BARKLEY LAKE SYMPOSIUM

GROWTH VARIATION IN SELECTED FISHES OF BARKLEY LAKE AND ADJOINING LAND BETWEEN THE LAKES SUBIMPOUNDMENTS

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Abstract: Population growth differences were demonstrated for channel catfish (*Ictalurus punctatus*), largemouth bass (*Micropterus salmoides*), white crappie (*Pomoxis annularis*) and freshwater drum (*Aplodinotus grunniens*) from mainstream bays of Barkley Lake, as well as between these bays and adjoining subimpoundments. Growth in Crooked Creek Bay fish was atypical, with those fish exhibiting overall superior growth. Subimpoundments contained viable fish populations, but those fish were generally in poorer condition than mainstream fish. Great heterogeneity in growth existed within a large flood control reservoir.

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Angling pressure on reservoirs doubled from 1960 to 1970 and is predicted to redouble by the year 2000 (Jenkins 1976). Since the rate of construction of new reservoirs has slowed in most areas, fishery managers must deal with the problem of increasing production in existing reservoirs. The large multipurpose reservoirs are not always designed or operated with the fishery in mind. The problems of increased pressure and outside demands on the resource will require innovative management approaches if the fishery is to keep pace.

Currently, research is progressing in the areas of habitat manipulation, predator-prey relationships, physicochemical characters of reservoirs and their relationship to production, stocking programs, subimpoundments for water level control, commercial fish utilization, and growth patterns, reproductive habits, and enviornmental tolerances at the population level.

Many management decisions are based on the rate of growth of a species, and for this reason accurate data on growth variation within an area is necessary. Significant growth variation and valid population differences were demonstrated in the rainbow trout (*Salmo gairdneri*) population of Flaming Gorge Reservoir, Utah-Wyoming, during the first 6 years of impoundment (Varley *et al.*, 1971). To effectively manage an area as varied as many of the large impoundments, data on growth must be accumulated from many locations. Variations such as growth or reproductive potential may make it necessary to manage separate populations rather than the reservoir as a whole.

Four species of fish--largemouth bass, white crappie, channel catfish and freshwater drums--were studied in Barkley Lake, Kentucky, a Cumberland River impoundment and 3 adjoining subimpoundments. The objectives were to characterize the growth of these species and determine if significant population differences exist within the reservoir or between study areas (i.e., between Barkley Lake and the subimpoundments).

MATERIALS AND METHODS

Barkley Lake is a 189 km long impoundment of the Cumberland River, completed in 1966 by the Army Corps of Engineers. The areas under study were the 3 subimpoundments of this reservoir (Honker Lake, Energy Lake, and Bards Lake), as well as their adjoining bays (Honker Bay, Crooked Creek Bay, and the Bear Creek management area termed here, Bards Bay).

Fish were collected between March and September of 1978, using variable mesh gill nets (1-1/2", 2", 3" bar mesh) and an electrofishing boat with d.c. pulse current.

Approximately one-half of the Crooked Creek Bay sample was collected during the September rotenone study conducted by the Reservoir Division of the American Fishery Society.

Scales were removed from the left side at the base of the pectoral fin from largemouth bass, white crappie, and freshwater drum; and the left pectoral spine was removed from the channel catfish. Scales were read following the methods described by Lagler (1952), while spines were examined following the method of Sneed (1951). Growth per year was determined by back-calculating to the time of annulus formation with the formula:

$$ln - a = Sn\ (1 - a)$$ (Bagenal and Tesch, 1978)

where: ln = total length at annulus n
Sn = scale (or spine) radius at the nth annulus
S = anterior radius of scale or posterior radius of spine
l = total length of fish at capture
a = correction factor derived from the body-scale relationship

Fulton's condition factor, length-weight relationship, and instantaneous growth rates were calculated for each species from all locations (Bagenal and Tesch, 1978). Growth curves were calculated from the generalized formula $li(t) = ai - bi(r^{t})$, or a regression of length on a function of time (Allen, 1976).

Data were analyzed statistically using analysis of variance, analysis of covariance, and multiple range tests (Zar, 1974).

RESULTS

Body-scale relationship

Body-scale (spine) relationships were calculated and the slopes and elevations for all species from all areas compared by analysis of covariance and multiple range tests. These relationships provide a basis for identifying irregular growth patterns, population differences, and confirmation of technique in age determination.

There were no differences between largemouth bass body-scale relationships from the 6 study areas. Data were pooled to give the relationship $L = 10.74 + 2.75\ SR$ ($r = .96$). Drum and channel catfish also exhibited no differences in this relationship, with pooled data yielding the formulas $L = 31.85 + 2.70\ SR$ ($r = .90$), and $L = -28.02 + 3.31\ SR$ ($r = .88$) for drum and catfish respectively.

