STUDIES OF COMMON FISHES OF THE MISSISSIPPI RIVER AT KEOKUK[1]

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CONTENTS

INTRODUCTION

In the course of an investigation begun in 1913 relative to the fish and fisheries of the upper Mississippi River as possibly affected by the great dam for hydroelectric power built across the river between Keokuk, Iowa, and Hamilton, Ill., much information was gathered, by observation and otherwise, regarding the chief fishes of the

[1] Submitted for publication Sept. 28, 1928. Prepared at the same time and based upon observations and collections made during the same period in which this report was prepared is an accompanying paper entitled "Keokuk Dam and the fisheries of the upper Mississippi River" (Bulletin, U. S. Bureau of Fisheries, Vol. XLV, 1929, pp. 87–139), in which are presented the details of studies and experiments concerning the possible effect upon the commercial or sports fisheries of the power dam at Keokuk, Iowa. Inasmuch as the present paper necessarily includes frequent reference to such effects, the two papers should be consulted together by those interested.

region.[2] About 60 species of fish were found in the Mississippi within 10 miles below the dam, while about 10 others were collected in near-by waters. About 30 species are common enough to be of direct or indirect economic importance; the discussion that follows is restricted principally to species of which 50 or more examples were observed. Each species is considered, as far as practicable, with reference to its economic importance, its breeding habit and range, its known or supposed migrations, its seasonal occurrence, and its abundance at Keokuk and in Lake Pepin (400 miles above) both before and after the construction of the dam. We have not hesitated to cull data from all available sources regarding the natural history of the significant species, not only because such information formed the necessary background for our own study but also in order that the reader might be able to make his own inferences regarding the probabilities or possibilities of the effects upon the several species both of the dam as an obstruction and of the pool above the dam as a body of water presenting a new set of conditions for feeding, growth, and breeding.

One thing in the account that we think of value is the directing of attention to the surprising gaps in our knowledge of the most elemental facts of the life histories of common fishes. To say nothing of the paddlefish and hackleback sturgeon, who knows when, where, and under what conditions occurs the breeding of fresh-water drum, blue sucker, river herring, or Ohio shad? The last-mentioned fish, potentially an excellent food fish and fairly abundant, as our observations indicate, has not even been recorded hitherto from the Mississippi River. Who has observed the breeding (in nature) of any of the larger catfishes of the Mississippi Basin? Where is the "niggerlip" catfish during the 10 months of the year, when it is rarely taken by commercial fishermen? Who has studied the modifications of form and color corresponding to habits or ages of any of the catfishes or buffalo fishes? There are excellent opportunities for useful studies of fishes that can be readily found in various streams of the Mississippi Basin.

Paddlefish or spoonbill cat. *Polyodon spathula* (Walbaum)

The paddlefish is valued for its flesh, used both fresh and smoked, and especially for its roe, which is made into caviar. It is of peculiar general interest as a species that is almost unique, being markedly different in form and structure from any other fish now living except a single species occurring in certain rivers of China. Sharklike in form, but not in behavior or in quality of meat, it ranks as one of the most estimable aquatic resources. At times it has seemed upon the verge of extermination from overfishing or other unfavorable conditions, yet apparently it shows remarkable powers of endurance or recuperation. Since the roe of an individual fish may weigh 10 to 15 pounds and is sometimes worth more than $2 a pound, a large paddlefish may represent a very valuable catch. Until recently, at least, the flesh of the fish was not generally sold under its own name but might appear in the markets fresh or smoked under the name of "sturgeon." In Lake Pepin, in fact, a common name used by the fishermen and applied to the living fish some time ago was "shovelnose sturgeon."

The paddlefish is found only in rivers and lakes of the Mississippi Basin and in some other tributaries of the Gulf of Mexico. While it is rare in shallow tributaries

[2] As related in connection with the companion report (Coker, 1929), the studies upon which the two papers are based were made during many years. For some time Emerson Stringham, then scientific assistant in the Bureau of Fisheries, collaborated in these studies. He spent the greater part of two years at Keokuk making experiments and observations that have contributed materially to both reports. The acknowledgments made in the other report apply as well to the present paper.

FIGURE 1.—Paddlefish about 4 feet long, photographed by Dr. A. D. Howard

and has been supposed to prefer waters exceeding 10 feet in depth, yet it occurs throughout nearly the whole course of the Mississippi River and is widely distributed in the basin; thus, one of the largest specimens of record was taken in Lake Chautauqua, N. Y. The more important fisheries for paddlefish have been in lakes of Louisiana, Mississippi, and Arkansas and in the Ohio, Illinois, and Mississippi Rivers (in the latter as far north as Lake Pepin, between Minnesota and Wisconsin). Paddlefish usually are taken along with catfishes, buffalofishes, and carp in large seines, which may be hauled from barges by the use of reels or pulled ashore by the use of stationary winches. They are also taken in hoop nets and in floating trammel nets fished at night. In the Mississippi in recent years the sizes generally taken range from 4 to 12 pounds. Large examples, 25 or 35 pounds in weight, are rare, but fish of 12 or 15 pounds weight are said to be more common in the last year or two (preceding 1926) at points on Lake Keokuk.

In spite of the most careful searches by various investigators working in many localities, virtually nothing has yet been learned concerning the breeding habits of the paddlefish. It is reported to breed in Louisiana (Stockard, 1907; Alexander, 1915), and it has been found in a nearly ripe condition at Louisville, Ky. (Evermann, 1902.) There is also some testimony that it spawns in central Illinois. (Forbes & Richardson, 1908; Richardson,1913, p. 405.) Fishermen and dealers at and near Keokuk report that they frequently take examples containing eggs and that the roe is marketed for preparation as caviar. Dr. Paul Bartsch, who lived in Burlington, Iowa, from about 1885 to 1896, has stated orally that in the spring these fish entered the sloughs on the Illinois side of the river in great numbers, and that specimens examined by him contained roe in an advanced stage of development. Wagner (1908, pp. 27–31) examined about 1,500 specimens from Lake Pepin, between Minnesota and Wisconsin, from June 11 to September 1, but none were found that were nearly ripe or recently spawned. He purchased there three young paddlefish, each measuring about 25 centimeters (10 inches) over all, among the smallest specimens ever collected.

Stockard (1907), from observations made in Louisiana and Arkansas, concluded that the breeding season in that part of the country was about the middle or latter part of April. Allen (1911) obtained specimens 4 to 6 inches long on July 1 near Cairo, Ill., and larger ones of 6 to 12 inches in length late in August or early in September. He inferred that the breeding season was in March. Dr. A. D. Howard, from observations made during several seasons (1919–1921) in Louisiana and some in Arkansas, concluded that spawning occurred early in spring. The Fairport station obtained a small specimen 26.1 centimeters in total length (about 10.3 inches) taken on a trot-line fished at a depth of 25 feet in the center of the channel of the White River, Ark., on June 19,1922.

All the evidence indicates that the paddlefish breeds either in late winter or early spring, and as young specimens have been obtained at Cairo, Ill.,and Lake Pepin, Minn., and (during the course of this investigation) near Montrose, Iowa, there is at least some evidence to indicate that its breeding activities are confined neither to the northern nor to the southern extremes of its territory.

There appears to be lack of any definite record of an extended migration of paddlefish in an upstream or downstream direction. It has not been known whether the paddlefish of Louisiana and Minnesota were bred and reared in their respective localities or whether migrations occurred between the extreme limits of the range of the

species. A "spring run" of paddlefish is sometimes spoken of, but this expression is used so generally and loosely that no particular significance can be attached to it as bearing upon a migration of the character in question. Stockard (1907, p. 761) furnishes observations of a conspicuous lateral migration from rivers to lakes and from lakes to rivers. This statement may be quoted:

> During the spring, when the water of the Mississippi River rises for several feet and backs into the bayous, thus establishing connections with the large lakes, Polyodon begins immediately to come into the lakes from the river and continues to come in large numbers so long as a sufficient connection is maintained. To do this it must often make long journeys through rather shallow water, in which many obstructions, such as bushes and trees, are frequently met. Thus, it finally reaches the lakes in a rather emaciated condition and with its body scarred and scratched. * * *. It is equally true that the fish in the river-lakes (those lakes more directly connected with the river) migrate out into the river when the water begins to back in during the spring, so that fishermen often abandon their fishing in these places at such a season, since most of the desirable Polyodon have made their escape.

Wagner (1908, p. 27) says: "Seemingly the spoonbill is of a rather roving disposition, cruising up and down the lakes in large schools." He observed that it might be taken abundantly in the seine one day, while the next day there might be none. At various places along the river commercial fishermen speak of "shoals" of paddlefish, suggesting a gregarious habit.

The peculiar feeding habit of the paddlefish doubtless makes necessary a relatively active life with extensive local migrations in search of food. The paddlefish, unlike other fish of like size, does not take large animals as food but subsists upon the minute plant and animal life, which it obtains by straining enormous quantities of water. It must be in constant movement when feeding, and its daily local distribution must be affected by conditions affecting the abundance of plankton food supply.

Dr. R. A. Muttkowski determined the stomach contents of five paddlefish taken by Stringham at various dates from April to August and found the material to consist chiefly of insect larvæ (burrowing May-fly nymphs, other May-fly nymphs, caddisfly larvæ, and odonate larvæ) and insect remains, with small quantities of plant and other débris, pieces of wood, and some parasitic nematodes. The stomach contents of a paddlefish submitted to the Bureau of Fisheries from Louisiana and examined by the author contained almost exclusively the pelagic and translucent Corethra larvæ. Such observations indicate that the paddlefish may feed either at the bottom or in the water above, a matter about which there has been difference of opinion.

There is one other matter for remark in reference to the paddlefish at Keokuk. The author has not infrequently observed paddlefish taken below the dam having the snout broken squarely off, the wound being fresh. We have not been able to discover the cause of this injury. Experiments elsewhere described (Coker, 1929, p. 111) show that the fish can be passed over the spillways or down through the turbine without experiencing such injury, but unquestionably there is some condition about the dam that permits of the paddlefish incurring the loss of its snout. It is conceivable that such an accident could occur to a paddlefish attempting unwittingly to pass between the submerged piles of old cofferdams and other construction work in the exceedingly swift waters of a tailrace. This fish, as is well known, has very deficient sight (Hussakof, 1911, p. 246), and in finding its way it apparently depends chiefly upon the delicate tactile sense organs in its snout. In cases of this kind the sensory warning might well come too late to save the snout. It has been suggested

that the injuries might occur where spillways were opened and water descended with irresistible force upon fish playing in formerly quiet pools below the dam. It is interesting, in this connection, to note that Stockard observed a well-conditioned paddlefish that had lost the greater portion of its "bill" but that evidently had thrived and grown without it. (Stockard, 1907.) Whatever the cause, the condition continues to the present time, for, according to reliable local reports in 1926, injured fish were still, and not uncommonly, seen floundering ineffectually in the river for at least 20 miles below the dam.

Just after the dam was completed an unusual abundance of paddlefish and other fishes was observed by Surber (July 10 and 11, 1913) in the water just below the dam. (Coker, 1914, p. 10.) The paddlefish was apparently third in abundance among the species noted. During the present investigation examples have been taken in the vicinity of Keokuk in each month of the year except November and December. No observations have been made in December, however, and few in November, so that it is a fair inference that the fish is present at all times of the year.

On the occasion of a visit to Keokuk in August, 1914, the paddlefish was common in the swift waters eastward of the tailrace, where it could be captured in floating trammel nets employed at night. During the whole of 1915 and in 1916 until late summer it was taken only occasionally; this may have been due to high water, but seining was not practiced during these times in localities where the paddlefish were taken subsequently. From August 1, 1916, until observations were stopped a month and a half later from 100 to 600 pounds per week were taken, as learned by weekly inquiries at the market. These were found in quiet waters between wing dams.

In Keokuk Lake (above the dam), near Montrose, Iowa, small paddlefish were taken in a seine during the late summer and fall of 1916. Earl Bauter, one of the owners of this seine, reported on August 9 that they had caught 8 or 10 during two weeks or so before that date; on August 24 he said they had taken 30 or 40 young in one haul and some nearly every day; on September 15 his brother, Fred Bauter, stated that they were getting about a dozen small ones in each haul. During the same period they took adults rarely, and these they sometimes returned in the hope that they would breed. Three young collected by them in August measured 38, 39, and 40 centimeters (15–16 inches) over all (our measurements), the snout making over one-third of the total length. These were possibly hatched in the same season, and their presence gives strong indication that the species breeds in the lake or river north of the dam. Five adults taken near Keokuk in the spring of 1916 were examined, but none was in an advanced stage of sexual development. On August 23 two men who dressed about 100 during the preceding week said that none of them contained eggs; that is to say, eggs such as would be visible on casual examination.

Considering, then, the facts that the paddlefish is found at all seasons at Keokuk and that very young specimens have been taken as far north as Minnesota, as far south as Cairo and Arkansas, and in the lake just above the dam three years after the completion of the dam, we find little ground to suspect that a barrier at Keokuk will necessarily exterminate the species either above or below the dam.

It is desirable to consider the available figures as to the extent of the commercial fishery. From computations based on the report of Smith (1898) this species appears to have constituted 2.4 per cent in quantity of the whole Mississippi River fishery product in 1897 [3] and 1.4 per cent of that part taken in Iowa, it being sixth in

[3] Roe sold separately for caviar not included.

rank among fishes taken from the Mississippi in Iowa. From computations based on the report of Townsend (1902), it constituted 5.1 per cent of the fish from the Mississippi River and tributaries in 1901 and 1.5 per cent of the fish taken in the whole of Iowa, standing eighth among Iowa fishes. From computations based upon the report of the United States Bureau of the Census (1911) it constituted 2 per cent of fishes from the Mississippi River and tributaries and 0.2 per cent of fishes taken in the whole of Iowa in 1908, rating fifteenth among Iowa fishes; but this report shows that the Iowa paddlefish were all taken in the Missouri River district.

Unfortunately, statistical figures regarding the paddlefish (prior to 1914) can not be regarded as accurate or complete because of the extent to which the fish, especially from northern waters, has been marketed under a false name. Neither Minnesota nor Wisconsin, for example, are credited in the census report for 1908 with the production of paddlefish, although paddlefish undoubtedly were being marketed then from Lake Pepin under the name of "shovelnose sturgeon."

In Table 1 comparison is made between the reported catches of paddlefish in 1899 (Townsend, 1902) and 1908 (U. S. Bureau of the Census, 1911), respectively, by States, arranged in the order of the size of the catch, in pounds, in 1899, and also between the reported catches of 1908 and 1922.

TABLE 1.—*Paddlefish product in 1899, 1908, and 1922, by States*[1]

State	Catch		Increase or decrease, 1908 compared with 1899		Catch, 1922	Increase or decrease, 1922 compared with 1908	
	1899	1908	Decrease	Increase		Decrease	Increase
	Pounds	*Pounds*	*Per cent*	*Per cent*	*Pounds*	*Per cent*	*Per cent*
Mississippi	948,305	463,000	51		352,260	20	
Arkansas	551,405	71,000	87		338,612		79
Tennessee	211,185	195,000	8		54,015	77	
Illinois	195,174	402,000		[2] 106	101,700	75	
Missouri	190,931	128,000	33		36,850	70	
Kentucky	147,260	65,000	56		15,015	77	
Louisiana	132,200	132,000	0	0	422,478		69
Iowa	36,390	6,900	81		48,930		86
Indiana	34,125	0	100		1,500		([3])
Nebraska	16,375	20,000		22	10,800	45	
Kansas	7,850	1,500	81			100	
South Dakota	2,050	0	100			100	
Texas	0	32,000		100	26,310	18	
Ohio	0	1,600		100		100	
Minnesota [4]							
Oklahoma					550		([3])
Wisconsin					29,471		([3])
	2,473,250	1,518,000	39		1,438,491		

[1] Roe sold separately for caviar not included. In 1922 the amounts of caviar were: Mississippi, 1,563 pounds; Arkansas, 4,077; Tennessee, 200; Kentucky, 150; Louisiana, 5,908; Texas, 500.

