BARKLEY LAKE SYMPOSIUM
PREY-PREDATOR RELATIONS IN CROOKED CREEK BAY, BARKLEY LAKE, KENTUCKY

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Abstract: Available prey-predator ratios (AP/P) in Crooked Creek Bay indicated a deficiency of prey for predators (largemouth bass equivalents) 200 mm long (total length) or less. Analysis of samples collected after the application of rotenone to small coves led to overestimates of available prey. Application of adjustment factors to account for differences in fish distribution in coves and in open water improved AP/P estimates based on small-cove samples. After reviewing previous food studies, we redefined crappies longer than 210 mm and catfishes longer than 390 mm as predators. Revised AP/P calculations then indicated no shortage of prey in the Bay. Comparison of these data with those from a 1965 study in Douglas Lake, Tennessee, showed that predators in Douglas Lake were more efficient in cropping available prey. This higher efficiency might have been due to greater water clarity, lack of threadfin shad, or inefficient recovery of small clupeids in the deep, open waters of Douglas Lake.

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A quantitative measure of predator-prey relations of reservoir fishes is essential to the development of effective reservoir management strategies. Swingle (1950) developed a series of ratios to quantify balanced and unbalanced bass-bluegill populations in ponds, and the utility of these simple 2-species population ratios in small impoundments is well known. Predator-prey relationships in large reservoirs are much less fully understood.

Jenkins and Morais (1977) developed a graphical method for displaying predator-prey relations in reservoirs, based on the ratios of the biomass of available prey to the biomass of predators of various sizes in samples collected from small coves after the application of rotenone. The method was originally developed from data on 23 reservoirs included in a 2-year cooperative predator-stocking evaluation (PSE). However, only data from a 1965 study in Douglas Lake, Tennessee (Hayne et al. 1968), were available to indicate whether these relationships are representative of those in large embayments or in the reservoir as a whole. Since the Douglas Lake results showed differences in numbers and sizes between fish in coves and those in open water areas of a 46.5 ha bay, there were also differences in the predator-prey relations.

The present study was undertaken to describe comparable differences in cove and open water habitats for a large, relatively shallow, mainstream hydropower reservoir (Summers and Axon 1979). It provided a unique opportunity to learn more about the similarities and differences in predator-prey relations among coves of various sizes. Comparisons between small coves and the 85-ha embayment of which they were a part should lead to a better understanding of the relationship between the fish populations in a small cove and those in the reservoir as a whole.

METHODS AND MATERIALS

Barkley Lake is a 23,440 ha mainstream reservoir (storage ratio = 0.04) formed by a dam 50 km above the mouth of the Cumberland River. The backwater stretches upstream 190 km, and has a shoreline length of 1,615 km. Average depth is 4.3 m and normal annual water level fluctuation is about 1.5 m. Water levels usually remain at normal full pool elevation from 15 May until 15 June and gradually decline to minimun pool level by 1 December.

The study area consisted of 85 ha in Crooked Creek bay, which was subdivided into 3 large, open water areas. Coves were further subdivided within the Bay into 0.4 ha, 1.4 ha, and larger segments. Four 0.4 ha enclosures in open water areas were used to measure the effectiveness of brush and tire fish attractors in concentrating fish (Pierce and Hooper 1979).

Rotenone was applied simultaneously to all areas on the morning of 26 September 1978, and fish were picked up in all areas 26, 27 and 28 September. All fish were identified to species and sorted into 1-inch groups, and fish of each 1-inch group were weighed in aggregate. Sub-sampling was used to determine the number of shad and freshwater drum less than 200 mm long because of the large number of individuals present. Standing crops were calculated for each discrete area and for the total arm.

Estimates of available prey-predator relations in various areas were based on fish recovered during the 3 days. A correction was made to account for incomplete recovery of fishes by applying recovery rates of dart-tagged fishes to estimate biomass not recovered (Axon et al. 1979). The biomass estimates thus treated are hereinafter referred to as standing crop. Adjustment factors used to compensate for different distributions of major species and length groups between coves and open water areas were developed by Aggus et al. (1979).

As in the PSE analysis (Jenkins and Morais 1977), fish considered as predators included all gars, pickerels, bowfin, white, yellow, and striped bass, black basses, crappies, and sauger; and skipjack herring and flathead, white, blue, and channel catfish more than 265 mm long.

