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The Concept of Balance for Coolwater Fish Populations

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Abstract

We propose a new approach to evaluate the state of balance or structure of coolwater fish populations and communities. All that is needed to calculate the index is a length-frequency distribution of a fish stock. The index, Proportional Stock Density (PSD) is calculated as the percentage of fish of a quality size (total length) that is longer than a minimum stock size. Minimum stock and quality sizes (20-26% and 36-41% of world-record length, respectively) are defined for: yellow perch (Perca flavescens) 13 and 20 cm; walleye (Stizostedion vitreum) 25 and 38 cm; smallmouth bass (Micropterus dolomieui) 18 and 28 cm; northern pike (Esox lucius) 35 and 53 cm; and muskellunge (Esox masquinongy) 43 and 66 cm. An analysis of model stocks based on representative growth and mortality rates and analogies between largemouth bass (Micropterus salmoides) and bluegill (Lepomis macrochirus) populations lead to the suggestions that the PSD for balanced populations of yellow perch may range from 30 to 50%; the PSD for balanced populations of coolwater game fish may range from 30 to 60%. Balanced fish communities are defined as those with the potential to provide a satisfactory catch and harvest of both game fish and panfish; i.e. both predators and prey. Overharvest is defined as harvest of more than the surplus of stock- or quality-size fish; the surplus is determined according to

management objectives for favorable values of PSD. Minimum length limits at a size longer than minimum quality size and protected size ranges (slot length limits) which protect some portion of quality-size fish are proposed as tactics to rebuild depleted stocks of game fish and to sustain balance in fish populations and communities. The goal is to achieve satisfactory sustained yield, benefits, and fishing quality.

The concept of balance is basic to the effective management of recreational fisheries and the goal of optimum yield. Swingle (1950) defined balanced populations as those that have the capacity to provide a satisfactory harvest of fish in proportion to the productivity of their habitat. Balance is a management term based on human values. At any given level of productivity or carrying capacity expressed as fish biomass, there is a broad range of potential densities and length-frequency distributions. Balanced populations have a structure that is intermediate between the extremes of a large number of small fish and a small number of large fish. For the structure of a fish population to be balanced, the rates of reproduction, growth, and mortality must be satisfactory.

Warmwater and coolwater fish communities are similar in that they include both game fish and panfish--i.e., both predators and prey. When a fish community of largemouth bass (*Micropterus salmoides*) and and bluegills (*Lepomis macrochirus*) is balanced, both populations can provide satisfactory yields. Balanced coolwater fish communities should also be able to provide satisfactory catch and harvest of both game fish and panfish.

A new index based on length-frequency distributions, Proportional Stock Density (PSD), has been developed to describe the structure of stocks of largemouth bass and bluegills (Anderson 1976). The objective of this paper is to extend the concept of PSD to populations of yellow perch (*Perca flavescens*), walleyes (*Stizostedion vitreum*), smallmouth bass (*Micropterus dolomieui*), northern pike (*Esox lucius*), and muskellunge (*Esox masquinongy*).

The PSD models that follow incorporate some speculations, assumptions, and simplifications. Our intention is to establish the concept of PSD as a technique for the evaluation of fish population and community structure. Research will be necessary to define optimal values and to develop management strategies and tactics that will achieve objectives for various species and ecosystems.

Methods and Definitions

Proportional Stock Density is the percentage of the stock that is of quality size:

$$\text{PSD (\%)} = \frac{\text{Number} \geq \text{quality size x 100}}{\text{Number} \geq \text{stock size}}$$

All that is needed to calculate the index is a definition of minimum lengths for stock- and quality-size fish and a length-frequency distribution of the stock. We define the minimum length for the stock of all species as some length within 20 to 26% of the world-record length; the minimum length for the quality size of all speices is defined as some length within 36 and 41% of the world-record length. For convenience the length is a whole number when expressed in centimeters or inches (Table 1). All lengths used herein are total lengths.

We developed models of PSD for stocks of coolwater species. Length-at-age data were selected for stocks with fast, moderate, and slow growth rates (Table 2). Survivorship curves that reflect annual mortality rates of actual or typical populations were developed when possible. Patterns of annual mortality in the PSD models include: a moderate constant rate; a moderate rate that varied with age; and a high rate for quality-size fish.

For all models we calculated the number in each age group by assuming a rate of reproduction of 100 age-I fish. The number of stock- and quality-size fish in each age group was estimated by assuming a range and a normal distribution about the mean length at a given age. The total number of stock- and quality-size fish for the populations was determined by summing each, for all age groups. Tables showing the actual numbers for all the models are available upon request.

PSD Models

Yellow Perch

The growth patterns selected for yellow perch are: fast, Lake Erie in 1927-1937 (Jobes 1952); moderate, West Okoboji Lake in Iowa (Moen 1964); and slow, an average size in Michigan (Laarman 1963). Yellow perch in these populations are recruited to stock in their second or third growing season and reach the minimum quality length in the third to fifth growing season (Table 2).

When annual length increment is plotted as a function of length at annulus formation, all three growth patterns exhibit similar length increments when fish are 20-25 cm long. The average Michigan yellow perch, however, exhibit a relatively low annual increment at lengths of 13-17 cm (Fig. 1).

The three survivorship patterns reflect: a constant 50% annual mortality; a concave curve with a high mortality rate of young fish and moderate rate for adults; and a convex curve with a low mortality rate for young fish and high rate for adults (Fig. 2). The second and third curves reflect survivorship patterns for bluegills from balanced and unbalanced populations, respectively (Anderson 1973). We have assumed that populations of these two important species of prey may exhibit similar dynamics.

