THE EFFECTS OF VARIOUS LARGEMOUTH BASS HARVEST LEVELS ON SOME DYNAMIC ASPECTS OF BASS-BLUEGILL POPULATIONS IN KANSAS FARM PONDS

by

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INTRODUCTION

Earthen dam reservoirs or ponds have become common features of rural landscapes since the early 1930's, largely due to the efforts of the Soil Conservation Service and the U. S. Department of Agriculture. These ponds were primarily constructed to provide rural water supplies, stabilize erosion and control run-off water. Many combinations of fish species were stocked in the ponds with little knowledge of possible interactions between the species or the ability of the pond environment to support them.

Studies began by H. S. Swingle and E. V. Smith in Alabama in the 1930's led to the recommended combination of the largemouth bass, <u>Micropterus salmoides</u> (Lacepede), and the bluegill, <u>Lepomis machrochirus</u> (Rafinesque), for small impoundments (Swingle, 1946). The roles of these species was to provide a balance of predator and prey that would simulate those relationships which have evolved in more diverse fish communities in natural environments. The largemouth bass serves as the top predator in the pond ecosystem and the bluegill as the major forage for the bass. Bluegill feed at a lower trophic level than bass, primarily on aquatic invertebrates and plant material, while bass feed almost exclusively on fish flesh. Since bluegill generally spawn two or more times in a growing season, they should provide an abundance of usable sizes of forage for the bass population.

Channel catfish, <u>Ictalurus punctatus</u> (Rafinesque), are commonly stocked with the bass and bluegill to provide more diverse angling opportunities and better utilization of the food resources. Channel catfish are presumed to increase the total standing crop of fishes without significantly reducing the standing crops of bass and bluegill, although definitive research of this hypothesis appears to be lacking. In any case, channel catfish are an important species and commonly make up a large proportion of the total harvest in many small impoundments.

Swingle (1950) defined balance as a condition of fish populations which yield, year after year, crops of harvestable fish which are satisfactory in relation to the basic fertility of the body of water. In so doing, he recognized the importance of natural fertility as a factor limiting carrying capicity or the capability of a specific aquatic environment to support fish biomass. Within this limit, balance is a dynamic state of predator-prey equilibrium which produces a harvestable surplus. Swingle (1950) developed a series of empirically derived ratios which were characteristic of balanced ponds in Alabama.

In the years following Swingle's work, numerous researchers have investigated management schemes to achieve and maintain balanced bass-bluegill populations in the face of ever increasing angling pressure and harvest. While Swingle's ratios are most useful for characterizing balanced populations, they require extensive effort for evaluation. As a result, they have limited use in monitoring results of applied management plans. In addition, what is considered a satisfactory crop, or a harvestable fish in one region of the country or by one group of anglers may be totally unacceptable in another region or by other fishermen (Bennett, 1962).

A major research objective has been to determine what the harvestable surplus is in terms of pounds or numbers. Nicholson (1954) referred to balance as the compensating reaction of a system to the disturbing forces which act upon it. Within this context, the major disturbing force is often angler harvest. It seemed reasonable to assume that those fish which were lost annually to natural mortality could be harvested without upsetting the balance. However, the amount which could be harvested is to some extent governed by the state of balance and that state is in turn controlled to some extent by the harvest as well as all the other biotic and abiotic factors impacting the system. It soon became apparent that some regulation of bass harvest was needed if satisfactory fishing was to be maintained. Because bass are often the preferred species by many anglers and are relatively easy to catch in small impoundments, they are often subject to overharvest. Bass overharvest means many things to many fishery biologists, but generally involves a shift in predator-prey equilibrium to a less desirable state typically resulting in reduced numbers and sizes of bass creeled by anglers as well as high density populations of stunted bluegills (Martin, 1974).

Improved management of small impoundments is necessary to meet the rapid increase in demand for sport fishing. Over seven million persons devoted approximately 80 million days to farm and ranch pond fishing in 1970 according to the United States Fish and Wildlife Service (1970). A survey of licensed Kansas anglers conducted in 1974 (Central Research Corporation, 1975) indicated that 22% of all licensed angler days in Kansas were spent in farm and ranch pond fishing. Kansas Fish and Game Commission (1977) has estimated that approximately 50,000 private ponds comprising 30,740 ha (75,926 ac) in Kansas provide significant sport fishing opportunities. These ponds make up 37% of

Kansas' total surface water area. Estimates in the 1977 plan indicate that the demand for pond fishing has not yet approached the supply. However, the quality of many existing pond fisheries leaves much to be desired.

Statewide objectives of the Kansas pond fisheries program are to improve the quality of fishing in Kansas ponds and to provide 1.3 million pond fishing days by 1982. Providing more fishing days can be done by increasing pond acreage or better management of existing ponds. Improving the quality of pond fishing is primarily a function of management. Meeting the anticipated demand for pond fishing and improving the quality of fishing in existing ponds are objectives which can both be met with more effective pond management. Well managed ponds should provide more angler days as well as a higher quality of fishing and increased yields.

Most ponds are never seen by fisheries personnel after they are stocked. Many ponds fail within a few years after stocking for a wide variety of reasons. Perhaps the most common cause of failure in bass-bluegill ponds is the overharvest of the largemouth bass. In 1972, fisheries administrators in 11 of 14 Midwestern agencies felt that bass overharvest was a problem (Bonneau and Conley, 1974). Bass overharvest reduces the predator density and often allows for the rapid expansion of bluegill populations. High density bluegill populations usually become stunted providing inadequate forage for the largemouth bass and an undesirable quality of fish for the angler.

The bass-bluegill combination can be effectively managed to maintain balance and provide satisfactory fishing according to Swingle's (1950) definition, but more commonly the scenario is one of a continually degrading fishery after angler harvest begins. Studies by Redmond (1974), Turner (1963) and others have shown an initial overharvest of bass when a new fishery is opened to angling, but an overharvest at a later date will eventually have the same effect. When bass are overharvested, the bluegill population expands rapidly as a result of reduced bass predation and often results in higher rates of bluegill reproductive success and recruitment. This produces a large population of stunted bluegills which consume virtually all food resources for maintenance thereby reducing growth rates to an unacceptable level. In addition, the dense population of bluegills further reduce the bass population via predation on bass eggs and fry. Raiding bass nests and consuming eggs reduces bass reproductive success. Increased predation on bass fry by stunted bluegills greatly reduces the number of bass available for recruitment into a size class which can effectively control the bluegill population. When bluegill population densities are high, their reproductive success is usually depressed also with the result that there are few small bluegill for any surviving small bass to feed on. This cycle continues with stunted bluegill dying through natural mortality and being constantly replaced by others of a similar quality while the mature bass remaining grow rapidly to a large size without reproducing successfully.

Numerous regulations have been employed in attempts to circumvent the previously outlined series of events. Restricted seasons, bag limits, number limits, and length limits have all been used with varying degrees of success. Length limits have generally been most successful, especially in preventing an initial overharvest in a new fishery or restoring a more desirable state of balance to a degraded fishery (Hackney, 1974). A relatively new approach to length limits is the protected length range or slot-length limit as it is frequently referred to. This method of regulation attempts to save those bass which are more efficient predators from angler harvest and keep them in the pond to control bluegill populations (Anderson, 1976). The range of sizes most commonly recommended for protection are those bass 30 to 38 cm (12 to 15 in) total length.

Another approach to harvest regulation is to limit the total kg/ha of bass removed by angler harvest. The logic of this method of harvest regulation lies in the assumption that angler harvest will not be particularly selective for either large or small bass and the average weight of bass harvested will be somewhat reflective of the average weight of harvestable size bass in the population. This would tend to circumvent the problems of harvest regulation with a number per acre quota since it will allow more individuals to be harvested in a population made up of many small bass and only a few individuals will be harvested in a population made up of large bass. This approach would appear to be satisfactory if the standing crop of bass is relatively constant with large numbers of small individuals being equivalent to small numbers of large individuals. It seems doubtful if this assumption is commonly met in most bass-bluegill ponds due to the dynamic qualities of predator-prey systems.

For pond management to be effective it must be a program that can be reasonably and effectively carried out by the pond owner. Regulating the harvest with a kg/ha quota is a relatively simple method providing the owner has control over who fishes the pond and is willing to spend a small amount of time record keeping. Prerequisites to this or any other sound management scheme are properly constructed ponds stocked with the appropriate numbers and species of fishes.

Anderson (1975) has pointed out that returning most of the catch through catch and release fishing not only improves the quality of fishing, but also greatly increases the number of angler hours per acre of managed water. For example, a low harvest such as a 11.2 kg/ha (10 lb/ac) quota on bass might simulate these conditions. Many bass could be caught and released while still providing a limited harvest. Bluegill populations under a low bass harvest scheme might be expected to show a favorable response in growth rate and a more desirable population structure. Low level bass harvest might produce larger numbers of older and larger fish for the angler. Shifting the size structure of bass populations to larger fish should also increase the rate of predation on bluegill resulting in more desirable bluegill population structure. Populations at equilibrium with low bass harvest levels are expected to have larger total bass populations and a larger average size of individual fish. Larger numbers of harvestable size bluegill are also anticipated.

At high levels of bass harvest, maximum sustainable yield (MSY) might be approached. This would provide the greatest total harvest of bass, but a decrease in quality or average size could be expected. Harvesting at high levels should result in smaller bass populations and high rates of growth. Harvesting at or near MSY could easily result in an overharvest since MSY will vary from pond to pond and from year to year within a pond. It is also doubtful if a reduced bass population made up of mostly small individuals could effectively control the bluegill population.

Intermediate levels of bass harvest should result in populations with properties somewhere in between those subjected to low or high harvests. An intermediate level of harvest is probably most desirable in terms of overall quality of the fishery and maintaining long term predator-prey equilibrium and sustainable harvests of both species. An intermediate level of bass harvest is expected to produce a more stable state of balance and less tendency toward domination by either species.

The primary purpose of this study was to regulate bass harvest with a total kg/ha harvest quota and observe the effects of various levels of harvest on those dynamic aspects of growth, reproduction and mortality which determine the state of balance in the pond ecosystem.

The secondary objective of this study was to test a simple management plan involving an annual kg/ha bass harvest quota which could be easily implemented by pond owners.

MATERIALS AND METHODS

Study Area and Pond Selection

Ponds in this study were located in the Northeastern Flint Hills area of Kansas within a 20 mile radius of Manhattan, Kansas. The primary topography of this area is moderately deep valleys surrounded by hills and plateaus with limestone bedrock and flint embedded limestone outcroppings. Soils are generally rather thin in depth but quite fertile with the dominant vegetation being native tallgrass bluestem prairie. Soils in the Northeastern portion of the study area are of glacial origin and tend to be sandy loams with few limestone outcroppings. The dominant vegetation here is native prairie also. Freshwater springs abound throughout the area and many ponds receive spring flow during some part of the year. Spring flow usually ceases during dry periods in midsummer and the water level decreases at this time due to leaks through fractured limestone layers in the pond basin.

Twelve ponds were selected in the study area for this project. Selection was based primarily on availability and willingness of owners to cooperate in regulating the harvest and record keeping. Other important criteria were the absence of extreme turbidity which is known to be a limiting factor in bass production (Buck, 1956) and relatively stable water levels.

Some of the ponds were renovated with rotenone and restocked with bass, bluegill, and channel catfish. If the desired species were already present and no contamination by other species was found, adult bass and bluegill were stocked as needed to bring the pond into balance. Channel catfish were stocked at the rate of 247/ha (100/ac) and restocked each fall with 178 - 203 mm

(7-8 in) fish in quantities equal to those which had been harvested during the year. Bass harvest quotas and record keeping had been established for most of the ponds by the summer of 1974.

Pond Description and Morphology

Ponds were mapped with the transit-alidade method and morphological parameters determined from the data (Table 1). Study ponds ranged in size from 0.15 to 0.87 hectares (0.38 - 2.15 acres) with corresponding volumes ranging from 1542 to 19,244 mm^3 (1.25 to 15.60 acre-feet). Shoreline development ranged from a low of 1.33 to a high of 2.16. Mean depth ranged from 1.00 to 2.21 meters. These morphometric data were used for management needs such as determining harvest quotas and herbicide applications to control aquatic vegetation.

Aquatic vegetation can be a problem in Flint Hills ponds due to the clarity of the water. <u>Chara</u> sp., <u>Potamogeton</u> sp., and <u>Naias</u> sp., are common genera which often produce dense growths when not controlled. Karmex was applied as needed throughout the growing season to control, but not eliminate nuisance aquatic vegetation. This was necessary to insure that vegetation did not inhibit bass predation on young bluegills and lead to unbalanced systems dominated by stunted bluegills.

All ponds were equipped with trickle tubes or drop outlets in addition to emergency spillways. All but one pond received some spring flow but the amount and duration was highly variable and no attempt was made to determine these parameters. Water levels fell in some of the ponds after spring flow ceased,

Table 1. Morphometric data for the 12 Kansas farm ponds used in this study.

Pond	Mapped Area		Mapped Volume		Shoreline length			Max. Depth		Mean Depth	
No.	ha.	acres	Ac-ft.	m^3	m	ft.	SLD	m	ft.	m	ft.
1	0.39	0.97	5.43	6698.6	377.9	1240	1.70	3.81	12	1.71	5.61
2	0.56	1.38	4.95	6106.4	353.6	1160	1.33	2.44	8	1.09	3.59
3	0.15	0.38	1.25	1542.0	286.5	940	2.06	2.13	7	1.00	3.29
4	0.87	2.15	15.60	19244.5	538.6	1767	1.63	4.27	14	2.21	7.26
5	0.44	1.08	6.75	8326.9	377.9	1240	1.61	4.27	14	1.91	6.25
6	0.29	0.71	2.22	2738.6	410.3	1346	2.16	2.44	8	0.95	3.13
7	0.70	1.72	9.92	12237.5	445.0	1460	1.50	4.27	14	1.76	5.77
8	0.47	1.16	5.68	7007.0	331.6	1088	1.37	3.35	11	1.49	4.90
9	0.48	1.19	6.07	7488.1	359.7	1180	1.46	3.05	10	1.55	5.10
10	0.68	1.69	7.80	9622.2	569.1	1867	1.94	3.05	10	1.41	4.62
11	0.26	0.65	2.19	2701.6	313.3	1028	1.72	2.44	8	1.03	3.37
12	0.17	0.43	2.08	2565.9	212.8	698	1.44	3.05	10	1.47	4.84

$$\text{SLD} = \text{Shoreline development} = \frac{\text{Shoreline length (m)}}{2\sqrt{\text{Surface area (m}^2\text{)} \times \pi}}$$

$$\text{Mean depth (m)} = \frac{\text{Volume (m}^3\text{)}}{\text{Surface area (m}^2\text{)}}$$

but tended to stabilize at some constant level usually associated with a break in a limestone layer within the pond basin.

Pond watersheds were almost entirely composed of prairie grasslands used for grazing livestock. Two ponds were fenced to exclude livestock from the dam, but all allowed access to the water. The effects of livestock access on turbidity and fertility may be significant, but were not evaluated in this study.

Harvest Regulation and Grouping of Study Ponds

Bass harvest was regulated with kg/ha (lb/acre) quotas based on the mean yearly pond area. Harvest levels of low, medium, and high involving targets of 11.2, 22.4, and 33.6 kg/ha/year (10, 20, 30 lbs/ac) of largemouth bass were set. Four ponds were assigned to each of the three harvest levels.

Ponds were posted with signs at each access point indicating that no fishing was allowed without permission of the owner. Pond owners issued fishing permits to anglers at their discretion. Anglers were requested to record numbers and lengths or weights of fish removed and return the permits to the pond owner. When the quota had been reached, the pond was closed to bass fishing. Records were also kept of the numbers, lengths, and weights of bluegill and channel catfish removed (Appendix A).

If the targeted quota had not been reached by late fall, the amount needed was removed while sampling the ponds. Ponds were then closed to all fishing until the following year.

For purposes of analysis, ponds were later grouped by the percent of the estimated population harvested. This was done because the harvest quotas do not reflect population size and standing crop. Since growth and recruitment are density dependent (Johnson and McCrimmon, 1967) these adjustments are necessary if the effects of harvest are to be adequately reflected in growth, recruitment and mortality. For example, the effects of a 33.6 kg/ha/yr bass harvest on a standing crop of 56.0 kg/ha is much different than the same harvest on a standing crop of 112.0 kg/ha.

Throughout the remainder of this paper, ponds will be grouped according to a scheme based upon the percentages of estimated population and standing crop harvested. All data points are illustrated with a ●, ■, or ★ indicating low, medium, and high levels of bass harvest respectively. The scheme for grouping ponds by the level of bass harvest is as follows:

Group		Range of percentages delineating groups: % of Est. Pop. Harvested	% of Est. Std. Crop Harvested	Pond Numbers
Low Har.	●	0-15	0-25	1,3,5,12
Med. Har.	■	16-30	26-50	2,6,7,9
High Har.	★	31-60	51-81	4,8,10,11

This classification system will be dealt with more thoroughly in the section on harvest.

Limnological Sampling and Analysis

Selected limnological parameters were evaluated in the spring, summer, and fall to assess natural fertility and suitability of the ponds for fish production. Means of selected parameters for the three samples taken in June, July, and October of 1976 (Table 2) suggest that natural fertility may be different between ponds. It is not possible to draw definite conclusions from these data because sampling was done so infrequently and at various times of the day. Total standing crops of all species are needed for a meaningful analysis of the impact of water quality measurements on natural fertility or carrying capacity of the ponds.

Water level was measured as the distance from the lowest point on the trickle tube or outlet to the surface of the water. These values were graphed to determine mean yearly pond area and volumes. Harvest quotas were adjusted to the mean yearly area.

Secchi disc transparency was determined with a standard 20 cm secchi disc. Temperature profiles were determined with an Applied Research model FT3 hydrographic thermal probe. Dissolved oxygen profiles were determined with a Yellow Springs Instrument Company model 54 dissolved oxygen meter. Temperature and dissolved oxygen values were recorded in 0.5 meter intervals from the surface to the bottom in the deepest part of the pond.

Liter samples were taken from the top and bottom of the water column in the deepest part of the pond with a modified van Dorn type sampler. These samples were returned to the laboratory and analyzed for turbidity, specific conductivity, pH, free CO_2, alkalinity, nitrate nitrogen, orthophosphate, and hardness. Specific conductivity was determined with a Hach dissolved solids meter model 2300. A Corning model 12 pH meter was used to determine pH. Free CO_2, alkalinity, and hardness were determined by standard titrametric methods. All other parameters were determined with a Hach model DR-A 1969 colorimeter using standard Hach methods.

Table 2. Limnological analysis of surface samples from the 12 Kansas farm ponds used in this study.

	Pond Numbers											
Parameter	1	2	3	4	5	6	7	8	9	10	11	12
Secchi disc (cm)	76.7	27.7	71.7	75.0	200.0	45.0	58.3	100.0	160.0	86.7	123.3	93.3
Temperature °C	23.1	20.0	22.7	23.2	23.1	22.5	20.2	20.3	24.5	23.8	24.3	24.4
Dissolved O_2 (ppm)	6.9	9.0	8.2	10.0	9.3	7.9	8.1	8.6	10.8	8.3	8.2	7.0
Turbidity (JTU)	28.0	65.7	16.0	18.7	9.0	48.0	42.7	10.7	11.3	17.0	9.0	14.7
Conductivity (u mho/cm)	367	276	370	222	353	259	238	403	437	247	468	370
pH	8.3	8.3	8.4	8.4	8.5	8.2	8.0	8.4	8.7	8.3	8.4	8.2
Alkalinity (ppm)	184.3	128.7	180.7	103.3	186.0	154.3	119.0	190.0	199.7	109.3	220.3	146.0
Ortho Phosphate (ppm)	0.07	0.05	0.06	0.07	0.05	0.08	0.07	0.08	0.04	0.07	0.04	0.07
Nitrate Nitrogen (ppm)	0.63	0.49	0.52	0.53	0.53	0.83	0.62	0.66	0.55	0.52	0.39	0.66
$CaCO_3$ Hardness (ppm)	143.0	132.0	169.0	93.0	149.0	140.0	110.0	219.0	184.0	108.0	219.0	117.0

Table values are means of June, July and October samples. Hardness was determined for the July and October samples only.

Fish Population Sampling

Bass and bluegill populations were sampled in the spring and fall. Total length to the nearest mm and weight to the nearest gram was recorded for all bass captured and up to 25 bluegill in each successive 25 mm size group. Scales were collected from all bass and up to 25 bluegill in each size group.

Spring sampling was done with a 230 volt A.C. boat mounted electrofishing unit. Attempts to estimate bass populations were abandoned due to the inefficiency of the electrofishing unit and suspected mortality from handling in the rapidly warming waters.

Fall sampling was done with a 1.82 x 30.4 mm (6' x 100') trammel net made up of 17.8 cm (7") bar mesh outer panels and 2.54 cm (1") bar mesh inner panel. Extra floats and weights were placed on the net and it was then attached to brailes and used as a seine. This equipment produced good population estimates with selectivity apparently limited to the minimum sizes of each species which the inner mesh would retain. These minimum sizes were 125 mm for bluegill and 200 mm for largemouth bass.

Population estimates were made using a mark-recapture technique. Chapman's modification of the Peterson formula, $N = (M+1)(C+1)/R+1$, was used to estimate the number of largemouth bass $\geq$ 200 mm total length (Ricker, 1975). Ninety-five percent confidence intervals were established by using Ricker's (1975) binomial table. Estimates were adjusted to the mean yearly pond area and bass standing crops were estimated by taking the adjusted population estimates times the mean weight of the fish sampled in making the population estimate.

Shoreline seining was done in the spring and fall with a 1.22 x 6.08 m (4' x 20') bag seine with 6.4 mm bar mesh to evaluate reproductive success and collect scale samples of fish not taken by other sampling methods. Five, 1/4 circle seine hauls were made and the numbers of small, medium, and large bass and bluegills counted. Means of the five seine hauls were expanded to mean yearly pond area to determine the approximate density of young bass and bluegill. This was accomplished by dividing the mean yearly pond area by the area covered by a 6.08 m, 1/4 circle seine haul and multiplying by the means of the five seine hauls. For purposes of this analysis, size groups are delineated as follows:

	Size Groups (mm)		
Species	Small	Medium	Large
Bass	≤ 125	126-250	≥ 251
Bluegill	≤ 75	76-150	≥ 151

Methods of Analysis

Scale samples were collected from the left side of the fish in the area posterior to the pectoral fin base and below the lateral line and ventral to the anterior origin of the dorsal fin. Scales were then cleaned and mounted between glass slides. Scales were soaked for a few minutes in 95% ethanol and read on a Bausch and Lomb Tri-Simplex microprojector. Annuli were distinguished primarily by crossing over in lateral fields and secondarily by dark bands through the ctenii and closely spaced circuli.