Fishes defined as prey were clupeids, cyprinids, catfishes, catostomids, and freshwater drum less than 265 mm long; white and striped bass, black basses, and crappies less than 165 mm long; and all sunfishes, darters, silversides, and yellow perch.

We derived estimates of the sizes of various prey species that predators could swallow on the basis of measurements of body depth of prey and predator pharyngeal diameter determined with plastic gauges inserted into the throat under gentle pressure. The relation between mouth sizes of all predator species were then estimated in relation to those of largemouth bass of equal length to yield largemouth bass equivalents (LBE), as described by Jenkins and Morais (1977). Formulas were derived to express curvilinear prey-size to predator-size regressions for the major taxa. The basic predator length-group classification was then set equal to the largemouth bass-prey relation for calculation.

Regressions expressing biomass of prey taxa available to predators in 25.4-mm length groups were derived and a computer program was written for the calculation of Lake Barkley AP/P ratios. Logarithmic plots of the ratios were drawn to portray the adequacy of the prey crop to sustain the predator crop through the rest of the growing season. Copies of the Lake Barkley AP/P computer programs may be obtained from the National Reservoir Research Program in WATFIV language for the IBM 370 computer, or in BASIC for the HP-9830A calculator.

We established a minimum desirable AP/P ratio of 0.5:1 on September 26, on the basis of the following assumptions:

1) Ecological growth efficiency was 0.20; i.e., 5 kilograms of prey were required to produce 1 kilogram of predator.

2) Inasmuch as 15% of the growing season remained, 15% of the annual food requirement was needed to maintain desirable predator growth to the end of the growing season.

3) About 5% of the prey required is produced after September 26.

4) The other 10% of prey required is represented by an AP/P ratio of 0.5:1 (5 x 0.10 = 0.5).

AP/P RATIO ANALYSIS

The adjusted standing crops of Barkley Lake prey fishes indicated that the total available prey consisted of 50% gizzard shad, 27% freshwater drum, 14% threadfin shad, 5% sunfishes, and 4% other species. Shad made up 97% of the prey available to 254 mm predators (LBE) and 80% of the prey available to 380 mm predators, and composed nearly two-thirds of the total available prey. The overriding importance of clupeids as potential prey in Barkley Lake is self-evident.

The total predator crop of 121 kg/ha was composed of 40% white crappie, 39% channel catfish, 7% white bass, 6% largemouth bass, 5% blue catfish, and 3% other species. White crappies and channel catfish dominated the predator population, collectively composing 90% of the 254-mm predators (LBE) and 87% of the 380-mm predators.

A plot of AP/P values for Crooked Creek Bay (Fig. 1) indicated a severe deficiency in available prey for predators (LBE) 200 mm long or less. These included largemouth bass ⩽ 200 mm, white crappies ⩽ 280 mm, and channel catfish ⩽ 330 mm. The maximum deficiency in prey (horizontal distance between the 0.5:1 AP/P line and the Crooked Creek AP/P plot) was at the 200-mm predator length group, and equaled 41 kg/ha. This deficiency suggested that about 60% of the predators ⩽200 mm long would be subject to starvation during the coming winter.

Cove-Open Water AP/P Comparisons

To describe differences in AP/P ratios derived from cove samples of various surface areas, we plotted calculated standing crops of available prey and predators (Fig. 1); these plots revealed that values based on collections from small coves overestimated the AP/P ratio derived from the collections in the Bay as a whole. The mean AP/P relation for 10, 0.4-ha cove samples indicated a superabundance of available prey (430 kg/ha) for a total predator crop of 51 kg/ha. Similarly, three 1.4 ha coves revealed an ample total available prey crop (573 kg/ha) to support 38 kg/ha of predators. However, for two larger (3.1- and 6.6 ha) coves the mean AP/P ratios indicated a deficienty of prey for predators ⩽ 150 mm long--a relation more similar to that for the total Bay. Maxim: The larger the area sampled the more likely it is to reflect the AP/P ratio in the total body of water.

Adjustment factors developed by Aggus et al. (1979) to account for differences in fish distribution in coves and open water were applied to improve the AP/P ratio estimates based on samples from coves of various sizes (Fig. 2). After these factors are further tested, they may be found applicable to mainstream reservoirs throughout the Nation.

