 days grew significantly faster than the redear sunfish in this age range.

Comparisons were made of the growth rates for each species among the three impoundments (Figure 8). The two age groups of redear sunfish from LLP grew significantly slower than those from WCL and DL.

Figure 8. A comparison of growth rates using 95% confidence intervals for both redear sunfish and bluegill in each impoundment and among impoundments. A = redear sunfish and B = bluegill.



GROWTH RATES
0.7
0.6
0.5
WCL
A
B
0.6
0.5
0.4
LLP
0.7
0.6
0.5
DL
91 - 100
81 - 90
71 - 80
61 - 70
AGE

Table 4. Mean growth rates (mm/day) for age groups of redear sunfish (RES) and bluegill (BLG) from all three impoundments.

	91-100 days		81-90 days		71-80 days	
	RES	BLG	RES	BLG	RES	BLG
Washington County Lake	0.68	0.60	0.63	0.61	0.59	0.57
Lake Land Pond	0.54	0.57	0.51	0.54	--	0.50
Dawson Lake	0.67	--	0.60	0.65	0.54	0.61

Table 5. Predictive regression formulas and R^2 values for otolith radius to fish length (TL). L = length in mm TL and R = otolith radius in mm; all are linear models. RES = redear sunfish and BLG = bluegill.

	Species	Equation	R^2
Washington County Lake	RES	L = 55.53R - 6.60	0.90
	BLG	L = 47.24R - 0.23	0.98
Lake Land Pond	RES	L = 46.68R + 0.76	0.76
	BLG	L = 46.68R + 0.56	0.98
Dawson Lake	RES	L = 54.27R - 7.15	0.86
	BLG	L = 45.67R + 1.32	0.97

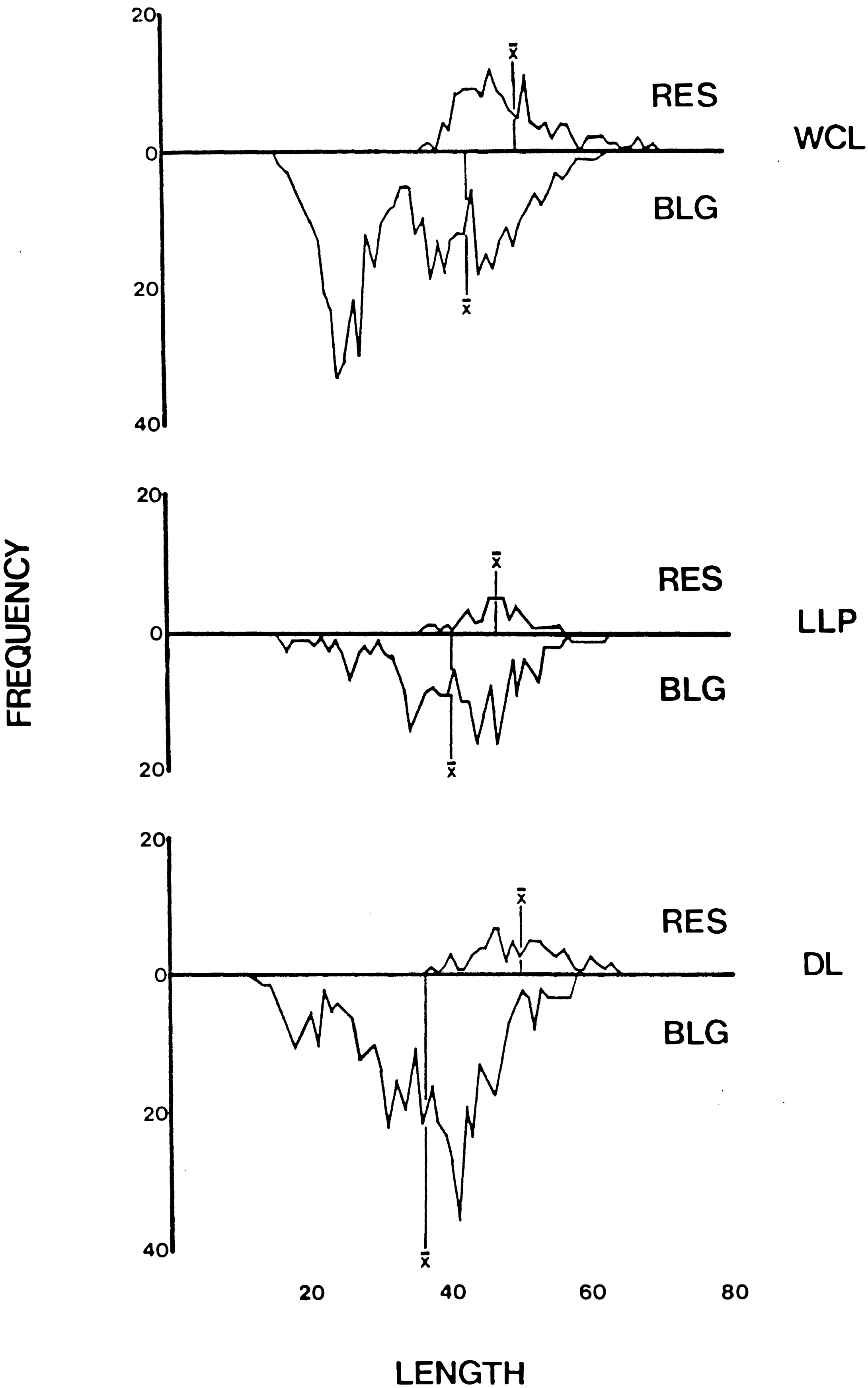
The redear sunfish aged 91-100 days old from WCL and DL grew at similar rates, but the redear sunfish aged 81-90 and 71-80 days old grew significantly faster in WCL than in DL. There were no bluegill aged 91-100 days from DL, but the fish this age from WCL and LLP grew at similar rates. The LLP bluegill aged 81-90 and 71-80 days grew significantly slower than those this age from WCL and DL. All comparable age groups of bluegill from WCL and DL grew at similar rates.