Distance between annuli was measured along a line bisecting the anterior field from the focus to the anterior margin of the scale and recorded as millimeters from focus to each successive annulus. All bass scales were read twice by the same person and any discrepancies were reconciled by assigning an age based on the most likely year class for the fishes length at time of capture. Bluegill scales were read and about 10% of them reread to spot check age determinations. If large discrepancies were discovered, the entire sample for that pond was read again. At least three scales from each fish were examined in an attempt to eliminate errors due to false annuli. A total of 886 bass and 1454 bluegill scales were aged.

The relationship of total body length to anterior scale radius of all fish combined was calculated by linear regression using the least squares technique. The calculated length-scale regressions, correlation coefficients and standard errors of slopes and intercepts for both species are shown below.

Species	Regression equation	r
Bass	L = 24.10338 + 61.8441 Sr	0.98
Std. Error	(1.684) (3.452)	
Bluegill	L = 26.84544 + 41.4423 Sr	0.97
Std. Error	(0.650) (1.066)	

The length-scale regression equations were used to back-calculate lengths at annulus formation. Back calculated lengths were determined for each pond individually, and then all the scale samples for a selected group of ponds were combined to calculate lengths for a group of ponds based on the level of bass harvest.

Length-scale relationships and age and growth calculations were determined with computer programs developed by the K.S.U. statistics laboratory.

Analysis of variance and covariance, correlation, and regression statistics were evaluated with SAS 76 programs (Barr, Goodnight, Sall, and Helwig, 1976). All programs were ran on an IBM 370-158 computer at Kansas State University.

RESULTS

Bass Population Estimates and Standing Crop

Considerable effort was expended in obtaining population estimates. The number of recaptures in the spring sample was too low to provide reliable estimates, but fall sampling was more successful and resulted in good estimates of the numbers of bass ≥ 200 mm total length. The sampling gear was not efficient in capturing smaller bass with the resulting estimates being applicable only to that portion of the population made up of individuals ≥ 200 mm. All population estimates referred to, whether by number or weight, are for the fall of 1976. The bass estimates reflect the status of the populations after the 1976 harvest had been taken. No attempt was made to estimate bluegill populations.

Estimated populations of largemouth bass ≥ 200 mm ranged from 28.6 to 407.5/ha (11.6-167.2/acre) and averaged 185.4/ha (75.1/acre). These estimates and 95% confidence intervals (Table 3) are generally considered to be within acceptable limits. The number of fish captured in making the estimates ranged from approximately 25 to 100% of the estimated populations.

Since harvest was regulated with a kg/ha (lb/acre) quota, an estimate of standing crop was needed to evaluate the effects of the harvest. To arrive at this, the mean weight of fish sampled in making the population estimate for each pond was multiplied by the point estimate of the population for that pond (Table 3). These standing crop estimates refer only to those bass ≥ 200 mm total length in the populations. Estimated bass standing crops ranged from 16.9 to 103.9 kg/ha (15.0 - 92.5 lb/acre) and averaged 53.8 kg/ha (47.9 lb/acre). The standing crop estimates are thought to be reasonably accurate for those segments of the population sampled.

Table 3. Fall 1976 population estimates, confidence intervals, mean weights, and standing crop estimates for largemouth bass ≥ 200 mm in the 12 study ponds.

Pond	Mean Area[a]		Population Estimate[b] and 95% Conf. Int.[c]					Data Summary[d]			Standing Crop Estimates[e]	
No.	ha.	Ac.	≤	$\hat{N}$	≤	No/ha	No/Ac	No.	Total Wgt.(g)	Mean Wgt.(g)	kg/ha	lbs/Ac
1	0.28	(0.68)	40.4	62.6	101.6	223.6	(92.1)	51	12471.0	244.5	54.7	(48.7)
2	0.42	(1.03)	40.2	54.4	88.3	129.5	(58.8)	51	14545.0	285.2	36.9	(32.9)
3	0.15	(0.36)	23.8	33.1	53.9	220.7	(91.9)	33	15537.0	470.8	103.9	(92.5)
4	0.84	(2.07)	7.3	24.0	43.6	28.6	(11.6)	7	4763.0	680.4	19.5	(17.3)
5	0.39	(0.96)	63.7	140.4	351.0	360.0	(146.3)	48	13450.0	280.2	100.9	(89.8)
6	0.23	(0.57)	43.0	55.2	103.6	240.0	(96.8)	53	17874.0	337.3	81.0	(72.1)
7	0.62	(1.53)	8.2	20.0	50.0	32.3	(13.1)	13	6813.0	524.1	16.9	(15.0)
8	0.40	(0.98)	27.6	37.6	75.9	94.0	(38.4)	35	11803.0	337.2	31.7	(28.2)
9	0.36	(0.90)	65.0	110.0	198.6	305.6	(122.2)	73	17827.0	244.2	74.6	(66.4)
10	0.68	(1.69)	31.5	59.7	153.9	87.8	(35.3)	43	16708.0	388.6	34.1	(30.4)
11	0.25	(0.62)	20.0	23.9	61.1	95.6	(38.6)	24	12884.0	536.8	51.3	(45.7)
12	0.16	(0.39)	30.8	65.2	150.4	407.5	(167.2)	33	3275.0	99.2	40.4	(36.0)

[a]Graphically determined mean 1976 pond area. [b]$\hat{N} = (M+1)(C+1)/R+1$ from Ricker, 1975. p. 78. Rickers modification of Chapman's version of the Petersen equation. [c]Table values of R from Ricker, 1975. Appendix II, p. 343. Substitute table values of R into equation b to calculate a 95% confidence interval for R variables distributed in a Poisson frequency distribution. [d]Summary of fish captured while making population estimates excluding recaptures and harvested fish. [e]Standing crop estimate = population estimate x mean weight.

There is an approximate linear relationship between population size and standing crop (Figure 1) with a correlation coefficient of 0.65. Also apparent from Figure 1 is the relationship of level of bass harvest to population and standing crop. In general, the low harvest ponds (1,3,5,12) have larger populations and standing crops than the high harvest ponds (4,8,10,11).

There is a good linear relationship between estimated population and mean weight (Figure 2) with a correlation coefficient of -0.79. This demonstrates density dependence with lower mean weights (smaller individuals) being symptomatic of high density populations. An extreme case such as pond No. 12 with a mean bass weight of 99.2 grams would most commonly be diagnosed as a stunted bass population. Very high mean weights and small populations as typified by pond No. 4 are common in bluegill dominated ponds. Reproduction and recruitment of bass are usually very limited in such a system while those adults present have an abundance of forage available and grow rapidly to a large size (Bennett, 1962).

Also of interest is the relationship of harvest to mean weight (Figure 2). Low harvest ponds tend to have larger populations and smaller individuals. Although the medium harvest level ponds do not form a distinct group, they do tend to have mean weights and population sizes somewhat intermediate to the high and low harvest groups of ponds.

There are linear relationships between pond area and estimated of population number and standing crop (Figures 3 and 4) with correlation coefficients of -0.67 and -0.62 respectively. Ponds 4, 7, and 10 make strong contributions to the linearity of these relationships. Since these are the largest ponds in the

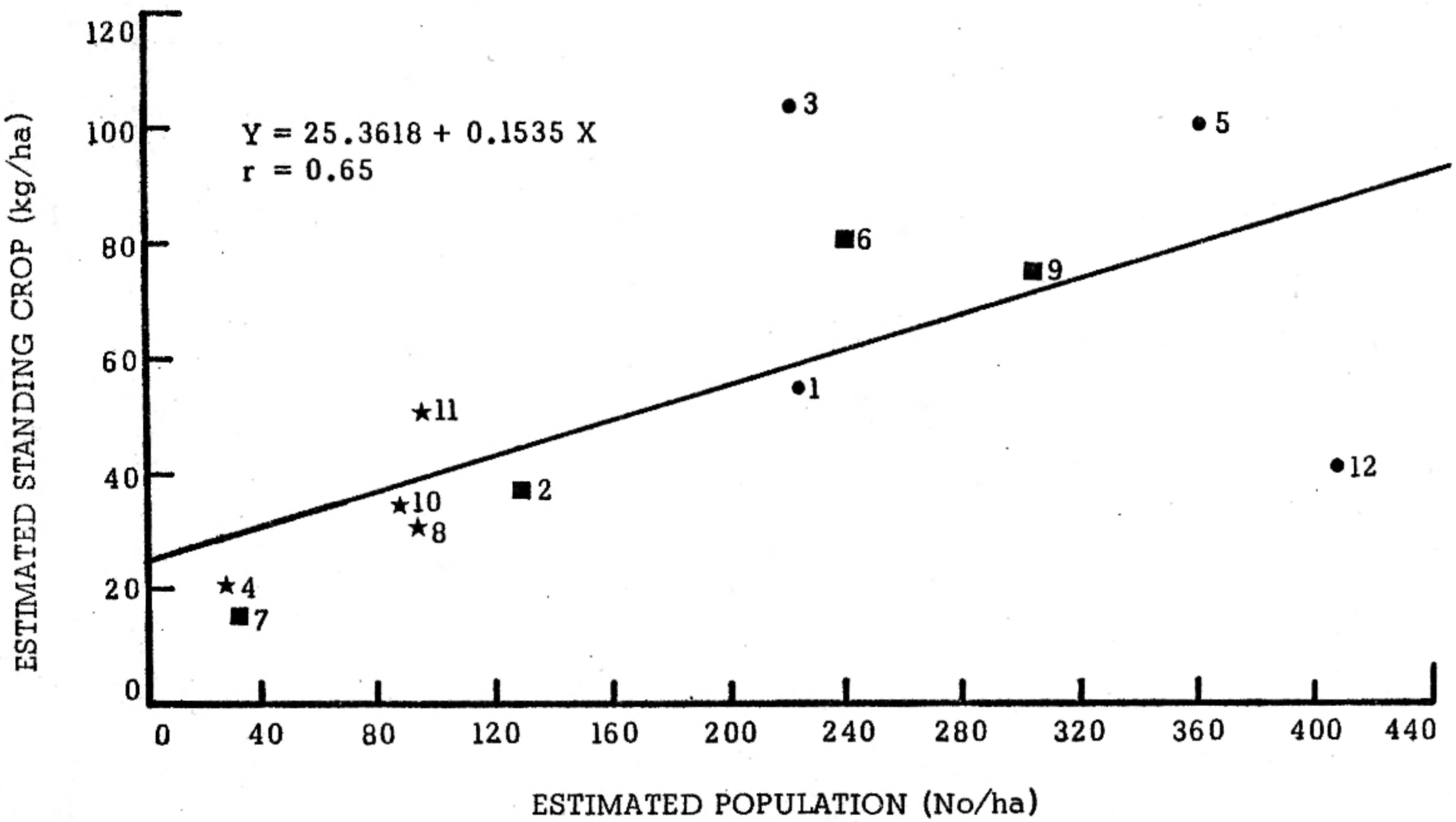

Figure 1. Relationship of estimated population to estimated standing crop for largemouth bass in the 12 study ponds. ●- Low harvest ponds. ■- Medium harvest ponds. ★- High harvest ponds.

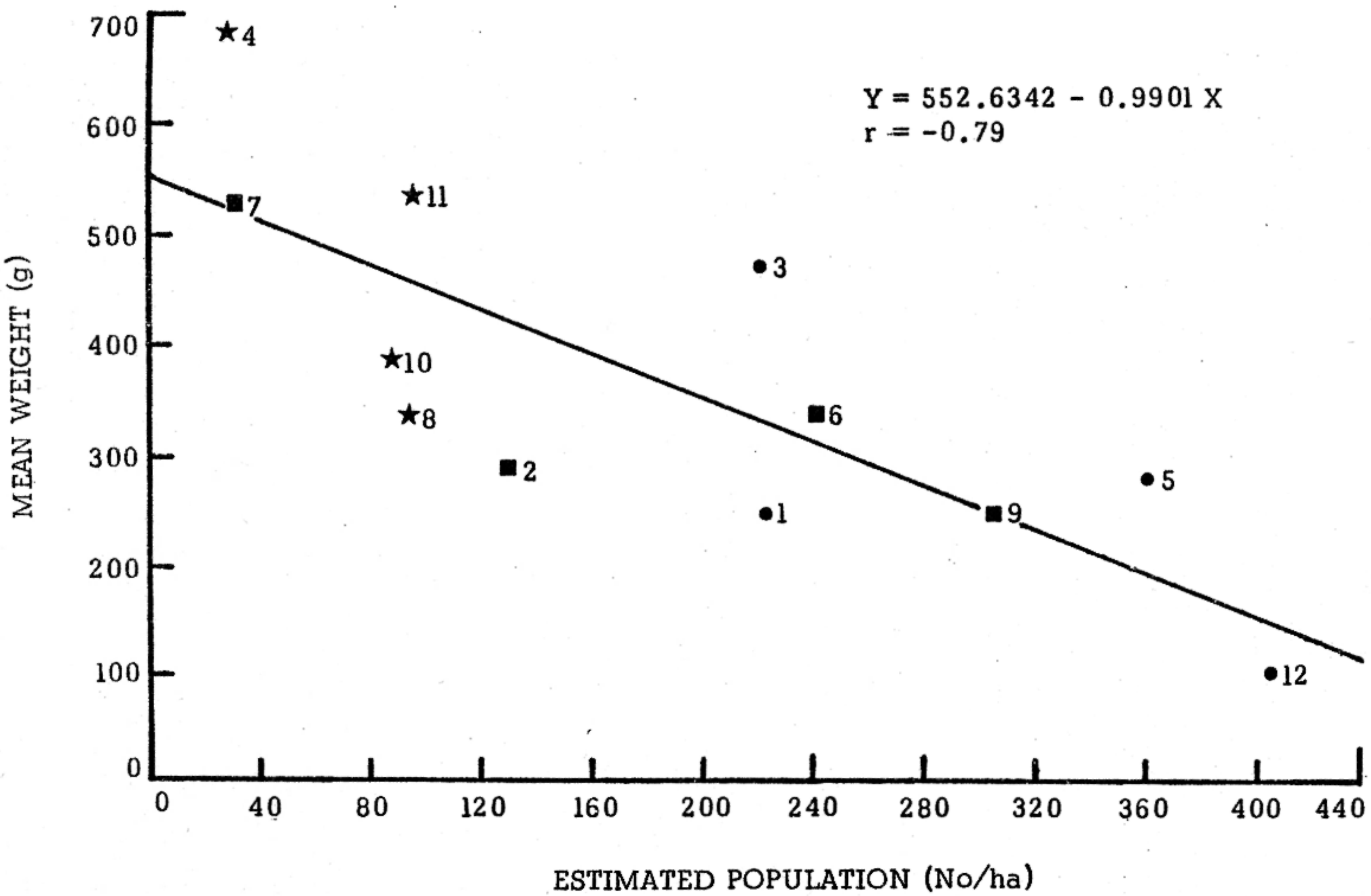

Figure 2. Relationship of estimated population to mean weight of largemouth bass ≥ 200 mm total length in the 12 study ponds. ● - Low harvest ponds. ■- Medium harvest ponds. ★- High harvest ponds.

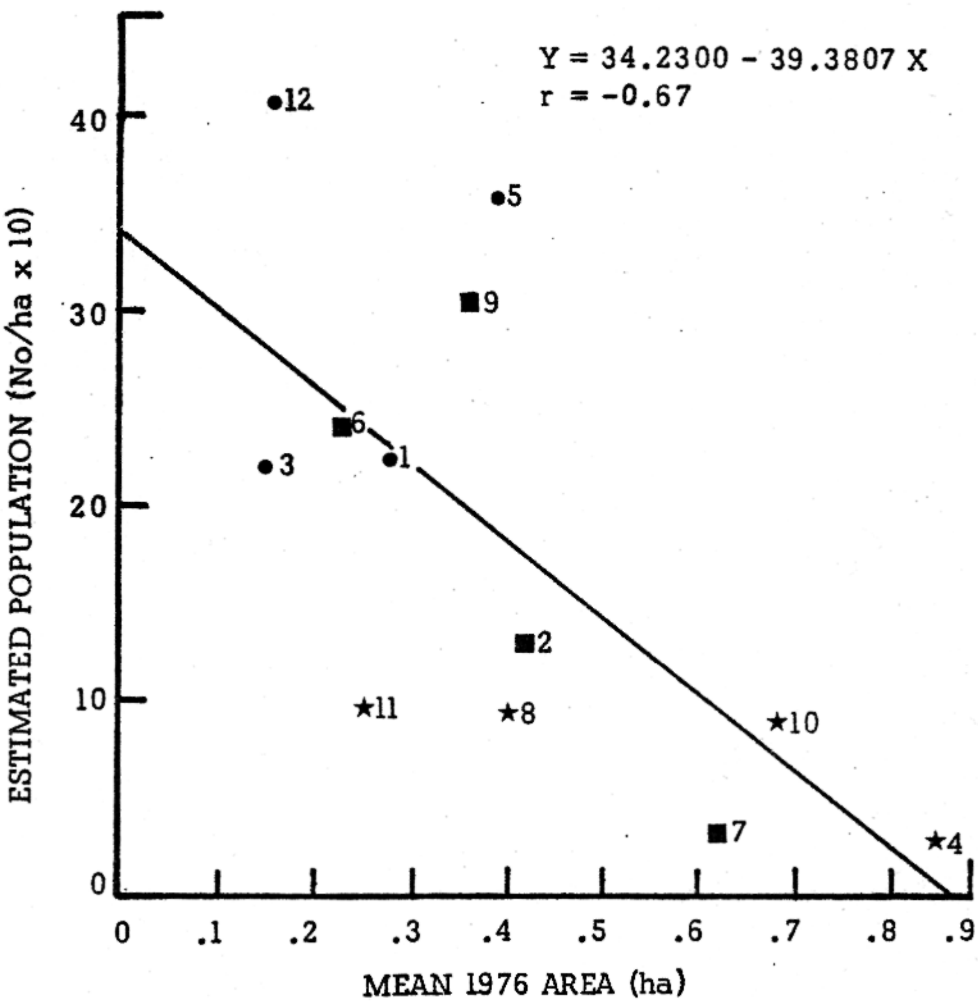

Figure 3. Relationship of mean 1976 pond area to estimated populations of largemouth bass ≥ 200 mm in the 12 study ponds. ● - Low harvest. ■- Medium harvest. ★ - High harvest.

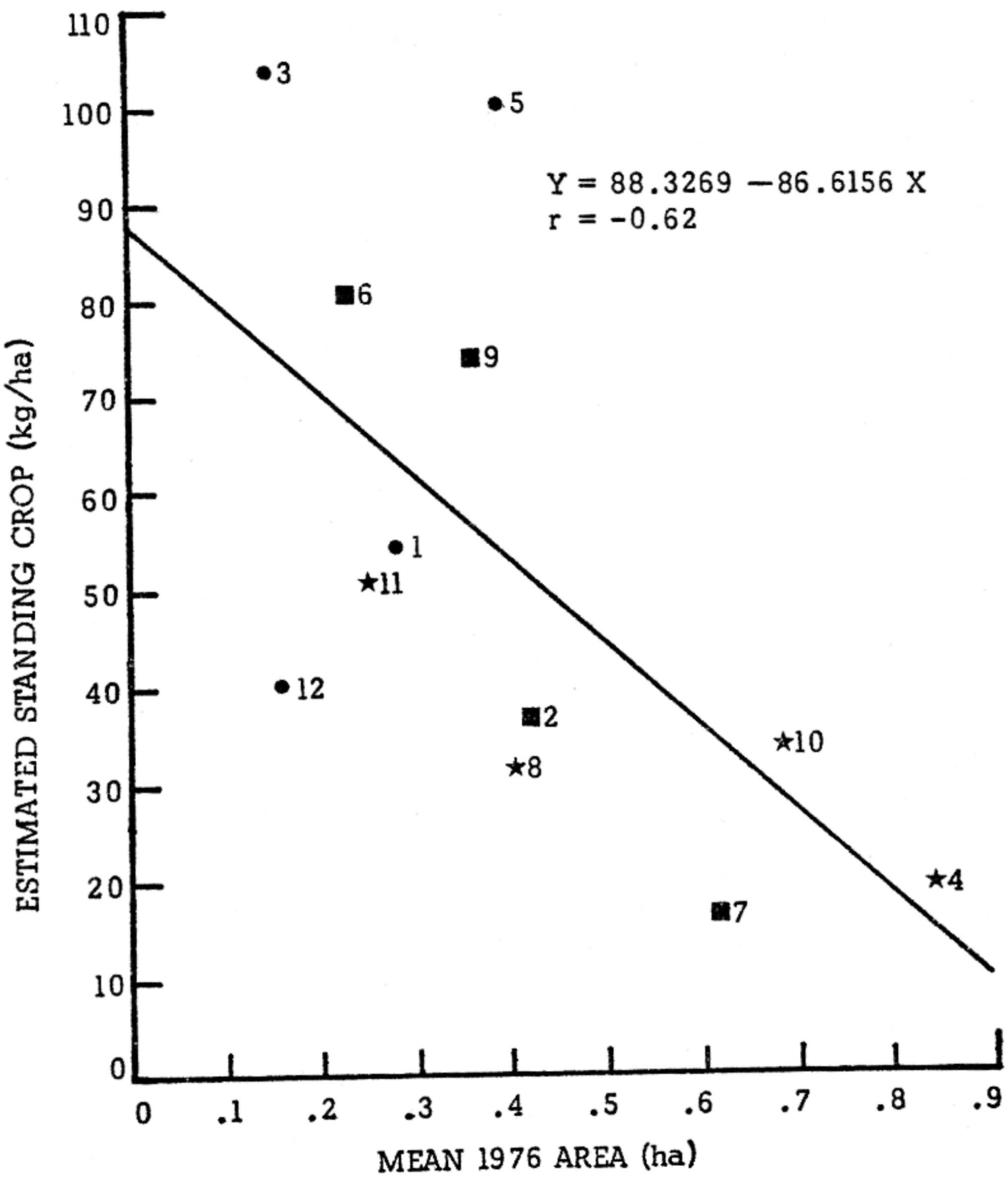

Figure 4. Relationship of mean 1976 pond area to estimated standing crop of largemouth bass $\geq$ 200 mm in the 12 study ponds. ● - Low harvest. ■ - Medium harvest. ★ - High harvest.

study, the low population and standing crop estimates for them may be due to the inefficiency of the sampling gear in ponds larger than 0.5/ha. Because population estimates and confidence intervals for these ponds (Table 3) do not stand out as being particularly deviant from those of the other ponds, it is thought that the disparity is more likely the result of some other factor or combination of factors. There is some evidence suggesting unreported harvests in these ponds. In addition, pond No. 4 was dominated by stunted bluegill at the beginning of the study and efforts to achieve a desirable state of balance may not have been completely successful.