RECONSIDERATION OF CRAPPIES AND CATFISH AS PREDATORS

Examination of length-frequency distributions of white crappies and channel catfish (Figs. 3 and 4) prompted questions concerning the size at which they become dependent on fish in the diet for survival--e.g., "Can small fish of these 2 species subsist without fish as prey?"

Swingle (1950) classified crappies heavier than 113 gm (200 mm) long as predators. Stunted, 6-year-old crappies were reported to have attained a length of only 200 mm in Oklahoma waters (Hall et al. 1954), apparently on a non-fish diet. We believe, therefore, that it is reasonable to assume that Barkley Lake crappies less than 215 mm long could survive the winter without fish as available prey.

Similarly, Conder and Hoffarth (1965) found that channel catfish in adjoining Kentucky Lake required 6 years to reach 360 mm (0.4 kg), but grew to 425 mm (0.7 kg) in the 7th year. Shortest lengths at given ages recorded in Oklahoma waters were 330 mm for 10-year-olds and 415 mm for 11-year-olds (Finnell et al. 1954). These findings suggest that

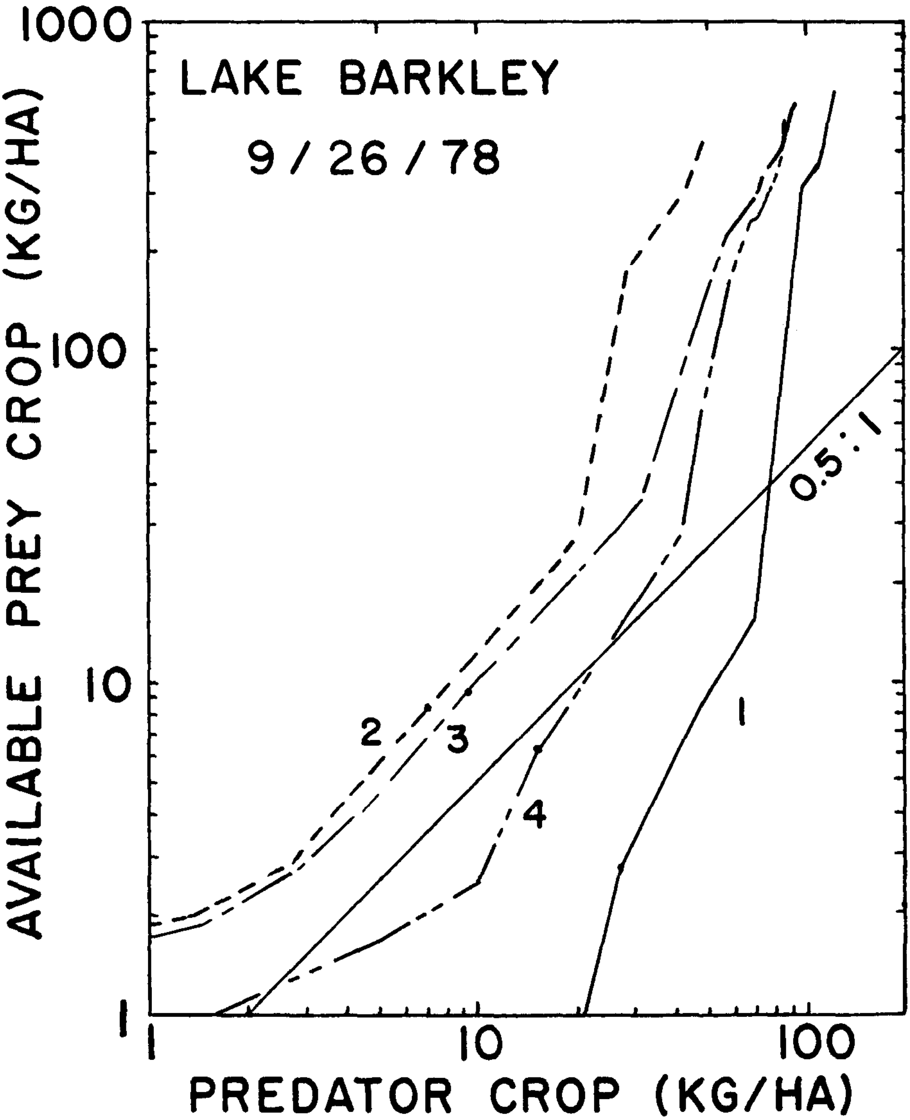

Fig. 1. Logarithmic plots, by 25.4 mm groups (50- to 735 mm predators LBE), of cumulative AP/P ratios calculated for (1) 85 ha Crooked Creek Bay, (2) 0.4 ha coves in the Bay, (3) 1.4 ha coves, and (4) larger coves (mean area, 4.9 ha). The 0.5:1 slope represents the minimum desirable AP/P ratio on September 26.