The model PSD values for yellow perch range from 8 to 46%. The lowest value and the poorest structure result from slow growth and high mortality of quality-size fish (Table 3).

Walleye

Growth patterns selected for walleyes are: fast, Minnesota lakes (Eddy and Carlander 1939); moderate, Clear Lake in Iowa (Carlander and Whitney 1961); and slow, Red Lakes, Minnesota (Smith 1977). With these growth patterns walleyes are recruited to stock size in the second and third growing season and reach quality size in the fourth to the seventh growing season (Table 2).

The three survivorship patterns reflect: constant 40% annual mortality; a concave curve with a mortality of 60% for age I, 50% for age II, and a low annual mortality of 35% for age III and older walleyes; and a convex curve with mortality of 20% for age I, 30% for age II, and a high annual mortality of 60% for age III and older walleyes. Carlander and Payne (1977) used an annual mortality of 42% in their analysis of the walleye population in Clear Lake, Iowa.

The model PSD values for the three growth and mortality patterns range from 3 to 55% (Table 3). The lowest value and the poorest structure are the result of slow growth and high mortality.

Smallmouth Bass

The selected smallmouth bass growth patterns are: fast, Norris Reservoir (Stroud 1948); moderate, Oneida Lake, New York (Forney 1972); and slow, the upper White River, Missouri (Purkett 1958). Smallmouth bass are recruited to stock size in the second and third growing season and reach quality size in the third to the sixth growing season in these populations (Table 2).

Two constant annual mortality rates were assumed -- 43 and 65%. A 43% rate is the average over a 14-year life span in Oneida Lake (Forney 1972); a 65% rate is estimated from the catch-curve analysis of smallmouth bass from ages I to VI in the Plover River, Wisconsin (Paragamian and Coble 1975).

The model PSD values for these growth and mortality patterns range from 4 to 64% (Table 3).

Northern Pike

The growth patterns selected for northern pike are: fast, Ohio (Roach 1948); moderate, a typical population in Michigan (Latta 1972); and slow, Bucks Lake, Wisconsin (Snow and Beard 1972). Northern pike in these populations are recruited to stock size in the second or third growing season and reach quality size in the fourth to the seventh growing season (Table 2).

The three survivorship patterns reflect: constant 50% annual mortality; 50% annual mortality for age I and II and 40% annual mortality for ages III and older; and 50% mortality for ages I and

II and 83% annual mortality for ages III and older. The third survivorship curve was proposed as typical for northern pike populations in Michigan (Latta 1972).

The model PSD values for the three mortality and growth patterns range from less than 1 to 50% (Table 3). The PSD values are low at all levels of mortality when growth is slow, and at all growth rates when mortality is high.

Muskellunge

The growth patterns selected for muskellunge are: fast, the Pennsylvania state average (Buss and Miller 1961); moderate, an average for the species (Karvelis 1964); and slow, an average for Minnesota (Carlander 1969). Muskellunge with these growth patterns are recruited to stock size in the second or third growing season and reach quality size in the fourth to the sixth growing season (Table 2).

The two survivorship patterns for the models are: a constant 30% annual mortality; and an annual mortality of 15% for ages I and II, 20% for age III, 50% for age IV, 64% for age V, and 80% for ages VI and older. A rate of 30% is similar to that of muskellunge age V-XVII in the life table for Lac Court Oreilles, Wisconsin developed by Johnson (1975); the second pattern is similar to the catch curve determined for the population in Nogies Creek, Ontario by Muir (1964).

The model PSD values for these growth and mortality patterns range from 23 to 62% (Table 3).

Young-Adult Ratios

A satisfactory annual rate of reproduction is necessary in order to sustain a favorable balance of fish stocks. We define the rate of reproduction as the number of age-I fish produced per unit area per year. Determining this rate is difficult, expensive, and impractical for management purposes.

Reynolds and Babb (in press) proposed a convenient index for evaluation of the success of reproduction--the Young-Adult Ratio (YAR). The favorable ratio for largemouth bass in the fall where populations and communities were balanced was 1-3:1 for the number of young-of-the-year bass to the number of quality-size bass.

The ratio was calculated for the populations developed in this paper by determining the ratio of age-I fish (100) to the number of quality-size fish. The average ratio for the populations of game fish with PSD values higher than 25% is 1.1-3.0:1 (Table 4). The ratios are higher for populations with PSD values less than 25% because of the relatively low density of quality-size fish. Ratios much less than 1:1 can obviously occur in real-world populations and indicate a weakness or a failure of a year class.

Centrarchid Analogies

Minimum stock and quality lengths for bluegills have been defined as 8 and 15 cm, respectively (Anderson 1976). These lengths are about 25 and 40% of the world-record length. The original balanced PSD suggested for bluegills was 25% with a range of 15-35% (Johnson and Anderson 1974; Anderson 1976). Subsequent analyses of bluegill populations in small Midwestern impoundments led to the conclusion that a range from 20 to 40% provided the best number of fish for anglers and prey for bass; a range of 40-60%

provided fewer bluegills as prey and for harvest but a higher average size of bluegills for anglers (Novinger and Legler in press). Research is needed to determine whether similar relationships exist for populations of yellow perch. On the basis of our models, we suggest that stocks of yellow perch exhibit satisfactory or favorable structure, i.e. balance when PSD is near or within a range of 30-50%.