[2] Great increase in all Illinois River fisheries occurred between 1899 and 1908 due to increased volume of river after construction of Chicago drainage canal.

[3] No report for 1908.

[4] The lack of report for Minnesota for all years is not understood. Possibly the paddlefish were included with other fish, such as shovelnose sturgeon or catfish. Paddlefish have been regularly taken on the Minnesota side of Lake Pepin for many years.

After all reasonable allowance for inaccuracies, the substantial decline of the paddlefish fishery throughout the region of report remains evident. The decline between 1899 and 1908 would have been even more notable but for the great increase in fish from Illinois, due in large measure to the exceptionally active and successful fisheries that were prosecuted on the Illinois River in the years immediately preceding and following 1908. Notable increases in 1922 are found only for Arkansas, Louisiana, and Iowa.

Statistical canvasses of the commercial fishery in Lake Pepin and Lake Keokuk, respectively, were made by the Bureau of Fisheries for 1914, 1917, 1922, and 1927. (Reports previously cited in Coker, 1929.) No catch of paddlefish was reported in Lake Keokuk in 1914, but 927 pounds were reported in 1917, 27,405 pounds in 1922, and 1,249 pounds in 1927. The commercial fishery for paddlefish in the lake in the earlier years was thus practically negligible, becoming of interest only in 1922. In Lake Pepin we find 8,877 pounds taken in 1914, 2,923 pounds in 1917, 15,971 pounds in 1922, and 1,191 pounds in 1927, the percentage of the weight of paddlefish to the entire catch for the lake being 1.17 in 1914, 0.24 in 1917, 0.45 in 1922, and 0.73 in 1927.

The decreased abundance of the paddlefish in Lake Pepin, evidenced by the comparative figures of 1914 and 1917, was confirmed by various observations. Wagner (1908), speaking of his observations in 1903 and 1904, said that the paddlefish was one of the most abundant fish in the lake throughout the summer. Pearse (1921) worked on the lake in 1920 and found the species "rather uncommon." When the author visited Lake Pepin in July, 1913, a catch of several hundred pounds of paddlefish in the big seine was not considered an event; while on the occasion of a visit in September, 1921, it was learned that the first paddlefish of the season, four in number, had been taken the preceding day (September 2). A catch of 20 examples on the 3d was greeted by the fisherman as a big find. While there has, no doubt, been a reduction in numbers of paddlefish throughout their range within the last 30 years, the decline of the fish in Lake Pepin seemed particularly rapid during the years immediately following the construction of the dam, although in the catch of 1922 there was a suggestion of recovery in that lake, as in Lake Keokuk. In each lake, however, an extreme slump was evidenced by the statistical canvass for 1927.

In 1926 there were no encouraging reports regarding paddlefish in the general vicinity of Lake Pepin, but the last few years have been bad for all fish. At Lynxville it was said that paddlefish were being taken abundantly in the Wisconsin River. About Fairport, Iowa, paddlefish are still taken, but not in substantial numbers; some fishermen regard the water conditions as unfavorable. Reports concerning the abundance of spoonbill below the dam (Keokuk to Canton) were not consistent. On the other hand, at all points on Lake Keokuk the fishermen were virtually unanimous in the opinion that paddlefish were becoming decidedly more numerous in the lake. It is always surprising to hear a commercial fisherman say that any desirable fish is increasing in abundance, but in this instance the reports conformed in detail. Not only were there more paddlefish, but each year the average size was greater, and several had made the usually rare observations of paddlefish 8 to 12 inches in length. These reports, taken together with the statistical data and the collection of small spoonbills at Montrose in 1916, left no doubt that paddlefish were breeding in Lake Keokuk and that the fish had received a new impetus to multiplication and growth in that part of the river. However, only a small catch was reported for 1927.

As regards the effect of the propagation of paddlefish in Lake Keokuk upon the upper portion of the river, no definite forecast can be made. The water of the river below the twin cities and as far down as Lynxville is reported to be increasingly dirty from pollution and lack of volume, and appearances give some support to the reports. In the vicinity of Fairport, below the tricities of Davenport, Rock Island, and Moline, not only was the appearance of the water bad in August, 1926, but we saw some dead fish and quantities of dead yellow sandshells, some empty and some with the meats

still in them. In such circumstances we would not venture a prediction that paddlefish, however abundant in Lake Keokuk, will regain the former status in the upper river, either by local propagation or by invasion from below.

From the figures brought together by Oscar E. Sette (1925, p. 209), it appears that the paddlefish, after a marked decline following the census year of 1899, has been holding its own as a commercial resource of the Mississippi Basin generally (not considering any particular part of the basin).

Below is shown, in pounds, the product of the paddlefish fisheries of the Mississippi River and tributaries (not including the Atchafalaya) for various years:

	Pounds
1894	1,028,445
1899	2,473,250
1903	1,421,086
1908	1,439,000
1922	1,328,991

SUMMARY

The paddlefish, though not looming relatively large in the product of the commercial fisheries of the basin, is, pound for pound, one of the most valuable fishes of the region. Formerly sold under a false name, it has now come to stand upon its own merits. Furthermore, its roe has a fancy value for the production of caviar. The breeding of paddlefish has never been observed but is presumed to occur in early spring.

Soon after the construction of the dam there was evidence of a marked decline of the fishery above the dam, with later suggestion of partial recovery. The recovery, particularly notable in Lake Keokuk, has been more marked in recent years, and there is little doubt that paddlefish are now self-propagating in the lake and are finding there favorable conditions for growth. From the time of construction of the dam up to 1926 paddlefish with broken snouts have been seen not infrequently in the river just below the dam; the precise origin of the injuries can not now be fixed. It has been shown experimentally that paddlefish can pass through the turbines or over the spillways without suffering such injury, but this does not prove that injuries may not be incurred in such passages.

THE STURGEONS (Acipenseridæ)

Among the most valuable of all fresh-water fishes are the representatives of the sturgeon family. These are esteemed for the staple food their bodies afford and for the high-priced delicacy prepared from their large eggs. The swim bladders of sturgeons are also useful for the preparation of fish isinglass. Like the paddlefish, the sturgeons are large in size but peculiarly inoffensive to other fishes. Their toothless jaws prohibit their deliberate preying upon their neighbors, and the only damage they can do is through participation in the general competition for small articles of food or the occasional sucking in of small fish and eggs along with the bottom material and organisms that seem to constitute their habitual diet. Again like the paddlefish, they have displayed wonderful abilities to survive through long ages the physical vicissitudes of the earth, while they have shown little power to resist the destructive activities of modern man in America. For we in America, it must be admitted, have been much more successful than the Russians and other Europeans in the destruction of the valuable sturgeon. Notwithstanding the long history of the sturgeon fishery

of eastern Europe, great fisheries still exist there, and consequently we import the greatest share of the caviar that we consume, although we have native sturgeon on both seacoasts, in the Great Lakes, and in our large rivers.

In America we have two general types of sturgeon, which might be distinguished roughly as conical-nosed and flat-nosed. All the sturgeons of the Atlantic and Pacific coasts (as well as those of Europe and some in Asia) belong to the first group, having a relatively short snout, rounded above, though flat underneath (something like a half cone), with spiracles on top and having a relatively stocky and rounded tail not completely surrounded by protective armor of bony plates. Of this type there are five American species—two upon each major seacoast, Atlantic and Pacific, and one that we know as the lake sturgeon in the Great Lakes and upper Mississippi Valley. The other type is without spiracles and has a shovel-shaped snout and a long, flattened,

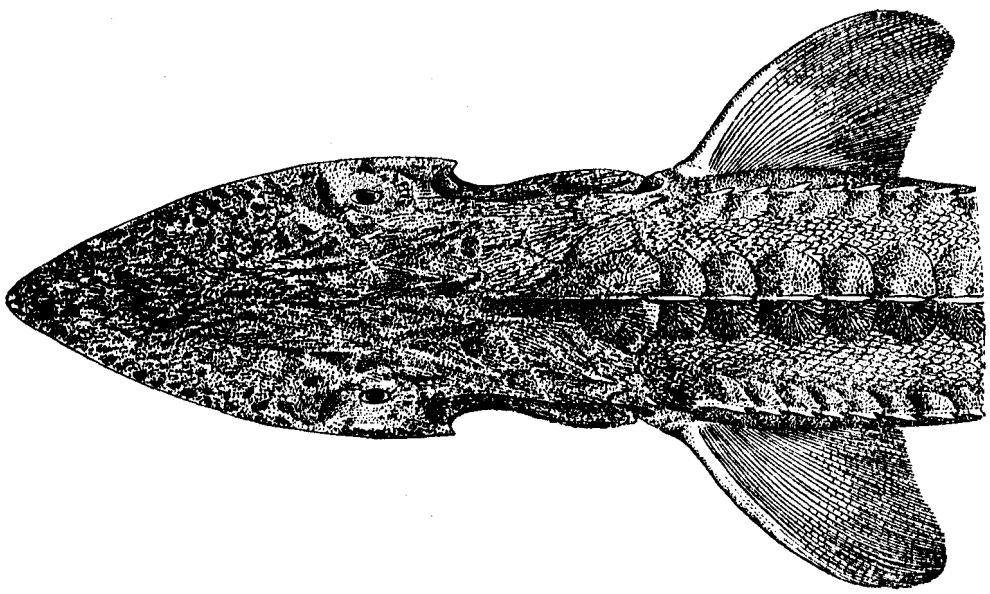

FIGURE 2.—Head of a shovelnose sturgeon, *Scaphirhynchus platorhynchus*

and completely armored caudal peduncle (the "tail," excluding the tail fin). We have seen that the paddlefish has but one near relative and that is found far away in a great river of China. So with the shovelnosed sturgeon, its only really close kin (of the same or a closely related genus), besides one rare species in the same basin, are several species found in central Asia. (Berg, 1904.)

Sturgeons are as toothless as their ancient comrade, the paddlefish, but they do not, like that fish, feed by charging through the water with widespread mouth to filter innumerable small organisms. Instead, they are said to lumber about sluggishly, thrusting out their very protrusible lips to suck in mud or small organisms that they find on or near the bottom. They are not ordinarily addicted to swift waters, and if other conditions are found favorable the impounding of river water is not in itself unfavorable to them.

Lake sturgeon. *Acipenser rubicundus* Le Sueur [4]

ROCK STURGEON; RUBBERNOSE STURGEON

The lake sturgeon, though formerly abundant in all the Great Lakes region and the Mississippi Basin, has for a long time been in process of extermination owing, in the first instance, to wasteful destruction by fishermen in past years when no use for them was known and they were regarded only as unmitigated nuisances if captured in trap nets or seines.[5]

The lake sturgeon attains a size of about 6 feet in the Great Lakes. There are reports, indeed, of 9-foot sturgeon, but the average length of mature fish is less than 5 feet. (Milner, 1873.) The food, according to many observers, consists of small shellfish, gastropods (Milner), crawfish (Smith, 1892), insect larvæ (Woolman; see Evermann and Latimer, 1910), larvæ of May flies (Wagner, 1908), and worms (Ryder, 1890). Fish eggs have been found in the stomachs, but not frequently, and the eggs observed have been mostly eggs of the sturgeon.

All observations indicate that lake sturgeon approach the shores and ascend smaller rivers at the spawning season, which in the more southern of the Great Lakes occurs in the month of June. When in the spawning migration they frequently "break" the surface and even leap entirely clear of the water. (Milner, 1873.) The

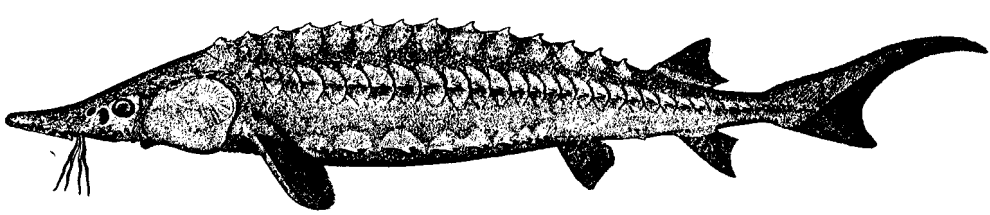

FIGURE 3.—Lake sturgeon, rock sturgeon, or rubbernose, *Acipenser rubicundus*

large eggs are strongly adhesive. Up to the present time very slight success has rewarded the many efforts that have been made to apply methods of artificial propagation, not only because the eggs are troublesome to handle but also because almost invariably great difficulty is encountered in securing ripe fish of both sexes at the same time. Barney (1924) has suggested that the lake sturgeon does not spawn yearly but has an extended reproductive cycle, since most of the adult fish caught in Lake Pokegama, Minn., during the breeding season were unripe.

As concerns the Mississippi River in the section near and above the Keokuk dam, Forbes and Richardson (1908, p. 25), writing in 1908, five years before the construction of the dam, said:

> Lake sturgeon have of late years been steadily decreasing and are now only rarely taken in the Mississippi on our own borders (those of the State of Illinois) and are seldom caught in Illinois. Fishermen at Alton now see but 5 or 6 a year that weigh over 10 pounds, whereas 15 years ago 40 or 50 large ones, weighing from 50 to 100 pounds, were taken each season.

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[4] Hubbs (1917) suggests that the name *Acipenser fulvescens* has priority over *rubicundus*. However, as Rafinesque gives no recognizable description of the species that he designates *A. fulvescens*, we think the suggestion should not be adopted. Identification of Rafinesque's species can be made only on the assumption that no other species of sturgeon could have been at the place where he collected an assumption that may be true but that clearly does not admit of scientific determination.

[5] Meek (1890) says (for Iowa): "The species is common in the Mississippi River in the spring; rather scarce at other times of the year." But, again, referring to the same observations, he says in 1892 (p. 221): "Not common; more abundant in the spring." He knew of no postive record for any other stream within the State. Woolman (1892) describes the lake sturgeon as common in the lower parts of the Cumberland and Tennessee Rivers, while Evermann (1902) says the rock sturgeon "does not appear to be common anywhere in the Ohio Basin."

We therefore have little concern with the species in this report, except in so far as a discussion of its decline in Lake Pepin is necessary to an understanding of changing conditions of the fishery and of resources generally in the upper Mississippi River.

Wagner, writing in 1908, says of the lake sturgeon or rock sturgeon in Lake Pepin (1908, p. 31):

> Pound for pound, this is the most valuable fish marketed by the seiners. Large specimens have become scarce, however, in late years, so that 12 or 15 in a season are considered a good catch. Smaller ones up to 50 centimeters (20 inches) in length are not uncommon.

H. O. Hesen, superintendent of fish culture at the Fairport station, showed me a small rubbernose sturgeon collected by Otto Stumne in Lake Pokegama, Minn., July 14, 1925. It had a total length of 19 centimeters (about 7½ inches) and is probably one of the smallest examples of record.

Pearse (1921, p. 12), writing of the same lake, says: "In 1920 the hackleback was abundant and the rock sturgeon (not seen by the writer) very rare." On September 3, 1921, the present author was informed by the operator of a large seine near Lake City, Minn., that he had taken only one rock sturgeon that year.

While a decided increase in the commercial catch was reported in 1922, it may be observed that the increase was in direct ratio to the increase in catch of all species. In 1926 all reports indicated continued scarcity of the fish in that part of the river, and none were reported in the canvass for 1927. They are known, however, to be not uncommon in Lake Pokegama on the Snake River, a tributary of the Mississippi in Minnesota, and reports are received of good catches in the Wisconsin River. The condition of the water of the Mississippi River must, therefore, be taken into account in considering the causes of scarcity in that stream.

It is of interest to note the conditions that, as early as 1871, were leading to the depletion of sturgeon resources in some of the Great Lakes. James W. Milner made an investigation of the fisheries of the Great Lakes in 1871. He relates (1873) that the sturgeon taken abundantly in the pound nets were drawn out with a gaff hook and either let go wounded or thrown on the refuse heap. The same author tells of the netting of sturgeon at Sandusky, where "the sturgeon taken by the nets were (formerly) uselessly destroyed or sold by wagon load for a trifle." A few years before his investigation a firm had established itself at Sandusky both to prepare caviar from the roe and to smoke the meat of the sturgeon. About 14,000 mature sturgeon averaging less than 5 feet in length and about 50 pounds in weight were handled by them in 1872—"out of a shameful waste of a large supply of food they have established a large and profitable industry."