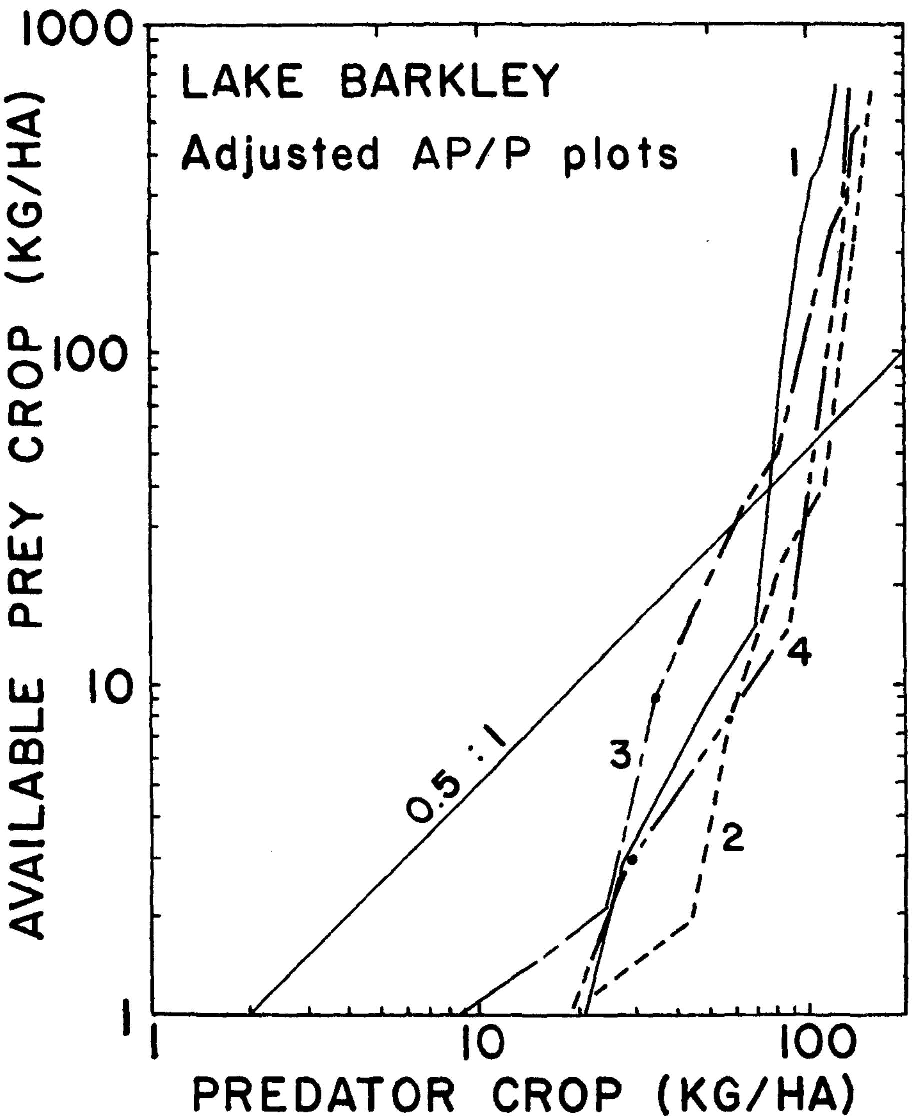

Fig. 2. Logarithmic plots, by 25.4 mm groups, of cumulative AP/P ratios, with adjustments to compensate for population differences between cove samples and the entire sample, for (1) the 85 ha bay, (2) 0.4 ha coves, (3) 1.4 ha coves, and (4) larger coves.

