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Introduction

Historically, the gizzard shad's, *Dorosoma cepedianum* (Le Seuer), role in the management of warm-water sport fisheries has evolved amid considerable controversy. Initially recognized as potential forage for piscivorous species in suitable waters (e.g. see Lagler and Applegate 1943 and Eschmeyer 1944), this species is currently maligned because of its "probable" competitive effects on desirable species (e.g. see Jenkins 1957), suggested no doubt by its great capacity for attaining and maintaining populations of mass proportions. Prevailing management practices in most areas call for its control if not its elimination (e.g. see Bowers 1955). It is interesting to note that evidence has recently been presented to the effect that under certain conditions at least, the shad's forage potential may be reflected in increased production of desirable species (Schneidermeyer and Lewis 1956).

Since fishery science has not yet perfected the tools with which to delineate effects of individual species in multiple-species populations, conclusions relevant to the effects gizzard shad may have on their contemporaries must be made with reservation. In a recent paper, the author gave evidence to support the view that direct competition for food may prevail between shad and desirable species during early life stages (Kutkuhn 1958). It was pointed out, however, that such competition may be offset by the forage that shad and their progeny provide for the initial competitors at later life stages.

The present paper represents an attempt to point out the relative importance of gizzard shad to the over-all economy of game fish populations in a shallow prairie lake, North Twin Lake, Calhoun County, Iowa. The study itself, carried out during the period 1953-55, constituted one phase of a long term program aimed at detecting and evaluating the effects of deepening such lakes by

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dredging. Information contained herein will serve as an adjunct to growth studies of the major contemporary game species, *viz.* the yellow bass, *Roccus mississippiensis* Jordan and Eigenmann, and the walleye, *Stizostedion v. vitreum* (Mitchill), currently underway by the Iowa Cooperative Fisheries Research Unit. Such studies, it is hoped, will reveal whether or not these species were materially affected by a suddenly increased food supply, the latent shad population having dramatically erupted in 1954 after a quiescent period of many years.

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Methods

Detailed descriptions of methods employed for sampling the North Twin lake fish populations and analyzing fish digestive tract contents have already been presented (Kutkuhn 1955). Very briefly, fish specimens destined for digestive tract content analysis were secured systematically with gill nets[1] and seines, both types of gear having been fished at two-hour intervals on an "around-the-clock" basis.

All specimens collected for digestive tract content analysis were dissected immediately after capture. Esophagi and stomachs were removed and their contents identified and measured volumetrically by displacement in a graduated centrifuge tube. The proportions each component contributed to the fore- and midgut contents were estimated ocularly. Volumes of individual items (or taxonomic groups) were then calculated and summed over all digestive tracts containing those items. Over-all estimates of the percentage contributions of each component were, in turn, calculated from these sums. For comparative purposes, estimates were derived for species belonging to each of two general categories arbitrarily formulated on the basis of age, viz., yearlings and adults.

The analytical method described above was found to be the most expedient for several reasons. A principal feature was that its rapidity of use, while maintaining a reasonable degree of accuracy, permitted examination of greater numbers of specimens in fresh

[1]"Experimental" nylon gill nets having equal footages of 1½, 2, 2½, 3, and 4 inch mesh (stretch measure).

condition per unit time than could have been examined using another method. Other features were its adaptiveness to the conditions under which the study was conducted and its requirement of a minimum amount of laboratory equipment.

The Degree of Shad Utilization by Predators

During the summer months (June to October) of 1953, 1954, and 1955, 3,045 yearling, sub-adult, and adult game and pan fishes were taken from North Twin Lake for food habit analyses (Table 1). Although the 1953 and 1954 data have already been summarized (Kutkuhn 1955), they are included herein in modified form together with the 1955 data to maintain continuity.

It is quite apparent (Table 1) that in 1954 and 1955 gizzard shad played a significant role in the economy of adult North Twin Lake game fish populations. Prior to 1954 this species occurred very infrequently in game and pan fish digestive tracts. The principal forage during 1953 was young-of-the-year yellow bass, this species having experienced a relatively good reproduction in the spring of that year (Kutkuhn 1955). However, small yellow bass in 1953 did not seem to attain quite as high a degree of over-all importance as a game fish food as did shad in 1954 and 1955 when high densities of this species prevailed. Diets of 1953 adult game fishes were substantially supplemented with significant amounts of other foods, primarily insects. For instance, adult yellow bass fed upon goodly quantities of immature *Chaoborus punctipennis* (Say) and various Chironomidae (Diptera), and *Oecetis inconspicua* (Walker) (Trichoptera). Walleyes frequently consumed measurable amounts of *Hexagenia limbata* (Serville) (Ephemeroptera) nymphs and subimagoes.

Although yellow bass reproduction during 1954 and 1955 did not compare with that of 1953, systematic shore zone seining nevertheless indicated that sizeable populations of yellow bass were available both years but were far outmassed by shad. Because of their disproportionately greater availability, young shad were consequently utilized to a greater degree than were the bass.