But, whether wasted or utilized, the lake sturgeon, like others of the rivers and the seacoasts, has been unable to withstand the effects of our fisheries. They have other enemies, such as the fishes that may destroy their spawn and the lampreys, which attack sturgeon of all sizes, but the armor of plates and spines makes the sturgeon, even in young stages, relatively immune to attacks from other fish with which they have lived through thousands of years. It is evident, therefore, that their principal enemy and the chief cause of their decrease in numbers has been man.

On April 3, 1915, Williams Jobe, using a trammel net below the mouth of the Des Moines River, captured a lake sturgeon 57½ inches in length. It weighed about 47 pounds when caught and 22 pounds dressed. The roe weighed 11¾ pounds. The stomach was empty. Another, 39 inches long and about 14 pounds live weight, was taken by him on February 16, 1916. These were the only captures of lake stur-

geon in the vicinity of Keokuk that came authentically to our attention during the investigation.

In 1926 we were informed of occasional catches of rock sturgeon in the lake. Mr. Brusor at New Boston, said that in 1925 he had taken one weighing 109 pounds; this and two or three small examples were the only ones he had seen in several years. Somewhat similar reports were received from others. A fisherman at Canton, Mo., 22 miles below the dam, said that small rubbernose sturgeon (about 15 pounds) were not infrequently taken in the spring.

Shovelnose sturgeon. *Scaphirhynchus platorhynchus* (Rafinesque)

HACKLEBACK

The common sturgeon of the Mississippi in the region affected by the Keokuk Dam is the shovelnose sturgeon or "hackleback," *Scaphirhynchus platorhynchus* (Rafinesque), a species that is generally common in the larger rivers of the Missisippi Basin. It does not attain a large size. Specimens seen in the markets are usually 2 feet or less in length, but these are no doubt undersized. At Fairport, Iowa, the average weight is said to be about 3 pounds, but 6-pound sturgeon are mentioned. Evermann (1902) said that the largest he had ever seen was under 4 feet. Little is known of the habits of this sturgeon. Evermann stated that it swims well toward the surface when running and is taken along with Ohio shad and paddlefish. In the Mississippi River, however, it is usually taken near the botton in drifting trammel nets leaded to drag on the bottom; some are captured on trot-lines baited with minnows or worms.

The fate of the sturgeon in the Mississippi is one of the tragedies of shortsightedness in the conduct of the fishery. Only a few years ago this fish was considered almost worthless and, when taken in the nets, was regarded by the fisherman as a nuisance; the labor of skinning them was not compensated for by the price obtainable. All testimony indicates that it was the common practice to break the necks of the sturgeon when caught or to throw them high on the bank to die. Sometime within the first decade of the present century the value of the roe for caviar and the profit in handling "hog-dressed" fish for smoking were first appreciated in a general way. Previously a few had been sold in local markets, but virtually none had been shipped. The hackleback is now one of the most esteemed of smoked-fish products from the Mississippi and is commonly seen in all the local markets. It is prepared by the practice of "hog dressing," that is, removing the entrails but leaving on the skin and scales. The roe is of high value, but statistics of the fishery indicate that, on the whole, the meat brings a greater return to the fisherman than does the more intrinsically valuable roe.[6]

The shovelnose sturgeon is said to spawn in the spring, probably ascending the smaller streams for that purpose (Goode, 1884, p. 663; Kirsch and Fordice, 1890, p. 247; Forbes and Richardson, 1908, p. 27), but no record of observation has been found. An example was collected in Louisiana in winter (Jordan 1884a, p. 318), but the species was not noted during an investigation conducted in April and early May (Evermann, 1899); possibly this was due to chance or to the fact that collections were not made at a breeding place. Trumer Jackson, of Warsaw, Ill., who formerly fished at Cairo, about 300 miles south of Keokuk, stated that the fish, though regu-

[6] On July 3, 1917, the price of sturgeon meat at Keokuk was 16 cents while the price of sturgeon roe was $2.75 per pound. The price varies greatly, being influenced by importations of Russian caviar; it may be as low as 50 cents a pound.

larly taken there, do not have eggs large enough for caviar. About Keokuk it is found with eggs suitable for caviar from late summer or fall until early June.[7] In 1915 the last can of caviar was shipped from Warsaw on June 7, but the eggs may have been taken several days earlier; in 1916 the last shipment was made on June 13. In the latter year a small shipment was made from Canton, Mo., on June 21. The fish itself continues to be taken in substantial though lessened numbers for another month.

Luther McAdams, of Keokuk, names May 10 as the height of the season for eggs of sturgeon. At about that date, using heavily loaded trammel nets drifting in the "channel lick," about 1.5 miles below the bridge at Keokuk, he has taken sturgeon in quantity with eggs and milt flowing from them as they were removed from the net. The nets were dragging the bottom, as evidenced by the fact that small rocks in numbers were caught in the pockets of the net.

The sturgeon was about fourth in abundance among the fish found immediately below the dam by Surber in 1913. (Coker, 1914, p. 10.) This was a month after the end of the spawning season. Such degree of abundance is not remarkable. The two principal dealers at Keokuk and Warsaw stated that the fish had been commoner after than before the erection of the power station. Surface observations are of no significance because the fish is of bottom habit and rarely seen at the surface; the author has never seen it free in the water. In the immediate neighborhood of the power plant, according to our observation, it is infrequently taken, although set lines are used there regularly; near the dam an example was caught in a trammel net on June 22, 1915, and another in a gill net on May 30, 1916. Three-quarters of a mile to a mile (1½ kilometers) below they were caught in set lines. From here to Warsaw the principal fishery existed, being prosecuted with trammel nets drifted in the current. Of all the recorded catches of fish about Keokuk, 11 contained this species, and all of these but one were products of the trammel net. The capture of a specimen in a slough (behind Mud Island) excited the interest (June 25, 1915) of the fishermen because the species is virtually never taken except in the river. It is known as a fish of the current.

Examples were seen about Keokuk during the years 1915, 1916, or 1917, in each month from February to September, inclusive. Dealers and fishermen said that it was occasionally taken in quantity during the winter. When weekly inquiries of the markets were started the season was almost ended; the quantities reported by the three markets, given to the nearest hundred pounds, are shown in Figure 4.

The "hackleback," as it is appropriately called, is reported to be less abundant on Keokuk Lake than it used to be on the river. The commercial yields of hackleback from Lake Keokuk in all years of the survey were insignificant, being 1,900 pounds in 1914, 454 pounds in 1917, 600 pounds in 1922, and none in 1927. Monthly inquiries during the open season of 1916 showed that from 100 to several hundred pounds a month were taken at Burlington. At Fort Madison, where the current is slight, a few were taken, but never as much as a hundred pounds in a month. Farther down, at Montrose, Iowa, the fish is rarely taken, no instance having come to the attention of the writers. These facts reflect the strong preference of the species for a current. All reports in 1926 indicated scarcity of hackleback in the lake and the river immediately above. George E. Smith, at Fairport, said in 1926 that there were still seasons of plenty and seasons of scarcity, but he believed that on the whole sturgeon were on

[7] George E. Smith, at Fairport, said that sturgeon with roe suitable for caviar are taken in fall, winter, and spring.

the decline. The only evidence to suggest the maintenance of the species in the upper river is the increasing abundance of the egg mussel ("glassy-back" or "Missouri niggerhead," *Obovaria ellipsis*); the only fish now known to carry that mussel in its parasitic larval state is the shovelnose sturgeon, although there may be other hosts that have not been detected.

The run of sturgeon in the river below Keokuk is said to be very variable; a good run is expected when the river is low during the spring, as in 1925 and 1926, when the expectations were fully realized. High water is said to be unfavorable. After the spawning period the fish continues to be taken in considerable but decreasing numbers,

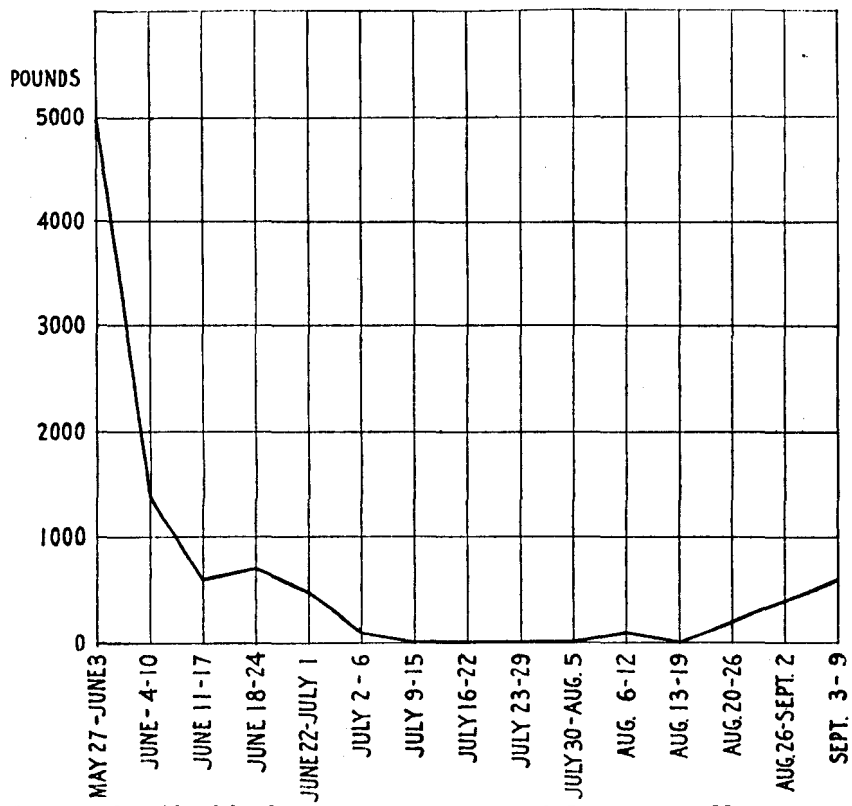

FIGURE 4.—Quantities of shovelnose sturgeon taken near Keokuk, Iowa, by weeks, May 27 to September 9, 1916

indicating that it spawns in this vicinity and then drifts southward, though probably some remain all year. For 1922, 1,080 pounds of shovelnose sturgeon were reported from Lake Pepin, but the fish has always been rare in that lake.

That propagation now occurs above the dam is attested by the fact that very small sturgeon have been taken in the river at Fairport, Iowa, on several occasions. The Fairport station now has examples measuring in standard lengths, respectively, about 2 inches (52 millimeters, taken in July or August), 2.8 inches (71 millimeters, taken July 11, 1919), and 4.6 inches (116 millimeters), all taken at Fairport.

White sturgeon. *Parascaphirhynchus albus* Forbes and Richardson

This species is relatively rare, and virtually nothing is known of its habits. Local fishermen report taking them not infrequently, and say that they rarely contain

visible eggs. An example taken near Keokuk on April 21, 1916, measured 69 centimeters (about 28 inches), 55.5 centimeters to base of caudal fin, and weighed 0.75 kilo (about 1½ pounds). The stomach, examined by Stringham, contained about a cubic centimeter of matter, consisting of insect débris (90 per cent), May-fly remains (5 per cent), and parasites (5 per cent). In the intestine were about 3 cubic centimeters consisting of fish (minnows 95 per cent) and May-fly nymphs (5 per cent).

SUMMARY AND CONCLUSION REGARDING STURGEONS

The rock sturgeon or rubbernose sturgeon was formerly a fairly abundant fish in the upper Mississippi River and of the highest value for its meat and roe (for caviar). It has now been virtually lost as a commercial fishery resource, but it would be impossible to connect its disappearance with the Keokuk Dam, inasmuch as the fish had been virtually lost to the middle section of the river at least five years before the building of the dam. It has also been lost to the fisheries of the Great Lakes.

The shovelnose sturgeon or "hackleback" is a small but very valuable fish. It makes the most generally esteemed smoked-fish product of the river, and its roe sells at a high price for production of caviar. It frequents regions of strong currents and swims near the bottom. Its breeding habits have never been observed, but in the vicinity of Keokuk the height of the spawning season is evidently in May, and reports indicate that spawning occurs on rocky bottom in swift water. The fish does not frequent still waters in numbers, and it is not now known to be abundant anywhere above the dam. Its abundance in the river a short distance below the dam seems unaffected. Its preference for current virtually eliminates it from Lake Keokuk or Lake Pepin. As regards the river between these lakes our evidence is hardly adequate but, as far as it goes, indicates a declining importance of the species in that region. Evidently, however, breeding occurs in the river above the dam. Further inquiries should be made during a season of good flow of water.

The white sturgeon is little known and is apparently of small commercial importance in the river.

THE GAR PIKES (Lepisosteidæ)

With the gars we come to another small group of fishes that is peculiarly North American. Reptilelike, flexible-bodied, air breathers, heavily armored, formidably toothed, they are so distinctive in appearance that everyone knows them. They are sluggish but powerful, stealthy but voracious. They are widely distributed and almost universally regarded as unmitigated nuisances. It can not, however, be said that they are universally despised, for the meat of gars is said to be esteemed by negroes and to have been a common food of Indians. Some white persons who have eaten the meat describe it as white, well flavored, and wholesome; others find it coarse and stringy. Possibly the ill favor with which it is generally regarded as a food fish by whites arises, as in the case of eels, from some suggestive features of its appearance more than from intrinsic qualities. The roe of the female, although made up, when mature, of large eggs that might be expected to be useful as a fresh food or as caviar, is said to be decidedly toxic, and it may therefore be that unpleasant experience from the use of the roe has had something to do with the establishment of a firm prejudice against the meat. Whatever may be the future place of the gar in dietetics, it is at present to be regarded as a generally unwelcome element of the fauna of the river. Nevertheless, any influence of the dam upon their numbers would be a proper

subject for consideration, even were they not, in one respect at least, useful agents in the larger rivers.

It may surprise most people to be told that the gar serves any useful purpose, but the interrelations of nature give frequent occasion for surprise. Within comparatively recent years it has been learned that the gar serves as the host of the parasitic young (glochidia) of the most valuable of all fresh-water mussels. (Howard, 1914.) The yellow sand shell (*Lampsilis anodontides*) yields a shell that for form, texture, and luster compares most nearly, of all fresh-water shells, with the marine "mother of pearl." It is useful not only for the manufacture of buttons of superior grade but also for the preparation of pearl handles for knives and for other novelties. From extended investigation, it appears that all species of gar may function as hosts of this mussel, and that no other fish will answer. Without the presence of gars in our rivers we could not have a fishery resource that has considerable present value and doubtless greater future value, unless this mussel can be maintained by artificial means.

The most striking feature of change in the fauna of the upper Mississippi in the last dozen years is the great increase in the numbers of yellow sand shells. From being a very infrequent shell culled out in small quantities to be exported for the production of novelties, it has now become a standard shell for use in button manufacture, yielding a high price because its elongate form, relatively uniform thickness, and good cutting qualities permit a high-quantity production of buttons. To a considerable extent it now replaces the niggerhead mussel, once the standard shell for button manufacture. The clammers of the river are now beginning to hold the gar in higher esteem.

Some notes regarding the habits of the gars will establish more clearly their place in the biological economy of the river.

More than other fishes, the gar is commonly in evidence, owing to its habit of swimming at the surface. Equipped with a cellular air bladder, which functions in part as a lung, the gar frequently "breaks" the surface, protruding it head and long snout, turning partly on its side, emitting a bubble of exhausted air, and gulping in a new supply. "The movements are very rapid and almost convulsive, as if the fish were suddenly oppressed by something and hastened to remove it." (Wilder, 1877, p. 7.) Garman found that when a gar was restrained below the surface air bubbles were allowed to escape and the fish became evidently very uneasy, "moved rapidly to and fro, turned and twisted and lashed its tail," until it was permitted to rise to the surface, when it apparently gulped in a large volume of air. After this it descended and remained quiet for the usual period. Mark (1890) concluded from his experiments that only oxygen exchange with the atmosphere was effected in this way, the respiration of CO_2 being effected in some other way; but Potter (1927) has recently shown that both oxygen and CO_2 exchanges take place through the swim bladder. Furthermore, Potter gives evidence to indicate that "the capacity of the swim bladder and the rate of inhalation are great enough to supply sufficient air for the needs of the body." It appears that gar pikes have alternate modes of respiration—by gills or by the swim bladder functioning as lungs—and that they will live for days when forced to depend exclusively upon either the one or the other.