For both species in all three impoundments, the mean daily growth rates were greater for fish spawned early in the season, indicating the initial length advantages associated with earlier spawning dates were increased through more rapid growth.

In September, age 0 redear sunfish were larger, on average, than age 0 bluegill in all three impoundments (Figure 9). The mean lengths of redear sunfish were similar in WCL and DL and were much larger than those in LLP. The mean lengths of bluegill sampled decreased substantially from south to north in the study impoundments, reflecting differences in temporal spawning distribution.

The relationship between sagittae radius (R, mm) and total body length (TL, mm) for bluegill and redear sunfish in all three impoundments appeared linear (Figures 10-12) with high coefficients of determination (Table 5). The TL intercepts were not significantly different from zero (t test, $\underline{p} \leq 0.05$) and consequently the length of the fish at any age may be calculated with Lea's formula as given by Bagenal and Tesch (1978). Further, the error variances for the three

Figure 9. Length frequencies of redear sunfish and bluegill in all three impoundments showing the mean length for each species ($\overline{x}$).



FREQUENCY
20
0
20
40
RES
BLG
WCL
x̄
20
0
20
RES
BLG
LLP
x̄
20
0
20
40
RES
BLG
DL
x̄
20
40
60
80
LENGTH

Washington County Lake.

Figure 10. Linear regressions (y = a + bx) plotting otolith radius (mm) against length (mm TL) for redear sunfish and bluegill in Washington County Lake.