It is possible that the relationships illustrated in Figures 3 and 4 have no sound biological explanation. The exclusion of Ponds 4, 7, and 10 results in much different regression equations which are even more difficult to explain.

Harvest

While bass harvest was actually regulated with a kg/ha quota, this procedure fails to consider variability in population size and standing crop. Any given quota will have a vastly different effect on a small population than on a larger one.

Graham (1974) has reported a 40% bass harvest by number as producing optimum growth and recruitment in Missouri ponds. In order to determine the effects of various levels of bass harvest on growth and other dynamic aspects of the fish populations, ponds were grouped on the basis of percent harvested rather than absolute numbers or pounds harvested.

The bass harvest varied from 6.2 to 56.3% of the estimated population by number (Table 4). Standing crop harvested ranged from 7.2 to 80.1%. When the

Table 4. Fall 1976 population and standing crop estimates for largemouth bass ≥ 200 mm, total harvest of largemouth bass in 1976, and percent of estimated population and standing crop harvested in 1976.

Pond	Estimated Population		Estimated Standing Crop		Total Harvest Numbers		Total Harvest Standing Crop		Percentage of estimates harvested in 1976	
No.	No/ha	No/Ac	kg/ha	lbs/Ac	No/ha	No/Ac	kg/ha	lbs/Ac	No.	Standing Crop
1	223.6	(92.1)	54.7	(48.7)	10.9	(4.41)	13.17	(11.76)	4.9	24.1
2	129.5	(58.8)	36.9	(32.9)	38.4	(15.53)	17.21	(15.35)	29.7	46.6
3	220.7	(91.9)	103.9	(92.5)	13.7	(5.56)	11.30	(10.08)	6.2	10.9
4	28.6	(11.6)	19.5	(17.3)	9.5	(3.86)	11.24	(10.02)	33.2	57.6
5	360.0	(146.3)	100.9	(89.8)	28.3	(11.46)	14.24	(12.70)	7.9	14.1
6	240.0	(96.8)	81.0	(72.1)	43.3	(17.54)	22.51	(20.07)	18.0	27.8
7	32.3	(13.1)	16.9	(15.0)	8.1	(3.27)	5.77	(5.15)	25.1	34.2
8	94.0	(38.4)	31.7	(28.2)	52.9	(21.43)	18.66	(16.64)	56.3	58.9
9	305.6	(122.2)	74.6	(66.4)	76.8	(31.11)	27.34	(24.38)	25.1	36.7
10	87.8	(35.3)	34.1	(30.4)	29.2	(11.83)	27.30	(24.34)	33.3	80.1
11	95.6	(38.6)	51.3	(45.7)	43.8	(17.74)	31.89	(28.44)	45.8	62.2
12	407.5	(167.2)	40.4	(36.0)	38.0	(15.38)	2.90	(2.59)	9.3	7.2

percent of estimated standing crop harvested is graphed as a function of the percent of estimated population harvested (Figure 5) the 12 ponds fall into three rather distinct, but arbitrary groups. For purposes of analysis, ponds are grouped into low, medium and high harvest categories according to Figure 5.

Bass harvest in the low harvest group was less than 15% of the estimated population and less than 25% of the estimated standing crop. The averages for the four ponds in the low harvest group (Ponds 1,3,5,12) are 7.08% of the estimated population and 14.08% of the estimated standing crop harvested.

In the medium harvest group are ponds in which 16-30% of the estimated population and 26-50% of the estimated standing crop were harvested. The four ponds in this group (2,6,7,9) had an average of 24.48% of the estimated population and 36.33% of the estimated standing crop removed.

The group of high harvest ponds (4,8,10,11) had more than 31% of the estimated population and more than 51% of the estimated standing crop removed by harvesting. The average harvest for this group of ponds is 42.15% of the estimated populations and 64.70% of the estimated standing crops.

There is no obvious relationship between the number per hectare harvested and the estimated populations of bass $\geq$ 200 mm in the 12 ponds (Figure 6). This provides additional support for grouping ponds on the basis of percentage harvested rather than the absolute amount harvested. Figure 7 indicates that no relationship exists between average harvest for the 3 years of the study and the estimated bass populations. A comparison of Figure 6 and Figure 7 indicates quite clearly that there is very little difference between the 1976 harvest and the average harvest for the 3 years of the study.

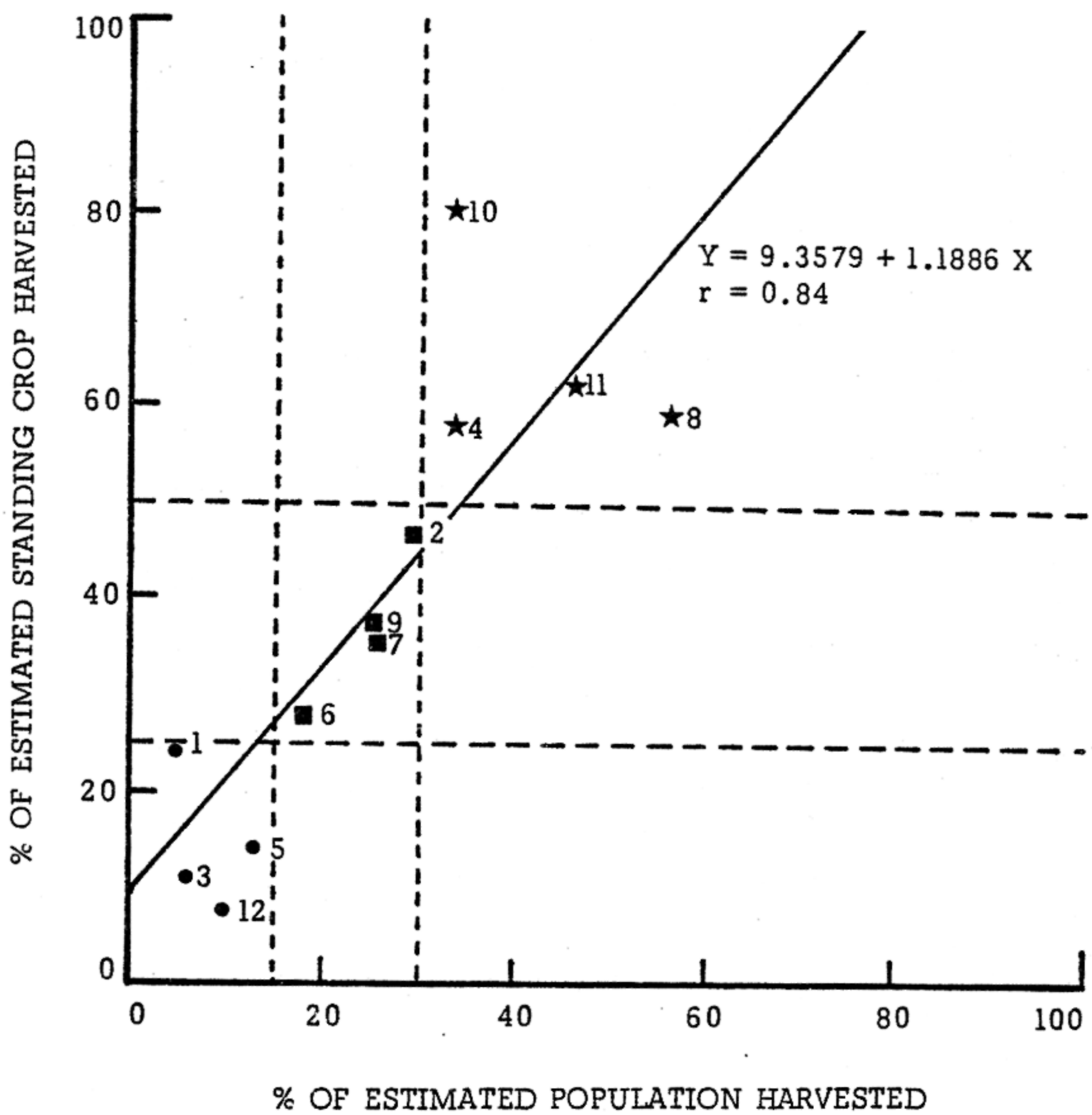

Figure 5. Relationship of percent of estimated population harvested in 1976 to percent of estimated standing crop harvest in 1976 for largemouth bass in the 12 study ponds. ● - Low harvest. ■ - Medium harvest. ★- High harvest.

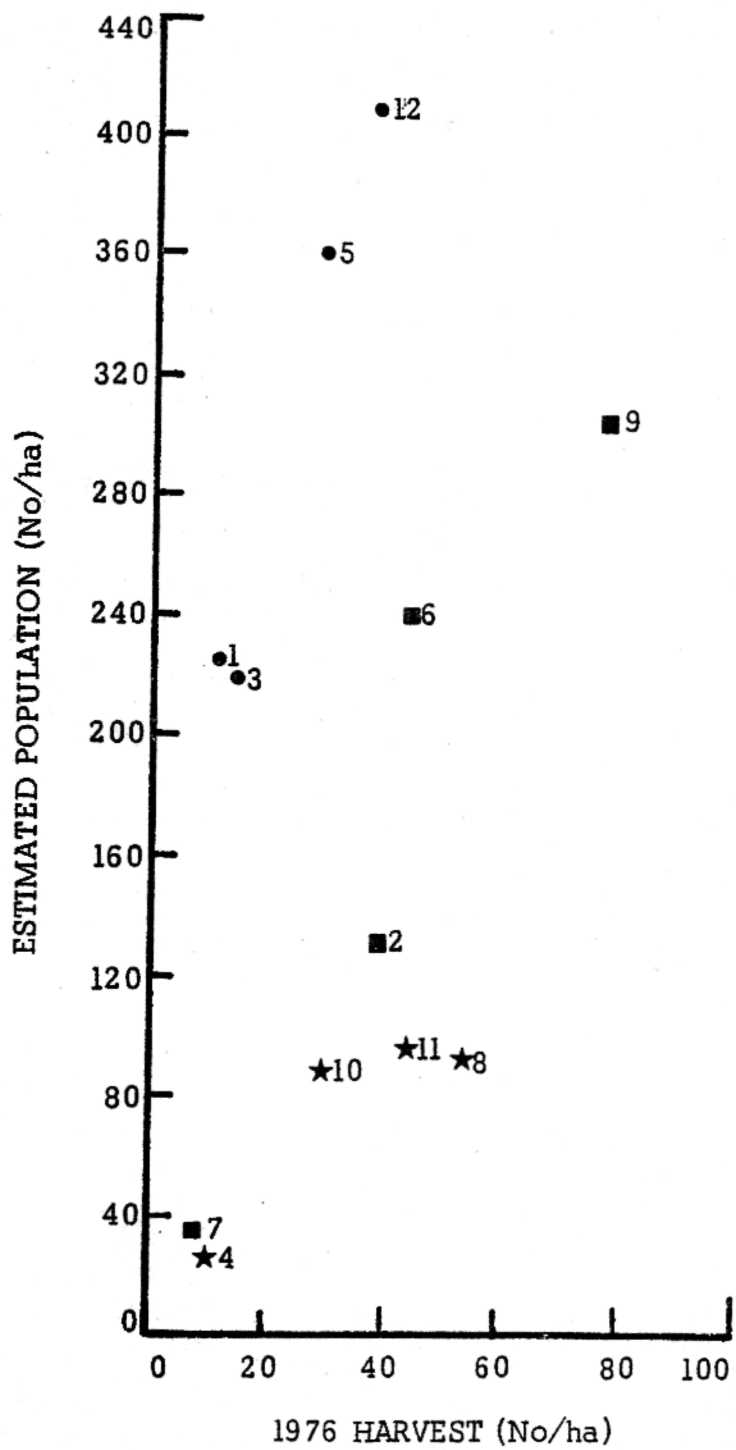

Figure 6. Relationship of number harvested to estimated populations of largemouth bass in the 12 study ponds. ● - Low harvest. ■ - Medium harvest. ★ - High harvest.

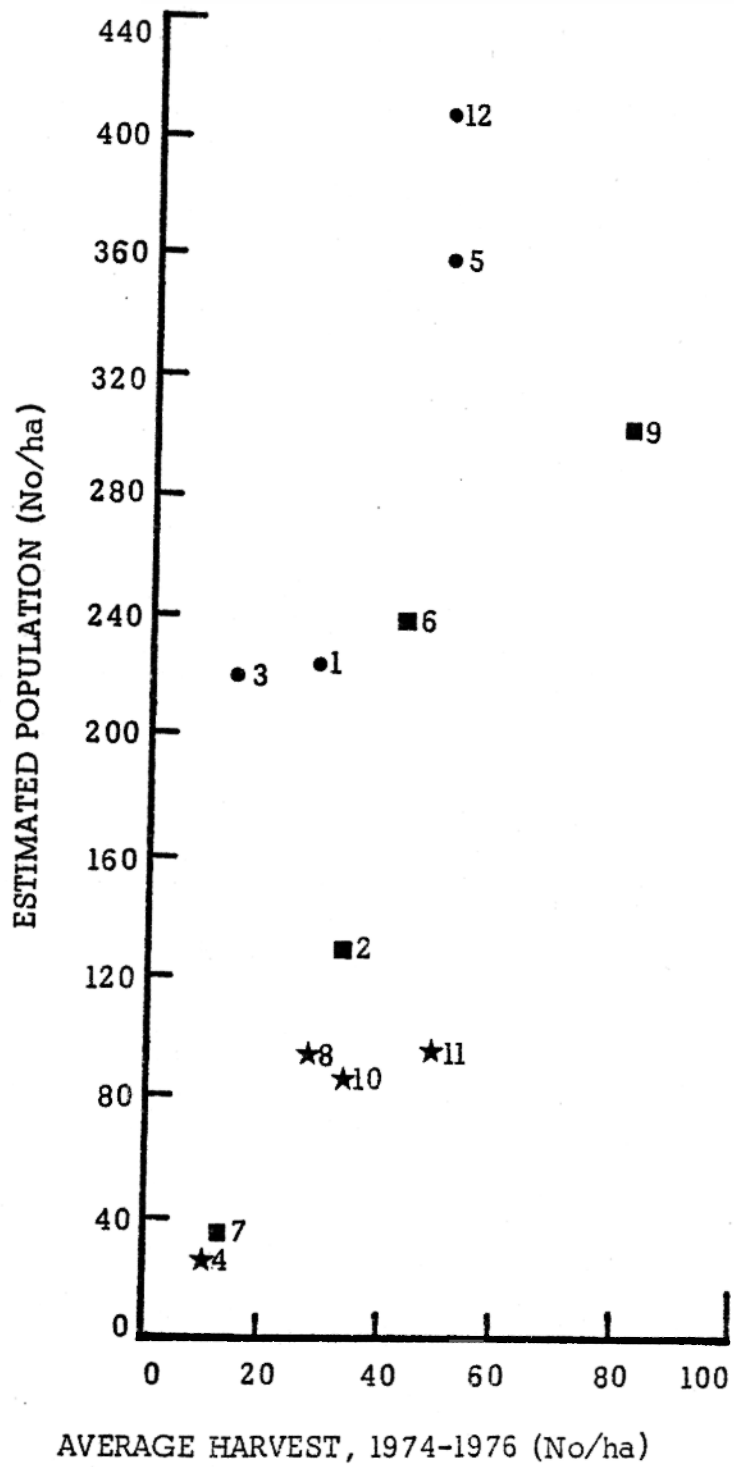

Figure 7. Relationship of average number of largemouth bass harvested from 1974 to 1976 to estimated population in the 12 study ponds. ● - Low harvest. ■ - Medium harvest. ★ - High harvest.

Figures 8 and 9 show similar relationships of biomass harvested to standing crop estimates. Again, there are no obvious relationships between harvest and standing crop. The average kg/ha harvested in the 3 years of the study are very similar to the 1976 bass harvest in the 12 ponds.

The total 1976 harvest of bass, bluegill, and channel catfish is in Appendix A. A summary of this data is in Table 5. The total harvest of all three species varied from 69 to 1112 fish/hectare (28-450/acre) and averaged 408/ha (165/acre) in the 12 ponds. Biomass harvested varied from 11.2 to 147.2 kg/ha (10.0-131.4 lbs/acre) and averaged 61.3 kg/ha (54.7 lbs/acre) for all species in the 12 ponds.

The total harvest was broken down by percentages of each species harvested (Table 5). Bass and channel catfish made up nearly equal percentages by number averaging 13.92 and 12.36 percent respectively in the 12 ponds. Bluegill averaged 74.65% of the total harvest by number.

When broken down by weight, bass and channel catfish again had similar averages with 30.96 and 32.53 percent respectively. Bluegill averaged 39.22% of the total harvest by weight (Table 5).

Ratios of bass to bluegill harvest by number and weight are also shown in Table 5. Bass : bluegill harvest ratios by weight ranged from 1 : 0.39 to 1 : 6.68 and averaged 1 : 1.61. Ratios by number ranged from 1 : 0.83 to 1 : 90.33 and averaged 1 : 19.06 (Table 5). These figures may be somewhat misleading since most of the bluegill harvest was taken while sampling the bass populations, and not by angler harvest. Bluegill are generally too small in these ponds to be of

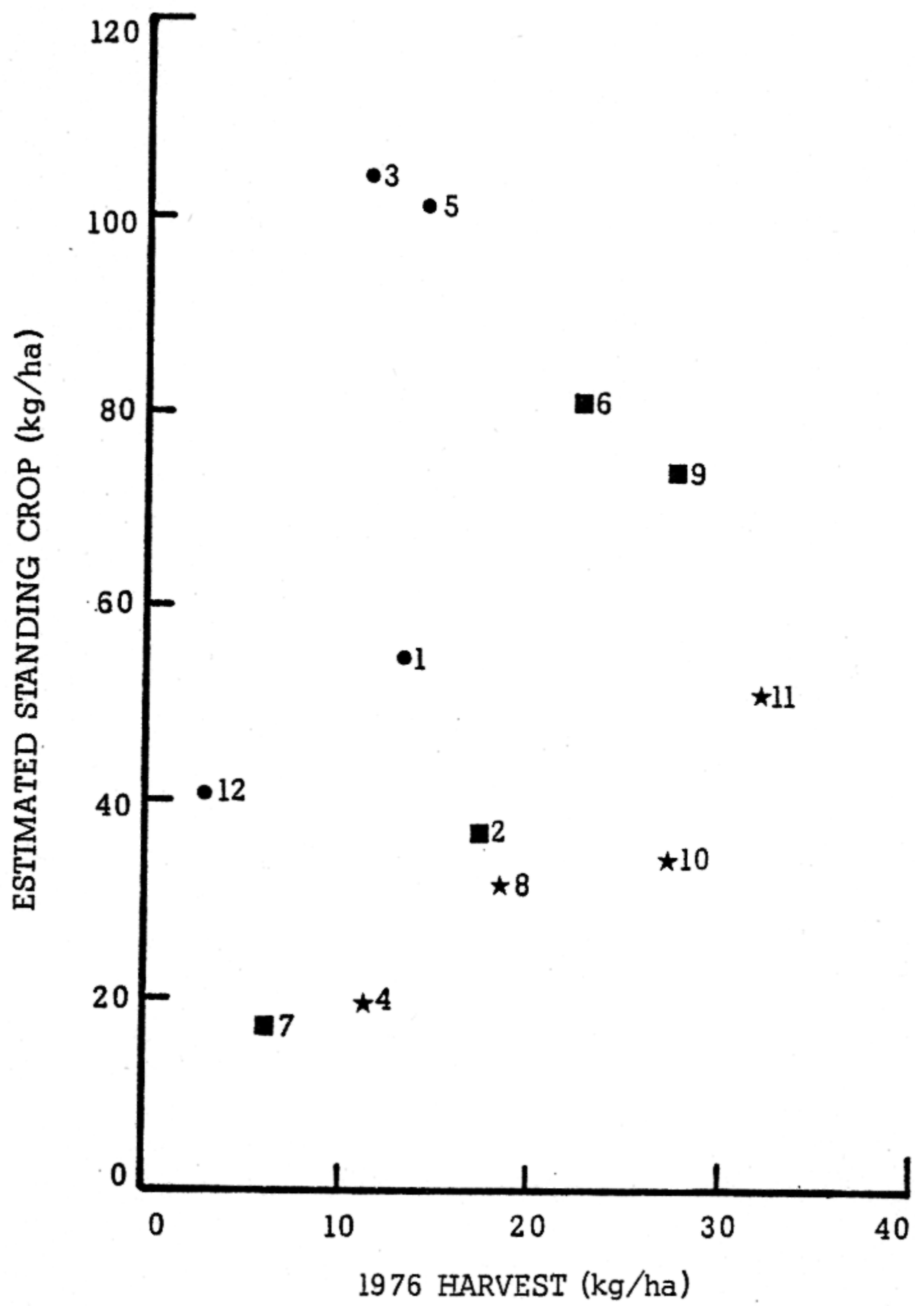

Figure 8. Relationship of biomass harvested to estimated standing crop of largemouth bass in the 12 study ponds. ● - Low harvest. ■ - Medium harvest. ★ - High harvest.