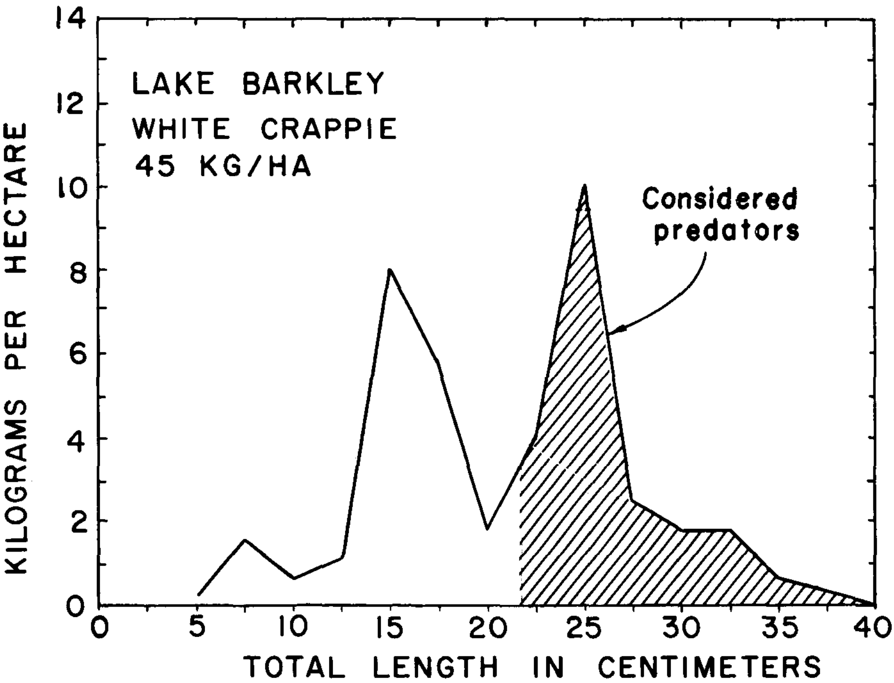

Fig. 3. Biomass-frequency distribution, by 25.4 mm length groups, of white crappies in the 85 ha sample. Only crappies longer than 215 mm were considered as predators in the revised AP/P program.

there is a critical size of about 380 mm (0.45 kg) at which predominantly omnivorous channel catfish become predominantly piscivorous. This hypothesis is consistent with findings in many food studies (e.g., Dendy 1946, Bailey and Harrison 1948, Busbee 1968).

Therefore, appropriate changes were made in the AP/P program by defining only crappies longer than 210 mm, and channel, white, and blue catfishes longer than 390 mm (rather than ⩾265 mm) as predators. The revised AP/P calculations (Fig. 5) indicated that there was essentially no shortage of available prey in the 85-ha bay, and a great abundance of prey for predators exceeding 210 mm (LBE).

The revised definitions of the lengths at which crappies and catfish become primarily piscivorous resulted in a total predator crop of 67 kg/ha and total available prey of 660 kg/ha. The revised predator crop per hectare included 26 kg of crappies, 24 of catfishes, 9 of white bass, 7 of largemouth bass, and 1 of other species. Total available prey (per hectare) included 420 kg of clupeids, 177 kg of freshwater drum, and 63/k of other species. It is apparent that additional predators (LBE) 230 mm long or longer (e.g., 280-mm striped bass, 330-mm walleyes, 405-mm flathead catfish) could be supported in Barkley Lake, but that the stocking of smaller fish in the fall would be inadvisable.

COMPARISON WITH DOUGLAS LAKE, TENNESSEE

Data from the cove sampling evaluation of Douglas Lake conducted by member agencies of the Reservoir Committee in 1965 were reexamined for comparative purposes. In the original data analysis, Hayne et al. (1968) used definitions of carnivorous and forage fishes comparable to those in the Y/C ratio described by Swingle (1950) as the total