"The manner of feeding is also unlike that of fishes and resembles that of reptiles. Other fishes take their food with open mouth and swallow it at once; but this one approaches its prey slyly, sidewise, and, suddenly seizing it, holds it in its jaws until

by a series of movements it succeeds in getting it into a proper position for swallowing, as is the habit of alligators and lizards." (Agassiz, 1859, referring to young gars.)

They are voracious from an early age. Forbes and Richardson found 16 minute minnows in the stomach of a long-nosed gar only 2 inches long and one-eighth inch deep. Others had small Cladocera. Mark (1890) regarded small insect larvæ (mosquito larvæ) as the principal food of very young gars.[8] All other observers agree that fish are the principal food of older gar pikes. Pearse, from observation in Madison Lake, Wis., found that fish comprised nearly 90 per cent of the food of 10 specimens examined. (Fish, 88.8; insect larvæ, 10.2; adult insects, 1.) Stringham (in connection with this investigation) noted the stomach contents of 20 examples of long-nosed gar taken at Keokuk; 9 contained nothing, 9 contained fish (one of these having a minnow and an insect larva), and 3 contained insect larvæ. He also observed the stomach contents of 41 short-nosed gar, 27 of which were empty, 6 contained fish, 4 insects, 1 crawfish, and 3 undetermined matter, apparently straw and seed. These are apparently the first recorded observations of the food of this species of gar.

While the food of gars is chiefly fish, there seems to be no record of their preying upon game fish. No doubt they do, but their injurious effect upon other fishes is probably based primarily upon their effective competition with other predatory fishes for the limited food supply.

The gar of the Mississippi Basin are variable in appearance and there has been some difference of opinion as to the number of species. According to common usage, there are three species in the United States [9]—the long-nosed gar or billfish, the short-nosed gar, and the alligator gar. The last-mentioned fish, which is said to attain a length of 20 feet, probably never ascends the Mississippi far above the mouth of the Illinois River and may be excluded from consideration. These three species comprise the sole representatives of a family that seems to have thrived at least as far back as the Carboniferous age, if not earlier. The genus Lepisosteus goes back to early Tertiary times. To-day it is found only in North and Central America and in Cuba. In the United States gar pikes are found in the Atlantic, Gulf, Mississippi, and Great Lakes drainages. The restricted distribution of the family is the more remarkable since the gar pikes are not altogether averse to salt water. (Smith, 1907, p. 59.) Their distribution indicates that they can withstand both high and low temperatures, although they are active only when the water is relatively warm. In cold weather the habit of coming to the surface is discontinued, and the fish remain below in a dormant or benumbed condition. Their strong armor protects them effectively against the depredations of other fishes.

Long-nosed gar. *Lepisosteus osseus* Linnæus

BILLFISH

The long-nosed gar is the most widely distributed species, occurring throughout the Mississippi and Great Lakes drainages, on the Atlantic coast, and even in Mexico, and frequenting the larger streams or sluggish waters. Most of the observations that have been published on the breeding habits of gar pike probably relate to this species.

[8] Apparently they will not bite at any object unless it is in active motion. They will, however, sometimes push an insect larva about until it demonstrates its vitality by actual motion, when it will be snapped up by a sideward movement of the bill. (Mark, 1890.)

[9] Fowler (1910), from study of museum collections, has proposed a number of species and a new genus. An account of the distribution of the several species is not attempted. His paper was not available when our observations were made, and we can not relate our observations to his diagnoses.

It frequents shallow water for spawning, depositing the eggs in grass or weeds or about stone piles (Forbes and Richardson, 1908, p. 33), the season of spawning in the United States being about June 1.[10] The eggs are apparently adhesive, becoming attached to stones or other objects. After hatching the young attach themselves by means of maxillary disks; they may suspend themselves from the surface film. (Mark, 1890.) "They are extremely interesting and even beautiful little animals, each marked with a broad black lateral band; they are especially noticeable for the evanescent lance-shaped upper lobe to the caudal fin." (Forbes and Richardson, 1908, p. 33.) The food of the young seems to consist of insect larvæ, Entomostraca, and very small fish, making them serious competitors if not direct enemies of the young of useful

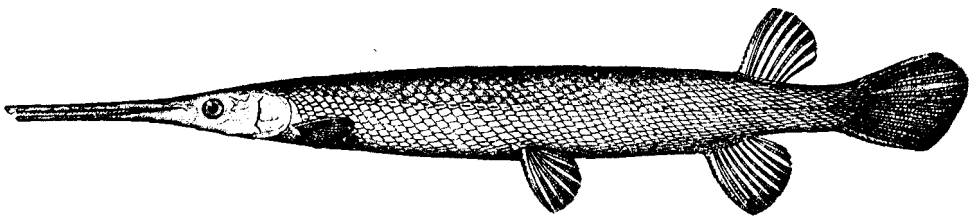

FIGURE 5.—Longnose garpike, *Lepisosteus osseus*. (Specimen from Florida)

fishes. Garman (1890) found, near Quincy, Ill., young long-nosed gar measuring 6 to 12¼ inches in length, the average length being 8.1 inches. Presumably they were gar of the season.

The long-nosed gar seems virtually unknown in Lake Pepin (Wagner, 1908), and it is much less common in the vicinity of Keokuk than the short-nosed gar, to which our observations chiefly relate. The two seem not to be essentially different in habit, and the discussion may apply equally well to both species.

Short-nosed gar. *Lepisosteus platostomus* Rafinesque

DUCK-BILL GAR

The short-nosed gar occurs throughout the Mississippi Valley, being the more common species in the vicinity of Keokuk. The two species are readily distinguished

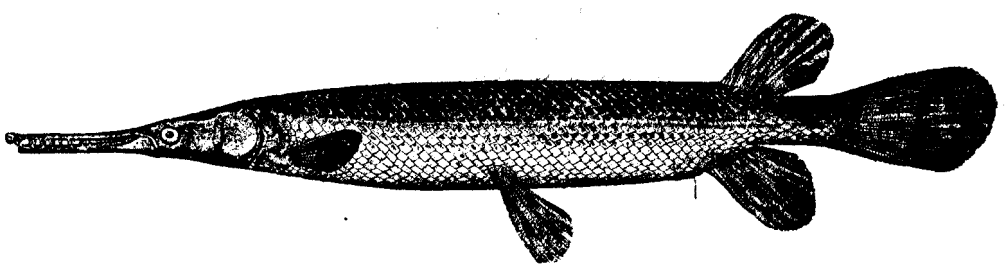

FIGURE 6.—Shortnosed gar, *Lepisosteus platostomus*

by the form of the beak, which in the long-nosed gar, according to observations by Stringham at Keokuk, is 14.5 to 20 times as long as the least width (average 16.7), while in the short-nosed gar the length varies from 5.7 to 7.4 times the least width (average 6.5).

Richardson (1913a) found the breeding season in the vicinity of Havana, Ill., to be from the early part of May to the end of June at least. (In 1899 spawning con-

[10] Evermann (1899) records the capture of a spawning female taken at Morgan City, La., on Apr. 23, having a standard length of 40 inches, weight 9 pounds, weight of ovaries 19 ounces, and number of eggs 36,450.

tinued until August. Forbes and Richardson, 1908.) The fish ran in pairs, each female with a smaller male, spawning in shallow water full of weeds or willows. The eggs adhered to grass and smartweed; they were found attached even above the surface of the water, and some of these hatched.[11] The eggs hatched in about eight days. The young were solitary in habit, being found always floating at or near the surface in the sun, sometimes with the back out. Young 3½ inches long were taken on July 7. Garman (1890) had found, in the vicinity of Quincy, Ill., in August, young short-nosed gar up to 12.5 inches in length, the average of 18 examples being 9.94. A rapid rate of growth in early life is indicated.

The adult gars are said to move in large schools both before and after the spawning season. The distribution of gar pikes indicates that breeding occurs in northern and southern regions, and there is no evidence that extensive migrations are necessary for reproduction.

In the vicinity of Keokuk the short-nosed gar is one of the most abundant fishes, being rivaled by the German carp, the river quillback (*Carpiodes carpio*), and two species of minnows. It is, of course, much in evidence from its surface-swimming habit. Adult fish were found everywhere below the dam and lock, in the river, sloughs and creeks. Many fingerlings were seen in 1916 near the lock, both above and below.

The inclosed portion of the unfinished part of the power house formed, in effect, an imperfect trap about an acre in extent, in which great numbers of gars were observed in 1915 and larger numbers in 1916. Observations in 1915 indicated that the aggregation of gars in the space corresponded roughly with the stage of the river. When the level of the river was above the top of the walls of the inclosure, or much below it, the aggregations were not noted; presumably the gars escaped, in the one case over the top of the wall and in the other through the submerged openings, which were nearer the surface at low stages. No correlation with breeding season could be noted. The times when aggregations were noted in 1915 were as follows: May 17–26, June 18–July 9, July 17–24, August 10–27, and September 15. Breeding was over by the end of June, as indicated by the examination of fish in July and later.

While generally reported as abundant in Lake Keokuk in 1926, the reports of fishermen were far less strong regarding gar in the lake than in the river; the gar is "more for current," some said. Nevertheless, it is extremely abundant in Lake Pepin. Several hauls were witnessed, and gar far outnumbered all other fish combined, although gars are particularly successful in escaping the net. Reference has previously been made to the remarkable increase in numbers of yellow sand shells, a mussel that is aided in propagation by the gars. This does not necessarily indicate an increased abundance of the fish, for there are other conditions that seem increasingly favorable to the survival and growth of yellow sand shells, to be discussed later.

There are, of course, no commercial figures concerning the gar pikes, but their continued abundance in the upper river is unquestioned. The lake probably offers suitable breeding places for them, but in 1926 it appeared that gar were relatively less abundant in the lake than in the river above and below. Presumably the gar pike is so well able to take care of itself under most varied conditions that the river will continue to be as abundantly stocked as the condition of the food supply and competition permit.

[11] H. L. Canfield found eggs of the gar adhering in quantities to flood trash on the banks of the White River near Clarendon, Ark.

Bowfin. *Amia calva* Linnæus

DOGFISH; MUDFISH; GRINDLE; LAKE LAWYER; ETC.

This odd fish is called by a dozen names, none of which probably is intended to be complimentary. In the classification of fishes it stands quite alone as the sole living representative of an order (the Cycloganoidea) with some characters regarded as most primitive and others as fairly modern. The swim bladder has a cellular structure, opens into the esophagus, and functions as a lung, aiding the gills in respiration. Its double respiratory apparatus makes the fish adaptable to a variety of conditions. It can live in lakes and rivers, in ditches and rain barrels. Live bowfin are said to have been plowed up in lowland fields of Louisiana some weeks after the subsidence of floods and the drainage of the land sufficiently for cultivation. It prefers sluggish waters and is not common in the river below the dam, although it occurs there. It is apparently quite common in the back waters of the lake, for the author was told on September 24, 1917, of a catch of 1,500 pounds of bowfin in two hoop nets set in Green Bay. In that year there was a very good winter demand for bowfin in the markets of some of the larger cities, but the summer price was low

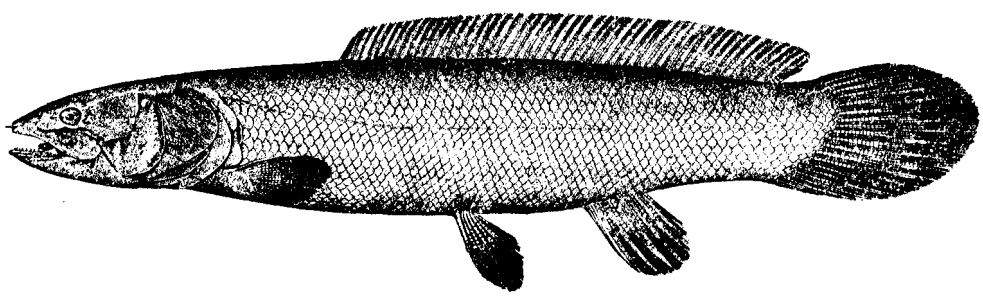

FIGURE 7.—Bowfin, *Amia calva*

because the fish had to be retained in cribs constructed for the purpose near the shores of the lake. It was an interesting fact that great quantities of live bowfin could be retained for months in small cribs at Dallas City. The owner said that the secret of keeping bowfin was to put in a few carp—the sluggish bowfin alone would settle thickly on the bottom and smother each other, but a few carp would keep the mass of fish stirred up so that all remained alive for a long time.

At the beginning of this investigation the bowfin was generally held in the lowest esteem as a food fish; its soft, pasty flesh renders it unfit for use unless prepared in some special manner, as by stuffing, seasoning, and baking. Strange to say, when properly prepared by smoking it makes one of the best of all smoked fishes. Partly, no doubt, as a result of educational work conducted by the United States Bureau of Fisheries, after experimental work at the Fairport station, there has developed a good demand for the fish in the markets of several cities. The bowfin, therefore, is no longer to be disregarded as a food fish.

It is unattractive in appearance and very predaceous, and these qualities loom largest in popular thought regarding the fish. It has strong sharp teeth and is said to bite a 2-pound fish in two at a single snap. Its food, as observed by Forbes and Richardson (1908), is about one-third fish (minnows, buffalo fish, etc.), about one-fourth small mollusks, and the remainder crawfish. Insects form a very small proportion of the food. Pearse (1918) examined 14 specimens from lakes near Madison,

Wis., and found a much higher ratio of fish to other food—fish remains 96.6 per cent, and crawfish remains 3.3 per cent. It is in any event a severe competitor to more esteemed fishes. It is a strange corollary of our prevailing schemes of conservation of fish that destructive species such as the bowfin are rather rigidly although unintentionally protected in many waters where, in the supposed interest of angling, prohibitions are imposed against the only methods of fishing by which the numbers of bowfin and other "coarse fishes" can be reduced effectively; that is, against the use of nets.

A lover of sluggish waters, the bowfin is abundant in the Great Lakes region, in the Mississippi Valley from Minnesota to Louisiana, and in the east from New York to Florida. It seems to like the weedy waters, frequenting shallows at night and returning to deeper places by day. In some places it is taken at night with jacklantern and spear. In winter they have been found closely huddled in gravelly pockets among water weeds. Nesting, as observed by Reighard and others, takes place in quiet shallow places among vegetation, stumps, roots, and logs, the male guarding the nest and protecting the young, which move in schools until they are about 4 inches long.

Under the conditions of our observations very few bowfin were observed, but we know of their presence in the lake and its environs, and it seemed a reasonable presumption that the sluggish backwaters, with their weeds and brush, would be favorable to the production of bowfin. The catches of bowfin in the four years of statistical canvass of Lake Pepin were 1,534 pounds in 1914, 2,402 pounds in 1917, 16,136 pounds in 1922, and 3,334 pounds in 1927. For Lake Keokuk the fish was reported only in 1917 (26,000 pounds) and in 1927 (14,055 pounds). In the case of this fish irregularities in commercial yield might reflect only fluctuations of demand, but it was the common report of fishermen in 1926 that "dogfish" were not very abundant in the lake or in the river, although still taken and marketed principally in the spring. One chief source of supply in 1917, Green Bay, was eliminated by drainage in 1919. From all we know of the habits of the bowfin, the dam could have no deleterious effect upon its propagation. Perhaps it was never so numerous as some have supposed; it would seem more abundant when regarded as a nuisance than when in some demand. The weightiest testimony as to diminution of bowfin comes from trotline fishermen of the lake and of the region of Fairport to the effect that large schools of "dogfish minnows" can no longer be found for use as bait.