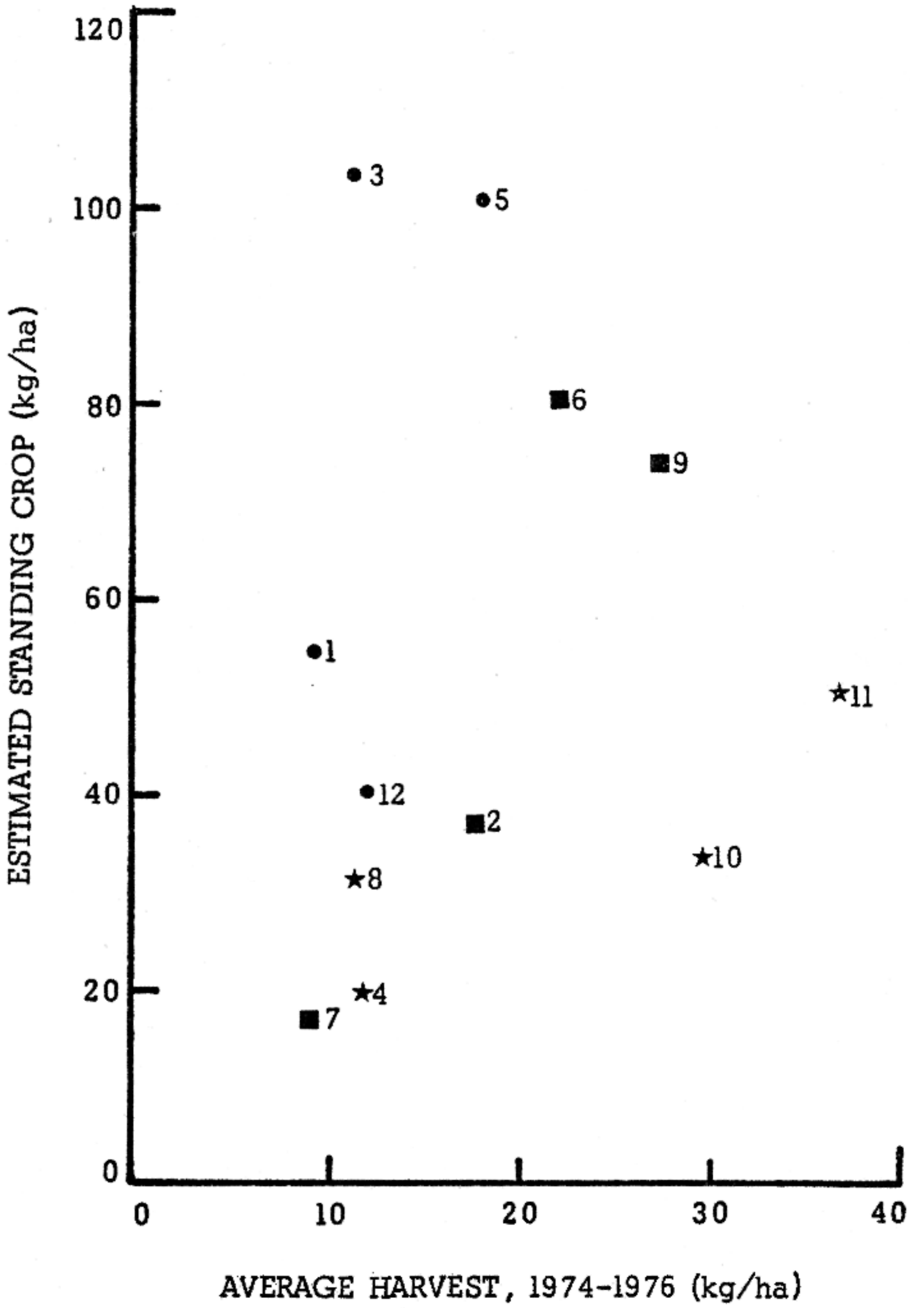

Figure 9. Relationship of average biomass harvested from 1974-1976 to estimated standing crop of largemouth bass in the 12 study ponds. ● - Low harvest. ■ - Medium harvest. ★ - High harvest.

Table 5. Total 1976 harvest, % harvest by species, and ratios of bass to bluegill harvest for the 12 study ponds

Pond	Total harvest of all species				% harvest by number			% harvest by weight			Harvest ratios LMB:BG	
No.	No.	No/ha	kg	kg/ha	LMB	BG	CC	LMB	BG	CC	by Wgt.	by Number
1	306	1112	40.6	147.2	0.98	88.56	10.46	8.95	59.79	31.26	1 : 6.68	1 : 90.33
2	219	526	23.9	57.1	7.31	90.87	2.01	30.08	60.77	9.15	1 : 2.02	1 : 12.44
3	21	143	5.6	38.2	9.52	71.43	19.05	29.61	23.98	46.41	1 : 0.81	1 : 7.50
4	465	556	40.9	48.7	1.72	92.47	5.81	23.04	16.86	60.10	1 : 0.73	1 : 53.75
5	130	334	15.5	39.9	8.46	90.00	1.54	35.72	56.05	8.23	1 : 1.57	1 : 10.64
6	57	247	16.0	69.1	17.54	47.37	35.09	32.51	12.62	54.87	1 : 0.39	1 : 2.70
7	120	193	21.8	35.2	4.17	79.17	16.67	16.41	26.04	57.55	1 : 1.59	1 : 19.00
8	60	151	20.1	50.5	34.30	34.30	30.00	36.92	36.92	26.17	1 : 1.00	1 : 1.00
9	227	622	33.2	91.2	12.33	80.18	7.49	30.00	42.81	27.18	1 : 1.43	1 : 6.50
10	350	511	51.9	75.8	5.71	90.29	4.00	35.96	36.89	27.16	1 : 1.03	1 : 15.80
11	105	418	17.7	70.6	10.48	85.71	3.81	45.12	45.12	9.75	1 : 1.00	1 : 8.18
12	11	69	1.0	11.2	54.55	45.45	----	47.20	52.80	----	1 : 1.12	1 : 0.83
Means	173	408	23.9	61.3	13.92	74.65	12.36	30.96	39.22	32.53	1 : 1.61	1 : 19.06

LMB = Largemouth bass BG = Bluegill sunfish CC = Channel catfish interest to most Kansas anglers. Even at the levels harvested in the sampling, bluegill remain a largely underutilized resource in these ponds. A much larger harvest is possible and would probably improve the quality of the fishery.

Mortality Rates

Since population numbers and biomass are removed through natural and fishing mortality, an evaluation of total annual mortality was deemed advisable. The method used here to estimate total mortality does not allow for separation of natural and angling mortality. However, it is generally accepted that angling mortality is compensatory with natural mortality. The hypothesis of compensatory mortality holds only for reasonable rates of harvest mortality. Targeted harvest quotas tested in this study should not be unreasonable for balanced populations.

Catch curves for the fall 1976 sample were constructed and evaluated. Because bass $\leq$ 200 mm and bluegill $\leq$ 125 mm were not sampled effectively, the catch curves are incomplete, but can yield information on mortality rates for selected ages of fish. Visual analysis of the catch curves revealed that recruitment was effectively complete to the sampling gear at Age III for bass and bluegill. Very few bass or bluegill older than Age V were present in any of the ponds.

For purposes of this analysis, survival rates were calculated for bass and bluegill from Ages III to V inclusive based upon the age composition of the catch in the fall sample. Ricker's (1975) formula was used to calculate survival.

$$S = \frac{N_4 + N_5}{N_3 + N_4}$$

Where: S = Estimate of fraction surviving.
N_x = Number of Age x present in the sample.

Table 6. Bluegill mortality rates - Age III to V

Low harvest		Medium harvest		High harvest	
Ponds	A(%)	Ponds	A(%)	Ponds	A(%)
1	5.45	2	12.77	4	94.23
3	72.73	6	73.33	8	20.00
5	39.84	7	88.00	10	90.97
12	57.69	9	50.67	11	11.54
Means	43.93		56.19		54.19

Table 7. Bass mortality rates - Age III to V

Low harvest		Medium harvest		High harvest	
Ponds	A(%)	Ponds	A(%)	Ponds	A(%)
1	91.67	2	64.71	4	25.00
3	40.00	6	68.71	8	----
5	81.25	7	25.00	10	61.11
12	50.00	9	88.89	11	75.00
Means	65.73		61.83		53.70

Mortality rates are the complement of survival such that when expressed as a percentage, mortality rate (A) = 1 - S. Mortality rates (A) expressed as percentages for Ages III to V are in Table 6 for bluegill and Table 7 for bass.

Mortality rates among bluegill averaged 51% for all ponds. The ranges of mortality rates for individual ponds within harvest groups are too great to evaluate the effects of various bass harvest levels on bluegill mortality.

Bass mortality rates (Table 7) averaged 60% in all ponds. There is an apparent inverse relationship between levels of bass harvest and mortality rates. The low harvest group of ponds has a higher average rate of mortality (65.73%) that the group of high harvest ponds (53.70%), but the ranges of mortality rates for individual ponds within a harvest group are too great to make an accurate determination of this effect. More detailed information on age specific mortality rates is needed to determine the effects of various levels of bass harvest on mortality. In particular, research is needed to determine the relationship of harvest mortality to natural mortality.

Stock Recruitment Relationships

Shoreline seining was done in the spring and fall to confirm reproductive success by looking for young of the year bass and bluegill. The fall sample is probably best for this purpose since the young of the year present at this time have survived a season of predation pressure and are more likely to represent the number available for recruitment into the Age I year class. Adequate recruitment is essential to maintaining balanced populations since young fish must be recruited to the population to provide a sustained harvest of larger fish and also to apply predation pressure to the bluegill population.

Estimates of the No/ha small bass ($\leq$ 125 mm) and small bluegill ($\leq$ 75 mm) were made by extrapolating the mean numbers taken in five, 6.08 m (20 ft), 1/4 circle seine hauls (Appendix B) to the mean 1976 pond area. These estimates (Table 8) represent relative densities and should not be considered exact quantitative values due to the extreme variability found in shoreline seining samples. These estimates were made from the fall shoreline seining sample (Appendix B, Table B 2) and are thought to be reliable estimates of reproductive success and potential recruitment.

Recruitment to the bass population is here defined as those fish present in the fall which are $\leq$ 125 mm. These may be either Age 0 or Age I bass. Potential recruitment to the bluegill population is defined as those bluegill $\leq$ 75 mm present in the fall. These are Age 0 or Age I fish also. Bass stock is defined as the estimated population of largemouth bass $\geq$ 200 mm in the fall after the harvest quota has been met. No estimates of bluegill stock are available.

Ricker (1958) has demonstrated a density dependent relationship between stock and recruitment for some species. Moderate stock densities generally increase levels of recruitment while either high or low stock densities tend to depress recruitment.

The relationship of bass stock to bass recruitment has been plotted for the 12 ponds in this study (Figure 10). An approximate line representing a theoretical recruitment curve has been drawn in. It can be seen that a general, but imprecise relationship exists. It is obvious that high stock densities depress recruitment. The group of low harvest ponds (1,3,5,12) are clearly clumped together at the upper end of the recruitment curve. Ponds in the high harvest

Table 8. Estimated number of small largemouth bass ($\leq$ 125 mm) and small bluegill ($\leq$ 75 mm) from Fall 1976 shoreline seine samples in the 12 study ponds.

Pond No.	Mean 1976 Area (ha)	Mean No. S-LMB in Fall seine	No/ha S-LMB	Mean No. S-BG in Fall seine	No/ha S-BG
1	0.28	0.4	137.1	4.0	1370.0
2	0.42	1.6	548.1	6.0	2055.7
3	0.15	0.8	274.0	8.8	3015.5
4	0.84	3.6	1233.3	2.6	890.8
5	0.39	1.2	411.0	71.4	24459.1
6	0.23	76.2	26104.8	207.0	70920.0
7	0.62	3.2	3329.7	0.6	624.3
8	0.40	5.0	1712.5	1.0	342.5
9	0.36	4.2	1438.9	345.0	118162.5
10	0.68	8.6	2946.2	4.0	1372.4
11	0.25	54.0	18499.6	51.6	17688.5
12	0.16	----	----	4.4	1507.0

No/ha = Mean number in Fall seine hauls adjusted to mean 1976 pond area.
LMB = Largemouth bass BG = Bluegill

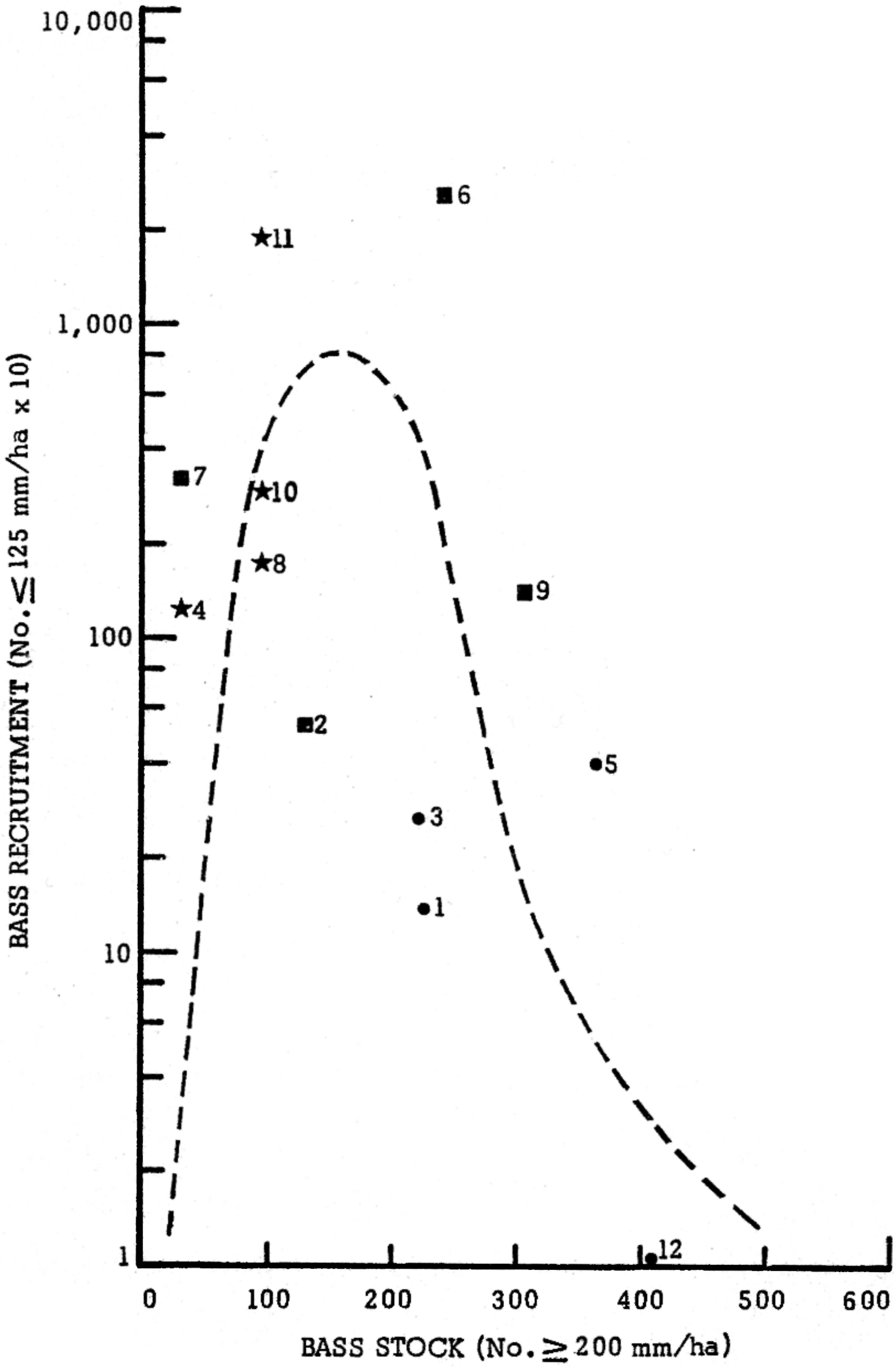

Figure 10. Stock-recruitment relationships for largemouth bass in the 12 study ponds. ● - Low harvest ponds. ■ - Medium harvest ponds. ★ - High harvest ponds.

group (4,8,10,11) fall into a fairly distinct group at the lower end of the curve, but overlap with ponds in the medium harvest group. Although the medium harvest group of ponds do not form a concise group, they generally fall between the other two groups.

There appears to be a wide range of bass stocks which will provide reasonable levels of bass recruitment. From these data, it looks as if that range is 50 to 200 adult stock/ha. Direct graphical interpretation indicates an optimum of about 150 stock/ha. This is vastly different than the results of Babb (1976) who found optimum recruitment between 20 and 30 bass/ha in a study of 33 central states farm ponds. There is too much scatter in these data to determine an exact optimum, but it appears as if the group of high harvest ponds are more likely to produce an optimum level of bass recruitment.

The same type of analysis was made for the estimated density of small bluegill ($\leq$ 75 mm) and bass stock $\geq$ 200 mm in an attempt to evaluate the effects of different levels of bass stock on potential bluegill recruitment (Figure 11). The effect of bass stocks on bluegill recruitment is much less obvious, but a general pattern does emerge. The group of high harvest ponds (4,8,10,11) and low harvest ponds (1,3,5,12) demonstrate some degree of depressed bluegill recruitment. The group of medium harvest ponds (2,6,7,9) show some overlap with both of the other groups, but tend toward an optimum level of bluegill recruitment as exhibited by pond 6.

Low harvest ponds (1,3,5,12) have high adult bass densities and probably depress bluegill recruitment through intense predation. High harvest ponds have much less dense bass populations and most likely show depressed bluegill

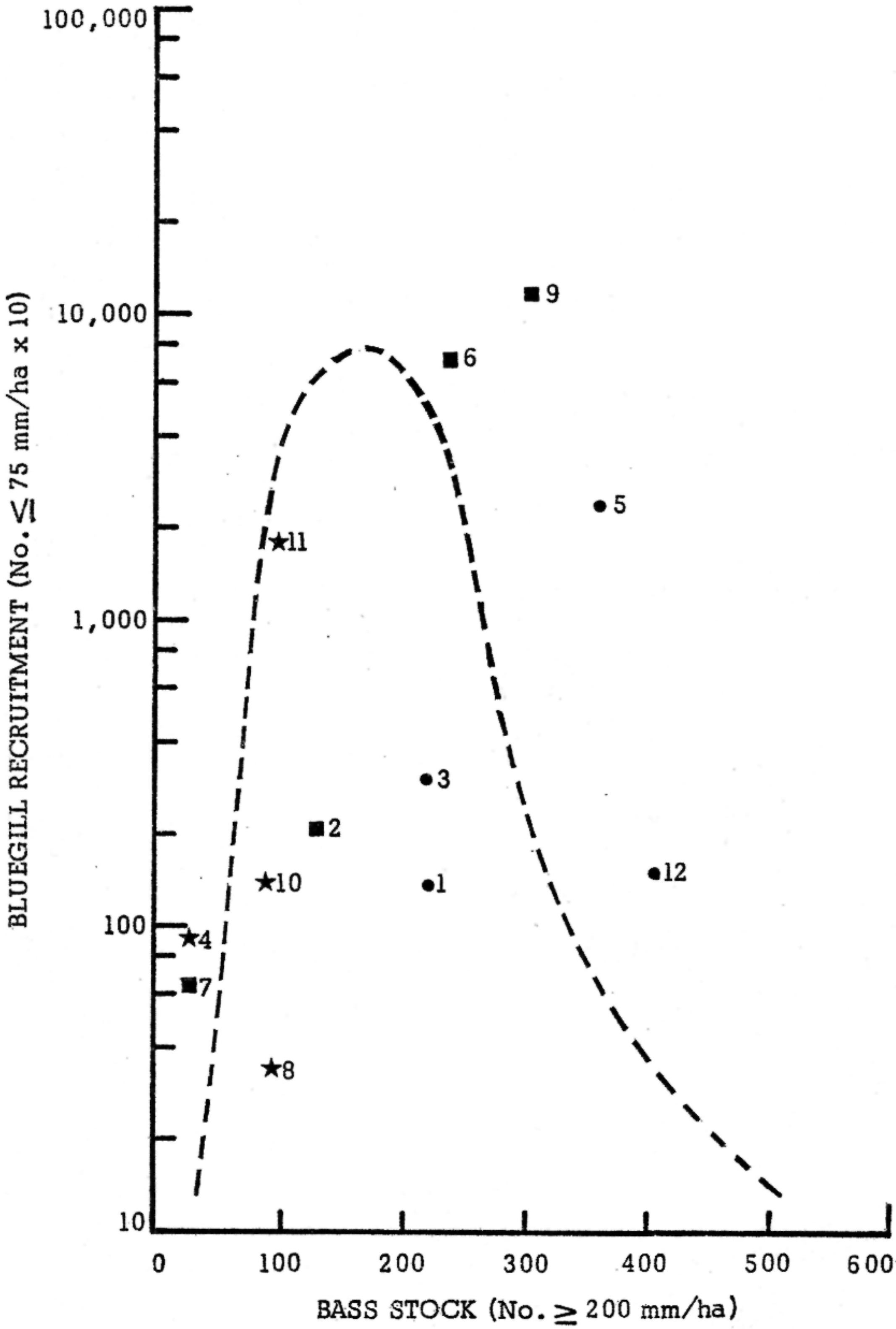

Figure 11. Relationship of largemouth bass stock to bluegill recruitment in the 12 study ponds. ● - Low harvest ponds. ■ - Medium harvest ponds. ★ - High harvest ponds.

recruitment as a result of larger bluegill populations and the subsequent density dependent effects of intraspecific competition on reproduction among bluegill.

Apparently a stock of 200 bass $\geq$ 200 mm/ha will allow for optimal levels of bluegill recruitment. A lower rate of recruitment is likely to be more desirable and beneficial to the quality of the fishery. A low to medium level of bass harvest appears most desirable in terms of bluegill recruitment while a medium to high level of bass harvest seems most desirable in terms of bass recruitment. Therefore, a medium level of bass harvest is a compromise likely to produce reasonable levels of recruitment for both bass and bluegill.

Age and Growth of Largemouth Bass

A total of 886 bass from the 12 ponds were scale sampled for age and growth determinations. Back-calculated lengths at annulus formation were determined for each pond and for each group of ponds (Appendix C). The scale samples for all fish in the ponds of a harvest group were pooled and a grand average calculated length determined for each age in each harvest group. These lengths are depicted graphically in Figure 12 and also appear in Table 9.

Weighted least squares and analysis of variance was used to determine if calculated lengths for the three groups of ponds were significantly different. Analysis of variance of the grand mean calculated lengths at ages for all fish in a group of ponds indicated that age is the dominant variable with a sum of squares equal to 27825.7 (Table 10). There is a significant group effect and an even more important group by age interaction. The interaction effects most likely occur where the length-age plot of one group crosses over that of another group.