A significantly lower slope and elevation (larger scales per unit body length) existed for the body-scale relationships of white crappie in Honker Lake. The Honker Lake relationship was $L = 30.36 + 2.32\ SR$ ($r = /92$), while the pooled relationship from the other 5 areas was $L = 42.50 + 2.44\ SR$ ($r = .92$). Low relationships such as the Honker Lake crappie are normally indicative of stunted populations (Carlander, 1969).

Length-weight relationship

Along with its usefulness in converting length to weight, the length-weight relationship also provides an indication of population growth differences. Relationships were computed for the 4 species from all study areas and compared. Significant differences in the relationships were found within all species (Table 1).

Honker Bay and Bards Bay largemouth bass exhibited similar patterns with high weight gains through approximately 300 mm total length (TL). The higher slopes from the other areas resulted in greater weight gain after 300 mm TL.

The white crappie relationships differed between the mainstream sites and the subimpoundments. After 200mm TL the mainstream crappie were heavier per unit body length than the subimpoundment crappie. The rate of increase in weight (slope) was lower in the Honker Lake population compared to all other areas. Low weight per unit length is another symptom of a stunted population (Carlander, 1969).

TABLE 1. Length-weight relationships for 4 species of fish. Vertical lines adjacent to rank denote significance. Ranks not within a single unbroken line are different at the 5% level. (Honker Bay-HB; Honker Lake-HL; Crooked Creek Bay-CB; Energy Lake-EL; Bards Bay-BB; Bards Lake-BL).

Rank	Location	n	Relationship	Correlation
		Largemouth Bass		
1	EL	17	$W = 2.81 (10^{-6}) L^{3.28}$	.99
2	BL	22	$W = 3.60 (10^{-6}) L^{3.25}$	.99
3	CCB	42	$W = 3.83 (10^{-6}) L^{3.24}$	.99
4	BB	10	$+ = 7.89 (10^{-6}) L^{3.11}$	.99
5	HB	25	$W = 1.29 (10^{-5}) L^{3.03}$	.99
		White Crappie		
1	BB	17	$W = 1.04 (10^{-6}) L^{3.46}$	.98
2	HB	46	$+ = 1.63 (10^{-6}) L^{3.40}$	.97
3	CCB	85	$W = 1.74 (10^{-6}) L^{3.38}$	.99
4	BL	52	$W = 2.85 (10^{-6}) L^{3.27}$	.99
5	EL	108	$W = 4.39 (10^{-6}) L^{3.18}$	.99
6	HL	125	$W = 3.99 (10^{-5}) L^{2.80}$	.96
		Drum		
1	HL	13	$W = 2.88 (10^{-6}) L^{3.23}$	.96
2	BL	24	$W = 4.62 (10^{-6}) L^{3.15}$	.95
3	CCB	71	$W= 7.34 (10^{-6}) L^{3.05}$	.99
4	EL	19	$W = 1.45 (10^{-5}) L^{2.94}$	.95
5	HB	45	$W = 2.03 (10^{-5}) L^{2.88}$	.99
6	BB	22	$W = 2.25 (10^{-5}) L^{2.81}$	.94
		Channel Catfish		
1	BB	35	$W = 1.46 (10^{-7}) L^{3.71}$	.92
2	HL	63	$W = 1.95 (10^{-7}) L^{3.62}$	.91
3	HB	34	$W = 7.16 (10^{-7}) L^{3.41}$	.96
4	CCB	83	$W = 1.75 (10^{-6}) L^{3.27}$	.99
5	EL	57	$W = 1.86 (10^{-6}) L^{3.24}$	.94
6	BL	49	$W = 4.82 (10^{-6}) L^{3.09}$	.92

The opposite pattern was observed in the freshwater drum populations. Subimpoundments drum were heavier per unit body length than mainstream populations. Bards Bay drum were lighter than all other areas, while Honker Lake and Bards Lake drum exhibited a faster rate of weight increase than all mainstream populations.

Crooked Creek Bay and Bards Lake channel catfish exhibited higher early weight gains per unit length; however, the Bards Bay channel catfish population had a higher overall rate than Crooked Creek, Energy Lake, and Bards Lake populations. Honker

Lake was the only subimpoundment in which channel catfish exhibited a substantial growth rate after approximately 350 mm TL.