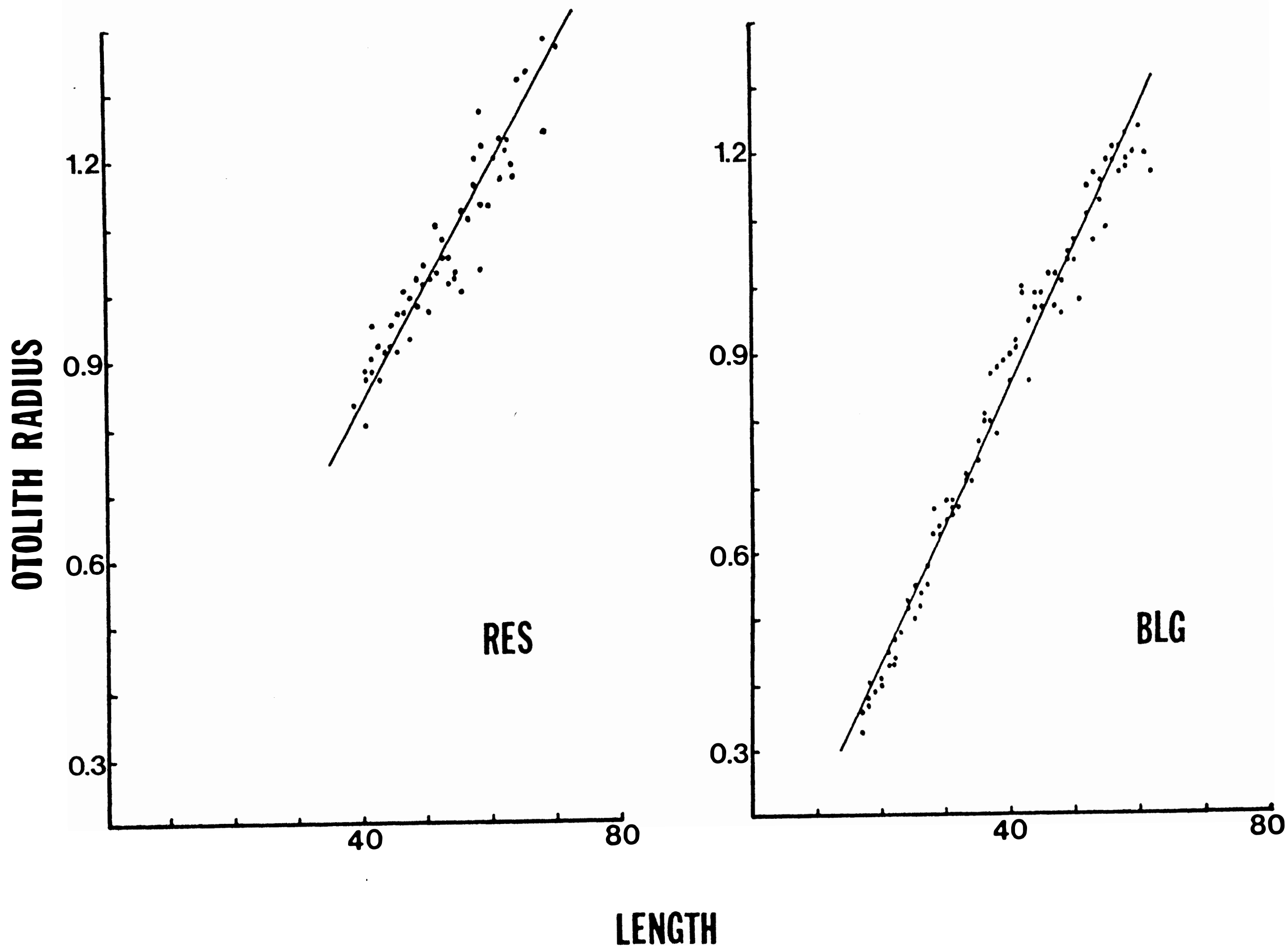

OTOLITH RADIUS
1.2
0.9
0.6
0.3
RES
40
80
1.2
0.9
0.6
0.3
BLG
40
80
LENGTH

Figure 11. Linear regressions (y = a + bx) plotting otolith radius (mm) against length (mm TL) for redear sunfish and bluegill in Lake Land Pond.