Although fairly good populations of other potential forage species were observed in the lake throughout the study period, they were utilized only to a very slight degree. Why the abundant northern common shiner, *Semotilis a. atromaculatus* (Mitchill); spotfin shiner, *Notropis spilopterus* (Cope); western golden shiner, *Notemigonus crysoleucas auratus* Rafinesque; fathead minnow, *Pimephales p. promelas* Rafinesque; and orange-spotted sunfish, *Lepomis humilis* (Girard), were rarely, if ever, encountered in game fish stomachs remains a mystery. Disproportionately high young yellow bass

Table 1

Percentage Frequency of Occurrence and Percentage of Total Volume of Gizzard Shad and Other Organisms in Digestive Tracts of Six Game Fish Species Taken from North Twin Lake, Iowa

Predator species	Age class	Year	Number of specimens	Number empty		Food Item: Gizzard shad	Other fishes[1]	Insects	Miscellaneous
Yellow bass	Y & s.-A	1953	17	3	Occurrence	0	71	79	14
					Volume	0	80.0	19.5	0.5
		1954	225	43	Occurrence	11	2	100	18
					Volume	48.0	2.0	48.3	1.7
		1955	211	54	Occurrence	19	4	90	28
					Volume	58.8	6.4	26.5	8.3
Yellow bass	A	1953	426	175	Occurrence	0	64	69	20
					Volume	0	82.0	16.7	1.3
		1954	319	158	Occurrence	80	6	39	15
					Volume	93.2	1.6	5.1	0.1
		1955	144	89	Occurrence	87	11	27	2
					Volume	96.1	2.7	0.9	0.3
Yellow perch	Y & A	1953	462	308	Occurrence	0	94	20	18
					Volume	0	98.7	1.2	0.1
		1954	172	89	Occurrence	77	1	75	50
					Volume	55.0	0.8	29.6	14.6
		1955	20	5	Occurrence	40	7	67	35
					Volume	74.1	1.8	18.6	5.5
Walleye	All	1953	82	53	Occurrence	3	91	10	3
					Volume	8.4	91.2	0.3	0.1
		1954	342	132	Occurrence	90	15	5	3
					Volume	84.3	15.2	0.5	Trace
		1955	202	94	Occurrence	80	28	0	0
					Volume	91.3	8.7	0	0

Table 1 (Continued)

Predator species	Age class	Year	Number of specimens	Number empty		Gizzard shad	Other fishes[1]	Insects	Miscellaneous
Black crappie	Y & A	1954	34	2	Occurrence	57	22	69	44
					Volume	47.4	30.2	11.3	11.1
		1955	5	2	Occurrence	100	0	67	33
					Volume	95.9	0	3.8	0.3
Largemouth bass	Y & A	1954	8	1	Occurrence	70	14	14	14
					Volume	81.5	7.5	7.0	3.0
		1955	48	17	Occurrence	35	23	55	13
					Volume	52.6	16.9	2.9	27.6
Black bullhead	Y & A	1953	231	118	Occurrence	0	24	78	33
					Volume	0	50.7	35.5	13.8
		1954	76	14	Occurrence	46	12	92	67
					Volume	28.2	4.1	33.2	34.5
		1955	17	4	Occurrence	23	8	85	75
					Volume	17.7	5.7	5.0	71.6

[1]Predominantly young-of-the-year yellow bass.
Y—Yearlings; s.-A—sub-Adults; A—Adults.

(1953) and gizzard shad (1954, 1955) densities resulted in an availability of these forms which apparently minimized predation on other potential but less abundant forage species.

Yellow bass and walleyes were the primary consumers of gizzard shad in 1954 and 1955. Very small shad were taken by yearling bass in small amounts early in both seasons but, in general, only a few yearling yellow bass ate fish of any kind. About one-third of the two-year-old yellow bass (six to seven inches total length—members of the strong and well-represented 1953 year class) examined in 1955 contained shad. Although fish comprised the bulk of their food, insects seemed to be the preferred items. From both frequency of occurrence and volumetric standpoints, gizzard shad predominated in the food of adult yellow bass during 1954 and 1955. Small yellow bass were the only other items taken in measurable amounts.

Fishes were by far the primary foods of walleyes examined in 1953 and 1954, and the exclusive component of the walleye diet in 1955. Gizzard shad were the dominant items in 1954 and 1955, occurring respectively in 90 and 80 percent of all walleyes (three to twenty-three inches total length) whose stomachs contained food and constituting 84.3 and 91.3 percent of the total food consumed (Table 1). Noteworthy is the fact that the walleye was the only species in which gizzard shad were encountered in 1953. In each of the few cases, comparatively large walleyes had ingested large shad, representatives of an apparently sparse population which was the precursor of the 1954 irruption.

Of the relatively few yellow perch, *Perca flavescens* (Mitchill), examined in 1954 and 1955, only the larger (six to nine inches total length) specimens seemingly utilized shad to any extent. In 1953 examination of 462 perch stomachs revealed no shad but mainly small yellow bass and yellow perch. A very evident but as yet unexplained decline in the North Twin Lake yellow perch population occurred during the study period. Since all gill-netted perch were retained for digestive tract content analysis and since the annual gill net effort was nearly uniform, the data in Table 1 reflect this rather dramatic decline.