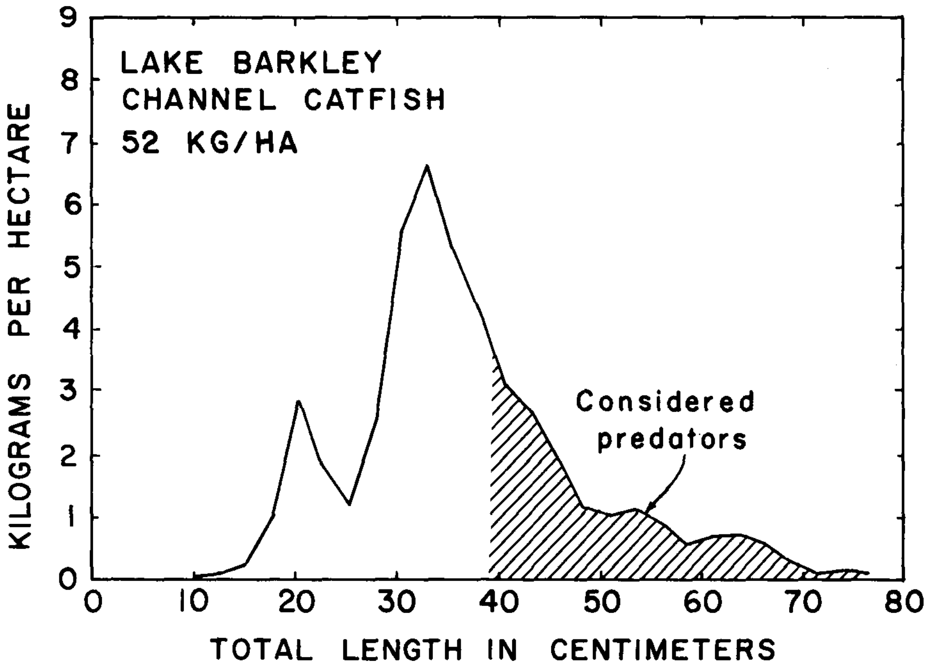

Fig. 4. Biomass-frequency distribution, by 25.4 mm length groups, of channel catfish in the 85 ha sample. Only channel catfish longer than 390 mm (shaded) were considered as predators in the revised AP/P program.

weight of forage fishes small enough to be swallowed by an averaged-sized adult carnivore, divided by the total weight of carnivores. They calculated a mean Y/C ratio of 4.0 for 2 ha coves, 1.7 for 0.4- to 1.2 ha coves, and 0.9 for the entire arm.

We reorganized the Douglas Lake data by grouping species into 25.4 mm length classes, and used the predator stocking evaluation AP/P program of Jenkins and Morais (1977) to calculate AP/P ratios, changing only the predator definitions of crappies to fish longer than 210 mm and catfishes to those longer than 390 mm. Our results indicated that there was ample prey for a predator crop of 68 kg/ha in the 46.5 ha arm of Douglas Lake (Fig. 6), including 23 kg of crappies, 24 of black bass, 17 of catfish, and 4 of saugers. There were 68 kg of available prey per hectare, including 38 kg of gizzard shad. In comparison, Barkley Lake had 67 kg of predators and 660 kg of available prey per hectare. It appears that predators cropped prey much more efficiently in Douglas Lake than in Barkley Lake. The total AP/P ratio on September 27 was 1 to 1 in Douglas Lake and 9.9 to 1 in Lake Barkley. This difference may be attributable to (1) greater water clarity, (2) lack of threadfin shad, or (3) inefficient recovery of clupeids in the deep, open waters of the Douglas Lake arm.

The 315 kg/ha of young-of-the-year (<115 mm) clupeids in Lake Barkley may not be a common occurrence. Samples from coves of 0.4 to 1.2 ha taken by the Kentucky Department of Fish and Wildlife Resources (McLemore 1975-77) and the Tennessee Valley Authority (1976) in 1974 through 1977 yielded only 7 to 57 kg of young clupeids per hectare. In 1978, 0.4 ha coves in Crooked Creek Bay averaged 138 kg of young shad per hectare, and 1.4 ha coves 186 kg.