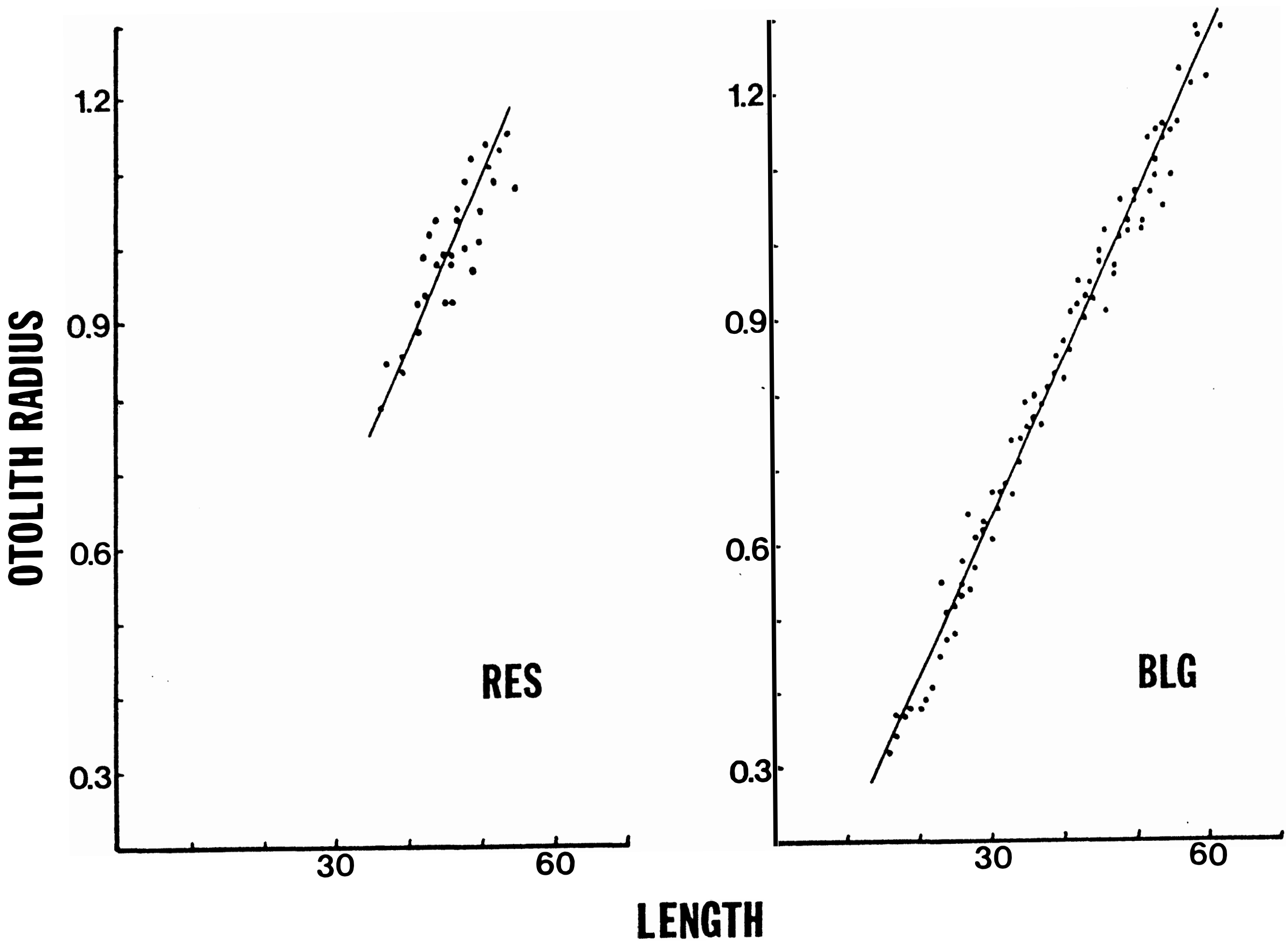