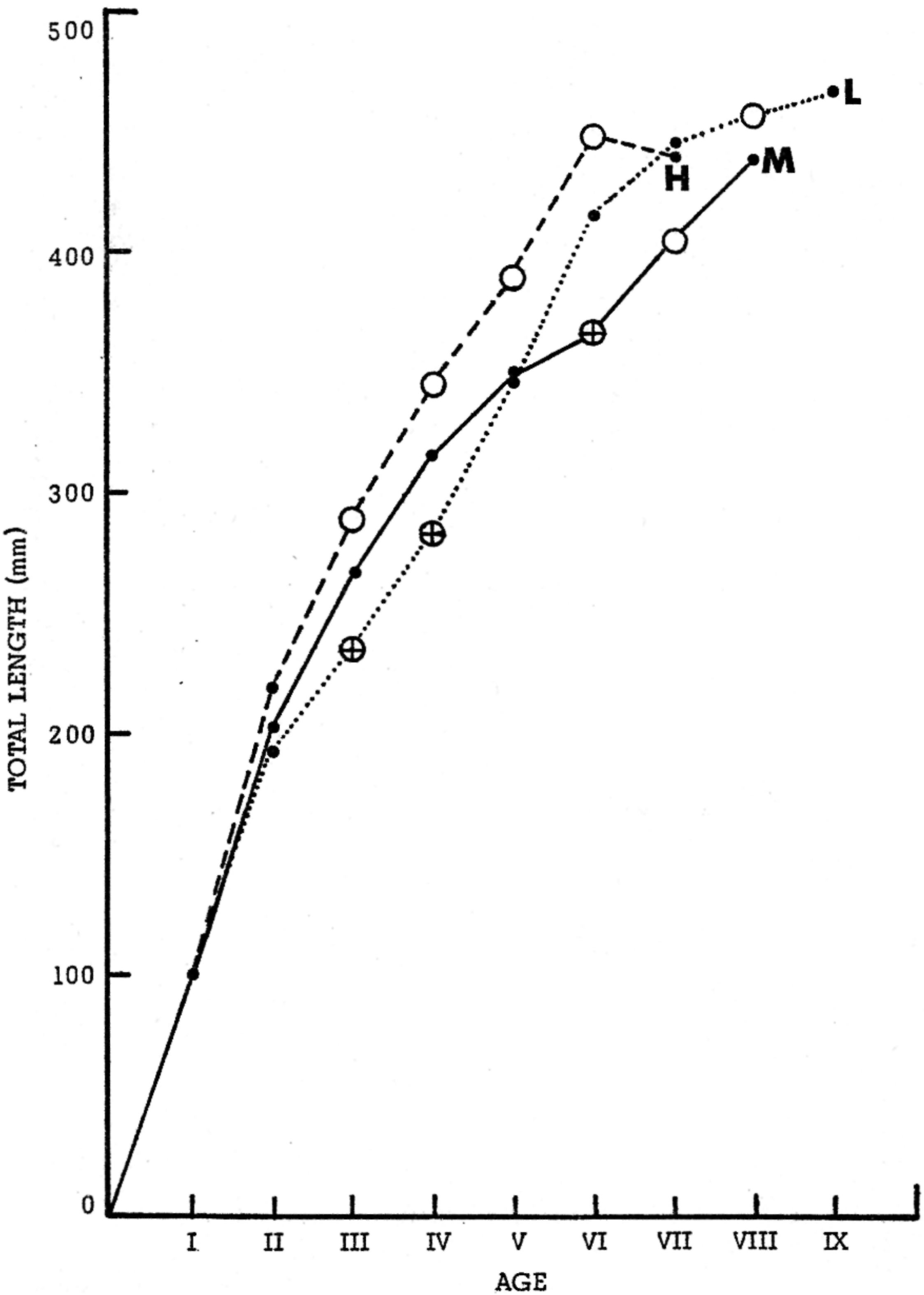

Figure 12. Mean calculated lengths at annulus formation for largemouth bass in the study ponds grouped by harvest. L - Low harvest. M - Medium harvest. H - High harvest. Any two or more points at a given age which are marked with the same symbol are not statistically different at the 95% level of significance.

Table 9. Grand mean calculated total lengths (mm) at annulus for largemouth bass in the 12 study ponds grouped by low, medium and high bass harvest.

Harvest (Ponds)		AGE I	II	III	IV	V	VI	VII	VIII	IX
Low	Length	103.2	193.7	235.7	282.8	346.2	414.7	444.2	457.8	468.0
Harvest	Std. Dev.	42.2	31.4	36.5	49.1	52.3	39.9	34.1	13.7	22.0
(1,3,	Ann. Inc.	103.2	90.5	42.0	47.1	63.4	68.5	29.5	13.6	10.2
5,12)	Number	277	264	151	64	26	14	11	6	2
Medium	Length	98.5	203.1	266.6	315.1	349.5	365.9	405.7	438.9	----
Harvest	Std. Dev.	27.3	28.8	30.0	32.2	36.7	38.7	4.8	----	----
(2,6,	Ann. Inc.	98.5	104.6	63.5	48.5	34.4	16.4	39.8	33.2	----
7,9)	Number	305	209	127	56	20	7	2	1	----
High	Length	100.0	218.8	289.1	344.8	389.2	447.9	442.9	----	----
Harvest	Std. Dev.	29.8	49.9	59.1	50.7	55.0	32.3	----	----	----
(4,8,	Ann. Inc.	100.0	118.8	70.3	55.7	44.4	58.7	----	----	----
10,11)	Number	207	159	145	58	19	3	1	----	----

Table 10. Analysis of variance of calculated lengths of largemouth bass in study ponds grouped by level of bass harvest.

Source	Degrees of Freedom	Sums of Squares	Chi-Square	P
Groups	2	627.6	10.60	<0.005
Age	8	27825.7	21.96	<0.005
Group x Age	11	770.5	26.76	<0.005
Total	21	29223.8		

Table 11. Analysis of variance of annual length increments of largemouth bass in study ponds grouped by level of bass harvest.

Source	Degrees of Freedom	Sums of Squares	Chi-Square	P
Groups	2	73.6	10.60	<0.005
Age	8	1431.0	21.96	<0.005
Group x Age	11	295.8	26.76	<0.005
Total	21	1800.4		

When sums of squares (Table 10) were compared to the appropriate Chi-square table for degrees of freedom, groups were found to be highly significant at the 0.005 level or beyond. This indicates that the differences indicated in Figure 12 can be taken as statistically real. Bass in the group of high harvest ponds (4,8,10,11) had significantly greater rates of growth than the low and medium harvest groups.

To more precisely locate significant differences, L.S.D. type 95% confidence intervals were calculated for each mean calculated length. The formula for calculating the confidence intervals is: $y \pm t.025 \text{ (d.f.)} \sqrt{\frac{\text{Std. Dev.}^2}{n}}$

If the confidence interval for any length of a given age overlapped the calculated length of another group at that same age, the two points were considered to be not significantly different at the 95% level. On Figure 12 and all other age and growth figures in this paper, any two or three points at a given age marked with the same symbol are not statistically different at the 95% level of significance.

This analysis reveals that calculated lengths of fishes at certain ages are different for the three groups of ponds. There are no significant differences in calculated lengths of Age I or Age II fish in any of the three harvest groups. Age V fish in the low and medium harvest groups and Age VII fish in the low and high harvest groups are not significantly different.

In general, high harvest ponds exhibit faster growth of bass than medium harvest ponds. Growth in medium harvest ponds is greater than in low harvest ponds for Ages III and IV. For ages VI through VIII, growth is faster in the low than in the medium harvest ponds.

The higher rates of growth for bass older than Age V in the group of low harvest ponds are in need of explanation. Because of the relatively higher population densities in the low harvest ponds, bass in these ponds may be slow growing due to intraspecific competition up to about Age V. Since mortality rates for Age III to V fish in the low harvest ponds are slightly higher than in the medium and high harvest ponds (Table 7), bass in the low harvest ponds may be showing growth compensation in response to reduced densities beyond Age V.

Other possible contributing factors are the short duration (3 years) of the experiment and the difficulty involved in aging older fish. Ricker (1975) has pointed out that populations may not reach equilibrium until enough time has passed to replace the oldest individual in the population with fish subjected to similar conditions throughout their lives. If this is the case, the older fish here are not likely to be in equilibrium with the harvest rates or with prey populations and calculated lengths may have very little to do with harvest rates. In addition, Carlander (1950) has pointed out that the high rate of error in aging older fish can result in difficulties in interpreting growth data from scales.

Another interesting feature of Figure 12 is the absence of fish older than Age VII in the group of high harvest ponds. The maximum age found was Age VIII in the medium harvest ponds and Age IX in the low harvest ponds. Lower rates of harvest will evidently preserve some individuals to an older age. However, the rate of growth in the high harvest ponds is so much greater that Age VI fish in these ponds have achieved a length of approximately 450 mm while fish in low and medium harvest ponds do not reach this length until Age VII and VIII respectively.

A similar analysis was performed on the annual length increments of bass in the three groups of ponds (Figure 13). Weighted least squares and analysis of variance indicated a rather small group effect with a sum of squares equal to 73.6 and a much larger group by age interaction (Table 11). As expected, age was the major source of variation. When sums of squares are compared to the appropriate Chi-square degrees of freedom, groups, age, and group by age interactions were highly significant at the 0.005 level or beyond (Table 11).

Ricker (1975) has pointed out that a rapid absolute increase in length for the first two years of life is frequently observed in centrarchids. This is quite evident for bass in the three groups of ponds (Figure 13). Placing 95% confidence intervals on the point estimates of annual length increments indicates that increments are significantly greater in the group of high harvest ponds than in the medium harvest ponds. The average increment in the medium harvest group is also greater than in the low harvest group from Age II to Age III.

Other important differences are the rapidly increasing length increments for bass in the low harvest group from Age III to Age VI. As has been suggested earlier, this may be a growth response to reduced density. Significant differences in length increments beyond Age VI in any of the groups are likely to be biased by the relatively small sample of fish Age VI and older (Table 9).

The grouping of ponds by percent harvest appears to be meaningful for both calculated lengths and annual length increments of bass. Except for the rapid growth of fish older than Age V in the low harvest group, high harvest generally results in greater lengths and length increments. Medium harvest ponds tend to have calculated lengths and length increments greater than the group of low harvest ponds and less than the high harvest group.

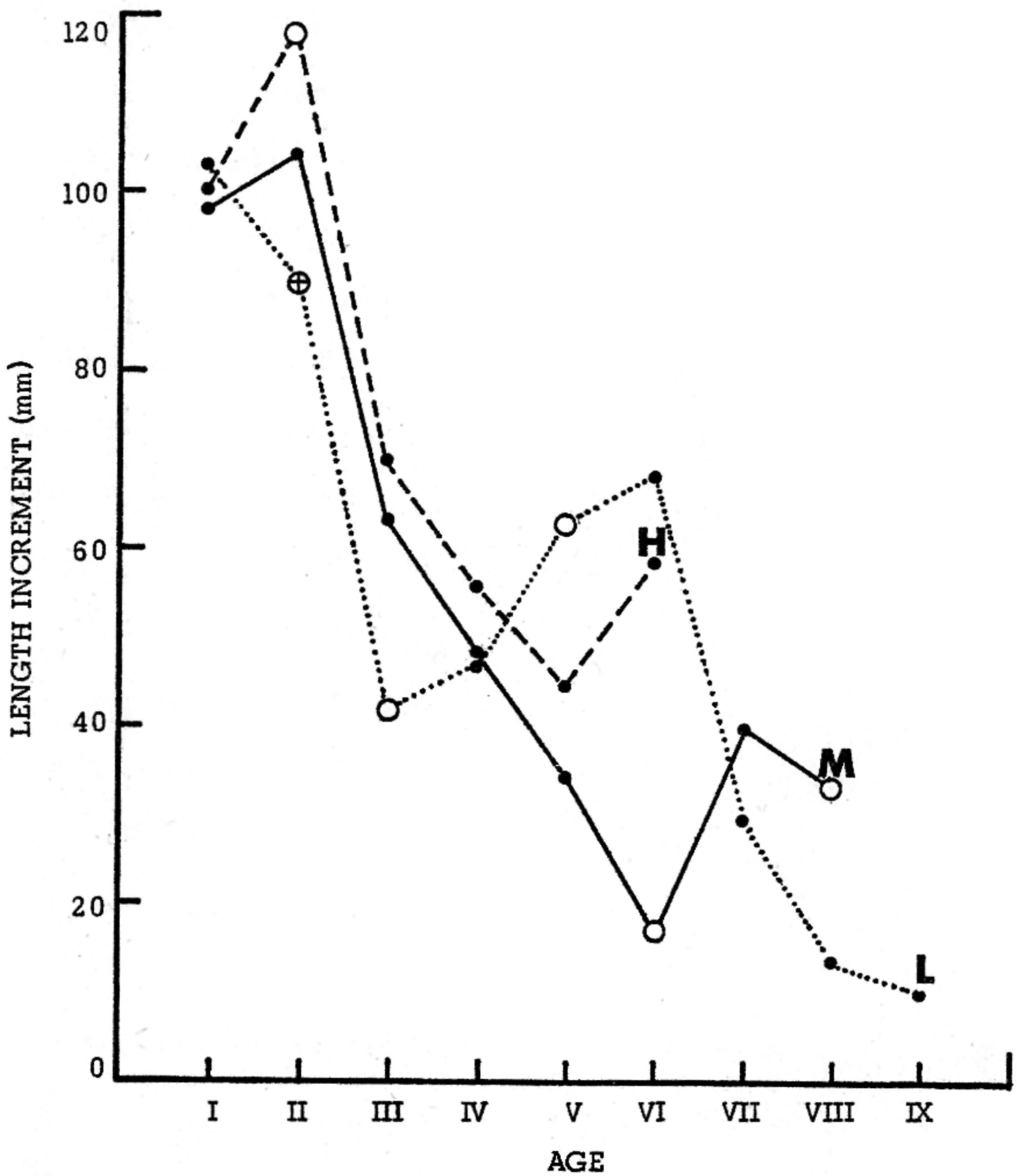

Figure 13. Mean annual length increments of largemouth bass in the study ponds grouped by harvest. L - Low harvest. M - Medium harvest. H - High harvest. Any two or more points at a given age which are marked with the same symbol are not statistically different at the 95% level of significance.

Age and Growth of Bluegill

Bluegill age and growth analysis was treated in much the same was as bass. Age determinations were made on a total of 1454 bluegill scales from the 12 ponds. Back-calculated lengths were determined for each pond individually (Appendix C) and for all samples in a group of ponds combined (Table 12).

The calculated lengths and points of significant difference at the 95% level are depicted graphically in Figure 14. The calculated lengths of bluegill in the medium harvest group are significantly different from the other two groups at Ages II, IV, and V. Calculated lengths for all three groups are significantly different at Age VI, but these differences are most likely due to the small sample size (Table 12) and the difficulty in aging older fish.

Weighted least squares and analysis of variance of calculated lengths indicates that groups are important, but actually account for only a small portion of the variation (Table 13). The group by age interaction accounted for approximately three times as much variation as did groups alone even though both were significant beyond the 0.005 level.

A similar weighted least squares and analysis of variance was performed on bluegill annual length increments depicted in Figure 15. Harvest groups accounted for only a very small portion of the variation and were significant beyond the 0.025 level (Table 14). The group by age interaction was more important and was significant beyond the 0.005 level.

Placing L.S.D. 95% confidence intervals about the length increments for each age in each group of ponds indicates that length increments are statistically different for Ages II and IV in the group of medium harvest ponds (Figure 15). No other significant differences were found.

Table 12. Grand mean calculated total lengths (mm) at annulus for bluegill in the 12 study ponds grouped by low, medium and high bass harvest.

Harvest (Ponds)		AGE I	II	III	IV	V	VI
Low	Length	53.5	88.6	117.4	143.6	166.6	164.9
Harvest	Std. Dev.	12.0	16.6	19.6	16.4	18.0	----
(1,3,	Ann. Inc.	53.5	35.1	28.8	26.2	23.0	----
5,12)	Number	381	376	324	150	39	1
Medium	Length	52.7	81.6	113.5	149.9	175.5	197.8
Harvest	Std. Dev.	10.4	14.6	19.5	17.8	18.4	15.4
(2,6,	Ann. Inc.	52.7	28.9	31.9	36.4	25.6	22.3
7,9)	Number	416	366	254	115	26	5
High	Length	53.1	86.0	116.4	143.2	161.5	181.3
Harvest	Std. Dev.	10.7	18.7	19.2	14.2	15.4	8.7
(4,8,	Ann. Inc.	53.1	32.9	30.4	26.8	18.3	19.8
10,11)	Number	535	486	279	84	28	3

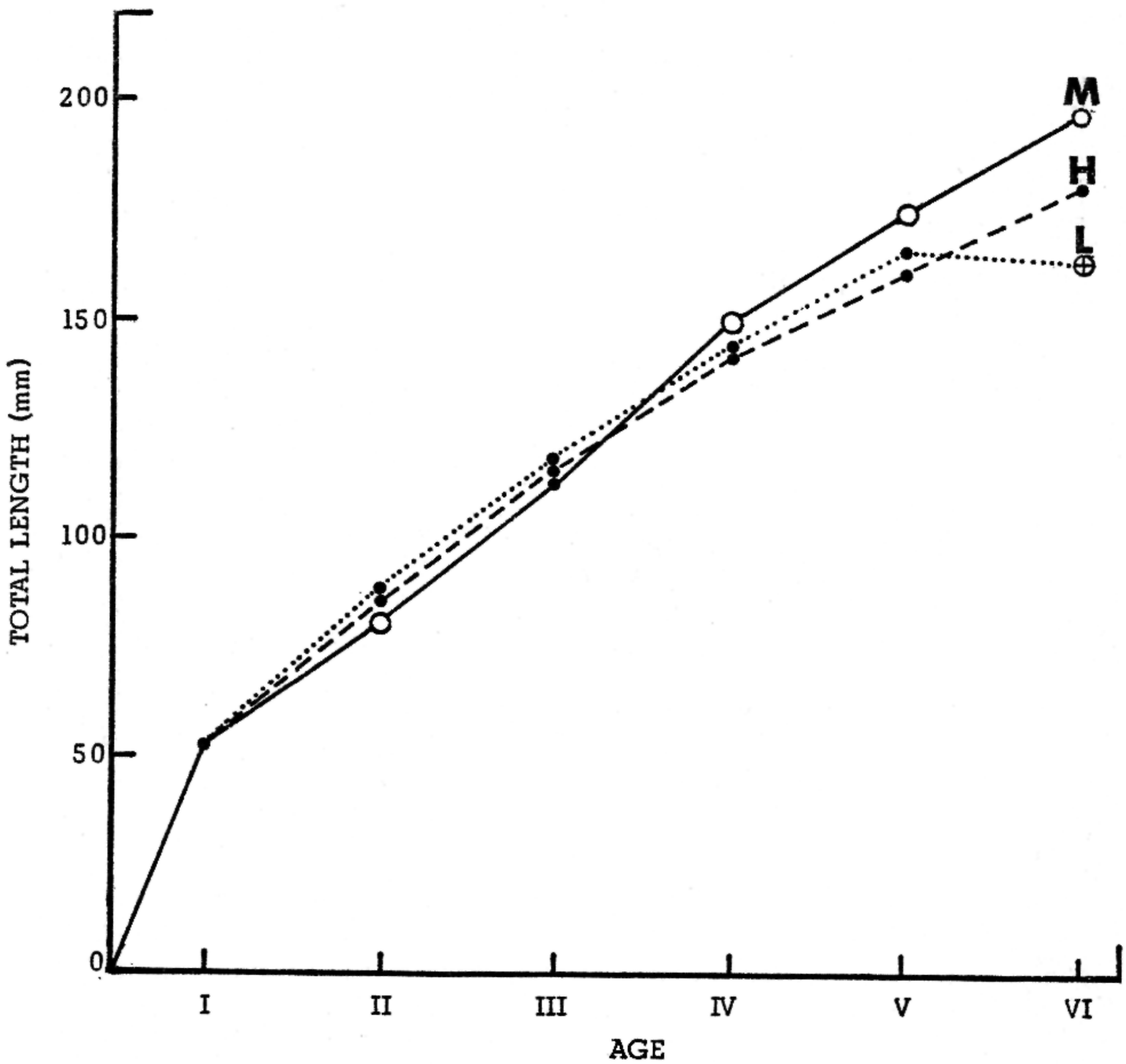

Figure 14. Mean calculated lengths at annulus formation for bluegill in study ponds grouped by bass harvest. L - Low harvest. M - Medium harvest. H - High harvest. Any two or more points at a given age which are marked with the same symbol are not statistically different at the 95% level of significance.

Table 13. Analysis of variance of calculated lengths of bluegill in study ponds grouped by level of bass harvest.

Source	Degrees of Freedom	Sums of Squares	Chi-Square	P
Groups	2	33.6	10.60	<0.005
Age	5	17836.2	16.75	<0.005
Group x Age	9	103.2	23.59	<0.005
Total	16	17973.0		

Table 14. Analysis of variance of annual length increments of bluegill in study ponds grouped by level of bass harvest.

Source	Degrees of Freedom	Sums of Squares	Chi-Square	P
Groups	2	8.9	7.38	<0.025
Age	5	1324.5	16.75	<0.005
Group x Age	9	64.5	23.59	<0.005
Total	16	1397.9		

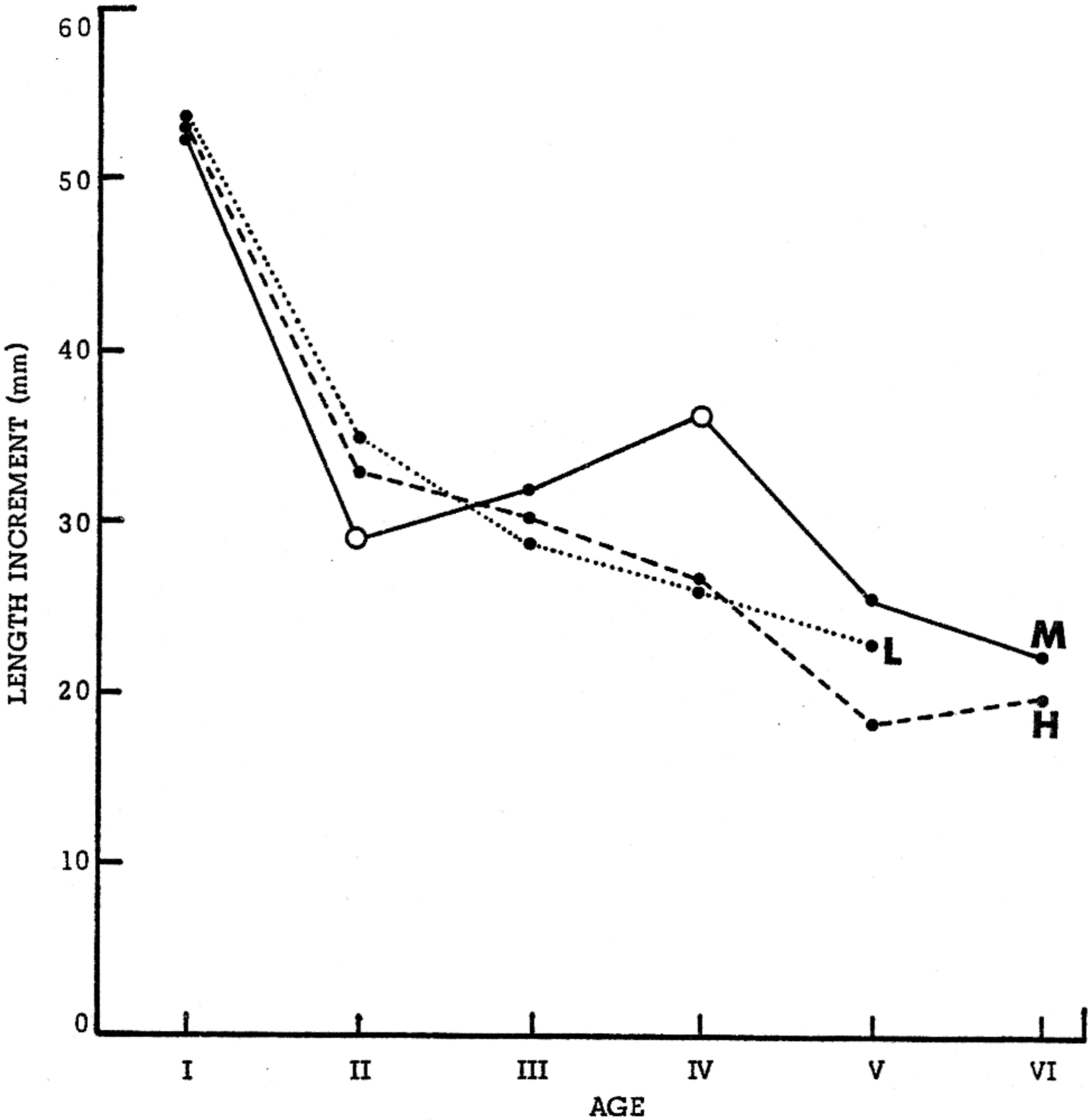

Figure 15. Mean annual length increments of bluegill in study ponds grouped by bass harvest. L - Low harvest. M - Medium harvest. H - High harvest. Any two or more points at a given age which are marked with the same symbol are not statistically different at the 95% level of significance.