Minimum stock and quality lengths for largemouth bass have been defined as 20 and 30 cm (Anderson 1976). These lengths are about 21 and 36% of the world-record length. Largemouth bass and coolwater game fish serve the same dual functions, i.e. a terminal link in aquatic food chains and popular species for anglers. The original models of balance for largemouth bass populations resulted in a range of PSD from 45 to 65 (Anderson 1975, 1976). Reynolds and Babb (in press) proposed 40-60% as the best model for largemouth bass in small impoundments. We recommend a PSD from 50 to 70% for largemouth bass in Missouri impoundments where gizzard shad (Dorosoma cepedianum) are a dominant species of prey (paper in preparation). Research will be needed to develop satisfactory ranges of PSD for coolwater game fish in different ecosystems. On the basis of our models, we suggest that stocks of walleyes, smallmouth bass, northern pike, and muskellunge exhibit satisfactory or favorable structure, i.e. balance when PSD is near or within a range of 30-60%.

PSD of Coolwater Species

The literature contains only a few sources with length-frequency distributions of coolwater fish populations that suit the purposes of this paper. As an example, only 1 of the 58 papers in the Percid International Symposium (Journal of the Fisheries Research Board of Canada, vol. 34, no. 10, 1977) includes a length-frequency distribution (Kelso and Ward 1977). West Blue Lake, Manitoba, sustains populations of yellow perch and walleyes. The yellow perch population was relatively stable and balanced, with a PSD of 42%.

Yellow perch populations have a PSD of less than 10% if game fishes are scarce or absent (Eschmeyer 1937; Chadwick 1976). Low PSD of perch populations may be caused by too few game fish preying on young perch or too many large predators feeding on adult perch. In Corrine and George Lakes, Wisconsin, yellow perch stocks had poor structure (Gammon and Hasler 1965); large young-of-the-year muskellunge were stocked in 1956 at densities of 23 and 27 per hectare. The PSD's of yellow perch changed from 7 to 12% prior to stocking to zero afterward (Table 5). The low PSD was evident even 8 years after the introduction (Schmitz and Hetfield 1965). The muskellunge also had a drastic effect on survival of young smallmouth and largemouth bass. The result was poor recruitment of bass to stocks, low bass density, and PSD values higher than those for favorable structure.

Clear Lake, Sawyer County, Wisconsin, was dominated by stunted bluegills (Snow 1968). The lake was stocked with walleyes (30 per hectare) in 1959 and with muskellunge (about 10 per hectare, 20-30 cm) in 1960 and 1961. A total of 5,188 bluegills were sampled by electrofishing in the fall from 1960 to 1967; PSD was always less than 1%. Yellow perch were second in abundance during the 8-year period; average PSD based on all the perch collected (222) was 7%. The PSD of largemouth bass was within the range for a balanced population, 53%. The absolute density, however, must have been low as only 53 bass of stock size were collected in 8 years. Although the relative density of bass of stock and quality size was favorable, the absolute density was obviously not. The rates of growth and mortality of bass were satisfactory; however, the rate of reproduction was much too low. Stocking a high density of walleyes and muskellunge did not improve the balance of fish populations in Clear Lake, Wisconsin.

Data provided us on the length frequency of yellow perch in Oneida Lake, New York in the years 1970-1975 indicate an unstable population (Forney, personal communication). The successive PSD values of 90, 25, 38, 95, 27, and 77% were above the model PSD range of 30-50% in 3 of the 6 years. We hesitate to speculate on factors related to this instability but suspect that it is related to unfavorable structure and density of the perch and walleye populations.

The walleyes in Clear Lake, Iowa, have been studied extensively by Carlander and his students. We made estimates of PSD in the absence of length-frequency data from calculated population densities by age groups and mean lengths at annulus for year classes 1948-1972 (Carlander and Payne 1977). The PSD estimates for the years 1948-1974 ranged from 15% in 1974 to 85% in 1959. The estimated PSD is within the suggested range of 30-60% for 16 of the 27 years. Low values were evident when strong year classes of walleyes entered the stock; high values were evident after successive years of a low rate of recruitment to the stock.

Problems and Solutions

Values of PSD that are too high or too low are symptoms of problems. The problems are unsatisfactory rates of reproduction, growth, or mortality. Management should aim to adjust unsatisfactory rates to solve the problem and eliminate the symptom.

Reproductive success is obviously a relatively difficult rate to manipulate. Studies have shown the importance of density independent variables such as water temperature, water level fluctuations, and wind. Density dependent relationships, however, have also been demonstrated (Anderson 1973; Reynolds and Babb in press). The reproduction curves for bluegills and largemouth bass exhibit a pattern in which the maximum number of young are produced when adult density or biomass is relatively low. To the right of the peak there is an inverse relationship between the number of young and the density or biomass of adults.

Year class weakness or failure for largemouth bass was always associated with exceptionally low densities of quality-size bass in small impoundments with favorable habitat (Reynolds and Babb in press). More favorable rates of reproduction were observed when the density of quality-size fish was intermediate. Reproductive success may be influenced more by the density of quality-size fish which serve as predators to balance community structure rather than just contributing to fecundity and egg production. We suspect that a less than satisfactory density of quality-size adults and a resulting higher than satisfactory density of prey may adversely influence the rate of reproduction for most populations of game fish in favorable habitat.