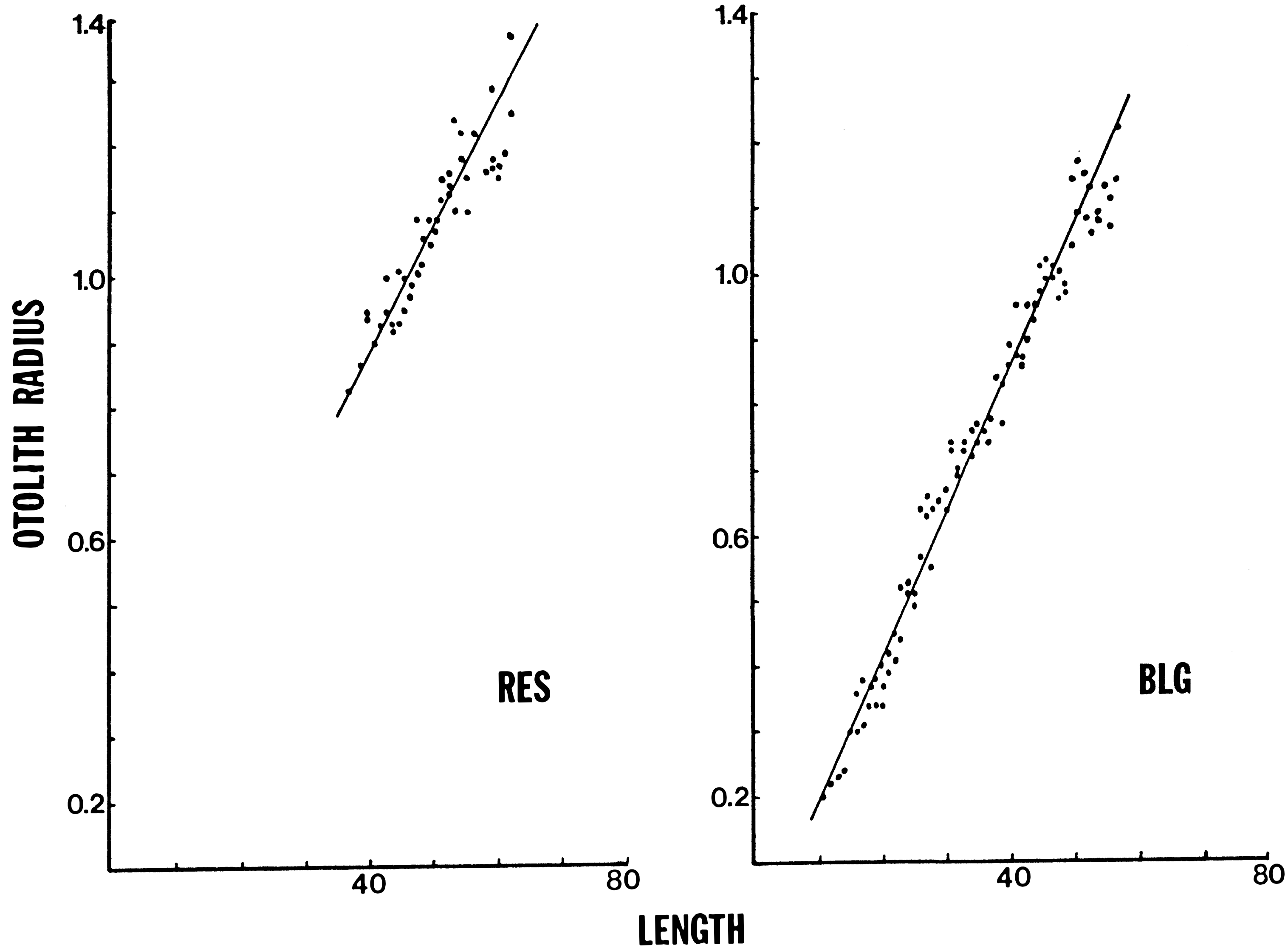