The observed differences in the length-weight relationships between areas and especially the differences observed between relative sizes are probably related to species and size specific food availability. It should also be noted that no one area exhibited superior weight gain per unit length for all 4 species. Honker Lake, for example, exhibited poor weight gain for white crappie, while drum and channel catfish were superior or equal to other areas.

Condition

Significant variation in condition existed for all species between size groups, with a trend for condition to increase with size (Table 2). Largemouth bass condition was higher in fish larger than 325mm TL than those smaller. Bass from Honker Bay, Crooked Creek Bay and Bards Bay were similar in condition. Condition factors of bass from Energy Lake and Bards Lake were significantly lower (Table 3).

TABLE 2. Condition-size group relationship for channel catfish, largemouth bass, white crappie, and freshwater drum. Mean ± standard error.

Species	Size group[a]	Sample size	Condition factor
Largemouth Bass	200	41	1.32±.040
	200-324	32	1.44±.030
	325-449	31	1.58±.029
	449	10	1.66±.035
White Crappie	100	20	.92±.021
	100-199	133	1.11±.014
	200-299	175	1.37±.018
	299	47	1.54±.026
Channel Catfish	200	18	.77±.038
	200-324	22	79±.017
	324-449	202	.83±.009
	449	49	1.02±.013
Drum	200	46	.85±.023
	200-299	123	.99±.012
	300-399	12	1.05±.010
	399	5	1.26±.110

[a]Size groups in millimeters total length.

White crappie showed significant condition variation at each 100mm size group. Condition was lower in subimpoundments than in mainstream, with Honker Lake crappie lower than all other areas (Table 3).

Channel catfish larger than 449mm TL had a significantly higher condition than smaller size groups. Bards Bay channel catfish exhibited a condition which was higher

TABLE 3. Variation in condition between study areas for largemouth bass, channel catfish, white crappie, and freshwater drum. Mean ± standard error.

Species Size Group	Bass 325-449	Crappie <299	Catfish 0.449	Drum 200-299
Location				
HB	1.59±.042	1.67±.032	.80±.016	1.07±.013
HL	[a]	1.16±.055	.74±.012	1.01±.024
CCB	1.57±.037	1.54±.017	.81±.014	.92±.018
EL	1.42±.081	1.37±.035	.76±.015	1.04±.019
BB	1.63±.034	1.50±.029	.96±.023	.83±.033
BL	1.35±.039	1.33±.048	.84±.015	1.05±.012

[a]Largemouth bass were not collected from Honker Lake.

than catfish from other areas. Bards Lake produced catfish with a condition higher than other subimpoundments populations (Table 3).

Drum condition was also related to size with fish less than 200mm TL being significantly lower, and fish greater than 399mm TL being significantly higher. Subimpoundment drum generally had higher condition factors than those of mainstream drum (Table 3). Bards Bay and Crooked Creek Bay populations had a lower condition than Bards lake, Energy Lake, and Honker Bay populations.

Back-calculated growth

Largemouth bass from Crooked Creek Bay exhibited superior growth in length and weight; Bards Lake was the only area that compared favorably. On the other hand, Bards Bay exhibited lower bass growth than all other areas (Fig. 1). Age groups at Energy Lake and Honker Bay were similar in length and weight. Largemouth bass were not collected at Honker Lake.

A difference in age-total length relationship in white crappie between subimpoundment and the adjoining mainstream bay existed only in Honker Lake which demonstrated lower growth in length and weight than all other areas (Fig. 2). Crooked Creek Bay white crappie growth was equalled only by smaller (<200mm) fish from Energy Lake. The growth of Energy Lake crappie exceeded Bards Bay, Bards Lake, and Honker Lake populations. Weight differences from subimpoundment to mainstream stations, as seen by the length-weight relationships, became evident after approximately age 4. Suitable forage for the larger fish may be less available in subimpoundments and result in the lower weights observed (Gasser, 1979a).

Crooked Creek Bay also possessed the fastest growing population of freshwater drum, greater than all areas except Energy Lake. Energy Lake drum grew significantly faster than Bards Bay, Honker Bay, and Bards Lake populations. Crooked Creek Bay and Energy Lake fish were significantly faster than Bards Bay, Honker Bay, and Bards Lake populations. Crooked Creek Bay and Energy Lake fish were also heavier at each age. Bards Bay possessed the slowest growing drum population in both length and weight (Fig. 3).

Subimpoundments and adjoining mainstream sites were remarkably similar in growth of channel catfish (Fig. 4). The only exception was Energy Lake; channel catfish here grew slower than both Crooked Creek Bay and Bards Bay populations. Crooked Creek Bay and Bards Bay catfish were heavier at each annulus than those from other sites.