The rate of reproduction for the largemouth bass population was a problem in Clear Lake, Wisconsin. This supports the concept that poor reproductive success is associated with a low density of quality-size fish and unfavorable fish community structure.

The rate of reproduction for the walleye population in Clear Lake, Iowa is a problem. Stocking of fry has significantly increased the number of young of the year. Average population biomass is relatively low for this productive lake (Carlander and Payne 1977). We tentatively speculate that the low rate of natural reproduction is related to a relatively low biomass of adult walleyes and less than favorable fish community structure.

Slow growth rate, characterized by the attainment of quality size at a relatively advanced age--V and older--is a problem that can lead to low PSD. Slow growth rate of stock-size game fish and panfish in favorable habitat is the result of higher than satisfactory densities. Relatively high densities are caused by either a higher than satisfactory rate of reproduction or survival of too many fish less than a quality size. The solution is to adjust the mortality rate with increased predation.

A favorable pattern of annual mortality is probably the most important of the rates determining the structure and dynamics of a population. High annual mortality rates of quality-size game fish always result in unfavorable PSD's. Low relative density of quality-size fish also leads to unfavorable reproduction and growth rates for the game fish, as well as for their prey, the panfish species and other non-sport fishes e.g. Catostomidae, Cyprinidae, or Clupeidae. The result is a fish community with unfavorable structure, and unsatisfactory yields and benefits.

Management Goals

The traditional goal of fishery management has been maximum sustained yield (MSY). A tactical approach to achieve MSY involves the concept of critical size (length). The critical size is reached when the instantaneous rate of mortality equals the instantaneous rate of growth. It can be demonstrated mathematically that MSY is achieved by high rates of exploitation of fish longer than the critical size. Critical size for populations with satisfactory growth and mortality rates is often about the same length as minimum quality size. We believe that the goal of MSY and the concept of critical size have contributed to the overharvest of quality-size game fish and poor structure of many fish populations and communities. Larkin (1977) suggested that MSY is dead--but what will take its place remains to be seen.

A new goal has been expressed as optimum sustained yield (Anderson 1974; Roedel 1975). The concept of optimality is important; however, better expression of a management goal might be satisfactory sustained benefits. For recreational fisheries, optimum or satisfactory yield and associated tangible and intangible benefits must obviously be related to the structure and dynamics of fish populations and communities and the resulting quality of fishing.

Manipulation of Population and Community Structure

If management is faced with the goal of satisfactory sustained benefits, the objectives must be satisfactory habitat, and balanced fish populations and communities. The latter are difficult objectives when anglers are increasing in number and knowledge, and are using more efficient and effective equipment. On the basis of evidence available, stocking of coolwater game fish as a general practice is often an ineffective tactic for improving the structure of stocks of stunted panfish. Guidelines or options have yet to be developed to determine what species, what number, what size, where, and when in order to most effectively use this hatchery product to improve the quality of fishing.

Minimum length limits on game fish have been struck from the code books for many species in many states. The results of studies that have evaluated this move is that the absence of length limits does not lead to extinction of species and loss of fishing opportunities. However, no study has demonstrated a positive effect on sustained harvest, population and community structure, or the quality of fishing after the size limits are removed.

Length limits have often been judged unfavorably, when evaluated. Snow and Beard (1972) concluded that a 46-cm minimum size limit for northern pike in Bucks Lake, Wisconsin, was not an effective management technique. Preliminary surveys before the initiation of the length limit revealed the presence of sparse and fluctuating populations of fast-growing panfish. Northern pike, the only predators present, were abundant and growing slowly. The results of the study demonstrate that it is illogical to expect to improve the rate of growth and structure of a population of slow-growing northern pike by protecting most of the fish in the population.

Based on the concept of critical size and equilibrium yield calculations, a size limit of 56 cm on northern pike was projected to achieve MSY in Escanaba Lake, Wisconsin (Kempinger and Carline 1977). However, the assumptions of no change in growth or mortality rates after the initiation of the minimum length limit proved invalid. This regulation resulted in a 73% reduction of harvest, a decline in growth rate by 40%, an increase in natural mortality from 14 to 76%, and a doubling of recruitment rates. After the length limit was established there was a collapse in the harvest of yellow perch, pumpkinseeds (Lepomis gibbosus), rock bass (Ambloplites rupestris), and black crappies (Pomoxis nigromaculatus)--all of the panfish species. Fishing effort also decreased substantially. The application of the concept of critical size was unsuccessful.

Latta (1972) rejected the calculated critical size as a basis for establishing a length limit on northern pike in Michigan. On the basis of typical growth and mortality rates, critical size was 41 cm. Such a size limit was projected to have an adverse effect on the biomass of spawners. A 51-cm minimum size limit was recommended instead.

Results of the studies in Wisconsin lead us to believe that a minimum length limit of 51 cm may have an adverse effect on northern pike populations and fish community structures in lakes where: (1) pike are the dominant predator; (2) the rate of northern pike reproduction is moderate or higher; (3) there is a higher than optimal density of stock-size fish; (4) growth is slower than satisfactory; and (5) natural mortality of stock-size northern pike is high. A new approach to regulating harvest may be needed for northern pike populations with these characteristics.