OTOLITH RADIUS
1.2
0.9
0.6
0.3
30
60
RES
BLG
LENGTH

Figure 12. Linear regressions (y = a + bx) plotting otolith radius (mm) against length (mm TL) for redear sunfish and bluegill in Dawson Lake.


OTOLITH RADIUS
1.4
1.0
0.6
0.2
40
80
RES
BLG
LENGTH

regressions for each species were homogeneous (Bartlett's test, $\underline{p} \leq 0.05$) but the slopes did differ significantly and consequently the data could not be pooled to form a single regression line for the data from each species.

DISCUSSION

The successful spawning interval, as used in this study, refers to the interval during which all surviving fish were produced. The otolith-derived estimates of temporal spawning distribution reflect only the populations of young-of-the-year fish that survived until September. If age or size related mortality occurred, the actual and successful spawning intervals would differ. Also, egg mortality in nests would not be reflected in the estimate of the successful spawning interval.

Redear sunfish are thought to spawn earlier and at lower temperatures than bluegill (Lopinot 1961, Childers 1967, Wilbur 1969), but the quantitative data needed to support these observations are lacking. In this study, otolith derived ages provided supportive evidence that redear sunfish initiate spawning earlier and spawn for a shorter interval than do bluegill. Further, the mean spawning dates of redear sunfish were earlier than those of bluegill. Also, redear sunfish and bluegill initiated spawning earlier in the southern and central impoundments than in the northern impoundment, following the expected geographical trend.

The results of this study show a pattern of redear sunfish success decreasing from south to north in Illinois impoundments. McCormick and Brigham (1979) found that redear sunfish populations were less successful in northern Illinois than in southern Illinois. Their findings are supported by data from this study which demonstrated that young-of-theyear redear sunfish grew significantly faster than the young-of-the-year bluegill in WCL, while growth rates were approximately the same in DL. Also, the age 0 redear sunfish in WCL grew faster than age 0 redear sunfish in DL. At the same time, age 0 bluegill from WCL and DL showed no differences in growth rates. This shows that the success of redear sunfish, but not of bluegill, is affected by latitude, decreasing from south to north in Illinois. Consistent with geographical differences in growth, the ratios of age 0 bluegill to age 0 redear sunfish increased from south to north in Illinois showing a possible decrease in the reproductive success of redear sunfish from south to north.

Gabelhouse (1978) found that redear sunfish show poor reproductive success in impoundments where they must compete with bluegill. The fact that adult bluegill were more numerous than adult redear sunfish in all three impoundments could account for the greater numbers of young-of-theyear bluegill that were produced in the overlapping interval of spawning. Another reason bluegill production was greater than that for redear sunfish was the fact that bluegill spawned for at least twice as long as redear sunfish in all three study impoundments.

The interspecific competition between redear sunfish and bluegill could contribute to the failure of redear sunfish to establish growing populations in impoundments where both species are present. This may also be an important factor in the overwinter survival of age 0 fish and their recruitment into the adult populations. With greater numbers of bluegill present, the redear sunfish are forced to compete more for the available foods and this could result in the fish not reaching the critical sizes necessary to survive their first winter. Thus, poor reproductive success of the redear sunfish, coupled with the good reproduction shown by bluegill, could explain why redear sunfish do so poorly in impoundments where they must compete with bluegill.

Despite an earlier mean spawning date for redear sunfish, there were more early spawned, larger bluegill present in the September collections from all three impoundments in this study. This larger size is an advantage and may be important to greater overwinter survival in bluegill than in redear sunfish.

Linear regressions relating length (mm TL) to age (days after swim-up) showed that spawning date was an important factor determining the length that fish of both species attained in September. In WCL, linear models provided the best fit of the data for both species. The high correlation coefficients indicate the advantage of being spawned early was constant across the spawning intervals examined. Curvilinear models were used to improve the fit of the regression lines for bluegill from LLP and for both species from DL. These curves indicate that the incremental length advantage of an earlier spawning date was greater for fish spawned earlier in the season and that this advantage decreased later in the season. The age structures of all populations derived from the daily ring counts of the otoliths indicate there was reasonably continuous spawning within the interval of spawning for both species from all three study impoundments.