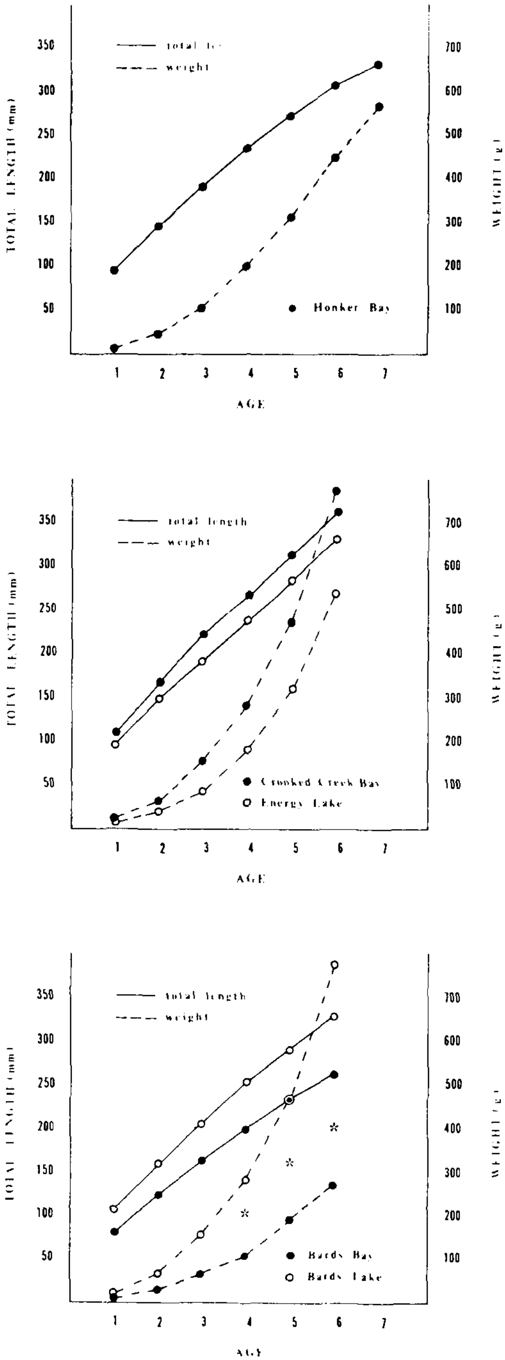

Fig. 1. Annual increases in length and weight for largemouth bass.

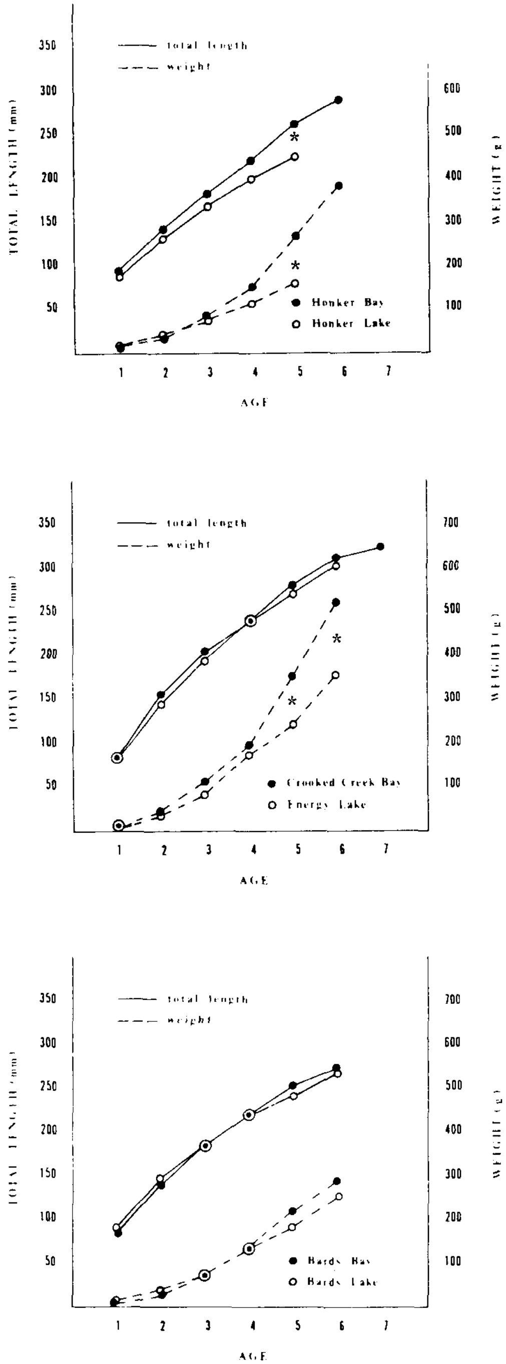

Fig. 2. Annual increases in length and weight for white crappie.