The symptoms of unfavorable population and community structure, and fair to poor fishing quality, caused by the problems of high mortality rates and overharvest of quality-size fish are common in warmwater and coolwater populations alike. One step in solving the problem is defining the concept of overharvest. We define overharvest as the removal of more than the surplus of stock- or quality-size fish. The surplus of game fish or panfish should be related to the existing stock density and biomass, population and community structure, and management objectives. For example, if the PSD of game fish in a lake is less than the objective range set by management, there is no surplus of quality-size fish. When the PSD of panfish populations is less than the objective range set by management, it is likely that annual length increment of stock-size fish is less than satisfactory and the annual rate of natural mortality of quality-size fish is too high. If the habitat is favorable, these problems are usually associated with a low stock density of game fish. In such circumstances there is no surplus of game fish.

Responses of northern pike to length limits near minimum quality size appear to be similar to those of largemouth bass to length limits of 30 cm. With warmwater communities in small impoundments, better community and panfish structure results than when no regulation is applied, but the resulting structure of the bass stock is less than optimal (Funk 1974). We conclude that minimum length limits set at or near the minimum quality size will not improve the balance of game fish stocks unless stock density is low, rate of growth is average or better, and the rate of natural mortality is low.

The symptom of low PSD for stocks of muskellunge may be relatively infrequent. Muskellunge are less vulnerable to angling than northern pike (Weithman and Anderson in press) and probably less vulnerable than smallmouth bass and walleyes. Growth and mortality rates of natural populations are usually satisfactory. Success of reproduction is usually low. The length limit of 76 or 81 cm is the only commonly applied state-wide length limit for a game fish that is longer than minimum quality size (66 cm). This tactic and the practice of catch and release of quality-size fish is apparently effective for a species with these dynamics.

Strategies and Tactics to Achieve Balance

Favorable balance or structure and dynamics of a fish population can be evaluated for management purposes by analysis of PSD and YAR. Balance in fish communities can be evaluated by plotting the PSD of panfishes or prey as a function of PSD of the predators or game fish. By defining the favorable ranges of PSD for panfishes and game fishes a tic-tac-toe graph results (Fig. 3). The central window represents a balanced fish community. In communities with a diversity of panfishes or game fishes, the overall balance of each component could be determined by appropriate weighting factors according to the relative abundance (biomass) of each species in the community or the relative importance to the fishery.

If the PSD of yellow perch or other panfish is consistently less than 20%, analysis of scale samples may reveal the problems of slow growth and high mortality. In such circumstances the PSD of game fish may range from 0 to 100%. Whatever the value, it may be inferred that there is no surplus of game fish. The first phase of management could be a minimum length limit above the minimum quality size. Stocking of large fingerling or subadult walleye, smallmouth bass, or largemouth bass may facilitate rebuilding the stocks if the PSD is in the balanced or high range and rate of reproduction is a problem. Stocking an esocid as well may be appropriate if large, non-sport fishes make up a significant proportion of the fish community. After the stocks of game fish have recovered to a favorable density, biomass, and structure, a second phase of regulating harvest that protects some portion of quality-size fish may be appropriate.

When stock density of game fish is relatively high and PSD is low, analysis of scale samples may reveal the same problems as observed in panfish--slow growth and high mortality. If the PSD of panfish is high or variable over time, it may be inferred that there is a surplus density of game fish of stock size but not quality size. In this circumstance also, a regulation to protect quality-size game fish may be appropriate.

Largemouth bass harvest in Philips Lake, Missouri, was regulated with a 30-cm minimum length limit from 1967-1973 and a protected size range or slot length limit of 30 to 38 cm from 1974 to 1977 (Johnson and Anderson 1974; Anderson 1976). The protected size range has produced more favorable results than the minimum length limit (Fig. 3). The strategy is to: (1) protect quality-size bass for about 25% of their expected life span at a time when they exhibit a high absolute annual weight gain; (2) allow a harvest of a surplus less than quality-size bass in the stocks; and (3) reduce the probability of excessive predation on young bluegills.

The initial results were also encouraging at Watkins Mill Lake, a state park lake in Missouri. In the fall of 1977, after the first fishing season a slot length limit of 30 to 38 cm, was in effect, largemouth bass PSD increased from 1 to 25% (S. Eder, personal communication). In Missouri this approach appears promising because for most bass anglers, size is more important than numbers caught; catch and release contributes to fishing quality and personal satisfaction (Weithman and Anderson in preparation).

The same regulation is now being evaluated for several state fishing lakes in Kansas (D. Gabelhouse, personal communication) and two lakes in Illinois (T. Miller, personal communication); the Central States Pond Management Work Group is evaluating the regulation for several small impoundments in the Midwest (G. Novinger, personal communication). It is important to evaluate not only the biological responses and the resulting structure of the populations and the fish community but also the response of anglers to a regulation that calls for the catch and release of quality-size fish. We expect that this approach to regulating harvest will suceed if anglers are interested, and are willing to support an effort to improve the state of balance of fish communities, the size of fish caught, and the quality of fishing. Many anglers are developing this interest and ethic. We believe this approach to regulating harvest of game fish holds great promise in the future of recreational fishery management for sustaining the balance of fish populations and communities, maintaining fishing quality, and approaching optimum yield.

Footnotes

1. Contribution from the Missouri Cooperative Fishery Research Unit, a cooperative program of the U. S. Fish and Wildlife Service, the University of Missouri, and the Missouri Department of Conservation.

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Table 1. Proposed minimum stock and quality total lengths for selected coolwater fishes and the percentages of the record length.