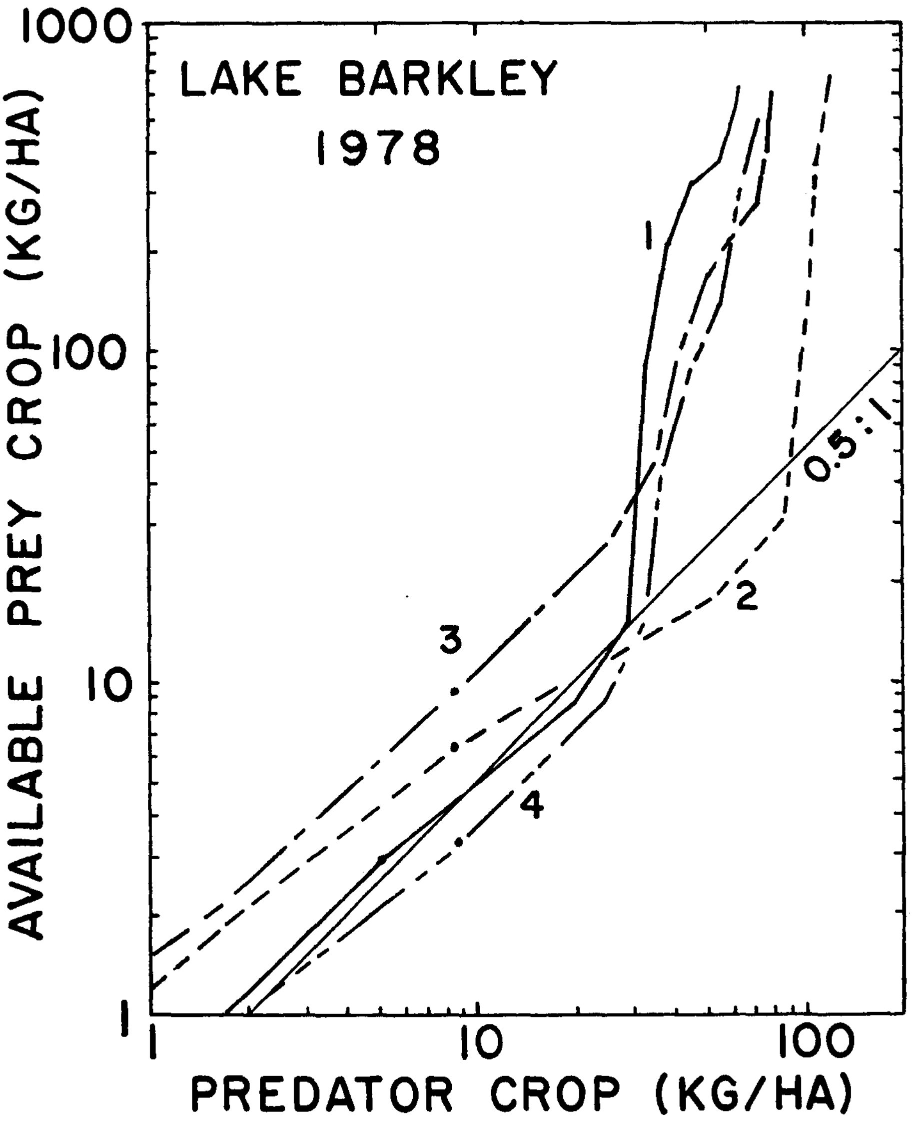

Fig. 5. Logarithmic plots of cumulative AP/P ratios revised by redefining (advancing) the lengths at which crappies and channel catfish become predominantly piscivorous by 25.4 mm groups, for (1) the 85 ha bay, (2) 0.4 ha coves, (3) 1.4 ha coves, and (4) larger coves; adjustments were made to compensate for population differences between small coves and the entire bay.