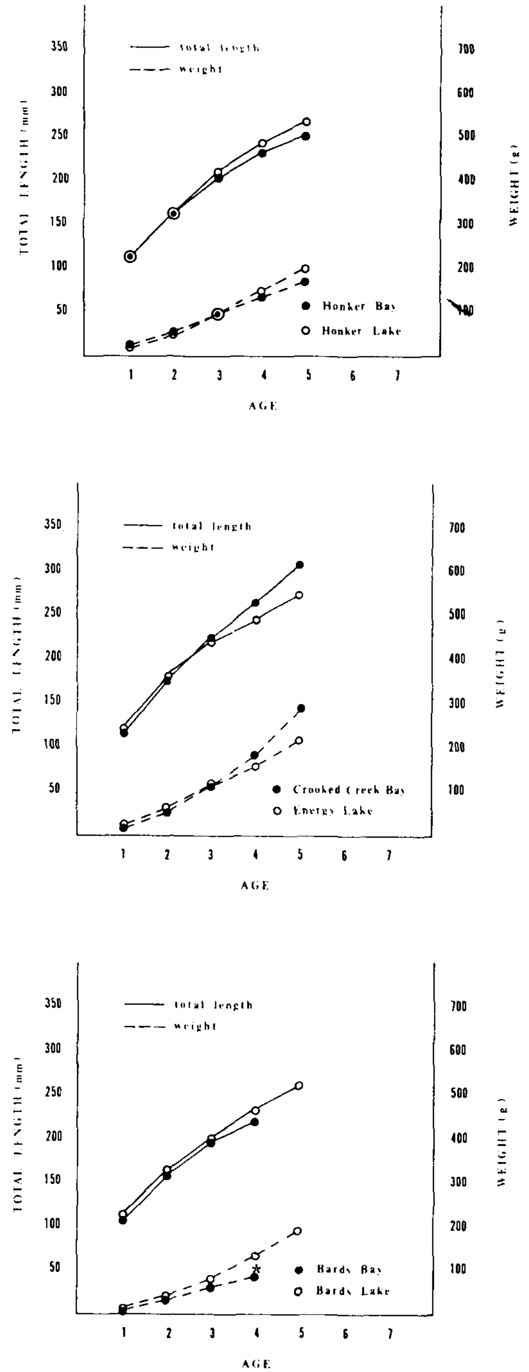

Fig. 3. Annual increases in length and weight for drum.

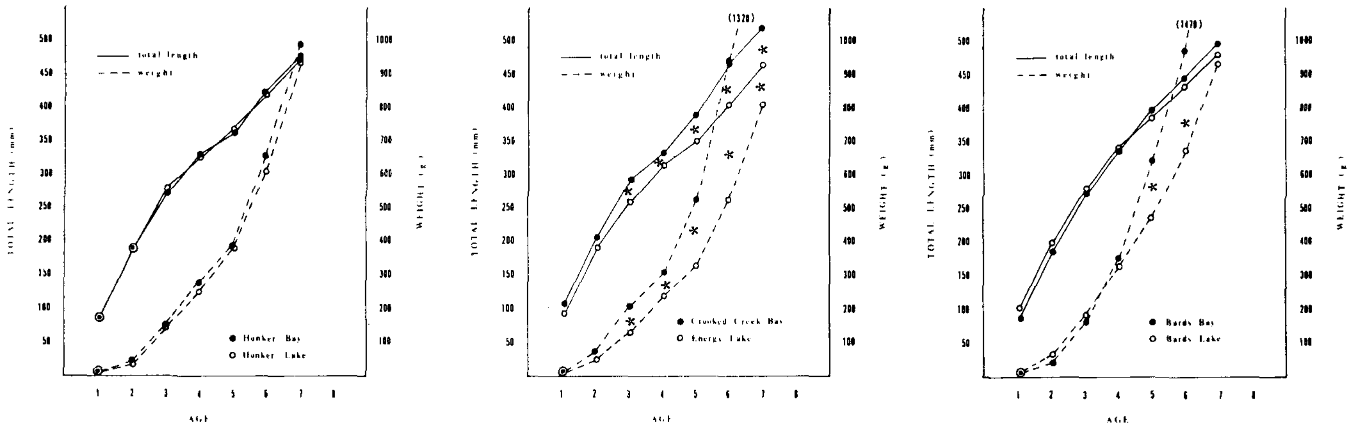

Fig. 4. Annual increases in length and weight for channel catfish.