THE HERRINGLIKE FISHES

Under this head we are concerned at Keokuk with a true shad, a herring or alewife, the gizzard shad, and the mooneyes. Following the systematic order, we consider first the mooneyes—silvery, herringlike fishes, of which there are two species that occur in the Mississippi Basin from the Ohio River northward and also in the Great Lakes region and the Saskatchewan.

Nowhere do the fishermen appear to distinguish the two species, which are, however, rather readily recognizable. Dr. Franz Schrader, while an investigator for the Bureau of Fisheries, observed that although both species have a tint of gold in the eye the larger species (*alosoides*) has a pronounced ring of gold where only a portion of the iris is washed with gold in the other. This is the basis for the names proposed in this report—goldeye and white-eye. There are distinguishing structural marks that are easily observed. *Alosoides* has the belly keeled in front of ventrals as well as behind, *tergisus* only behind; the dorsal fin of *alosoides* is short, with only 9 rays, and

rises above or a little behind the anal, while that of *tergisus* is longer, of about 12 rays, and rises before the anal.

The toothed herrings, or mooneyes, have been generally regarded as nearly worthless because of the large number of bones; but in comparatively recent years the practice of smoking them has developed, and the product is excellent. In the smoked condition the bones offer no special difficulty. The smoking of mooneyes has been most prevalent about Lake Pepin, where *tergisus* seems most abundant. In quite recent times, according to information received at Muscatine, Iowa, in 1926, there has been a market for fresh mooneyes; *alosoides* is apparently most common in that region.

THE TOOTHED HERRINGS (Hiodontidæ)

Gold-eyed Mooneye. *Hiodon alosoides* (Rafinesque)

"TOOTHED HERRING;" "WAP"

At Keokuk the goldeye attains a length of 44 centimeters (18 inches) and a of nearly three-fourths of a kilogram (3 pounds).

We have found virtually no published data regarding the habits, except the note of Forbes and Richardson that it is commonest in rather swift open water, is a gamey fish, and feeds mainly on terrestrial and aquatic insects, mollusks, and small minnows. At Keokuk it was found only in the river, never in the lake. It was taken both in hoop nets on the bottom near the banks and in floated trammel nets at the surface.

The stomach contents of about 29 examples were examined for us by Dr. R. A. Muttkowski. The food is almost exclusively insect. A single stomach of those examined contained fish (2 gizzard shad) but it is known that anglers, using live bait, occasionally catch a goldeye. A few small crustaceans and a trifle of plant matter also occured in the stomachs. Listed approximately in the order of their abundance, the following insects were reported: May-fly nymphs and imagos; beetles, chiefly terrestrial but including Gyrinus (whirlgig beetle) and Stenelmis; caddisworms, midges, and beach flies; Corixa (water boatmen); dragon-fly and damsel-fly larvæ; grasshoppers and crickets; stone-fly nymphs; dobson-fly larvæ or hellgrammites.

Except that fish and the largest insects are found in the larger fish, there appeared no differences in food corresponding with age as regards goldeyes varying in length from 16 centimeters (5.5 inches) to 42 centimeters (18 inches). There was also no seasonal variation in food except that terrestrial forms and adults of most aquatic insects were not available in winter. Rarely were specimens taken with empty stomachs, from which it may be inferred that the fish is actively feeding throughout the day.

The fish was taken at Keokuk from February to August. Although specimens were examined in every month from March to August (with one examination on February 29) only one fish was found that seemed sexually mature—a female taken March 29, 1915. Possibly the breeding season is in the late winter or early spring.

This fish has but little commercial value, although some are shipped in the north (Evermann and Latimer, 1910, p. 132) and from Muscatine and points near Keokuk, Iowa; it is said to have considerable value as an article of food in the basin of Lake Winnepeg (Jordan and Thompson, 1910, p. 353). The flesh is white and rich and particularly good when smoked.

The goldeye is not sufficiently abundant about Keokuk to support a large fishery. The biggest catch noted during the two seasons was 44 taken in a trammel

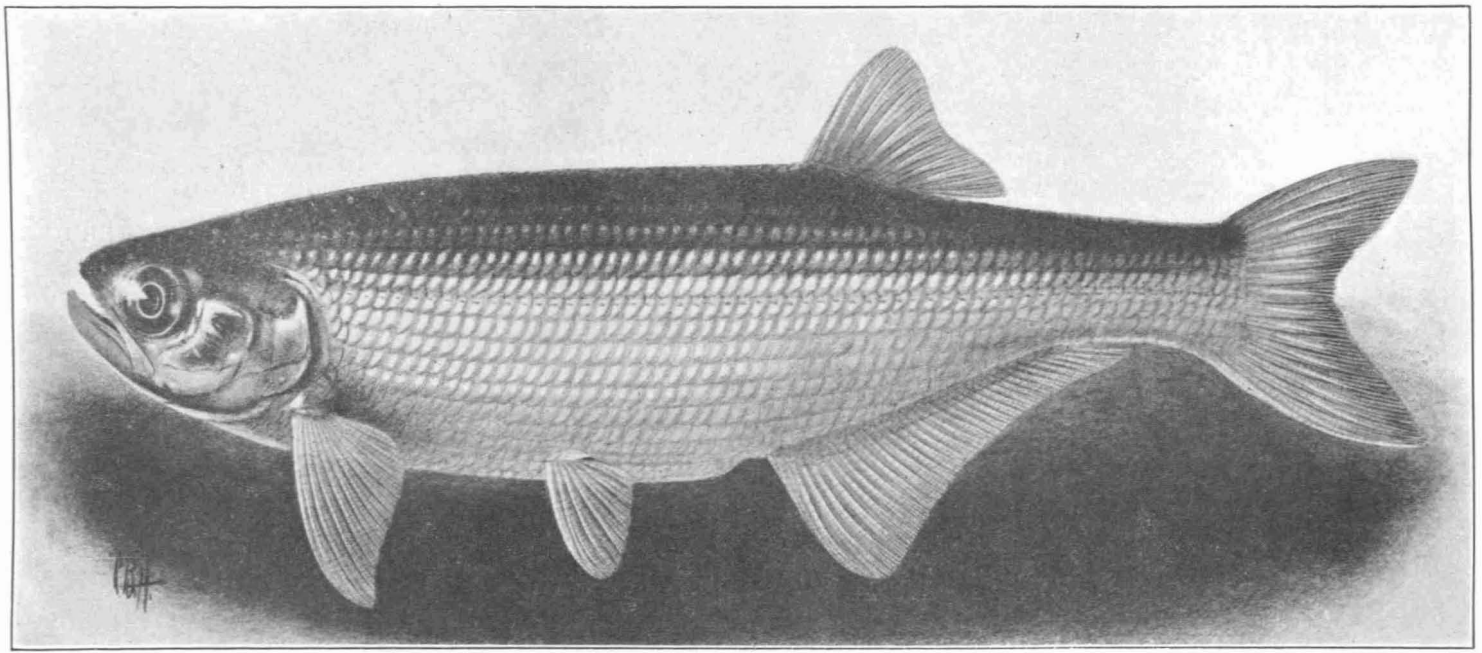

FIGURE 8.—Gold-eyed mooneye, *Hiodon alosoides*

net near the unfinished half of the power house on the evening of May 30, 1915; on June 26 of that year 28 were taken in the same locality. The fish was found about Keokuk from February to August and probably spawns in February or March. There was no indication that the dam interfered with its habits. Many years before the dam was built Forbes and Richardson wrote:

> This large and handsome silver-coated fish is now too rare in Illinois to have any special significance in our waters. Some years ago it was much more abundant than now in the Mississippi and the Ohio, as many as a thousand pounds at a time having been caught, according to Mr. Ashlock, from the former river near Alton and the latter at Cairo.

White-eyed Mooneye. *Hiodon tergisus* Le Sueur

"TOOTHED HERRING"

Although said to be very abundant in the Ohio River and in Lake Erie (Forbes and Richardson, 1908), the white-eyed mooneye was found to be much less common in

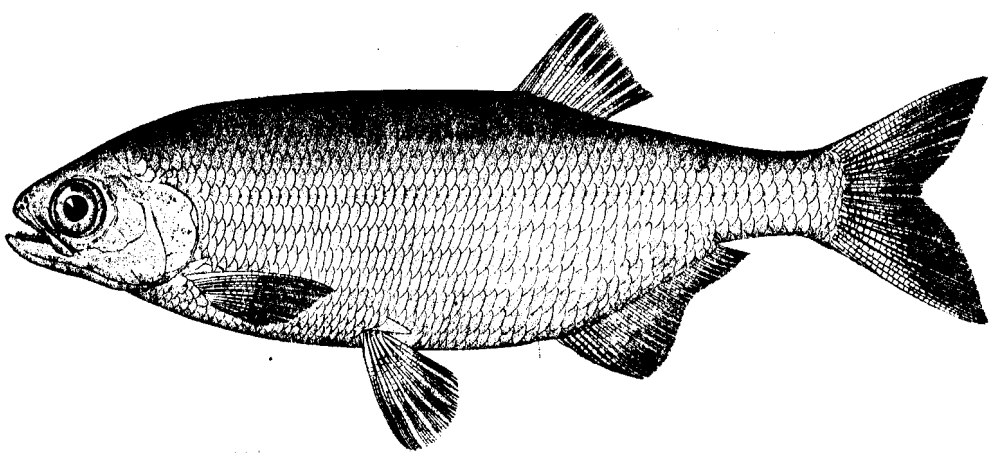

FIGURE 9.—White-eyed mooneye, *Hiodon tergisus*

the vicinity of Keokuk than the other species. The two fishes are apparently not distinguished by the fishermen of that region. It is smaller than the goldeye; the largest taken at Keokuk was 30 centimeters (12 inches) in length, but a somewhat longer specimen was taken in Lake Pepin. Fish were examined by Stringham for reproductive condition in each month from February to August (except June). Sexually mature fish with eggs flowing on pressure were taken at Keokuk on March 15. The fish varied in length from 23 to 28 centimeters (9.5 to 11 inches), and the eggs were 1.7 to 2.3 millimeters in diameter.

The contents of the stomachs of a dozen examples that were examined for us by Doctor Muttkowski comprised chiefly May-fly larvæ of various kinds (Hexagenia, Ephemera, Heptagenia, Siphlurus, Bætinæ, etc.), black-fly larvæ and pupæ (Simulium), caddis-fly larvæ (Hydropsyche), dytiscid beetles, and water boatmen (Corixa). Forbes and Richardson say that the food is chiefly insects and their larvæ, mollusks, and small minnows. It is described as a vigorous biter and gamey on the hook. It does not, however, seem to have the good qualities as a fresh food fish that the other species possess.

On several occasions the author has taken mooneye in Lake Pepin, and in all cases the species was *tergisus*, which we assume to be the more common species in that

water. About 1917 there appeared to be developing about Lake Pepin a smoking industry of significance, based chiefly upon mooneye. In 1922 and in 1927 the mooneye was not reported as a commercial fish, but this was undoubtedly an oversight, arising possibly from the fact that mooneyes were not sold from the nets but were given away or taken home to be smoked and subsequently sold. Inquiries in 1926 indicated that there had been no cessation of the practice, although little development had occurred for relative paucity of material.

In the region just below Lake Pepin some fishermen speak of a large herringlike fish locally called "cisco." Possibly this name refers to the larger mooneye, *alosoides*. Such information as we have in hand would suggest the association of *tergisus* with slacker water and *alosoides* with swift current. The respective habits and distribution of the two species offer a favorable subject for study.

SUMMARY AND CONCLUSION REGARDING MOONEYES

Mooneyes of two species are generally distributed in the upper Mississippi, one species or the other seeming to predominate in each locality. In some localities mooneyes are described by fishermen as frequenting only the swiftest current, but in other places they are found in slack water. The fish have had no significant commercial standing in the past but are now marketed in most places as smoked fish and in some localities as fresh fish. The quality of the smoked mooneyes is very high. Mooneyes appear not to have been unfavorably affected by the dam. At only one or two points on the river, either above or below the dam (as far as Canton, Mo.), was there reported in 1926 a diminution in numbers of these fish. "More than ever" was the substance of reports at Lynxville, Wis., Fairport and Keokuk, Iowa. Mooneyes may have a growing value, but they are not now so abundant, relative to other species, as to promise to take a place of great importance in the fishery.

THE GIZZARD SHADS (Dorosomidæ)

Gizzard shad. *Dorosoma cepedianum* (Le Sueur)

The gizzard shad offers an instance of a fish that has no commercial rating but nevertheless is one of the most valuable fishes in the larger rivers. Garman (1890) says that predaceous fishes confined in the sloughs depend very largely on this shad for sustenance. Forbes and Richardson (1908) speak of it as "one of the most useful in our waters because of the almost exhaustless food supply which it offers to all the game fishes of our larger streams and lowland lakes. Living itself mainly upon food derived from the muddy bottom of our very muddy rivers and lakes, it serves as a means of converting this mere waste of nature into the flesh of our most highly valued food fishes." In its earliest stages of free life, when it is remarkably different from the adult in form and habit, it competes with game fishes for the active elements of the plankton. It soon transforms itself, adopts new habits of feeding, and becomes itself the prey of young bass and other predatory fishes. Even as an adult it is still able to feed upon plankton strained from the water through its gill rakers.

The breeding season of the gizzard shad in the vicinity of Havana, Ill., begins in May, and growth is evidently rapid. Garman (1890), having collected fish near Quincy, Ill., in August, 1888, reported that "young of the year 1.5 to 2 inches long and still wearing the black shoulder mark occur in countless numbers. * * *. The bottoms and sloughs and lakes are preeminently the spawning ground of this fish."

No necessity for extensive migrations of the gizzard shad is known. It is extremely widespread in its occurrence, being found in brackish water along the Atlantic and Gulf coasts, throughout the Mississippi Valley, and in Lake Erie and Lake Michigan. It is found about Keokuk all the year, having been recorded each month from February to November (except March.) It is not remarkably abundant in the relatively strong current of the Mississippi River but occurs in great numbers in the sloughs, backwaters, and lakes. The conditions offered by the creation of the lake

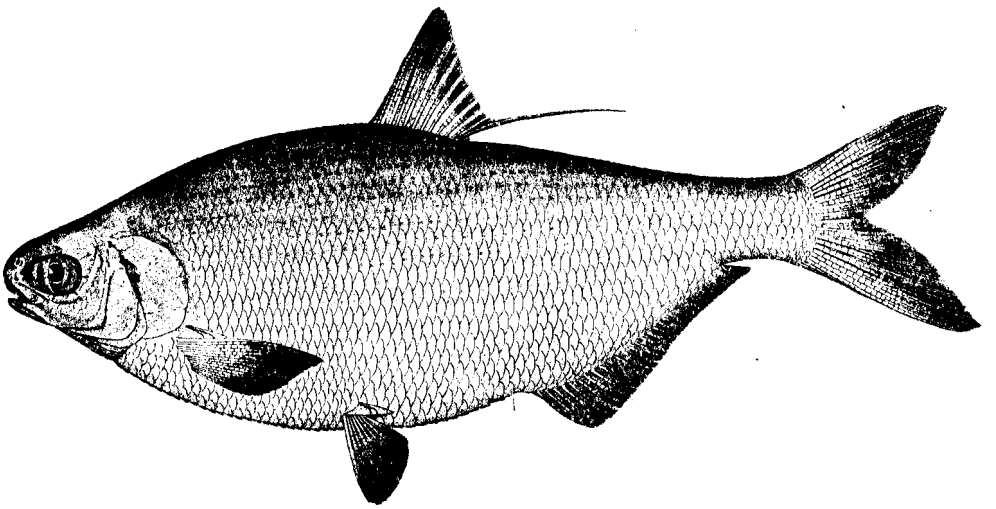

FIGURE 10.—Gizzard shad, *Dorosoma cepedianum*

may be thought to be favorable to its productivity, and we have had no evidence of any unfavorable effect arising from the presence of the dam.