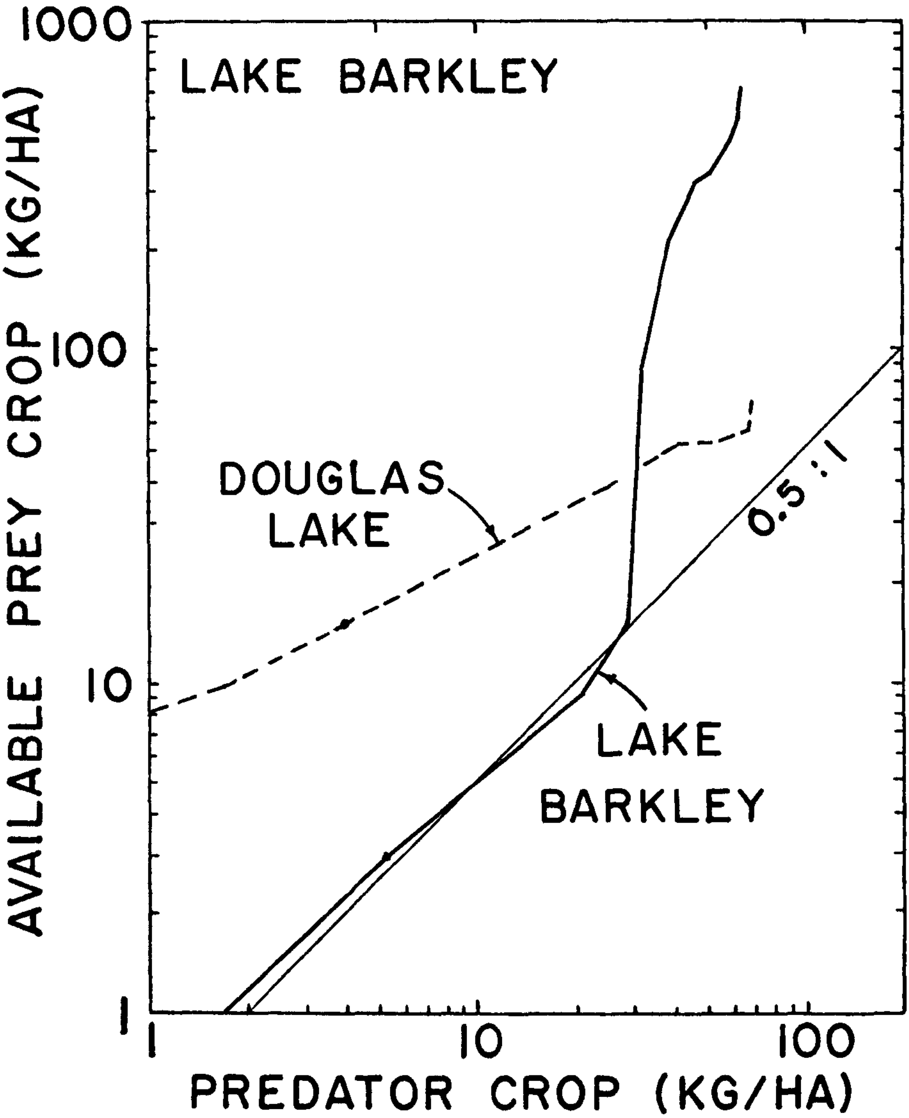

Fig. 6. Comparison of AP/P plots (revised program) for the 1965 Douglas Lake sample and the 1978 Lake Barkley sample (see text for explanation).

CONCLUSION

This analysis has demonstrated that there are striking differences in calculated AP/P ratios between samples from coves of various sizes and an 85-ha bay in a mainstream hydropower reservoir. The smaller the sample area, the greater was the overestimate of the AP/P ratio. However, the application of correction factors calculated from comparisons of species biomasses and length-frequency distributions in the coves and the bay yielded much closer approximations of the actual AP/P ratio from small samples.

Changes in the definition of predator size for crappies (> 210 mm) and catfishes (> 390 mm) to conform more closely to those advanced by Swingle (1950) were justified on the basis of previous food and growth studies. With this revision, the AP/P ratio for the entire bay depicts an adequate prey base for smaller predators, and a superabundance of prey (primarily 75- to 100 mm young-of-the-year gizzard and threadfin shad) available to 280 mm predators (equivalent to 0.45 kg white and striped bass and walleyes, 0.7 kg crappies, and 0.8 kg catfish). Hypothetically, Barkley Lake could support about 7 times the September 1978 biomass of 280 mm predators (LBE).

Data from the Predator-Stocking-Evaluation and subsequent unpublished analyses of data from these reservoirs show a general tendency for predation to be more efficient in deep, relatively clear, storage impoundments than in shallow, more turbid, mainstream reservoirs.

Essentially none of the 162 kg of buffalofishes and 153 kg of carp per hectare were available as prey to even the longest predator (735 mm, LBE), but they do represent an obvious target for commercial exploitation. Harvests of these species in adjoining Kentucky Lake have ranged from 1 to 3 kg/ha per year (Carter 1962; Renader and Carter 1967), indicating that a large, untapped resource may await development of economical methods of capture and profitable markets.

Harvests of predators by anglers in adjoining Kentucky Lake (Turner 1967-70; TVA 1975-77) averaged about 9 kg/ha per year during the period 1964-77, including about 3 kg of crappies per hectare, 2 of catfishes, and 1 each of largemouth bass, white bass, and saugers. If Barkley Lake has similar harvest rates, only about 15% of the predator crop is being taken annually.

Simulation of the AP/P relation rests on assumptions as yet incompletely defined. However, additional evaluations of cove sampling accuracy and studies of predator food will hasten the day when managers have a sound method of measuring the adequacy of the prey base to support desired predator crops.

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