Instantaneous growth

Weight gain can also be analyzed in terms of the instantaneous growth rate of each population, based on the annual increase in fish weight. Relative annual rates can be compared between areas.

Largemouth bass from Bards Bay, Bards Lake, and Honker Bay gain weight at proportionally the same annual rate (Fig. 5). Crooked Creek Bay was similar to the previously mentioned areas except for a higher rate during the 6th year. Energy Lake bass possessed the highest instantaneous rate of increase throughout the 7 years of growth analyzed. This high rate is indicative of the somewhat slower growth in length of this population coupled with the high weight gain per unit length seen in the length-weight relationship.

White crappie from Honker Lake produced lower instantaneous growth rates which reflected their low length-weight relationship and annual length increments. No difference was observed between mainstream sites; rather, a high degree of similarity existed (Fig. 6). Rates decreased steadily through year 4 in all mainstream sites followed by a slight leveling of the rate during the 5th year and decreasing again during the 6th year. The high 5th year rate may be related to the crappie reaching a size which allows for exploitation of a new forage species. Subimpoundment patterns were also similar, with the exception of Honker Lake. The rate leveled at year 3 and increased at year 6. This pattern may also indicate 2 levels of food utilization related to the size of the crappie.

The instantaneous growth pattern of subimpoundment and adjoining mainstream site fish was similar in the case of channel catfish (Fig. 7). Honker Bay and Honker Lake decreased through year 5, increased during year 6, and decreased at year 7. Bards Bay and Bards Lake decreased through year 5 and leveled during years 6 and 7. Crooked Creek Bay increased during year 5 and decreased again at year 7, while Energy Lake catfish did not increase until year 6, probably due to the smaller size of this lake. The patterns of instantaneous increase were significantly different between the 3 subimpoundment-bay groups. The factors which produce the observed patterns are undetermined, but may be related to food availability.

Crooked Creek Bay drum instantaneous growth was higher than in Energy Lake, Bards Bay, or Honker Bay. There was no difference between Honker Lake, Bards Lake, or Crooked Creek Bay (Fig. 8).

Generalized growth curves

When the primary interest is in comparing growth curves from several areas for one species, the use of a simple model which describes the shape of the curve may be desirable (Allen 1976). The technique is loosely modeled after the von Bertalanffy growth curve. This approach avoids the difficulties of nonlinear comparisons and allows for standard tests for multiple comparisons of curves. The maximum length and mean growth rate are dependent upon the span of ages used (Southward and Chapman 1965). Equal age spans were used for each species for all areas.

In terms of growth rate (slope) and maximum length (elevation), the largemouth bass from Crooked Creek Bay were superior, followed by Energy Lake and Bards Lake; Honker Bay and Bards Bay bass were less (Table 4).

White crappie patterns were similar to the largemouth bass, with those from Crooked Creek Bay and Energy Lake growing at a faster rate (Table 4). The Honker Lake crappie were the lowest in rate and maximum length attainable. Bards Lake, Bards Bay, and Honker Bay populations grew at similar rates, intermediate between Honker Lake and Crooked Creek Bay fish.