These results indicate that in general, grouping ponds by level of bass harvest does not identify differences in bluegill growth rate. Only a few significant differences in bluegill growth in the group of medium harvest ponds were found. This is somewhat contrary to expectations since it is known that growth in natural populations is density dependent. Since bass population size and growth is clearly related to harvest, it was speculated that different levels of bass populations would have some effect on bluegill density and growth. While the effects on density are unknown, it seems quite clear that different levels of bass harvest had few detectible effects on bluegill growth in this study.

Length-Weight Relationships of Largemouth Bass

Length-weight data has been commonly employed to describe a mathematical relationship between length and weight. The major use of equations expressing the relationship of weight to length has been to calculate one or the other when only one is known.

The length-weight relationship may be expressed as an exponential equation of the type $W = a L^n$ or in logarthmic form as $\log W = \log a + n \log L$. An exponent of $n = 3.0$ indicates isometric growth with both length and weight increasing at the same rate. Other values indicate allometric growth. For example, if $n > 3$ the fish becomes heavier for its length as it grows larger.

The exponent n differs with species and often varies for isolated stocks of the same species. The magnitude of the n may also vary with sex, season, maturity, and time of day (Ricker, 1968).

The extensive sampling conducted in this study made it possible to calculate length-weight regressions for the three groups of ponds at three different times of the year. These equations appear in Table 15 in log form for largemouth bass in each group of ponds from March, June, and November samples. The equations are also depicted graphically in Figure 16.

The low, medium, and high harvest groups are considered to be different stocks for the purposes of analysis. Length-weight data were subjected to analysis of variance to detect stock and seasonal differences (Table 17). This analysis shows highly significant group and seasonal effects.

To isolate specific differences, t-tests were made for pairs of slopes and levels of significant difference determined. Slopes of groups within seasons were compared to identify specific group differences. Slopes of each group between seasons were compared to identify seasonal cycles.

Significant differences between groups were found in each season. All groups were significantly different from one another beyond the 0.001 level in the June sample. They were also significantly different beyond the 0.10 level in the November sample. In the March sample, the low and high harvest groups were not significantly different, but low-medium and medium-high comparisons were significantly different beyond the 0.10 level.

All comparisons of slopes between seasons for the high harvest group were significant beyond the 0.05 level. The medium harvest group was not significantly different between November and March, but was significant beyond the 0.05 level for March-June and June-November comparisons. November-March and March-June comparisons in the low harvest group were not significantly different, but slopes for June-November were significantly different beyond the 0.10 level.

Table 15. Largemouth bass length-weight regression equations by season and bass harvest group.

Harvest Group	SEASONS (1) June-July	(2) October-November	(3) February-March
Low (1, 3, 5, 12)	log W= -5.44766+3.21226 (log L)	log W= -5.72885+3.33633 (log L)	log W= -5.70823+3.31978 (log L)
Medium (2, 6, 7, 9)	log W= -4.48350+2.81252 (log L)	log W= -5.08948+3.07496 (log L)	log W= -4.97665+3.03823 (log L)
High (4, 8, 10, 11)	log W= -4.78448+2.96761 (log L)	log W= -5.24667+3.14890 (log L)	log W= -6.01926+3.45949 (log L)

Table 16. Bluegill length-weight regression equations by season and bass harvest group.

Harvest Group	SEASONS (1) June-July	(2) October-November	(3) February-March
Low (1, 3, 5, 12)	log W= -5.27218+3.25618 (log L)	log W= -5.10055+3.16964 (log L)	log W= -5.07012+3.15130 (log L)
Medium (2, 6, 7, 9)	log W= -4.29643+2.77827 (log L)	log W= -5.16569+3.19492 (log L)	log W= -4.28292+2.79580 (log L)
High (4, 8, 10, 11)	log W= -4.57482+2.91281 (log L)	log W= -5.43338+3.32003 (log L)	log W= -5.34426+3.25881 (log L)

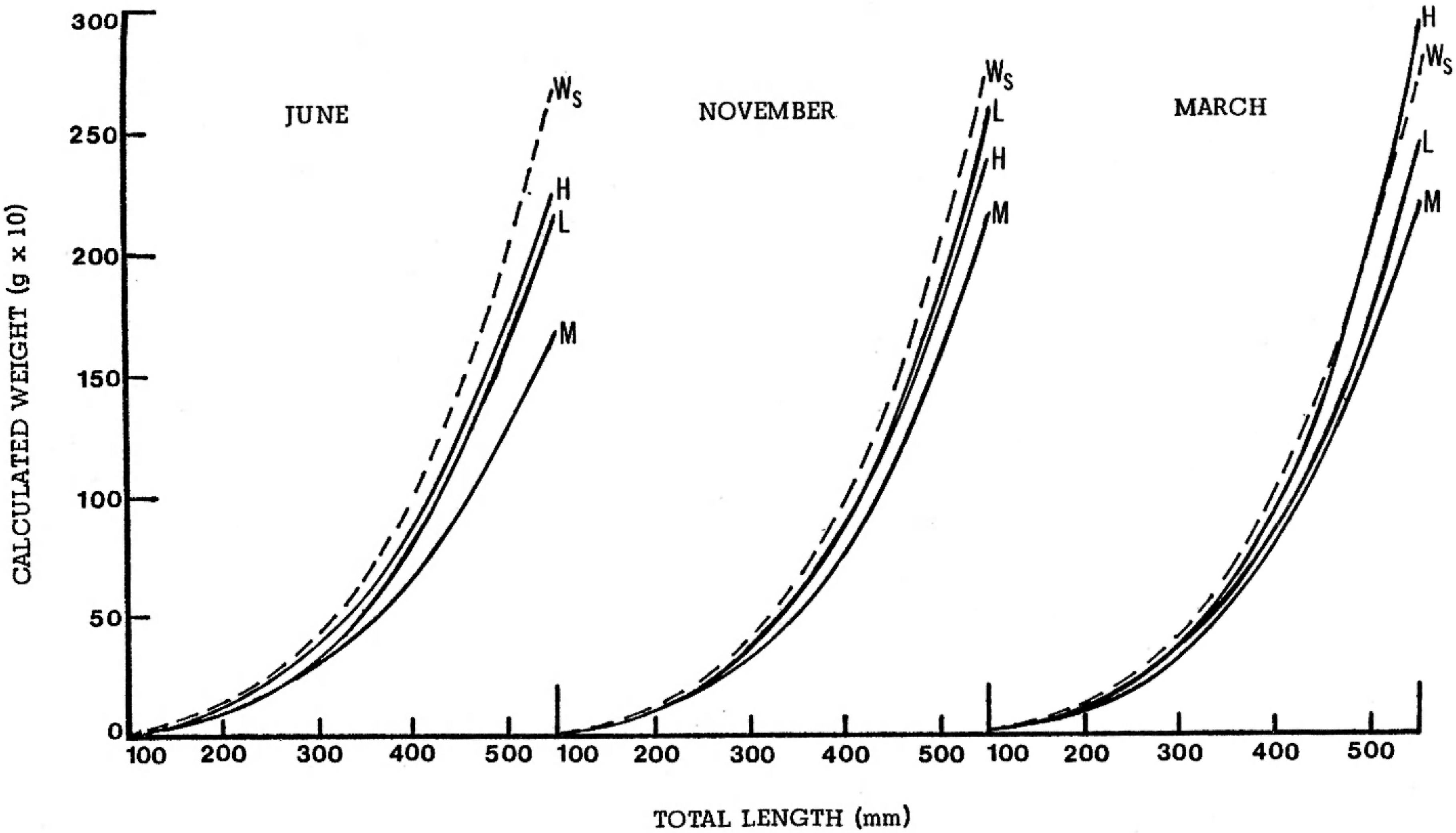

Figure 16. Seasonal cycle of length-weight relationships for largemouth bass in study ponds grouped by bass harvest and relationship to a standard weight curve (W_S). L - Low harvest. M - Medium harvest. H - High harvest.

In all but one case, groups were significantly different from one another within a given season. Slopes of high and low harvest groups were always greater than the medium harvest group. The high harvest group showed a significant seasonal cycle through all three sampling periods. The medium harvest group had a seasonal cycle from March through November, but not from November to March. The low harvest group was significantly different from June to November only.

Seasonal and group differences are most likely due to food availability and gonad development. Differences between groups within seasons reflect population densities and the amount of food available per individual. Seasonal differences within groups are probably due to gonad development as well as food availability.

Length-Weight Relationships of Bluegill

Bluegill length-weight data were analyzed in the same manner as bass. Length-weight regression equations were determined for each group of ponds in June, November, and March (Table 16). These regressions are depicted graphically in Figure 17.

Analysis of variance (Table 18) indicates significant group and seasonal effects, but groups are much less important than seasons. When slopes of bluegill growth are compared with t-tests, all groups are significantly different at the 0.025 level in June. In November, the low and medium harvest groups were not significantly different, but low-high and medium-high combinations were significantly different beyond the 0.025 level. There were no significant differences between any of the three groups in March.

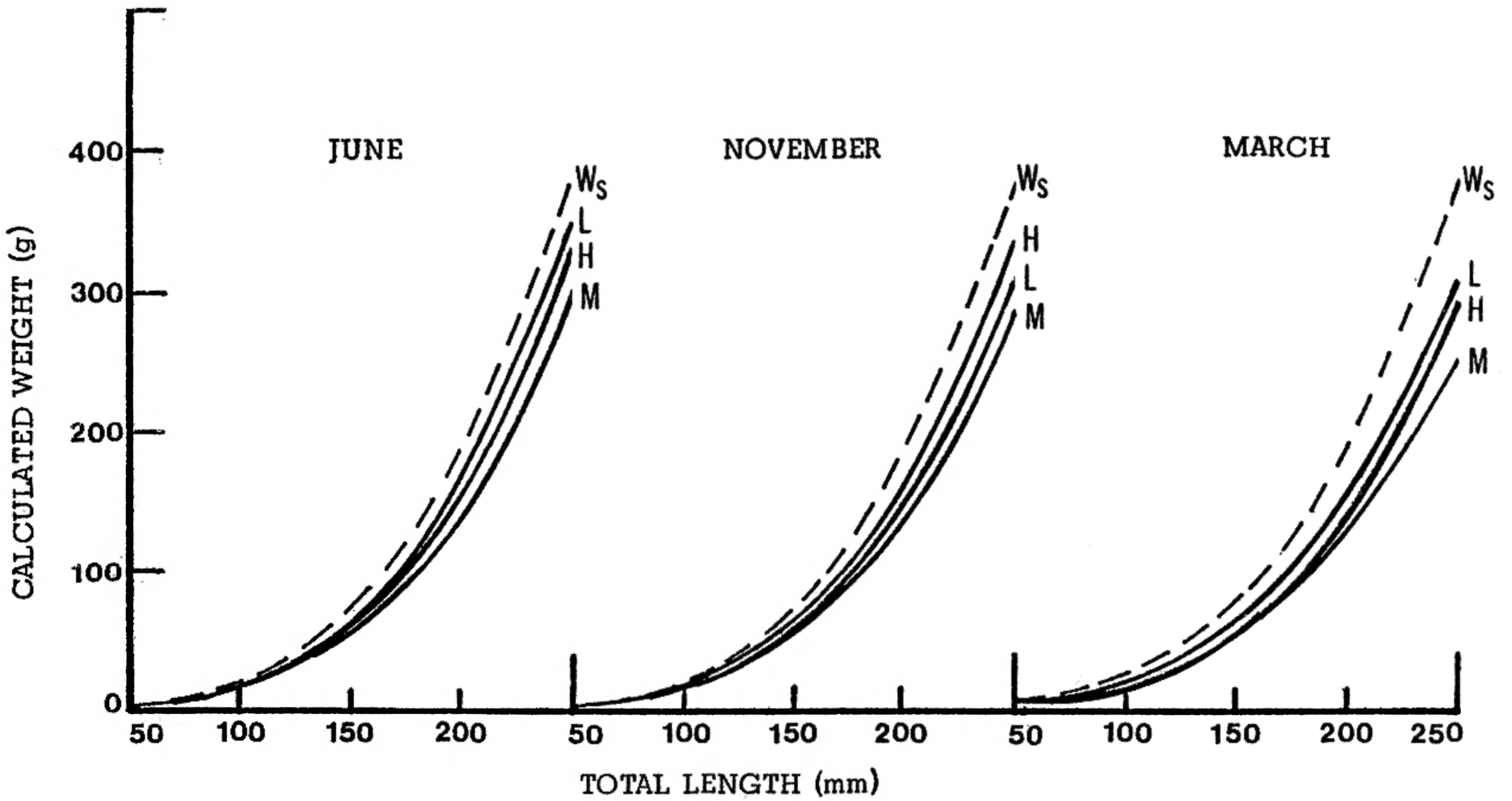

Figure 17. Seasonal cycle of length-weight relationships for bluegill in study ponds grouped by harvest and relationship to a standard weight curve (W_S). L - Low harvest. M - Medium harvest. H - High harvest.

Table 17. Analysis of variance of length-weight data for largemouth bass in study ponds grouped by level of bass harvest and seasons. (Weight = dependent variable)

Source	Degrees of Freedom	Sums of Squares	F	PR > F
Length	1	450.72	20455.81	0.0001
Length x Group	2	0.69	15.60	0.0001
Length x Season	2	2.02	45.81	0.0001
Error	4	0.12	1.30	0.2670
Total	9	453.55		

Table 18. Analysis of variance of length-weight data for bluegill in study ponds grouped by level of bass harvest and seasons. (Weight = dependent variable)

Source	Degrees of Freedom	Sums of Squares	F	PR > F
Length	1	76.42	2506.64	0.0001
Length x Group	2	0.13	2.06	0.1284
Length x Season	2	0.26	4.30	0.0138
Error	4	1.34	10.99	0.0001
Total	9	78.15		

Bluegill in the low harvest group of ponds were not found to follow a seasonal cycle. Slopes of the medium harvest group were not significantly different from November through June, but the June-November comparison was significant beyond the 0.001 level. In the high harvest group of ponds, slopes were significnatly different beyond the 0.001 level between June and November. Other comparisons of bluegill in the high harvest group were not significantly different.

There are some important differences between groups in June and November, but not in March. No seasonal differences were found in the low harvest group. Medium and high harvest groups show seasonal differences from June to November, but not throughout the remainder of the year.

Relative Weight

Numerous methods of measuring condition or relative plumpness of fish have been devised and used by fishery biologists. Condition factors are used to determine the well-being of a fish population. A low condition factor is often indicative of a high density population and slow growth. High condition factors are often associated with low density populations exhibiting rapid growth (Cooper, Hidu, and Anderson, 1963).

While condition factors have been very useful, they all have certain limitations which must be considered. Condition factors change with age and may vary with sex and season (Lagler, 1956). The most serious objection to the commonly used condition factors is based upon the fact that the shape of fishes changes as they grow. This results in changing condition factors with each growth stanza in the fish's life. Ideally, then, condition factors are meaningful for comparison only if they are for the same species of fish collected on the same date and are of the same sex, age, and length (Lagler, 1956).

Wege and Anderson (1978, unpublished) have proposed a new index of condition called relative weight (W_r) which is free of the effects of changing body conformation with increased length. W_r compares the empirical weight (W) of a fish to a standard weight (W_s) for a fish of the same length. The index is calculated from the formula $W_r = (W/W_s) \times 100$ and is expressed as a percentage.

Proposed standard weights are based on a summary of length-weight data from Carlander (1977). A power curve fitted to the 75 percentile weights has been recommended by Wege and Anderson for use as the standard length-weight relationship. This indicates that 25% of the samples summarized had larger mean weights. The standard weight curves suggested are:

$$\text{Bass: } \log W_s = -5.316 + 3.191023 \log L$$

$$\text{Bluegill: } \log W_s = -5.013 + 3.166071 \log L$$

These standard weight curves (W_s) have been included in Figures 16 and 17 for comparison to actual length-weight relationships determined in this study. Only large bass in the high harvest group of ponds in the March sample exceeded the W_s curve. Bluegill were below the standard weight curve in all groups and seasons.

Relative weight (W_r) does not change with units of measurement as do other condition factors. It is also useful for comparing fish of different lengths from the same and different populations. Optimal W_r for largemouth bass and bluegill in late summer or early fall in midwestern ponds with satisfactory habitat and productivity is 95-100% (Wege and Anderson, 1978, unpublished).

Table 19. Largemouth bass average relative weight values (W_r) for selected length groups and mean relative weights for bass harvest groups of ponds in the fall of 1976. Number in each group in parenthesis.

Harvest Group	Pond Nos.	Length Interval <203 mm		203-304 mm		305-380 mm		≥381 mm	
	1	96	(1)	85	(17)	----	--	105	(1)
Low	3	----	--	91	(19)	89	(8)	99	(6)
Harvest	5	----	--	83	(9)	91	(1)	113	(1)
	12	82	(11)	67	(5)	----	--	----	--
Means		89	(12)	82	(50)	90	(9)	106	(8)
	2	----	--	86	(40)	70	(7)	82	(3)
Medium	6	100	(14)	96	(17)	89	(26)	97	(2)
Harvest	7	----	--	86	(4)	81	(1)	85	(2)
	9	98	(14)	94	(13)	94	(9)	----	--
Means		99	(28)	91	(74)	84	(43)	88	(7)
	4	102	(4)	89	(2)	104	(4)	121	(1)
High	8	----	--	87	(20)	87	(12)	----	--
Harvest	10	93	(28)	103	(1)	103	(1)	100	(9)
	11	95	(3)	112	(6)	93	(11)	94	(4)
Means		97	(35)	98	(29)	97	(28)	105	(14)

Table 20. Bluegill average relative weight values (W_r) for selected length groups and mean relative weights for bass harvest groups of ponds in the fall of 1976. Number in each group in parenthesis.

Harvest Group	Pond Nos.	≤76 mm		Length Interval 77-152 mm		≥153 mm	
	1	----	--	82	(30)	84	(43)
Low	3	----	--	83	(35)	95	(11)
Harvest	5	----	--	79	(51)	75	(28)
	12	----	--	----	--	94	(44)
Means		----	--	81	(116)	87	(126)
	2	----	--	82	(46)	85	(51)
Medium	6	----	--	76	(36)	82	(6)
Harvest	7	----	--	81	(51)	86	(20)
	9	----	--	79	(34)	83	(29)
Means		----	--	80	(167)	84	(106)
	4	56	(27)	73	(76)	66	(13)
High	8	----	--	91	(10)	99	(27)
Harvest	10	----	--	78	(85)	87	(22)
	11	139	(1)	88	(19)	86	(46)
Means		98	(28)	83	(190)	85	(108)

Relative weight values have been calculated for selected length groups of bass and bluegill in the November 1976 sample and appear in Tables 19 and 20 respectively. The W_r values were calculated for each pond in the study and means for each group of ponds determined.

For bass, the high harvest group is within or greater than the optimal W_r range for the size groups considered. In only two other cases were bass W_r values greater than or within the optimal range. Bass $\geq$ 381 mm in the low harvest group had an average W_r = 106 and bass $\leq$ 203 mm in the medium harvest group had an average W_r = 99. None of the other length groups or harvest groups had mean W_r values within the proposed optimum range.

Bass in the group of high harvest ponds are in the best condition. Bass $\leq$ 304 mm are in better condition in the medium than in the low harvest group, but this pattern is exactly reversed for bass $\geq$ 305 mm (Table 19).

Bluegill relative weights (Table 20) show uniformly low average values in all three harvest groups. Bluegill $\geq$ 153 mm do appear to be in slightly better condition than those in the 77-152 mm size group.

Proportional Stock Density

Swingle (1950) developed a series of biomass ratios based upon total recovery of fish populations with which he could evaluate balanced and unbalanced populations. He later developed a method which could be used to evaluate balance on the basis of relative abundance of young of the year fishes (Swingle, 1956). This method is grounded in the results of the empirically determined biomass ratios.

Management biologists are generally limited to sampling for determining the status of fish populations. Biomass relationships are difficult and time consuming with the result that they have been little used by management biologists.

Anderson (1976) has suggested a model of proportional stock density (PSD) for assessing balance on the basis of length-frequency distributions. Balance is a function of length-frequency or size distributions. Three important rate functions; mortality, reproduction, and growth determine the length-frequency distribution or structure of a population (Reynolds and Babb, 1978, unpublished). These are also the functions which a fishery manager can manipulate to alter or achieve balance.