Species	Record length (cm)	Stock length		Quality length	
		cm	Percent of record length	cm	Percent of record length
Yellow perch	53.3	13	24	20	38
Walleye	104.1	25	24	38	37
Smallmouth bass	68.6	18	26	28	41
Northern pike	133.4	35	26	53	40
Muskellunge	163.8	43	26	66	40

Table 2. Growth data used to develop models of PSD for selected coolwater fishes.

Species and growth rate	Total length at age (mm)									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Yellow perch										
Fast	94	170	216	241	264	279				
Moderate	53	127	183	216	244	264				
Slow	117	155	178	203	229	251	272			
Walleye										
Fast	124	231	323	401	485	549	615	676		
Moderate	178	287	373	434	480	526	559	605		
Slow	142	211	267	310	345	376	396	419	442	
Smallmouth bass										
Fast	118	258	358	411	445	457	473			
Moderate	94	173	249	309	346	373	393	410	421	433
Slow	64	142	201	234	269	325	348	376	389	399
Northern pike										
Fast	152	330	483	635	762	864	965	1041	1092	
Moderate	287	417	508	577	635	686	754	833	876	
Slow	208	328	391	439	483	526	559	683	752	
Muskellunge										
Fast	198	437	622	754	861	958	1036	1105	1133	1163
Moderate	267	432	569	671	770	848	922	991	1041	1087
Slow	175	318	434	546	655	737	848	993	1062	1105

Table 3. Proportional stock densities (%) of model populations of selected coolwater fishes. A concave mortality pattern represents high mortality of young fish and moderate mortality of adults; a convex mortality pattern represents low mortality of young fish and high mortality of adults.

Species and mortality pattern	Growth rate		
	Fast	Moderate	Slow
Yellow perch			
Constant, 50%/yr	46	31	15
Concave	42	28	10
Convex	37	10	8
Walleye			
Constant, 40%/yr	53	44	18
Concave	55	40	19
Convex	34	35	3
Smallmouth bass			
Constant, 43%/yr	64	42	22
Constant, 65%/yr	48	20	4
Northern pike			
Constant, 50%/yr	41	32	5
Concave	50	40	12
Convex	16	19	<1
Muskellunge			
Constant, 30%/yr	62	49	47
Convex	54	35	23

Table 4. Ratios of young to adults (YAR) for model populations of selected coolwater fishes as related to Proportional Stock Densities (PSD).

Species	PSD > 25%		PSD < 25%	
	Mean	Range	Mean	Range
Yellow perch	3.6	2.2-5.5	9.0	7.0-13.3
Walleye	2.4	1.6-3.2	20.0	7.1-41.7
Smallmouth bass	3.0	2.3-3.7	23.8	14.0-33.6
Northern pike	3.0	2.3-3.8	16.0[a]	6.7-31.2
Muskellunge	1.1	0.8-1.6	3.1	-

[a] Model population with PSD < 1% not included

Table 5. Proportional Stock Densities (%) of yellow perch and bass before and after stocking muskellunge.

Lakes and Species	Year									
	53	54	55	56[a]	57	58	59	60	63	64
Corrine										
Yellow perch	-	7	-	6	9	9	24	0	0	2
Largemouth bass	-	20	-	16	22	43	56	100	-	-
George										
Yellow perch	12	10	3	2	28	0	0	0	-	-
Smallmouth bass	79	13	30	17	17	52	63	97	-	-
Largemouth bass	35	9	16	10	22	47	75	65	-	-