THE HERRINGS AND SHADS (Clupeidæ)

River herring or "skipjack." *Pomolobus chrysochloris* Rafinesque

One of the most beautiful and lively fishes of the Mississippi Basin is the river herring, blue herring, or "golden shad," marked with its green and silvery color and golden reflections. It has a striking habit of leaping from the surface when feeding upon schools of minnows or in mere play. From this it has derived, in some places, the name of "skipjack," a designation that is applied in one locality and another to so many species of fish that it is quite indeterminate; its use should be discouraged. By a few fishermen they are very inappropriately called "mackerel." Another misleading local designation is that of "Government shad"—a name applied apparently in the belief that the river herring are the result of former Government plantings of Atlantic shad.

The river herring has no importance as a food fish, being very bony and lacking good flavor. Its liveliness and vigor, however, make it one of the gamiest fishes in the river, so that it affords real sport to the angler who fishes with live bait in swift water, as about the ends of wing dams. An insight into its habits was had by the author and an aide as they fished for herring in the swift waters just below the chute alongside the lock. The fish played about the boat in great numbers, darting through the water, leaping from the surface, taking the line and making the reels spin busily, only to release themselves when a strain was put upon the line. After a time it was

found that the fish were taking the spindle-shaped lead in the mouth rather then the baited hook. The very swiftness of the fish prevented an earlier discovery of the trouble. With the leads removed from the lines and the bait kept close at the surface the fish were caught in fair numbers.[12]

Notwithstanding its poor qualities as a food fish, the river herring represents a very distinct economic asset. The niggerhead fresh-water mussel has been regarded as the most valuable of all the pearly mussels of the Mississippi Basin because of its abundance in all the larger waters of strong current and because it yields a shell of the best quality for buttons. Until quite recently, at least, most of the highest-grade pearl buttons of domestic manufacture have been produced from niggerhead shells, and these owe their existence to the river herring. The reproduction of the niggerhead mussel, so far as all evidence goes, is accomplished only through the parasitism of its young (glochidia) upon river herring; there can be no beds of niggerhead mussels except in waters frequented by river herring. It is, then, economically desirable to maintain the stock of river herring in all waters to which it is adapted and in which the bottoms are suitable for the mussel. As matter of fact, however, it

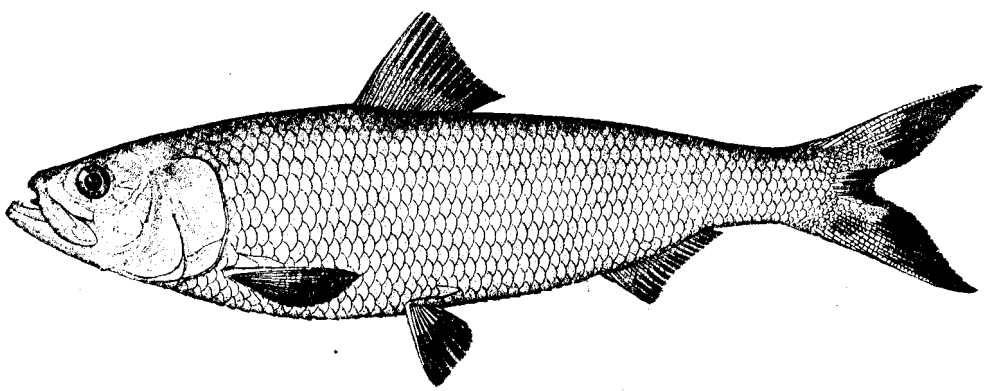

FIGURE 11.—River herring of the Mississippi River, *Pomolobus chrysochloris*

was found in 1926, by inquiry of manufacturers and shellers and by examination of shell heaps on the river bank, that the niggerhead is a vanishing species in the upper river, its place being taken to a considerable extent by other kinds of mussels.

There have been no published observations concerning the breeding of the river herring. Our records throw some light on the question, although we did not succeed in determining the place or the precise time of spawning in the vicinity of Keokuk.

Fish full of roe were taken by the author on April 29, 1914, at the very beginning of the "run" of river herring. Eggs and milt were exuded when pressure was applied. It was supposed that the spawning season was almost at hand, and in the course of the next few weeks attempts were made to obtain clearly spawning fish, but without success. On May 23 of the same year females full of roe were taken and one that was possibly spent. Stringham in 1915 examined, for reproductive condition, 191 fish from April 19 to September 22. Testes and roe, developed nearly or quite the full length of the abdominal cavity, were found April 29 and 30 and on various dates thereafter. Eggs measuring 0.8 millimeter were found as early as May 24, and eggs of 1.1 millimeters on June 5. Milt issuing on pressure was first noted June 23, and on

[12] Stringham examined the stomach contents of about 150 river herring. Approximately one-third were empty; a little more than one-third contained fish, chiefly minnows, with some mooneyes, gizzard shad, and other fish not determinable; and less than one-third contained insects and larvæ, principally May flies, with some caddis flies and others.

the same date was recorded "possibly a spent female." For July 1 and 2 occur the records "eggs flowed on pressure." After the latter date no fish were found with well-developed reproductive organs.

In 1916, 19 fish in all were examined on 12 dates between May 8 and August 30. The following records are of interest: May 23, "eggs flowed from dead fish"; June 3, "milt flowed slightly on pressure"; June 17, "eggs 0.8 millimeter"; July 14, "possibly spent female." At practically all times fish of considerable size were found with reproductive organs in undeveloped condition.

Many attempts made during several years to find a particular place and time where and when river herring were clearly spawning met with no success, although various methods of capture were tried. The problem proved unexpectedly baffling. Our data suggest only that the spawning season is prolonged, possibly beginning early in May; that the fish do not spawn in large aggregations; that during the spawning operations they are not readily captured by ordinary methods of fishery; and that spawning is ended soon after the first of July.

The river herring is classed by local fishermen as an "early-run" fish—that is, one of those that appear in numbers at Keokuk on the Mississippi and at Ottumwa on the Des Moines at the beginning of the fishing season, or about April 15 to 30. Other fish of the same season are hickory shad, sturgeon, bass, pike, and pickerel, followed a little later by channel cat and then buffalo and carp. In 1914 they appeared at Keokuk about April 22 and were extremely abundant below the dam on April 29. The first herring recorded by Stringham in 1915 was on April 19, and the first record of 1916 was for May 8, although they may have been present earlier. The fish were not so abundant in 1915 as in 1914 and were still less numerous below the dam in 1916. Whether this was due to actual diminution in the abundance of fish in the river, or whether the fish, having encountered the obstruction for one or two years, had been diverted to other waters can not be determined. In 1926 herring were reported to be abundant below the dam, some alleging that they were more abundant than before the dam.

The aggregation of herring below the dam in 1914 was so striking that we may refer to the observations recorded by the author in another place (Coker, 1914, p. 25) and quoted in part on page 94 of the companion report (Coker, 1929). No herring had been in evidence when the writer was at Keokuk on April 15, while the water was still cool.

A local informant, Mr. Joe MacAdams, was requested to write me of the first appearance of the herring. After a card from him, I visited Keokuk again April 29. He stated that the herring first appeared April 20, and that they became enormously abundant within a few days; on the 27th according to several informants, during a warm day, one could at any moment see hundreds of them breaking the water in every part of the river below the plant.

Then followed the personal observation of a remarkable assemblage of herring, which is described in the paragraphs quoted on page 94 of the companion report. (Coker, 1929.) The further observations not previously quoted are relevant.

It was observed that the roe of the herring was large, and it was thought that they would ripen within a few weeks. A visit was made by Superintendent Canfield May 29, and a number of herring were examined, but they were found to be not quite ready for spawning. A later visit was made by Mr. W. B. Gorham, June 11 and 12, when it was found that the herring had disappeared. This disappearance had not been noted by the local fisherman for the reason that there were present in large numbers the Ohio shad, *Alosa ohiensis*, which is not generally, if ever, distinguished by fishermen from the herring. There was no clew, therefore, as to what had become of the herring.

(Later observations, in August, indicated that the disappearance was only temporary.)

So far as is now known, the herring is to be found at Keokuk only from April to September. In 1915 they were captured principally between June 13 and July 11, a condition quite different from that of 1914.

As to conditions above the dam, seining was inaugurated at Montrose, Iowa, midway of the lake, in 1916, and herring were reported to be taken frequently. Two examples were examined by Stringham on July 14. The fishermen, who were visited from time to time, reported the more or less regular capture of herring in small quantities during August and up to September 15.

In Lake Pepin in 1913 the catches of herring by the bureau's seining crew were made from July 29 to the end of operation on the lake—September 11. In 1914 a single specimen was caught on May 12 and a few about the middle of June, after which they were taken more plentifully, particularly in the middle and latter part of July. (For dates, see Coker, 1914, p. 27.) The fish taken in Lake Pepin were noticeably smaller than those taken at Keokuk, suggesting that they were not escapements through the lock. Subsequently it was found that fish 4 to 6 inches in length could be taken in Lake Pepin, thus leading to the conclusion that breeding occurs in the upper river.

Kirsch (1892) collected six small examples of *Clupea chrysochloris*, Rafinesque, in the Wolf River near the mouth of Willis Creek, Clinton County, Ky. Garman (1890, p. 142) records the capture of small herring 2.62 inches in length in the vicinity of Quincy, 30 miles below the dam; but there is the possibility that these were young Ohio shad, for he so called them, although applying the scientific name of the river herring. Such records suggest that breeding occurs in regions south of Keokuk.

The river herring belongs to a group of fishes of very anadromous habit (including shad and alewives), and we were therefore uncertain as to whether or not extensive migrations were necessary for its propagation and distribution. Did it spawn in the upper waters and migrate southward? Could the stock of river herring be maintained in both the upper and the lower sections of the river while there was an effective barrier midway of the stream? The question of the maintenance of the fish in the portions of the river above and below the dam, respectively, ought, it seemed in 1926, 13 years after construction of the dam, to be answerable by further observations in Lake Pepin and at Keokuk and below.

There is no question that during the three years immediately following the construction of the dam there was a decided decline in numbers of fish appearing at Keokuk and in the numbers taken in Lake Pepin. The records of collections in Lake Pepin by our seining crew for the years 1914, 1915, and 1916 were as follows: 4,189 in 1914, 2,288 in 1915, and 42 in 1916. These observations led us to suppose that these fish were rapidly decreasing in numbers in the upper part of the river.

In August, 1926, the author witnessed several seine hauls in Lake Pepin, in each of which one or two river herring were taken. They were evidently not rare, relative to other fish, for, exclusive of gars and pickerel, not a tubful of fish was taken in any haul. Furthermore, it was the testimony of several commercial fishermen that "the herring were coming back," although all say that present abundance can not compare with that of a dozen or more years ago. It is an undoubted fact that in former times herring were often a nuisance to anglers fishing for pike in swift waters at the ends of wing dams, whereas in recent years a herring rarely takes the hook.

Herring are still taken by the seining crew at the Fairport (Iowa) station and are reported by commercial fishermen at various points on the river. At Keokuk and below at Warsaw, Ill., and Canton, Mo., herring were said to be as plentiful (in 1926) as ever and even more plentiful than before the dam was built. Many of the fish seen near the last-mentioned places may, of course, be headed for the Des Moines River, which enters the Mississippi only a little below the dam. The swift current of the Des Moines seems well adapted for the river herring, which is known to frequent it.

CONCLUSIONS REGARDING THE RIVER HERRING

These facts seem now reasonably clear: Just after the dam was placed, river herring, at the approach of the spawning time, gathered in enormous numbers just below the obstruction. These assemblages became less conspicuous in succeeding seasons (for 2 or 3 years) but are still observable after 13 years. During the first few years after the construction of the dam the herring in the upper part of the river rapidly declined in abundance until a relatively low point was reached. The stock, which has been in a depleted condition, has been maintained up to the date of most recent information (1926), when there was reported to be noticeable evidence of partial recovery. Even while the decline was most rapid, there was evidence of breeding in the upper part of the river in the numerous small herring taken in the bureau's seining operations in Lake Pepin. Breeding must also take place below Keokuk, since the herring appear at Keokuk in as great or greater numbers than were known before the dam was built 13 years previously. These facts would all comport with the supposition that the herring are extensively migratory but do not necessarily go to extreme northern or extreme southern waters, and that the breeding places from which the upper river was formerly chiefly stocked are no longer accessible to a great number of herring. The evidence points to the fact that one effect of the dam was to bring about a substantial diminution in the herring population of the upper river, and that this may account in part for the decline of the niggerhead mussel in the upper river.

Ohio shad. *Alosa ohiensis* Evermann

Almost nothing has been known about the indigenous shad of the Mississippi Basin. Although recognized by many fishermen, it was unknown to science until 1902, when it was described by Evermann (1902). It is, according to him, much longer and slenderer than either the Alabama or the Atlantic shad, females having the depth scarcely more than one-fourth the length, and the males being still more slender. Although a true shad, it is more herringlike in form; its specific distinctness, as compared with the Alabama shad, has, however, been questioned by Regan (1916). While we found the shad very common at Keokuk for a brief season, we know of no previously published record of its occurrence in the Mississippi. Our specimens and photographs were destroyed by fire in 1917. The illustration herewith is from a photograph of a preserved specimen; it will serve to enable one to distinguish the shad from the river herring. Note especially the form of the mouth and the shape of the cheek.

The Ohio shad in the Mississippi has no present economic value but must be treated as a potential asset, for Evermann (1902, p. 283) says that those who are familiar with the delicious Atlantic shad and who know how to prepare it find the Ohio shad not at all inferior; and Stringham, after many trials, concurred in that

opinion. It is comparatively small for a shad, not attaining a weight greater than about 2¾ pounds. A few have been handled commercially on the Ohio River.

Shad were marketed from that stream and its tributaries to the extent of 6,950 pounds in 1899 (Townsend, 1902) and 8,750 pounds in 1903 (U. S. Bureau of Fisheries, 1904). Since the average price in the latter year was 10 cents a pound to fishermen, it is evident that the fish were purchased for food rather than for bait. It is an interesting commentary upon the state of knowledge of our aquatic recources that while Federal and State governments in the eighth and ninth decades of the last century were making serious efforts to introduce the Atlantic shad into the Missisippi Basin the native shad remained generally unutilized and unknown. Evermann reported its use only as bait for catfish. Should it be utilized as a food fish, it would be necessary carefully to distinguish it from the river herring, a distinction that need offer no serious difficulty.

It was reported to Evermann that the fish was first taken about Louisville, Ky., in 1896, and that a great increase in the catch came in 1897 with the adoption of surface-fishing seines in lieu of the bottom-fishing seines previously used. Lightly leaded seines fishing in the upper few feet of water took Ohio shad along with spoonbill, the runs of the two species occurring at the same time, principally the latter part of May.

There were many Ohio shad at Keokuk in 1915, enough, it is believed, to support a substantial fishery. No effort was made to secure them, but Stringham examined more than a hundred that chanced to be taken and saw many more. In 1916 there were comparatively few, only 35 being handled by him. In the experimental net used on the top of the lock gate, the shad was taken more abundantly than any other fish except the river quillback and the spotted catfish.

All shad seen at Keokuk were taken during a short season extending from early in May to the middle or latter part of July—May 3 to July 12, 1915, and May 16 to June 25, 1916. Not one was seen at another season. All fish examined during these seasons were either sexually ripe or approaching that condition. It is evident that their presence at Keokuk coincides with a period of spawning migration. Whether they come from salt water in the Gulf, and how far north they would go—these are questions for answers to which there are no data.[13]

The fact that there are no records of the capture of this fish above the dam has no significance, because there were no records for the river at all before the dam was constructed. Locally the fish has been confused with other species, and such shad as were identified were assumed to be Atlantic shad introduced by the Federal Government. This applies to three specimens, numbered 21,345 among the collections of the National Museum, taken May 3, 1878, in the Ohio River. The experiment with the trammel net on the lock gate (Coker, 1929, p. 100), in which 45 Ohio shad were taken from the lower side, and only one from the upper, suggests strongly that the fish were endeavoring to pass the dam. If the fish occurs in West Virginia, as stated by Townsend (1902, p. 664), it is there at least 125 miles farther from the Gulf than at Keokuk. The Ohio shad came abundantly to the dam during spawning migration, and it is extremely improbable that the dam had chanced to be constructed precisely at the upper limit of the path of migration. We must assume, then, that the dam checks the upward course of the fish.