In Anderson's (1976) model, population structure is assessed with PSD indices. PSD is defined as that percentage of a stock larger than a specified length. Stocks are defined as the number of bass $\geq$ 203 mm (8 in) and the number of bluegill $\geq$ 76 mm (3 in). Proportional stock density (PSD) is defined as the percentage of bass $\geq$ 203 mm which are $\geq$ 305 mm (12 in) (Anderson, 1976). For bluegill, PSD is the percentage of bluegill $\geq$ 76 mm which are $\geq$ 152 mm (6 in) (Novinger and Legler, 1978, unpublished).

Anderson (1976) determined that optimum PSD for bass was 45-65%. Reynolds and Babb (1978, unpublished) found 43-65% to be optimum in a study to evaluate PSD indices. Both authors have subsequently agreed on an optimum range of 40-60% as being more suitable for management purposes (Novinger and Legler, 1978, unpublished).

Unfortunately, this study was not undertaken with the objective of determining PSD's. As a result, bluegill PSD's cannot be determined due to the size selectivity of the sampling gear.

Bass PSD's were determined for both the spring and fall sampling. Spring sampling was conducted by electrofishing before any bass had been harvested. Fall sampling was completed with a trammel net after the 1976 harvest had been taken. It is not known whether the two sampling techniques yield comparable results.

Spring and fall PSD's for bass have been plotted in Figure 18. Ponds falling exactly on the diagonal line show no shift in PSD before and after harvesting. Pond No. 6 is the only one of the 12 which falls into this category. It is important to note that this is one of the medium harvest ponds.

Ponds 1 and 2 (low and medium harvest ponds respectively) were within the optimum range of 40-60% in the spring, but had fallen well below the optimum after harvesting. Pond 8 went from 0 to a PSD of 53% in the fall. Pond 8 is atypical, however, since it was stocked with 1 and 2 year old bass in 1975 and was not harvested until 1976. As such, it is representative of expanding populations in a new environment and cannot be expected to be at carrying capacity or to have achieved a stable predator-prey equilibrium. Pond No. 3 is the only other pond which shows a shift into the optimum range between the spring and fall samples.

There are some general patterns which emerge from a study of Figure 18. With the exception of pond 8, the group of high harvest ponds tend to have high PSD's and show little shift before and after harvesting. The group of low harvest ponds have low PSD's with ponds 5 and 12 showing little change before and after harvesting.

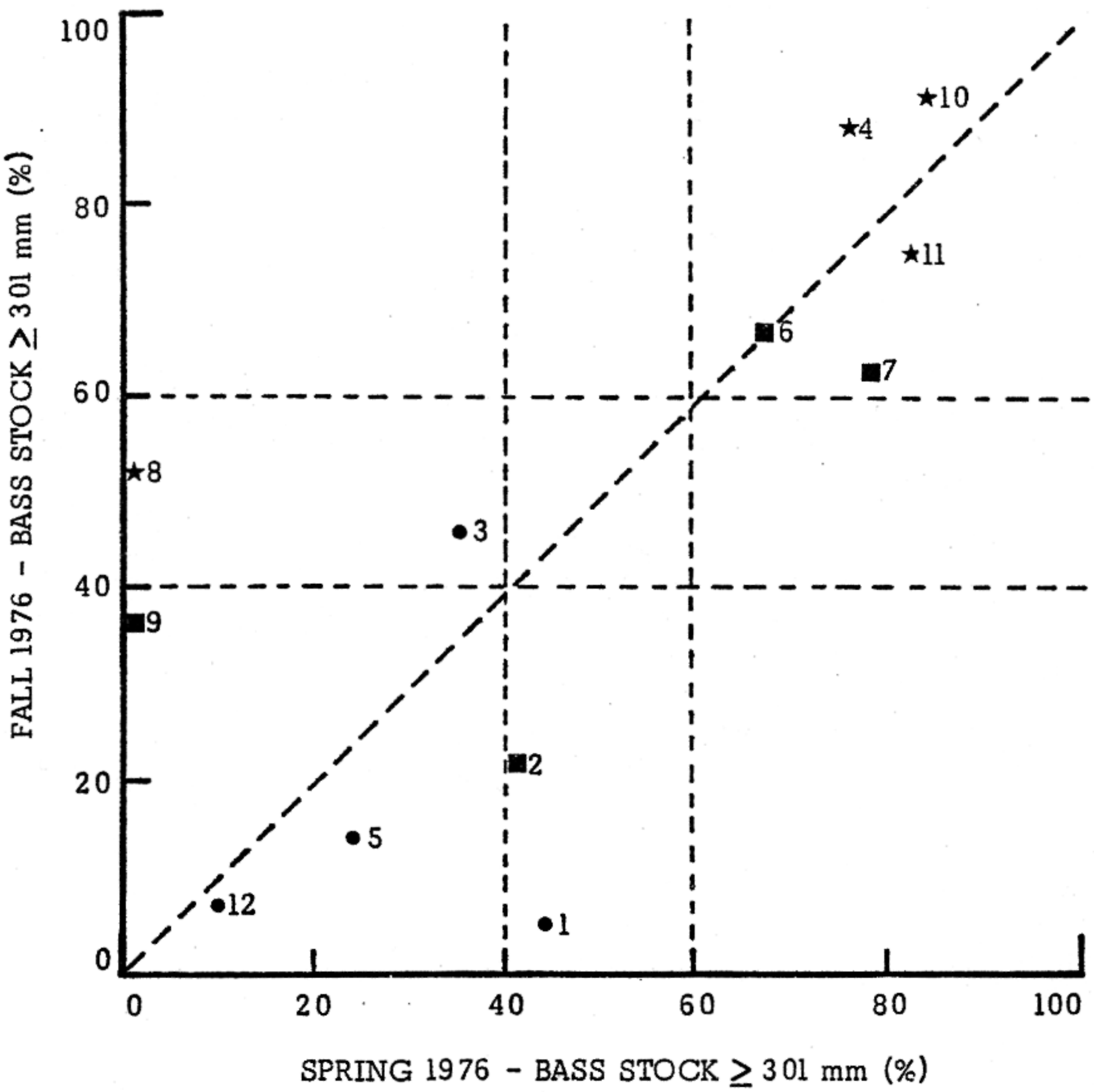

Figure 18. Relationship of spring and fall proportional stock densities of largemouth bass in the 12 study ponds. ● - Low harvest. ■ - Medium harvest. ★ - High harvest.

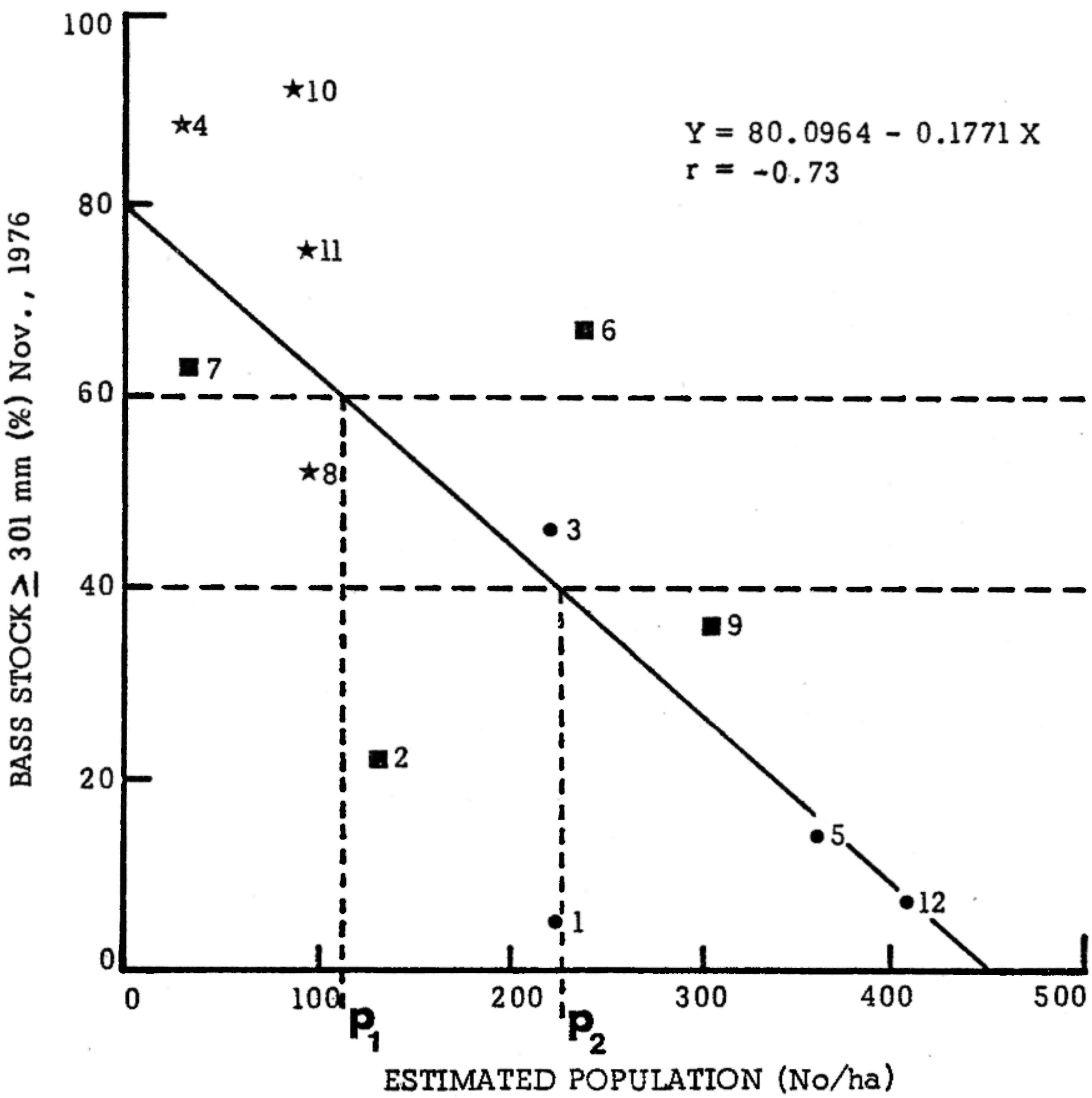

Figure 19. Estimated population of largemouth bass ≥ 200 mm and proportional stock densities of largemouth bass determined from the fall 1976 sample in the 12 study ponds. ● - Low harvest. ■ - Medium harvest. ★ - High harvest. Range of population size P_1 - P_2 (113 - 227/ha) indicates population sizes most likely to result in optimum proportional stock densities of 40 to 60 percent.

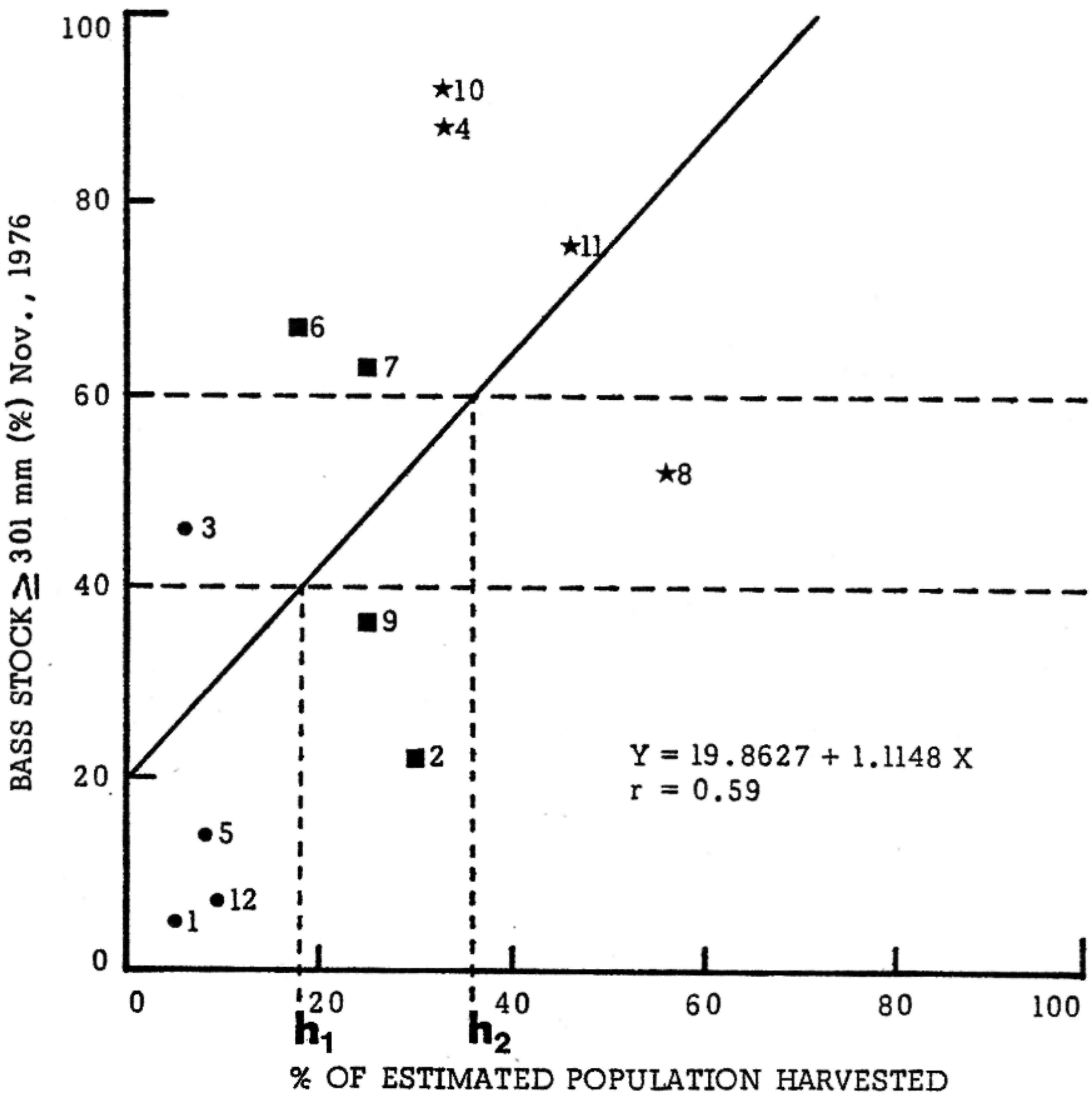

Figure 20. Percent of estimated population of largemouth bass ≥ 200 mm harvested in 1976 and proportional stock densities of largemouth bass determined from the fall 1976 sample in the 12 study ponds. ● - Low harvest. ■ - Medium harvest. ★ - High harvest. Range of harvest H_1 - H_2 (18 - 36%) indicates levels of harvest most likely to result in optimum proportional stock densities of 40 to 60 percent.

Of the medium harvest ponds, pond 6 had no change while ponds 7 and 9 appear to be shifting toward the optimum. Pond 2, however, dropped out of the desired range following the 1976 harvest. It seems that a medium level of bass harvest is most likely to result in optimum bass PSD's in these ponds.

To evaluate the effects of population size on PSD, fall PSD's were plotted as a function of estimated fall population size (Figure 19). A significant correlation ($r = -0.73$) was found. Dropping perpendiculars from points where the regression line intersects the optimum PSD ranges indicated that a population size of 113-227 bass $\geq$ 200 mm/ha (46-92/acre) is most likely to result in an optimum bass PSD. It should be obvious that either larger or smaller populations can be within the optimum range to the extent that variations in the rate functions of growth, mortality, and reproduction allow for various sizes of balanced populations.

Since population size appears to be inversely related to level of harvest, the percentage of the estimated population harvested was plotted against fall PSD's in Figure 20. It is quite apparent that low harvest generally results in low PSD's and high harvest often results in PSD's exceeding the optimum range. Medium harvest ponds tend to be closer to the optimum PSD range, even though none of them were within it. Dropping perpendiculars to the regression line ($r = 0.59$) indicates that a harvest of 18-36% of the population is most likely to result in optimum proportional stock densities of 40-60 percent.

DISCUSSION

Predator-prey systems such as the largemouth bass-bluegill combination in farm ponds are probably in a state of dynamic equilibrium or balance at all times. Some states of balance are much more desirable than others for a quality sport fishery. It is the mission of management biologists to identify and promote the desired state of balance and ensuing populations. This leads to some subjective analysis because of the diversity of opinion as to what is most desirable in a sport fishery. Most anglers, however, have no philosophical bias. They simply want more and larger fish in the creel.

Three rate functions determine the state of balance in bass-bluegill populations and what is subsequently available to anglers. These functions are growth, mortality, and reproduction. This study evaluated these rate functions in 12 different populations subjected to various levels of bass harvest. Standing crop, population size, and structure are measurable results of the rate functions and consequently, the state of balance.

Heidinger (1975) has suggested that population densities of adult bass ranging from 120-240/ha (50-100/ac) indicate "strong" populations and that densities exceeding 240/ha are likely to be stunted populations primarily made up of 200-250 mm fish. Two low harvest ponds (5 and 12) in this study and one medium harvest pond (9) had estimated populations exceeding 240/ha. While pond 12 obviously had a stunted bass population, 5 and 9 had several bass greater than 250 mm. Heidinger also states that "weak" populations are made up of a few large individuals. All four high harvest ponds (4,8,10,11) and one medium harvest pond (7) had estimated populations of less than 120/ha made up of large individuals. Ponds 4 and 7 with estimated populations of 28.6 and 32.3/ha respectively had mean adult bass weights of 680.4 and 524.1 g. The conclusion which can be drawn from this is that while a low harvest may produce a stunted bass population, a high harvest is almost certain to result in low density bass populations and an undesirable state of balance.

Total standing crop in a pond is a function of fertility, production, and mortality. Bass standing crops involve all of these in addition to predator-prey interactions. Bass standing crops in the study ponds averaged 53.8 kg/ha (47.9 lb/ac) and ranged from 16.9-103.9 kg/ha (15.0-92.5 lb/ac). Turner (1960) reported average standing crops of 49.0 and 41.0 kg/ha in 9 balanced and 9 unbalanced Kentucky ponds respectively. Hackney (1975) found an average standing crop of 39.3 kg/ha in 14 Midwest ponds. While the average standing crops of bass in these ponds are slightly higher than those reported by Turner and Hackney, the more important aspect is the relationship to harvest. High harvest results in low standing crops and small populations of large individuals. Low and medium harvest ponds are not clearly separable, but low harvest ponds (1,3,5,12) indicate a general trend toward higher standing crops.

The average bass harvest in the study ponds was 22.7, 41.6, and 33.9 bass/ha (9.2, 16.9, 13.7/ac) in the low, medium and high harvest ponds respectively. The average bass biomass harvested was 10.4, 18.2, and 22.3 kg/ha (9.3, 16.2, 19.8 lb/ac) in the low, medium and high harvest groups respectively. Hackney (1974) has suggested that a harvest of 30-35 bass/acre totaling 20 lbs might be reasonable for many small impoundments. These data indicate that such a rate might be an overharvest in Flint Hills farm ponds producing an undesirable state of balance and low catch per unit of effort.

Mortality rate is an extremely important rate function in population balance. The only mortality rates which could be calculated in this study were limited to certain ages and were so variable within groups of ponds that few reliable conclusions can be drawn from them concerning the effects of various levels of bass harvest. Bluegill mortality rates show no clear trend, but do not appear to be related to bass harvest levels. Average mortality of Age III to V bass seems to be inversely related to level of harvest with average mortality in high harvest ponds < medium harvest ponds < low harvest ponds. It is possible that mortality may be higher in low harvest ponds as a consequence of slow growth and stunting due to higher densities and more intense competition for food. Fishing mortality is compensatory with natural mortality under increased angling pressure and harvest (Heidinger, 1976). Unfortunately, angling and natural mortality cannot be separated with these data.

Reproduction of bluegill was found in all ponds. Potential bluegill recruitment was lower in the group of low bass harvest ponds, probably the result of increased predation by high density bass populations. Bluegill recruitment was also low in the group of high harvest ponds. In this case, probably the result of intraspecific competition from dense populations of stunted bluegill.

Bass reproduction was found in all but pond 12. This pond clearly has a stunted bass population and any young bass produced were most likely consumed by the adults. All of the low harvest ponds show reduced bass recruitment. Medium and high harvest groups do not demonstrate a clear pattern, but the high harvest group has a slightly higher average rate of bass recruitment.

Growth is a rate function which has been found to be density-dependent by several investigators. In systems subjected to an annual harvest, growth rates are indirectly related to level of harvest. In this study, bass growth rates are directly proportional to level of bass harvest. With a few notable exceptions, higher harvests produced greater rates of bass growth. Babb (1976) reported calculated lengths of bass Age I through VIII as 111, 223, 306, 367, 432, 456, and 612 mm in a study of 33 ponds located throughout Illinois, Indiana, Iowa, Kansas, Kentucky, Nebraska, Missouri, and Ohio. Bass at all levels of harvest considered in this study had smaller calculated lengths at annulus.

Bluegill demonstrated very little difference in growth between groups of ponds. The only significant differences found may be more a function of sample size than any other factor. The obvious conclusion of this study is that bass harvest levels considered here have no discernable effects on bluegill growth rates.

In a study involving Missouri ponds, Burress (1949) reported calculated lengths of bluegill Age I through V as 56, 117, 145, 157, and 163 mm. Bluegill growth rates in this study are generally less than those reported by Burress. Moorman (1957) reported calculated lengths of bluegill Age I through IV as 43, 104, 155, and 178 mm in balanced Iowa ponds and 30, 76, 127, and 147 mm in ponds containing too many bluegill. With the exceptions of Age I bluegill, calculated lengths of bluegill in this study are similar to those in Iowa ponds containing too many bluegill. In any case, bluegill growth in the study ponds was too slow to produce satisfactory catches of acceptable sizes of fish.

Significant harvest group and seasonal differences in length-weight relationships of bass were detected in this study. Seasonal cycles were found in all three groups and appear to be more pronounced at higher levels of harvest. Significant group effects were also detected with low and high harvest groups showing a more pronounced trend toward allometric growth than the medium harvest group. As pointed out earlier, these seasonal and group differences are thought to be a reflection of density and consequently, the amount of food available per individual.

Bluegill length-weight relationships showed some group and seasonal differences, but groups were much less important than seasons. Seasonal cycles were present only through the growing season. This is doubtless a reflection of food availability and perhaps bluegill density as well.

Relative weight, an index of condition, is quite similar to an analysis of length-weight relationships. With the exception of bass $\geq$ 450 mm in the high harvest group, all groups in all seasons were below the standard weight curve. Calculated relative weight values indicate that higher harvest levels tend to result in more nearly optimal relative weights or better condition. Bluegill relative weights are uniformly low and very similar in all harvest groups and size groups considered. While bass condition is a function of density and harvest, bluegill condition appears to be unaffected by any of the harvest levels considered in this study.