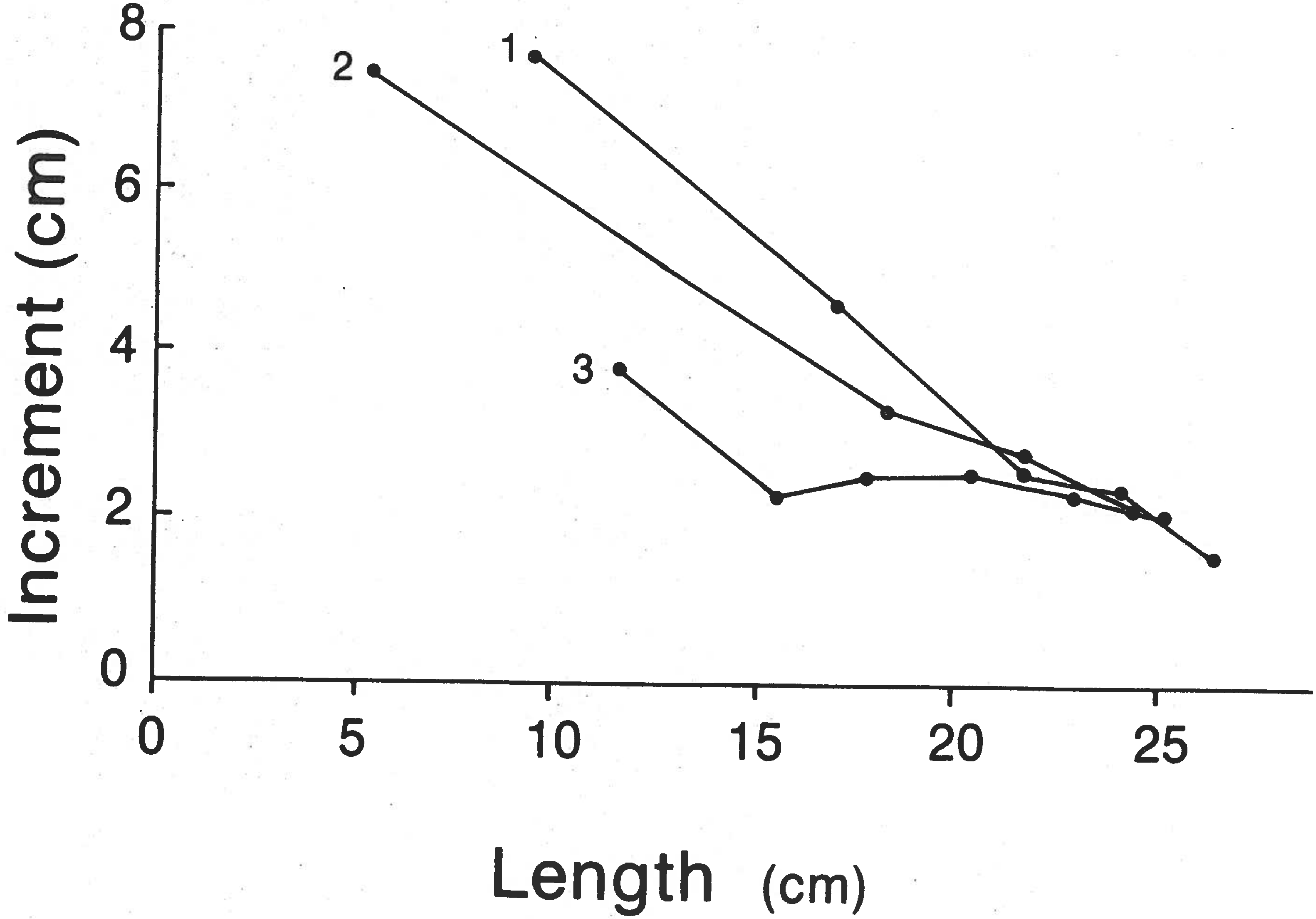
[a]/Year muskellunge stocked

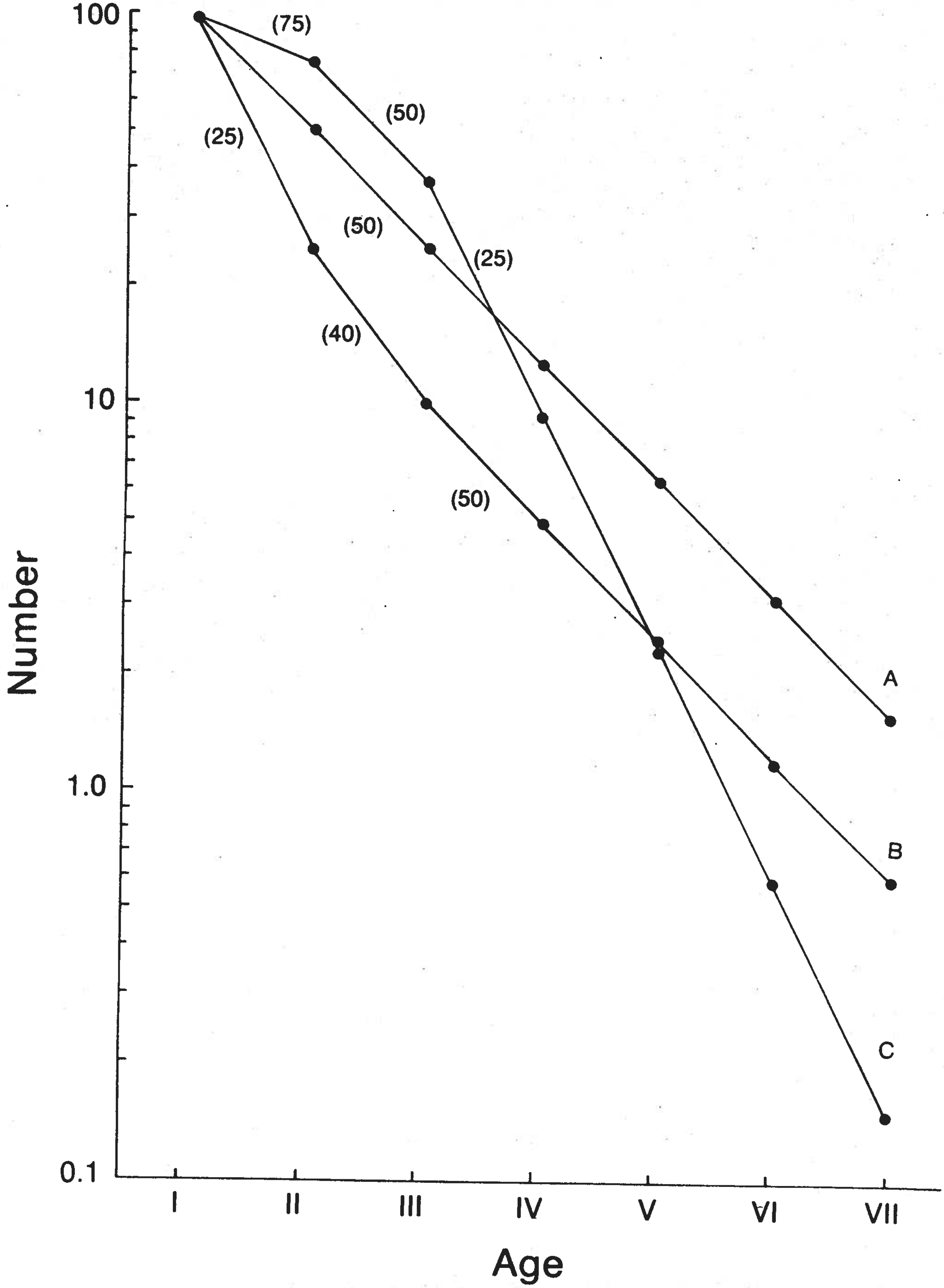
Figure Legends

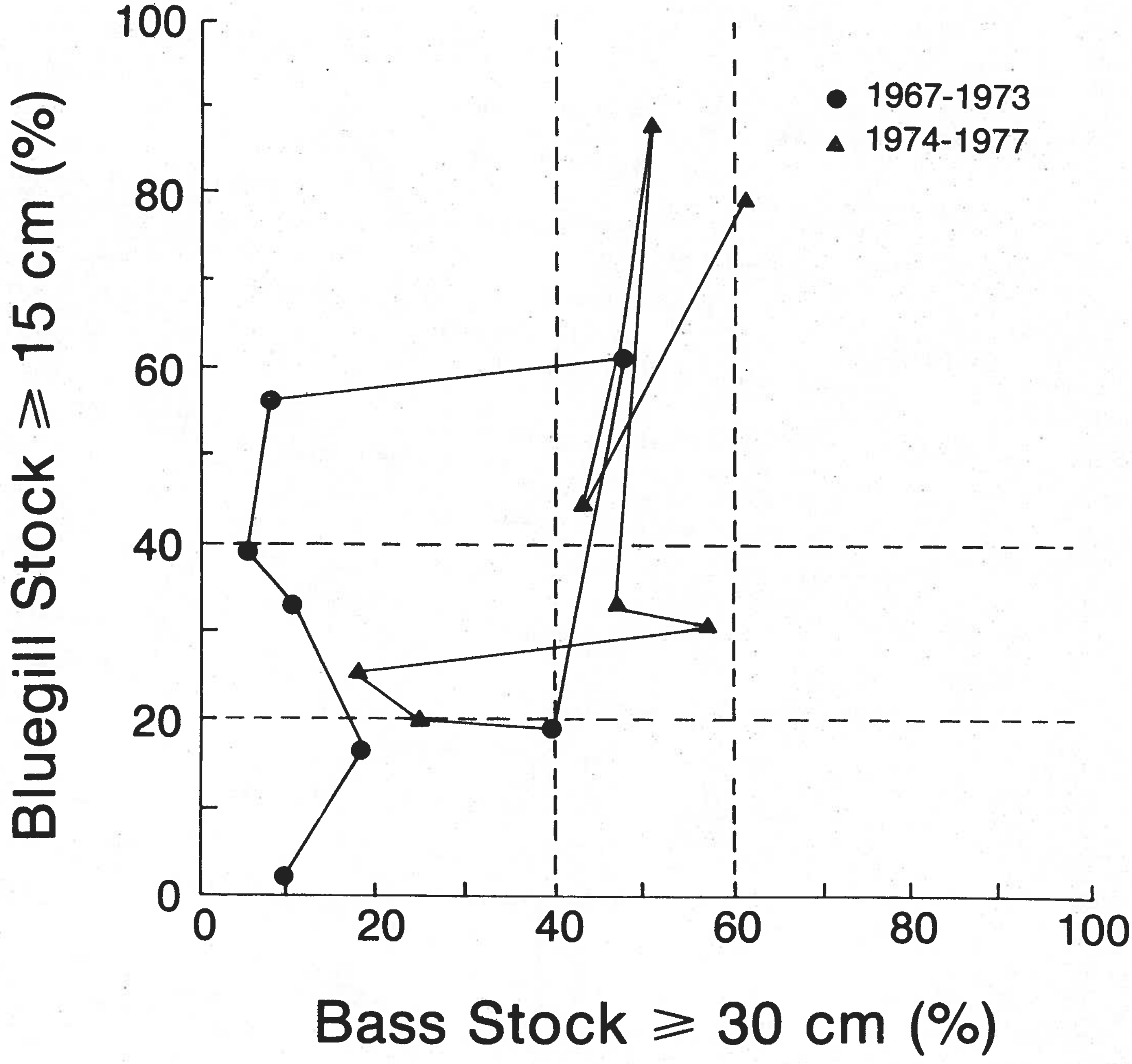
Figure 1. Annual length increment as a function of total length at annulus for selected yellow perch populations. Lines 1, 2, and 3 represent fast, moderate, and slow growth, respectively.

Figure 2. Survivorship curves for model populations of yellow perch; numbers in parentheses are annual survival rates in percent. Lines A, B, and C represent constant, concave, and convex mortality patterns, respectively.

Figure 3. Proportional stock densities of largemouth bass and bluegills in Philips Lake, Missouri. The sequence of points reflect samples collected in (month and year): 3/67, 4/68, 3/69, 5/70, 5/71, 5/72, 6/73, 5/74, 6/75, 10/75, 5/76, 11/76, 5/77, and 10/77.


Increment (cm)
8
6
4
2
0
0
5
10
15
20
25
1
2
3
Length (cm)


100
10
1.0
0.1
Number
I
II
III
IV
V
VI
VII
Age
(75)
(50)
(25)
(25)
(50)
(40)
(50)
A
B
C



Bluegill Stock ≥ 15 cm (%)
Bass Stock ≥ 30 cm (%)
1967-1973
1974-1977
0
20
40
60
80
100