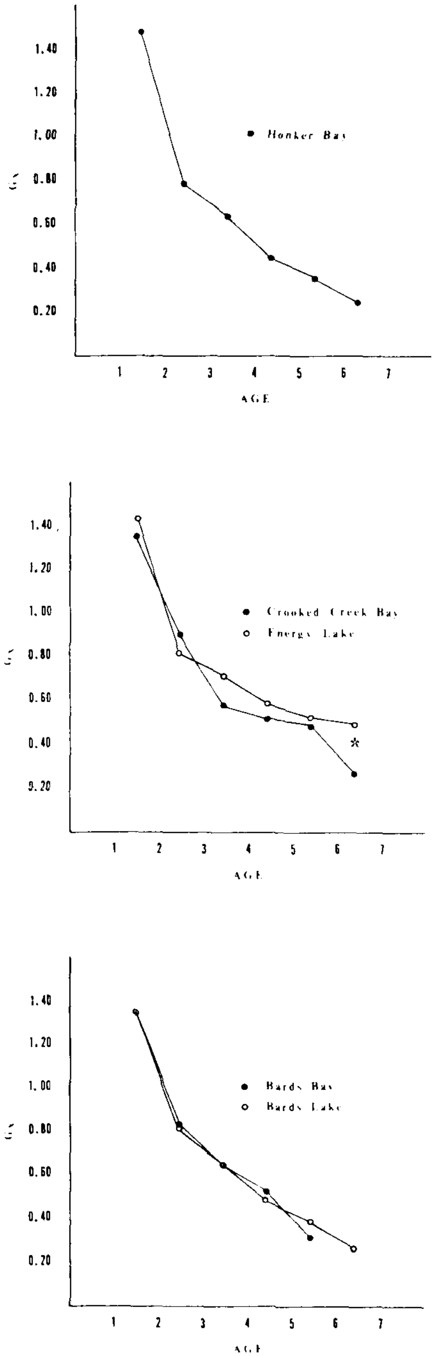

Fig. 5. Population instantaneous rate of growth (Gx) for largemouth bass.

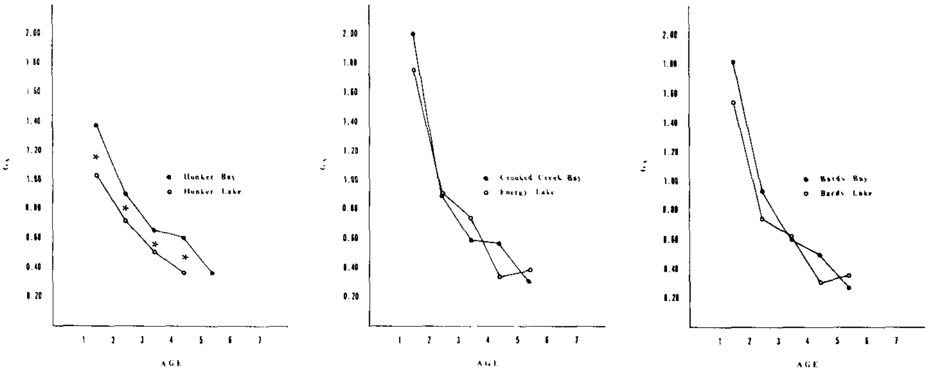

Fig. 6. Population instantaneous rate of growth (Gx) for white crappie.

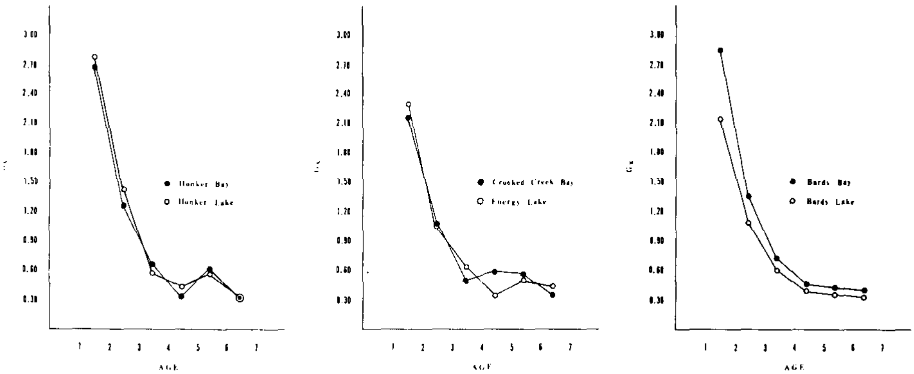

Fig. 7. Population instantaneous rate of growth (Gx) for channel catfish.

Channel catfish rate of growth was generally lowest in the subimpoundments, with Crooked Creek Bay and Bards Bay fish growing significantly faster than those from the 3 subimpoundments (Table 4).

Drum growth rates were similar in most areas (Table 4). However, Crooked Creek Bay drum grew faster than those from Bards Lake, Bards Bay, and Honker Bay.

DISCUSSION AND CONCLUSIONS

Growth of white crappie and channel catfish between subimpoundments and adjoining bays of Lake Barkley were similar. The populations of these areas apparently do not mix since significant meristic differences exist (Gasser 1979b).

In some cases, marked differences were seen between subimpoundment and bay fishes. For example, the largemouth bass in Bards Lake was one of the fastest growing populations, while Bards Bay contained the slowest growing population of bass. The white crappie populations of Honker Bay and Lake also showed marked differences. The crappie from Honker Lake are stunted based on the following criteria: low body-scale relationship, low length-weight relationship, slow annual growth in length, and a high relative abundance (Gasser 1979a).