Proportional stock density seems to be a very useful tool for evaluating balance and the status of fish populations. While testing is needed to evaluate P.S.D.'s taken by electrofishing with those made by other methods, the trammel net used in this study appears to produce comparable results in small impoundments.

Analysis of P.S.D.'s calculated in this study indicates that a medium level of bass harvest is most likely to result in an optimum P.S.D. as described by Anderson (1976). A medium level of harvest in this case amounts to 18 to 36% of the population or an average of 41.7 bass/ha (16.9/ac) in the four medium harvest ponds. This corresponds to an average biomass harvest of 18.2 kg/ha (16.2 lb/ac). Further analysis of these data indicate that an optimum bass P.S.D. in the range of 40-60% is most likely to be achieved in ponds having total populations of bass $\geq$ 200 mm in the range of 113-227/ha (46-92/ac). In Kansas Flint Hill farm ponds, this range of population sizes is symptomatic of medium levels of bass harvest.

SUMMARY AND RECOMMENDATIONS

A summary of the more important findings of this study is contained in items 1 through 5 below.

1) Bass population size (No/ha) and standing crop (kg/ha) are inversely related to bass harvest.

2) Higher levels of bass harvest result in lower bass standing crops and smaller populations made up of larger individuals having characteristically faster rates of growth.

3) The various levels of bass harvest considered here have no discernable effect on bluegill growth or mortality.

4) A medium level of bass harvest is most desirable in terms of predator-prey equilibrium and a sustained quality of bass fishing.

5) While a medium level harvest quota for bass can be a workable management plan, it leaves much to be desired, particularly in terms of a quality bluegill fishery.

The most obvious of the conclusions which can be drawn from this study is that kg/ha quotas have limited utility as management tools. If used, however, a medium level of bass harvest consisting of 36 - 49 bass/ha (15-20 bass/ac) with an aggregate weight of 16.8 - 22.4 kg/ha (15-20 lbs/ac) is recommended. Such a management scheme does not produce a quality bluegill fishery. Some preliminary evidence indicates that harvesting 3-5 kg of bluegill for every kg of bass removed can result in a dramatic improvement and very high quality bluegill fishery. The problems involved in taking such a large bluegill harvest in anything but a very small impoundment are well known to most fishery biologists and will rapidly become apparent to any novice attempting to carry out such a program.

A more suitable approach would seem to be a modification of the slot-length limit. While the slot-length limit looks very promising, it is possible that bass overharvest may still occur in small ponds such as those studied here. Intense angling pressure may significantly reduce recruitment to the protected range if there is no upper limit to the harvest. As a result, it is recommended that a slot-length limit combined with a total bass harvest quota of 16.8-28.0 kg/ha (15-25 lbs/ac) be tested. Concurrent evaluation of various levels of bluegill harvest in conjunction with the slot-length, kg/ha quota scheme should provide insight for improved bluegill management plans.

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APPENDIX A

1976 bass, bluegill and channel catfish harvest in the 12 Kansas farm ponds used in this study.

Table A1. 1976 largemouth bass harvest for the 12 study ponds.

Pond No.	Mean 1976 area ha	(Acres)	No.	No/ha	No/Ac	Lbs.	kg/ha	Lbs/Ac	Mean Weight Lbs.	Grams
1	0.28	0.68	3	10.9	4.4	8.00	13.17	11.76	2.67	1211.11
2	0.42	1.03	16	38.3	15.5	15.81	17.19	15.35	0.99	449.06
3	0.15	0.36	2	13.8	5.6	3.63	11.29	10.08	1.82	825.55
4	0.84	2.07	8	9.6	3.9	20.75	11.22	10.02	2.59	1174.82
5	0.39	0.96	11	28.4	11.5	12.19	14.22	12.70	1.11	503.50
6	0.23	0.57	10	43.2	17.5	11.44	22.48	20.07	1.14	517.10
7	0.62	1.53	5	8.2	3.3	7.88	5.77	5.15	1.58	716.69
8	0.40	0.98	21	52.9	21.4	16.31	18.64	16.64	0.78	352.30
9	0.36	0.90	28	76.9	31.1	21.94	27.31	24.38	0.78	355.43
10	0.68	1.69	20	29.2	11.8	41.13	27.26	24.34	2.06	934.42
11	0.25	0.62	11	43.7	17.7	17.63	31.85	28.44	1.60	725.76
12	0.16	0.39	6	38.0	15.4	1.01	2.90	2.59	0.17	77.11

Table A2. 1976 bluegill harvest for the 12 study ponds.

Pond	Mean 1976 area								Mean Weight	
No.	ha	(Acres)	No.	No/ha	No/Ac	Lbs.	kg/ha	Lbs/Ac	Lbs.	Grams
1	0.28	0.68	271	984.8	398.5	53.44	88.03	78.60	0.20	90.72
2	0.42	1.03	199	477.4	193.2	31.94	34.73	31.01	0.16	74.59
3	0.15	0.36	15	103.0	41.7	2.94	9.15	8.17	0.20	90.72
4	0.84	2.07	430	513.2	207.7	15.19	8.22	7.34	0.04	16.02
5	0.39	0.96	117	301.2	121.9	19.13	22.32	19.93	0.17	74.86
6	0.23	0.57	27	117.1	47.4	4.44	8.73	7.79	0.16	74.59
7	0.62	1.53	95	153.5	62.1	12.50	9.15	8.17	0.13	59.68
8	0.40	0.98	21	52.9	21.4	16.31	18.64	16.64	0.78	352.30
9	0.36	0.90	182	499.6	202.2	31.31	38.97	34.79	0.17	78.03
10	0.68	1.69	316	462.0	187.0	42.19	27.96	24.96	0.13	60.56
11	0.25	0.62	90	358.8	145.2	17.63	31.85	28.44	0.20	90.72
12	0.16	0.39	5	31.6	12.8	1.13	3.25	2.90	0.23	104.33

Table A3. 1976 channel catfish harvest for the 12 study ponds.

Pond	Mean 1976 area								Mean Weight	
No.	ha	(Acres)	No.	No/ha	No/Ac	Lbs.	kg/ha	Lbs/Ac	Lbs.	Grams
1	0.28	0.68	32	116.4	47.1	27.94	46.02	41.09	0.87	394.63
2	0.42	1.03	4	9.6	3.9	4.81	5.23	4.67	1.20	544.32
3	0.15	0.36	4	27.4	11.1	5.69	21.06	15.80	1.42	644.11
4	0.84	2.07	27	32.1	13.0	54.13	29.29	26.15	2.00	909.30
5	0.39	0.96	2	5.2	2.1	2.81	3.28	2.93	1.41	637.31
6	0.23	0.57	20	86.7	35.1	19.31	38.07	33.99	0.97	437.95
7	0.62	1.53	20	32.4	13.1	27.63	20.23	18.06	1.18	535.93
8	0.40	0.98	18	45.5	18.4	11.56	13.22	11.80	0.64	291.31
9	0.36	0.90	17	46.7	18.9	19.88	24.74	22.09	1.17	530.31
10	0.68	1.69	14	20.5	8.3	31.06	20.59	18.38	2.22	1006.43
11	0.25	0.62	4	16.1	6.5	3.81	6.89	6.15	0.95	432.05
12	0.16	0.39	--	--	--	--	--	--	--	--

APPENDIX B

Results of 1976 shoreline seining in the 12 Kansas farm ponds used in this study.

Table B1. Spring 1976 shoreline seining data for the 12 study ponds. (Means of 5, 1/4 circle, 20' x 4', 1/4" mesh bag seine hauls)

Pond	Sample	Largemouth bass				Bluegill			
No.	Date	S	M	L	Total	S	M	L	Total
1	7-26	1.4	0.4	---	9	23.6	0.2	0.4	121
2	7-26	8.8	---	0.4	46	35.4	0.6	0.2	181
3	7-22	26.8	---	0.4	136	3.8	0.4	---	21
4	7-28	1.4	---	---	7	0.8	1.4	---	11
5	7-26	10.2	---	---	51	3.4	---	---	17
6	7-22	14.6	0.2	0.2	75	5.2	0.6	---	29
7	7-21	17.6	1.0	---	93	1.6	4.4	---	30
8	7-28	25.6	---	---	128	---	---	---	---
9	7-26	0.8	---	---	4	4.2	0.2	---	22
10	7-28	19.0	1.0	---	100	1.2	0.2	---	7
11	7-22	45.8	---	---	229	6.4	2.4	0.2	45
12	7-28	1.0	---	---	5	21.8	---	---	109

Size groups	bass	bluegill
S = small	0 - 125 mm	0 - 75 mm
M= medium	126 - 250 mm	76 - 150 mm
L = large	≥ 251 mm	≥ 151 mm

Table B2. Fall 1976 shoreline seining data for the 12 study ponds.
(Means of 5, 1/4 circle, 20' x 4', 1/4" mesh bag seine hauls)

Pond No.	Sample Date	Largemouth bass S	M	L	Total	Bluegill S	M	L	Total
1	10-1	0.4	0.4	---	4	4.0	0.2	---	21
2	10-21	1.6	0.2	---	9	6.0	0.4	0.4	34
3	10-14	0.8	2.0	1.6	22	8.8	2.6	---	57
4	9-30	3.6	---	---	18	2.6	19.0	---	108
5	10-1	1.2	0.4	---	8	71.4	---	0.2	358
6	10-14	76.2	2.4	1.2	399	207.0	8.8	0.4	1081
7	10-26	3.2	---	0.2	17	0.6	---	---	3
8	10-21	5.0	---	0.4	27	1.0	0.2	---	6
9	10-1	4.2	---	---	21	345.0	1.2	---	1731
10	9-30	8.6	1.0	---	48	4.0	1.0	---	25
11	10-14	54.0	0.6	0.2	274	51.6	6.2	---	289
12	9-30	---	1.2	---	6	4.4	---	0.2	23

Size groups	bass	bluegill
S = small	0 - 125 mm	0 - 75 mm
M= medium	126 - 250 mm	76 - 150 mm
L = large	≥ 251 mm	≥ 151 mm

APPENDIX C

Grand mean calculated total lengths (mm) at annulus, standard deviation of calculated length, annual length increment and number for largemouth bass and bluegill in the 12 study ponds.

Table C1. Grand mean calculated total lengths (mm) at annulus, standard deviation of calculated length, annual length increment and number for largemouth bass in the 4 "low harvest" study ponds.

Pond Nos.		AGE I	II	III	IV	V	VI	VII	VIII	IX
1	Length	111.4	205.4	248.8	301.1	369.9	412.4	434.8	456.5	468.0
	Std. Dev.	24.4	22.0	20.9	38.7	27.6	16.5	13.7	14.9	22.0
	Ann. Inc.	111.4	94.0	43.4	52.3	68.8	42.5	22.4	21.7	11.5
	Number	75	67	41	16	10	8	7	5	2
3	Length	104.6	229.5	320.7	369.4	434.8	461.5	501.2	----	----
	Std. Dev.	17.8	34.7	36.8	30.4	28.6	27.8	21.1	----	----
	Ann. Inc.	104.6	124.9	91.2	48.7	65.4	26.7	39.7	----	----
	Number	53	51	12	8	3	3	2	----	----
5	Length	97.7	172.4	224.1	256.3	313.0	373.8	419.9	464.6	----
	Std. Dev.	71.6	19.0	21.8	30.2	31.0	52.9	42.2	----	----
	Ann. Inc.	97.7	74.7	51.7	32.2	56.7	60.8	46.1	44.7	----
	Number	81	80	65	35	10	3	2	1	----
12	Length	99.4	179.8	211.2	271.6	289.3	----	----	----	----
	Std. Dev.	12.8	14.9	21.8	18.6	25.0	----	----	----	----
	Ann. Inc.	99.4	80.4	31.4	60.4	17.7	----	----	----	----
	Number	68	66	33	5	3	----	----	----	----
1,3,	Length	103.2	193.7	235.7	282.8	346.2	414.7	444.2	457.8	468.0
5,12	Std. Dev.	42.2	31.4	36.5	49.1	52.3	39.9	34.1	13.7	22.0
Comb.	Ann. Inc.	103.2	90.5	42.0	47.1	63.4	68.5	29.5	13.6	10.2
	Number	277	264	151	64	26	14	11	6	2

Table C2. Grand mean calculated total lengths (mm) at annulus, standard deviation of calculated length, annual length increment and number for largemouth bass in the 4 "medium harvest" study ponds.

Pond Nos.		AGE I	II	III	IV	V	VI	VII	VIII	IX
2	Length	98.5	199.2	265.8	315.0	332.3	379.2	409.1	438.9	----
	Std. Dev.	19.6	20.3	31.1	27.9	23.0	11.5	----	----	----
	Ann. Inc.	98.5	100.7	66.6	49.2	17.3	46.9	29.9	29.8	----
	Number	79	78	44	14	5	2	1	1	----
6	Length	104.7	214.8	272.2	319.9	352.1	370.4	402.3	----	----
	Std. Dev.	38.7	44.0	35.7	32.7	40.8	8.6	----	----	----
	Ann. Inc.	104.7	110.1	57.4	47.7	32.2	18.3	31.9	----	----
	Number	75	46	27	13	5	2	1	----	----
7	Length	87.0	198.7	284.0	337.2	377.9	426.7	----	----	----
	Std. Dev.	20.1	20.3	22.0	26.0	23.1	----	----	----	----
	Ann. Inc.	87.0	111.7	85.3	53.2	40.7	48.8	----	----	----
	Number	62	22	18	12	7	1	----	----	----
9	Length	101.3	201.1	255.2	295.8	307.4	317.6	----	----	----
	Std. Dev.	23.6	24.3	22.7	29.8	23.8	1.0	----	----	----
	Ann. Inc.	101.3	99.8	54.1	40.6	11.6	10.2	----	----	----
	Number	89	63	38	17	3	2	----	----	----
2,6,	Length	98.5	203.1	266.6	315.1	349.5	365.9	405.7	438.9	----
7,9	Std. Dev.	27.3	28.8	30.0	32.2	36.7	38.7	4.8	----	----
Comb.	Ann. Inc.	98.5	104.6	63.5	48.5	34.4	16.4	39.8	33.2	----
	Number	305	209	127	56	20	7	2	1	----

Table C3. Grand mean calculated total lengths (mm) at annulus, standard deviation of calculated length, annual length increment and number for largemouth bass in the 4 "high harvest" study ponds.

Pond Nos.		AGE I	II	III	IV	V	VI	VII	VIII	IX
4	Length	90.9	220.1	290.3	349.3	365.7	----	----	----	----
	Std. Dev.	24.7	61.6	48.5	36.8	----	----	----	----	----
	Ann. Inc.	90.9	129.2	70.2	59.0	16.4	----	----	----	----
	Number	23	21	19	13	1	----	----	----	----
8	Length	116.1	206.7	246.1	283.3	----	----	----	----	----
	Std. Dev.	16.0	15.9	23.4	21.9	----	----	----	----	----
	Ann. Inc.	116.1	90.6	39.4	37.2	----	----	----	----	----
	Number	55	53	51	10	----	----	----	----	----
10	Length	97.9	243.9	343.5	393.7	429.1	485.0	----	----	----
	Std. Dev.	36.7	66.9	64.2	35.4	42.1	----	----	----	----
	Ann. Inc.	97.9	146.0	99.6	50.2	35.4	55.9	----	----	----
	Number	89	52	45	18	9	1	----	----	----
11	Length	87.7	197.9	280.1	325.7	352.0	429.4	442.9	----	----
	Std. Dev.	19.3	25.4	27.1	33.2	40.3	5.8	----	----	----
	Ann. Inc.	87.7	110.2	82.2	45.6	26.3	77.4	13.5	----	----
	Number	40	33	30	17	9	2	1	----	----
4,8,	Length	100.0	218.8	289.1	344.8	389.2	447.9	442.9	----	----
10,11	Std. Dev.	29.8	49.9	59.1	50.7	55.0	32.3	----	----	----
Comb.	Ann. Inc.	100.0	118.8	70.3	55.7	44.4	58.7	----	----	----
	Number	207	159	145	58	19	3	1	----	----

Table C4. Grand mean calculated total lengths (mm) at annulus, standard deviation of calculated length, annual length increment and number for bluegill in the 4 "low harvest" study ponds.

Pond Nos.		AGE I	II	III	IV	V	VI
1	Length	52.8	89.8	121.1	148.8	172.1	164.9
	Std. Dev.	12.3	16.0	15.8	16.6	16.2	----
	Ann. Inc.	52.8	37.0	31.3	27.7	23.3	----
	Number	119	117	91	62	30	1
3	Length	54.5	76.2	95.3	126.4	145.1	----
	Std. Dev.	7.1	9.0	15.9	14.0	9.5	----
	Ann. Inc.	54.5	21.7	19.1	31.1	18.7	----
	Number	67	67	49	9	6	----
5	Length	52.1	89.1	118.7	140.5	154.6	----
	Std. Dev.	13.4	16.9	18.2	15.4	7.6	----
	Ann. Inc.	52.1	37.0	29.6	21.8	14.1	----
	Number	150	147	144	62	3	----
12	Length	58.4	102.5	131.4	144.6	----	----
	Std. Dev.	11.0	13.0	15.6	12.4	----	----
	Ann. Inc.	58.4	44.1	28.9	13.2	----	----
	Number	45	45	40	17	----	----
1,3,	Length	53.5	88.6	117.4	143.6	166.6	164.9
5,12	Std. Dev.	12.0	16.6	19.6	16.4	18.0	----
Comb.	Ann. Inc.	53.5	35.1	28.8	26.2	23.0	----
	Number	381	376	324	150	39	1

Table C5. Grand mean calculated total lengths (mm) at annulus, standard deviation of calculated length, annual length increment and number for bluegill in the 4 "medium harvest" study ponds.

Pond Nos.		AGE I	II	III	IV	V	VI
2	Length	55.9	86.9	122.2	159.1	180.3	197.8
	Std. Dev.	10.8	15.8	19.9	13.7	15.9	15.4
	Ann. Inc.	55.9	31.0	35.3	36.9	21.2	17.5
	Number	120	107	79	52	19	5
6	Length	57.6	83.0	108.7	134.2	----	----
	Std. Dev.	10.9	10.6	16.1	18.6	----	----
	Ann. Inc.	57.6	25.4	25.7	25.5	----	----
	Number	98	68	50	18	----	----
7	Length	50.7	75.5	100.6	139.4	156.4	----
	Std. Dev.	8.0	12.6	15.1	18.2	12.3	----
	Ann. Inc.	50.7	24.8	25.1	38.8	17.0	----
	Number	119	115	67	14	6	----
9	Length	44.9	81.9	121.0	148.2	198.5	----
	Std. Dev.	6.0	15.5	16.7	14.1	----	----
	Ann. Inc.	44.9	37.0	39.1	27.2	50.3	----
	Number	79	76	58	31	1	----
2,6, 7,9 Comb.	Length	52.7	81.6	113.5	149.9	175.5	197.8
	Std. Dev.	10.4	14.6	19.5	17.8	18.4	15.4
	Ann. Inc.	52.7	28.9	31.9	36.4	25.6	22.3
	Number	416	366	254	115	26	5

Table C6. Grand mean calculated total lengths (mm) at annulus, standard deviation of calculated length, annual length increment and number for bluegill in the 4 "high harvest" study ponds.

Pond Nos.		I	II	III	IV	V	VI
4	Length	50.9	78.1	104.6	148.7	169.5	----
	Std. Dev.	7.3	17.8	18.2	16.8	25.7	----
	Ann. Inc.	50.9	27.2	26.5	44.1	20.8	----
	Number	182	181	83	10	2	----
8	Length	58.0	91.2	122.4	146.4	165.8	180.4
	Std. Dev.	10.0	13.7	13.7	9.8	9.1	----
	Ann. Inc.	58.0	33.2	31.2	24.0	19.4	14.6
	Number	37	36	21	13	6	1
10	Length	55.2	96.5	125.5	140.3	144.9	----
	Std. Dev.	13.1	17.3	18.0	11.7	18.4	----
	Ann. Inc.	55.2	41.3	29.0	14.8	4.6	----
	Number	203	176	102	10	3	----
11	Length	51.3	79.6	115.6	141.9	162.0	181.7
	Std. Dev.	9.5	14.2	15.7	14.9	15.1	12.2
	Ann. Inc.	51.3	28.3	36.0	26.3	20.1	19.7
	Number	113	93	73	51	17	2
4,8,	Length	53.1	86.0	116.4	143.2	161.5	181.3
10,11	Std. Dev.	10.7	18.7	19.2	14.2	15.4	8.7
Comb.	Ann. Inc.	53.1	32.9	30.4	26.8	18.3	19.8
	Number	535	486	279	84	28	3

THE EFFECTS OF VARIOUS LARGEMOUTH BASS HARVEST LEVELS ON SOME DYNAMIC ASPECTS OF BASS-BLUEGILL POPULATIONS IN KANSAS FARM PONDS

by

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This study was designed to evaluate the effects of selected harvest rates on populations of largemouth bass and bluegill in Kansas farm ponds. Channel catfish were stocked and harvested also. Largemouth bass populations in 12 ponds were harvested at specified quotas (kg/ha) for 3 years. In the third year, sampling was conducted by electrofishing and trammel net seining to determine the size of the bass populations and relative abundance of bluegill. Lengths, weights, and scales were collected from 886 bass and 1454 bluegill for age and growth determinations. Shoreline seining was done three times per year to evaluate reproduction and recruitment of young of the year fishes. Selected limnological parameters were sampled three times per year to assess differences in fertility between ponds.

Growth, recruitment, mortality, length-weight relationships, relative condition factors, and proportional stock densities are evaluated in terms of bass population size and harvest levels. Results indicate that a 16.8-22.4 kg/ha (15-20 lb/acre) annual harvest of largemouth bass may be near the maximum sustainable yield for "balanced" ponds in this area of Kansas. A medium level of bass harvest amounting to 18-36% of the population or an average of 41.7 bass/ha (16.9/ac) equivalent to 18.2 kg/ha (16.2 lb/ac) is most likely to result in an optimum bass P.S.D. of 40-60%. A total population of bass $\geq$ 200 mm total length in the range of 113-227/ha (46-92/ac) is highly correlated with optimum bass P.S.D.'s.

The various levels of bass harvest produced no obvious differences between bluegill populations in the experimental ponds. Bluegill populations

often exhibited characteristics of overabundance and are apparently underutilized by both sportsmen and predatory fish.

A 305 to 381 mm (12-15 in) protected length range (slot-length limit) used in conjunction with a bass harvest quota of 16.8-28.0 kg/ha (15-25 lb/ac) is recommended for evaluation. Testing of a program involving accelerated rates of bluegill harvest is also suggested.