[13] At Lynxville, Wis., Mr. Kaya described a second kind of herring in such terms as to suggest the Ohio shad; the fish had formerly been taken in seines, not with hook and line.

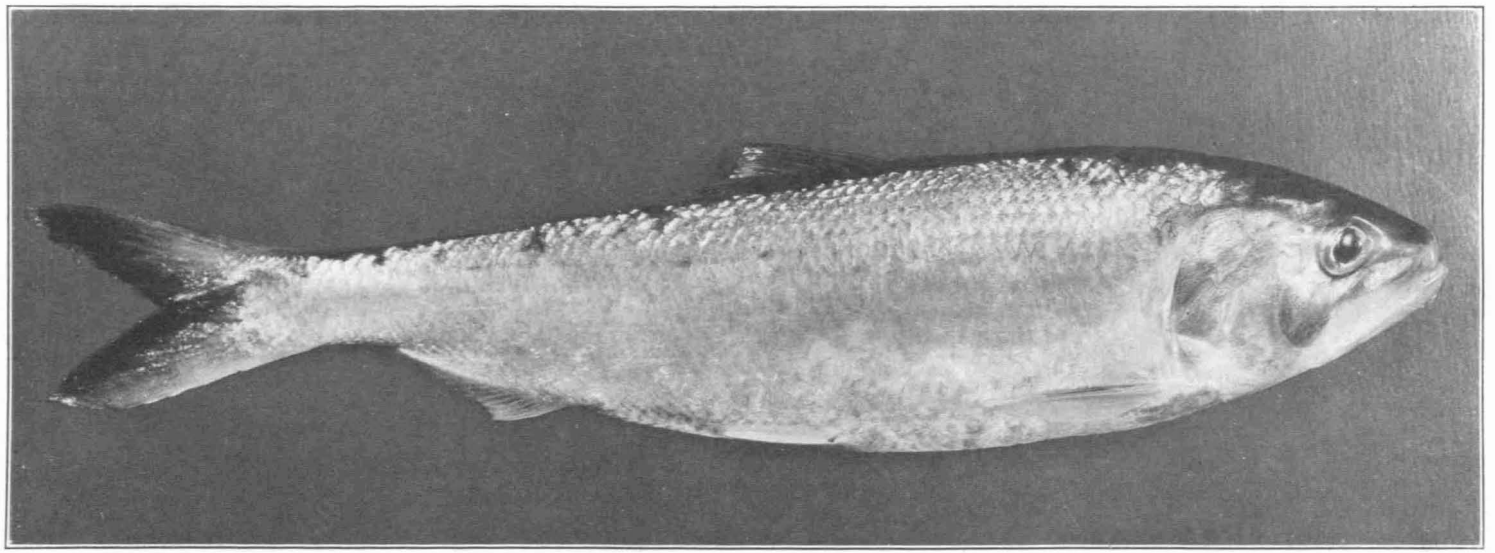

FIGURE 12.—Ohio shad, *Alosa ohiensis*. (From a preserved specimen)

Stringham examined the stomachs of 163 examples (118 in 1915 and 45 in 1916) at all dates of collection. Most of them were empty and none had more than an insignificant amount of food. The records for those containing any sort of materials follow:

TABLE 2

Date	Locality	Stomach contents
1915		
May 1–7	Canton, Mo.	4 examples containing traces of food, kind not determined.
May 15	Keokuk, Iowa	1 example, matter in alimentary canal not determined.
May 27	do	Do.
May 29	do	3 examples contained particles of matter, probably fragments of vegetation.
May 31	do	Several out of 36 specimens contained fragments, probably vegetation and insects. 1 contained the remains of a lady beetle; 1 a little piece of wood and unrecognizable insect débris; 1 plant remains and unrecognizable débris.
June 5	do	2 contained fragments of food.
June 6[1]	do	1 contained minute food remains.
1916		
May 23		2 contained remains in duodenum, including insect remains.
June 11		1 contained Hexagenia May-fly nymph in stomach.
June 14		1 contained particles of insect remains.
June 21		1 contained particles of Anisopteran dragon-fly nymph and plant remains in duodenum.
June 24		1 contained particles of plant remains in stomach.
Do.[2]		1 contained particles of plant remains in duodenum.

[1] Examination continued to July 12, with all stomachs found empty. [2] No examinations after June 25.

The records are significant. Of 163 examined, 105 were empty, if not more (record not complete for 36 specimens of May 31); 5, and a few of May 31, contained small quantities of food—recognizable insect remains; 6 had particles of plant materials; 1 had a piece of wood and unrecognizable débris; and one had plant hairs and unrecognizable débris. It may be inferred that the fish are not feeding when at Keokuk. It is known that fish, when under conditions where feeding is not a normal habit, do not altogether lose the instinct of snapping at objects in the water, and so may sometimes take into the alimentary canal living or dead material. The food records suggest a strongly anadromous habit for the Ohio shad. Clearly the life history and migrations of the fish offer a nice subject for study.

CONCLUSIONS

The Ohio shad, a fish not utilized at present but of great intrinsic value as a food, is strongly anadromous in habit. It visits Keokuk in May, June, and early July while in upstream migration to spawning grounds, but is stopped by the dam, save for a very few that may pass through the lock. The extent to which they formerly ascended beyond Keokuk is not known and may never be known. Apparently, it is not normally feeding when at Keokuk.

American eel. *Anguilla rostrata* Le Sueur

The eel, of course, is unique among our fresh-water fishes in spawning only in the sea. While not an anadromous fish, but the reverse, a catadromous species, there can be no argument as to the possibility of its continued existence above an impassable barrier. Our only question would be, first, whether the barrier is impassable for eels, and, second, whether the exclusion of the eel from the upper part of the basin is of any consequence.

As to the first question, the eel is so powerful and so rapid in movement, such an inveterate prowler, and so able to pass over places that are virtually closed to other

fish, that we can not readily dismiss the possibility that eels find their way beyond the dam, both in upward and downward migration. However, when we consider the physical condition of the dam at Keokuk (Coker, 1929) the very nicety and completeness of its construction, it becomes evident that there is no possible passageway upward except the lock, and that few can pass through this. Not one eel was taken in the trammel net operated on the lock gate, nor was one reported from the catches on the gate itself.

In the Mississippi River and its tributaries above the dam the eels that were there before the dam was constructed and the few that may pass through the lock may live and come to maturity, but without a better passageway than now exists there can not be an important eel population in that region. If, however, we examine the statistics of commercial fisheries we find that the eel has never been of commercial importance in the upper waters of the Mississippi. (Table 3.)

TABLE 3.—*Catch of eels, in pounds, in States bordering the Mississippi River in 1899, 1908, and 1922* [1]

State	1899	1908	1922	State	1899	1908	1922
Minnesota	900	800	540	Arkansas	3,702		0
Wisconsin	1,745	1,600	313	Kentucky	3,900	300	0
Iowa	10,943	5,400	0	Tennessee	14,180	3,100	578
Illinois	29,263	31,000	10,500	Mississippi	3,930	0	0
Missouri	6,456	17,000	3,000	Louisiana	1,670	0	0

[1] Data for 1899 from Townsend (1902); for 1908 from U. S. Bureau of the Census (1911); for 1922 from Sette (1925).

It is evident from these figures that the yield of eels in past years has been greatest neither in the extreme lower portion of the Mississippi River nor in the upper portion but in the middle section where the river flows between Illinois and Iowa, Missouri, and Tennessee. The catches in Minnesota and Wisconsin have never been significant. We are only surprised that 10 and even 15 years after the construction of the dam eels should be taken at all in the extreme Northern States. However, it is understood that eels may remain in fresh water for as much as 18 years. It must be understood that there is no special eel fishery with appropriate apparatus, and, therefore, that even a small catch suggests that eels are not uncommon.

In 1926 the author inquired regarding eels of fishermen at various points on the river from Lake City, Minn., to Canton, Mo. At all places it was reported that eels are still captured occasionally—two or three a year, perhaps. Only one fisherman above Keokuk spoke of seeing small eels in recent years. Eels taken in the lake and above are usually 3 pounds or more in weight, up to 7 pounds.

On the other hand, below the dam, at Keokuk, small eels are reported as taken commonly. Market reports were that many were too small to buy. The smallest seen by the author was at Canton, Mo.; it weighed 9 ounces in the rough. Luther McAdams, a careful observer, said that in the fall of 1925 he observed and caught large numbers of eels about the size of a lead pencil. They were on the apron of the dam below a closed spillway and were trying to follow up a small stream that came from a leak in the gate above. They would work up the face of the spillway 3 or 4 feet and fall back again. He gathered about a half bushel of them. William Stanton, a fish dealer, said that a diver had reported to him the presence of enormous numbers of small eels in the lower part of the drift chamber below a turbine. If such aggregation

of eels can be found each year, it would be desirable to collect the small eels and transfer them to the waters above, so that they might continue in migration.

If the dam at Keokuk is an effective barrier, as we suppose, eels should in time cease to be found in Minnesota and Wisconsin and in Iowa, except in the Des Moines and Missouri River systems, and in Illinois in a little more than one-third of the Mississippi bordering Illinois and the tributaries of that portion.

Unfortunately, it appears that future statistics of the eel fishery will be of little significance with reference to the effect of the dam, for the reason that the eel is evidently rapidly and steadily disappearing from the whole basin. This is a fact that arrests our attention, particularly because it can not be attributed to any obvious cause. The fishery for eels has been so small that we can hardly suppose it to have had a material effect. The steady decline of the eel fishery in the Mississippi and tributaries is indicated in the following table:

TABLE 4.—*Eels taken in the fisheries of the Mississippi River and tributaries for various years*

Year	Pounds [1]	Percentage of decrease	Period since last survey, years	Year	Pounds [1]	Percentage of decrease	Period since last survey, years
1894	133,223			1908	61,000	17.8	5
1899	93,905	29.5	5	1922	16,060	73.7	14
1903	74,210	29.7	4				

[1] Figures from Sette (1925, p. 211).

The decline in catch is so regular and has extended so far that one might suppose that the next two or three decades would witness the complete disappearance of eels from the basin.

SUMMARY

The eel is stopped in upward migration by the dam at Keokuk and must virtually disappear from the river and its tributaries above the dam. However, the eel has never been of commercial importance in the upper part of the basin. Furthermore, for at least 30 years the eel has been steadily disappearing from the whole basin, so that without a change of trend it will soon cease to count as a natural resource of the region.[14] There is suggested the possibility of rescuing young eels collected at the base of the dam and passing them over in baskets.

THE CATFISHES (Siluridæ)

The catfishes rank next to the buffalo fishes and carp in commercial importance. In 1922 the product from the Mississippi Basin alone (Atchafalaya River included) was valued at nearly $750,000. Of about half a dozen species found at and near Keokuk three were present in substantial numbers. One or more of the bullheads (Ameiurus) are probably abundant in quiet waters but are uncommon in the river. As with the buffalo fishes, all kinds of catfishes are lumped together in statistical reports, so that it is impossible to apply the returns in the consideration of individual species. We may first see, however, what has been the general trend of the fishery during the past 30 years, as shown by the figures assembled by Sette (1925, p. 209),

[14] For possible future reference it may be recorded that during the four months from May to August, inclusive, 1916, there were handled by the markets at Burlington about 125 eels and by the markets at Fort Madison (principally in June) about 700 eels. Only one or two dozen were handled by dealers at Warsaw, Ill., and Alexandria, Mo., during the three summer months of 1916.

showing the yield of catfish from commercial fisheries of the Misisssippi River and tributaries, not including the Atchafalaya River.

	Pounds
1894	9, 689, 034
1898	7, 648, 179
1903	5, 191, 850
1908	8, 073, 000
1922	6, 263, 025

The fishery has evidently been fairly uniform; the fluctuations during a long period as shown by these figures, are not striking, except perhaps for the low point reached in 1903.

Fulton cat. *Ictalurus furcatus* (Le Sueur)

BLUE CAT; CHUCKLEHEAD CAT

Locally known by the distinctive name of Fulton cat, this species is the largest of the Mississippi River catfishes.[15] In fact, among all the food fishes it is rivaled in

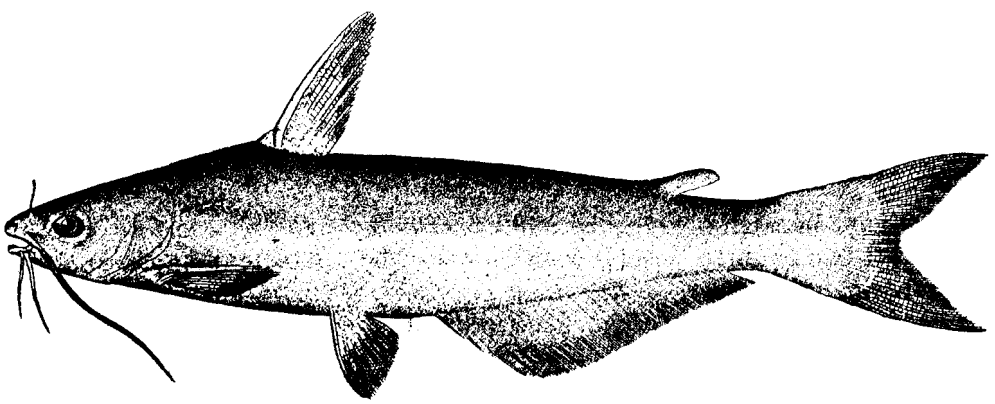

FIGURE 13.—Fulton catfish, *Ictalurus furcatus*

size only by the paddlefish and lake sturgeon, and large examples of these are not now common. It sustains an important fishery in the south (Evermann, 1899, p. 305), where it is most abundant, but many were taken in the vicinity of Keokuk during 1915 and 1916, the latter year being reported by fishermen as the best they could remember for Fulton cats. According to Forbes and Richardson (1908), it frequents the deeper waters of the river channels, coming out into the shallow sloughs and backwaters in spring. Some fishermen say that it prefers rocky bottoms. On June 1, 1915, in the slack water of a creek near Keokuk, three large Fulton catfish were taken in nets along with the buffalo fishes subsequently to be mentioned, the largest having a total length of 30 inches (76 centimeters).

This catfish is reported to breed in Louisiana. (Evermann, 1899, p. 294.) The observations made by Stringham indicate that it breeds near Keokuk, probably about June. On June 10, 1915, there were seen at Canton, Mo., 20 miles below Keokuk, three Fulton catfish with eggs nearly or quite ripe and another with small eggs, possibly

[15] Evermann (1902) says: "I have been told that one was taken weighing 185 pounds, and another 250 pounds." Forbes and Richardson (1908) say: "It grows to a great size, specimens weighing as much as 150 pounds being occasionally caught, although the average size of the larger ones is only 15 to 20 pounds." Meek (1890), speaking of *Ameiurus nigricans*, a name formerly but erroneously applied to large examples of the Fulton cat, spoke of it as the largest catfish found in Iowa and said that examples weighing 200 pounds were reported to have been taken in past years, but that, about 1890, it seldom attained a weight of 60 pounds. He added that in Iowa the fish was known only from the Mississippi River.

a spent fish. In 1916 eggs about mature were received from Luther McAdams, who had obtained them from six large Fulton catfish purchased June 17 near Alexandria, Mo. The eggs attain a diameter of 2.5 millimeters. The species is not known to breed north of Keokuk, nor is there even a definite record of its occurrence north of that point; [16] but the absence of records signifies little, since the fishes of the Mississippi River have been little studied. Confusion arises from the fact that the spotted cat in a certain phase is frequently called Fulton or blue Fulton. At Keokuk, however, commercial fishermen and dealers usually distinguish the species correctly.