Stomach content analyses of small samples of yearling and adult black crappies, *Pomoxis nigro-maculatus* (Le Sueur), suggested that this species relied on shad for practically all of its food during 1954 and 1955. Since it is known that a good population of crappies was present in the lake during this period,[1] it is likely that shad

[1]Revelation made during rough fish control operations conducted by the Iowa State Conservation Commission in September, 1955.

consumption by all crappies was of a correspondingly high magnitude.

The relatively small North Twin Lake largemouth bass, *Micropterus s. salmoides* (Lacépède), population also utilized shad to some extent. Half of the largemouth bass examined in 1955 were yearlings which constituted part of a plant made by the Iowa State Conservation Commission in the middle of that summer. It was interesting to note that small yellow bass were taken by these small bass to almost as great a degree as were small gizzard shad. This can be partly explained by the fact that, having been placed in the lake rather late in the season, they could not make adequate use of the young-of-the-year shad, most of which had already grown to a size too large for consumption. The smaller young-of-the-year yellow bass were apparently more suitable food items.

Food of other centrarchids examined did not include fish. The major portion of the digestive tract contents of yearling and adult orange-spotted sunfish; bluegills, *Lepomis m. macrochirus* Rafinesque; and green sunfish, *Lepomis cyanellus* Rafinesque, consisted of insects (Kutkuhn 1955, 1958).

No northern pike, *Esox lucius L.,* were captured for food analysis in 1955 but the stomachs of several taken in 1954 contained gizzard shad exclusively. In each instance, shad of large size (upwards of nine inches total length) constituted the stomach contents.

Even though fairly large numbers of black bullheads, *Ameiurus m. melas* (Rafinesque), were captured throughout the study, few were in a condition suitable for digestive tract content analysis. This was due to the large quantities of water consistently found in the alimentary tracts of gill-netted specimens. Bullheads have a tendency to swallow water, apparently while in the process of attempting to free themselves from the net. Analysis of stomach contents of specimens collected by seining had to suffice for purposes of obtaining a picture of bullhead feeding habits but the small numbers taken by this method attest to the seine's general inefficiency in sampling this species. In general, insects and filamentous algae comprised the major portion of material encountered in all bullhead digestive tracts. However, about one-half and one-fourth of those examined in 1954 and 1955, respectively, had consumed small gizzard shad.

Size and Age of Shad Utilized

Varied opinion currently prevails among fisheries workers as to the length of time gizzard shad remain vulnerable to predation by piscivorous species. Several studies have shown that in the midwestern United States, shad growth rates are usually of such a

magnitude that the species often passes out of the range of effective utilization by the middle of its second year of life. Lagler and Applegate (1943) have termed the length at which shad no longer serve as forage ". . . the minimum threshold length for survival." The ability to attain this length at an early age, they feel, appears to insure the future reproduction of the species and thus provide for the continued existence of forage supplies. Such an attribute is, however, considered to be detrimental in those cases where the magnitude of shad productivity far exceeds that of the collective productivity of contemporary predator species.

In their studies in Indiana, Lagler and Applegate (1943) estimated the mean standard length of age group I shad (collected in summer and fall) to be 152 millimeters. Although growth studies have not yet been made, North Twin Lake shad apparently do not attain such a length until early in their third summer. Total lengths of yearling (age group I) shad collected in October 1955 ranged from about 100 to 120 millimeters. Young-of-the-year collected at the same time fell into the 75 to 85 millimeter size range. Indications were that the yearling shad present in 1955 probably would not pass out of what might be considered the range of effective utilization until some time during their third summer of life. Hence they would be subject to "normal" predation by walleyes and yellow bass over a somewhat longer period than might generally be expected on the basis of data collected elsewhere.

To show the degree to which young-of-the-year and yearling shad were utilized in 1955, note was made of the incidence of shad of each age group in the food of those walleyes and adult yellow bass that contained shad. The ratio of young-of-the-year to yearling shad encountered in all walleye stomachs was approximately 1:2. The same ratio in adult yellow bass was about 3:1 indicating, perhaps, an inability of the bass to consistently utilize the slightly larger yearling shad. That they did utilize at least a portion of the older shad seems to be an important aspect in assessing the shad's over-all importance as a bass food.

Two-year-olds and older shad were frequent items in the food of larger walleyes, and undoubtedly, in the food of northern pike.

Summary

1. Examination of digestive tract contents of over 3,000 yearling and adult North Twin Lake game and pan fishes (comprising seven species) during 1953, 1954, and 1955 revealed forage fishes to be the predominant items.

2. Whereas young-of-the-year yellow bass were the principal forage species in 1953, gizzard shad, by virtue of a mass population

irruption, constituted the dominant forage in 1954 and 1955. Utilization of insects by the predatory fishes was less when shad were readily available, than before.

3. Large walleyes constituted the only specimens examined in 1953 that contained gizzard shad. These shad were of a large size (unavailable to smaller fish) and represented the stock which gave rise to the tremendous recruitment observed in 1954 and 1955.

4. North Twin Lake gizzard shad, because of slower growth, remain vulnerable to predation by a greater proportion of the predator populations over longer periods of time, than in some other waters.

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