Since the early spawned redear sunfish grew faster than the early spawned bluegill in WCL, these fish maintained a slight size advantage over the bluegill throughout the summer. Likewise, the redear sunfish began spawning earlier than the bluegill in DL, but exhibited similar growth rates to the bluegill. Consequently, the redear sunfish were larger in September. There are several reasons for this size difference. First, redear sunfish spawned before bluegill in WCL and DL, thus, giving the early spawned fish a longer period of growth than the earliest spawned bluegill. Second, redear sunfish grew faster than or at similar rates to the bluegill in all impoundments. Third, and probably the most important, were the numerous small, late spawned bluegill that were included in the samples from each impoundment. These small fish caused a big reduction in the overall mean lengths of the age 0 bluegill, resulting in average mean lengths that were smaller than those of age 0 redear sunfish.

Sagittae radius and total body length of bluegill were positively correlated in all three impoundments. The same was true for redear sunfish, but the correlation coefficients weren't as high as those for the bluegill, possibly due to the small sample sizes. Apparently, the relationship between sagittae radius and body length is population specific. The predictability of this relationship between otolith radius and TL of the fish is valuable because it can be used to back calculate a fish's length at any age. These data can then be used to reconstruct growth histories of individual young-of-the-year fish and thus, to compare the seasonal growth patterns of different fish populations from different impoundments.

LITERATURE CITED

Bagenal, T. B. and F. W. Tesch. 1978. Age and growth. Pages 101-103 in T. B. Bagenal, editor. Methods for assessment of fish production in fresh waters. Blackwell Scientific Publication, Oxford, England.

Buck, D. H. 1956. Effects of turbidity on fish and fishing. Transactions of the North American Wildlife Conference 21:249-261.

Childers, W. F. 1967. Hybridization of four species of sunfish (Centrarchidae). Illinois Natural History Survey Bulletin 29: 159- 214.

Gabelhouse, D. W. 1978. Redear sunfish for small impoundments? Pages 109-123 in G. D. Novinger and J. G. Dillard, editors. New approaches to the management of small impoundments. American Fisheries Society, North Central Division. Special Publication 5.

Lopinot, A. 1961. The redear sunfish. Illinois Wildlife 17:3-4.

McCormick, D. A. and W. U. Brigham. 1979. Preliminary life history of the redear sunfish, Lepomis microlophus (Gunther). Federal Aid in Fish Restoration. Annual Report, Project F-32-R, Segment 1. Illinois Department of Conservation. Springfield, Illinois, USA.

Miller, S. J. and T. W. Storck. 1982. Daily growth rings in otoliths of young-of-the-year largemouth bass. Transactions of the American Fisheries Society 111:527-530.

Pannella, G. 1971. Fish otoliths: daily growth layers and periodical patterns. Science 173:1124-1126.

Pannella, G. 1980. Growth patterns in fish sagittae. Pages 519-560 in D. C. Rhoads and R. J. Lutz, editors. Skeletal growth of aquatic organisms: biological records of environmental change. Plenum Press, New York, N. Y.

Pflieger, W. L. 1975. The fishes of Missouri. Missouri Department of Conservation. Pages 255-256.

Taubert, B. D. and D. W. Coble. 1977. Daily rings in otoliths of three species of *Lepomis* and *Tilapia mossambica*. Journal of the Fisheries Research Board of Canada 34:332-340.

Wilbur, R. L. 1969. The redear sunfish in Florida. Florida Game and Freshwater Fish Commission Fisheries Bulletin 5.

William, T., and B. C. Bedford. 1974. The use of otoliths for age determination. Pages 114-123 in T. B. Bagenal, editor. Aging of fish. The Gresham Press, Old Woking, Surrey, England.