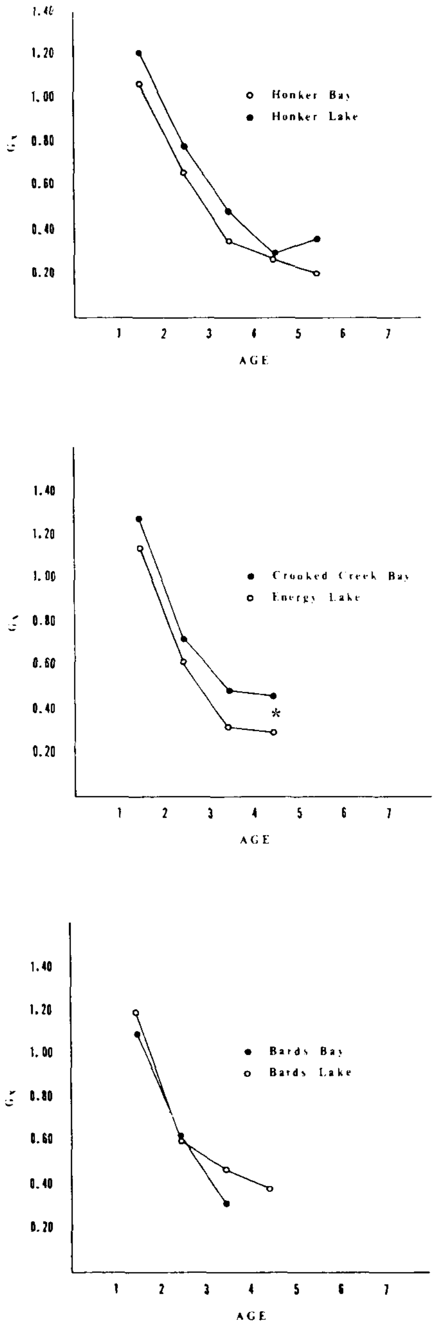

Fig. 8 Population instantaneous rate of growth (Gx) for drum.

TABLE 4. Growth curve parameters; slope (rate of growth) and elevation (theoretical maximum length), for largemouth bass, white crappie, channel catfish, and freshwater drum. (Vertical lines adjacent to slopes and elevations denote significance. Slopes or elevations not within a single unbroken line are different at 5% level.)

Location	Slope	Elevation	Location	Slope	Elevation
	Largemouth Bass			White Crappie	
CCB	530.8	553	CCB	376.2	361
EL	494.9	507	EL	364.2	349
BL	472.6	502	BB	322.9	320
HB	451.7	473	HB	314.0	316
BB	390.5	406	BL	290.7	305
			HL	264.9	277
	Channel Catfish			Drum	
CCB	698.7	671	CCB	356.7	390
BB	709.7	663	HL	309.5	348
HB	658.5	628	EL	302.5	357
BL	652.8	635	HB	286.5	331
HL	650.3	623	BL	287.3	336
EL	625.8	600	BB	275.3	321

Slower weight gain, especially in larger fish, from subimpoundment populations is likely related to lower abundance of available forage compared to mainstream sites. Threadfin shad (*Dorosoma petenense*) were not collected in any of the subimpoundments. Their absence may result in slower weight gain until fish are large enough to utilize gizzard shad (*D. cepedianum*).

The increased instantaneous rate of growth of channel catfish during the 5th year may be related to its increased utilization of fish as its primary food organism. Channel catfish larger than 300mm TL feed primarily on other teleosts (Johnson and Sickel, 1979). The delayed increase seen in the Energy Lake channel catfish is correlated to its slower growth in length.

Growth differences were demonstrated not only between subimpoundments and mainstream bays, but also between the mainstream locations. Crooked Creek Bay fishes were noticeably superior in growth to those from all other areas examined. Energy Lake patterns, although similar to Crooked Creek Bay, indicated lower weight gains for most species. Poor growth was observed in the Honker Lake crappie population and Bards Bay largemouth bass popultion. Productivity estimates for the reservoir as a whole based on information from a part could be erroneous and lead to errors in management and harvest. For example, Crooked Creek Bay largemouth bass weighed approximately 300% more than Bards Bay bass at age 6.

Subimpoundments were shown to have viable populations of most species. Separate management of these areas could produce populations with an excellent sport fishery potential. Stable water levels in the subimpoundments may increase their reproductive potential compared to the fluctuating water levels of mainstream locations.

Differences in growth demonstrate the variable nature of the large mainstream impoundments. By the use of predictive methods in the areas of water quality, species diversity, food availability, and lake morphometry it may be possible to characterize good versus poor growth areas. However, conditions which favor the growth of one species may not favor other speices. For example, largemouth bass grew poorly in Bards Bay, while channel catfish exhibited superior growth. Reservoir fisheries offer the opportunity for extended research of growth in subimpoundments, mainstream bays of variable morphometrics, as well as channel and flood plain areas.

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