From the best information obtainable, Fulton catfish were always rare in the vicinity of Muscatine and Fairport, Iowa, but, before the construction of the dam they were not uncommon at Keithsburg, Ill., and were seasonally abundant in the old rapids just above Keokuk. Mr. Kaya, at Lynxville, Wis., stated that he had seen rare examples in that vicinity. Evidently the rapids at Keokuk marked the normal upper limit of range in the Mississippi River for most of the fish of this species.

In 1916, the banner year for Fulton catfish at Keokuk, the unusual abundance was quite local, not extending even to Canton, 20 miles down the river. Examples were seen by Stringham each month from May to September, the earliest record being May 2, 1915, and the latest September 15, 1916; but Trumer Jackson, of Warsaw, Ill., had one on April 23, 1915, and again two in October of the same year. Diligent inquiry among fishermen failed to elicit a single report of the Fulton cat having ever been taken locally in winter, and, as the fish is highly esteemed it would almost certainly be captured sometimes, and remembered, if it were present.

According to information received in 1926, Fulton catfish are still commonly taken in the river just below Keokuk, especially in the latter part of May and in June and July. Only rarely is one ever taken northward of the dam near Montrose or above. It likes rocky bottoms, so that the rapids was a favorite haunt before the dam intercepted the passage way from the south to the rapids. The author obtained a freshly caught specimen at Warsaw, Ill., on August 24, 1926.

The principal apparatus of capture at Keokuk is the set line, operated anywhere in the river. From Keokuk, southward, they were taken by "jugging," short lines being attached to floats or jugs, which are watched from small boats as they float down the river. In 1926 that practice was said to have been discontinued except as a mode of sport fishing. They are now taken in floating trammel nets, but occasionally a Fulton is found in a fyke net.

The indications, then, are that Keokuk is near but not quite at the northern limit of the summer range of the Fulton cat, and that, if not checked by the dam, they might still proceed a little farther north. It is thought that in the vicinity of Keokuk the fish breed in June.

Spotted cat. *Ictalurus punctatus* (Rafinesque)

CHANNEL CAT; FIDDLER

The spotted cat, the most widely distributed and most generally esteemed of all catfishes, is commonly known in the Mississippi when small as "fiddler," and when large as channel cat. Some are also called, unfortunately, blue Fultons, the form of the blue Fulton being said to be intermediate between fiddlers and channel cats.

This catfish occurs throughout the Mississippi Valley and the Gulf and Great Lakes regions. Its range extends from Florida and northern Mexico to Ontario and

[16] Meek (1890, p. 70) refers to it as not common in Iowa, and found only in the larger rivers.

Winnipeg; it has been successfully acclimatized in the Potomac River. Relatively small, finely flavored, attractive in appearance, trim and gamey, it is esteemed by anglers as well as by commercial fishermen. It rarely exceeds 5 pounds in weight, though it may attain a weight of 10 pounds or even, according to Forbes and Richardson, 15 or 20 pounds. It is the species of catfish principally taken at Keokuk. Although individually smaller than either the Fulton cat or the goujon, it is so much more numerous that it constitutes the bulk of the total catch of catfish. It is the predominant catfish in all sections of the river from Canton, Mo., to Lake City, Minn.

There is no reason to suppose that the breeding of spotted cat is geographically localized. The fish was bred at Washington, D. C. (U. S. Commissioner of Fisheries, 1894, p. xxxix; Worth, 1895, p. 96; U. S. Commissioner of Fisheries, 1912, p. 17), and in ponds at the Fairport (Iowa) station (Shira, 1917 and 1917b). There are also reports of breeding in Kansas (Wampler, 1895, p. 10), but in this case the identification of the species was not confirmed. Although there are general statements in the literature regarding the breeding of spotted cats, we know of no recorded obser-

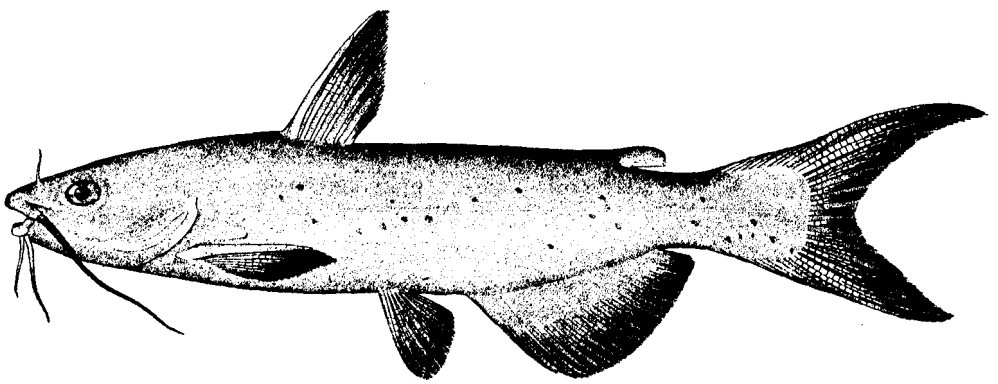

FIGURE 14.—Spotted catfish, *Ictalurus punctatus*

vations of breeding in nature. Examples containing large eggs have been collected at Fairport, and young were taken near Homer, Minn., in 1916, by Superintendent D. C. Booth of the United States Bureau of Fisheries. The observations at Keokuk that bear upon the breeding season were as follows: One fish with eggs in an advanced condition taken on set line near the power house, July 2, 1915; three with eggs in advanced condition seen in a market at Fort Madison, Iowa, June 2, 1916; two that seemed to have spawned recently seen in the Warsaw market, July 26, 1916; six examples in similar condition seen at Keokuk, August 1, 1916. Small fish, probably yearlings, were taken near Keokuk on several occasions.

The author in 1914 initiated experiments at Fairport in the pond culture of this species. Prompted by a chance observation of the nest of a catfish of another species found in an old pitcher in a lake in Michigan, he had 66 brood fish placed in a small pond having pieces of tile drain and nail kegs half buried in its banks below the water level. The water was roily much of the time and no signs of the fish were seen, but when the pond was drained in the fall nine young were obtained. The experiment was repeated the following year with almost identical result, seven young catfish 4 to 8 inches long being found in addition to the brood stock. It was evident that breeding had occurred each year, but the young had largely disappeared, probably devoured

by the predacious older fish. In the following year (the experiment being then under the supervision of A. F. Shira and H. L. Canfield), 34 fish, including some of the original brood stock, were placed in a larger pond similarly equipped with nesting places. Again no signs of spawning could be seen from the banks, but early in July the pond was slowly drained, and on July 6, when the greater part of the bottom was exposed, Superintendent Canfield saw a catfish of 3 or 4 pounds weight with a school of fry near by. Further examination showed that there were still fry in one of the kegs, and in another a glutinous mass of eggs adhering to the lower side of the keg, the individual eggs averaging 3.53 millimeters (about 0.14 inch) in diameter. It was found possible to hatch the eggs and to rear the young in ponds. After that time the experiment was repeated many times and with general success, except that the number of nests occupied and the number of young obtained was disproportionately small relative to the number of available breeders. The channel catfish, however, is not supposed to be primarily adapted to life in small ponds. Nevertheless, the experiments established the practicability of the propagation of spotted catfish under artificial conditions.

In 1926 the testimony was universal that channel catfish had greatly increased in abundance in the river above the dam, from Keokuk to Oquakwa at least. The evidence of the statistical surveys, referring to all species of catfish, is to the same effect.

The channel catfish, as its popular name implies, likes swiftly flowing water but is not restricted to regions of strong current. It is very common, for example, in Lake Pepin. It must have migratory habits at one or another stage of its life, for, in the words of Forbes and Richardson (1908), "the young of this species have * * * a much wider range than the adults and are frequently abundant in headwater streams and creeks, in which full-grown individuals are never taken."

Spotted catfish are taken in all parts of the river about Keokuk and by nearly or quite every kind of tackle used. Examples were seen in each month except November and December, and it is believed that they are present all the year. While the fish are evidently nomadic, there was found no evidence of migratory movements such as would be significantly hampered by the dam.

Niggerlip. *Ictalurus anguilla* Evermann and Kendall

PONEHEAD

The niggerlip catfish, or ponehead, well known to fishermen throughout the greater part of the course of the river, has proven somewhat elusive to the student of fishes. It is so evidently different in appearance from any other catfish as to be readily recognizable to the uninitiated. On the other hand, it conforms in so many diagnostic characters to the spotted catfish as to be puzzling to the scientific analyst. Externally viewed, it differs from the latter fish chiefly in proportions, in color, and in appearance of the integument—characters that are manifestly difficult of strict definition; as yet there are no adequate expressions of the variable proportions of either *punctatus* or *anguilla*, and both species undoubtedly manifest different proportions and peculiarities of appearance at different ages and perhaps at different seasons.

Stringham encountered no examples of the niggerlip at Keokuk, unless they were the fish locally and inappropriately called "bullheads," which were thought to be a phase of the variable channel catfish. Forbes and Richardson (1908) associate the

name "niggerlip" at Grafton and Alton with the species *anguilla*. In 1926 the author obtained specimens of niggerlip at Dallas City, Ill., taken in the lake, and at Canton, Mo., below the dam. A positive identification did not seem possible on the basis of the published descriptions and the limited amount of material available, but the fish were provisionally assigned to the species *Ictalurus anguilla* Evermann and Kendall, known in Louisiana as "eel cat" or "willow cat." A difficulty in identification arises from the fact that, with both *punctatus* and *anguilla*, the proportions vary markedly with age. Several of the probably diagnostic ratios of dimensions of niggerlip catfish 60 centimeters in length were found to agree closely with corresponding ratios for spotted catfish 30 centimeters long, although distinctly different from those of spotted catfish 56 centimeters in length. A careful study of channel catfish and niggerlip catfish at all sizes not only would serve to clear up doubts as to the identity of the latter fish but would also make a valuable contribution to the systematics of American catfishes. In almost any locality fishermen distinguish three phases of the

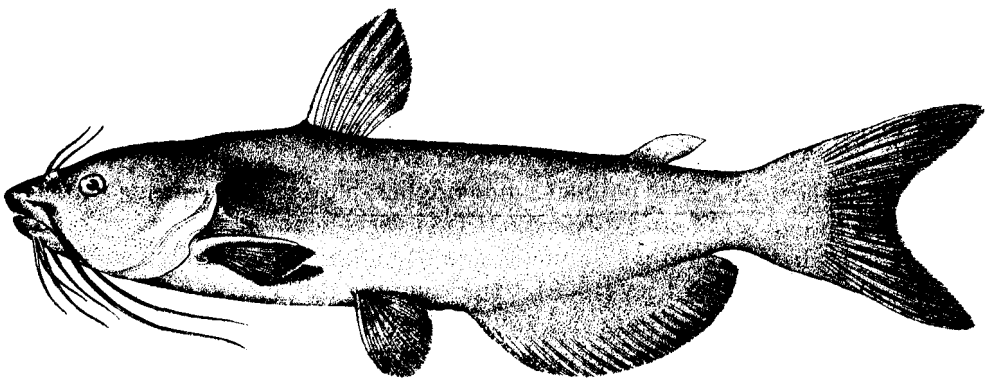

FIGURE 15.—Eel cat, willow cat (niggerlip?), *Ictalurus anguilla*

spotted catfish, as previously mentioned. Some distinguish two forms of niggerlip, but distinction by name was not heard.

As compared with the spotted catfish, size for size, the niggerlip, as known from our examples, has a larger and more prominent head with shorter chin barbels, the teeth on lower jaw extend back in longer and more tapering bands, the head is more fleshy, the body is decidedly slenderer behind, the color is blackish without spots, and the skin is conspicuously slimy in contrast to the usually clean integument of the channel catfish. The flesh is regarded as very inferior in quality to that of the highly esteemed channel catfish, although the local markets, at least, commonly take catfish as "catfish" without distinction in price.

The species has been identified so rarely that statements regarding its habits and abundance must be based exclusively upon the reports of commercial fishermen. A notable feature of the niggerlip fishery is its very brief seasonal duration—they are said to be taken in quantity only in June, or a little earlier toward the south, when they enter dark traps in great numbers; box traps are more effective in capture than net traps. The month of June is supposed to be the season of breeding, when the fish are running in schools. One informant said that he had seen the fish nesting in hollow logs about sawmills. At other seasons than early summer the fish are thought to be widely scattered over rough bottoms and therefore rarely caught. The specimens obtained by the author were taken in the last week of August. Presumably the niggerlips are

very vigorous fighters, for fishermen claim that they are "hard on set lines," escaping readily and doing damage to the lines.

The fish is not large, as compared with the Fulton or the yellow cat, having about the same range of sizes as the spotted cat (attaining a weight of 15 pounds). Its abundance in season makes it of distinct value to the fishermen, although, because of its slimy and emaciated appearance, it it not usually spoken of with respect.

At Lynxville, Wis., a June run of niggerlip is customary, but, like other fishes in that part of the river, it has recently appeared in less abundance than in former years. In the vicinity of Keokuk, above the dam and possibly below it also, niggerlip catfish are reported to be more abundant now than formerly.

Flathead. *Leptops olivaris* (Rafinesque)

GOUJON; YELLOW CAT; HOOSIER

This large catfish has goujon for its distinctive local name, while it shares with the other species the names of "mud cat" and "yellow cat." It attains nearly as great a size as the Fulton cat [17] and is as common or commoner at Keokuk. Unlike the Fulton

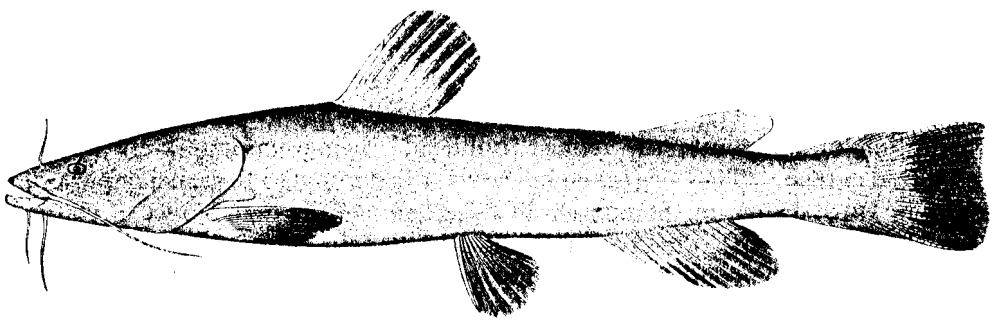

FIGURE 16.—Goujon, flathead, hoosier, or yellow catfish, *Leptops olivaris*

cat, it is taken regularly northward of that point, as far as Lake Pepin, at least. It was observed at or near Keokuk each month, except January, November, and December, but fishermen report that it is captured all during the winter. It is taken in traps but probably more frequently on set lines, and live bait is best. The fall of the year is considered the best season for "hoosiers." The flathead is described as a strong and quick fish and very predaceous, roaming in the channels but preferring the more sluggish waters. It is likely to be found about garbage dumps and the mouths of sewers, being perhaps attracted to such places by the opportunity to feed upon smaller fish of scavenger habit. It is highly esteemed as a food fish.

The goujon breeds in Louisiana and probably somewhat later than the Fulton cat. (Evermann, 1899, p. 296–298.) In 1915 two examples that were ripe or nearly so were taken in the lake within a few miles of the dam, on July 19 and 24, respectively. Nine others, examined at various places and between May 30 and June 15, contained large eggs. On June 2, 1916, eight females with well-developed eggs were seen in a market at Fort Madison, Iowa, and on June 29 one nearly or quite ready to spawn was taken in the lake near Keokuk.

[17] "This fish frequently reaches a weight of 50 to 75 pounds and is said by Doctor Evermann occasionally to weigh as much as a hundred pounds." (Forbes and Richardson, 1908.) Limits of maximum weight as given by various fishermen vary from 70 to 85 pounds.

Large goujons are taken in the lake above the dam. Some distance north of the lake, at New Boston, Ill., a pretty catch of 14 was made on September 5, 1916, the fish ranging in total length from 57 to 89 centimeters (22.5 to 35 inches.) It is said to be found in all suitable waters throughout the Mississippi Valley as well as in the Gulf States, being most abundant in the lower courses of larger streams. It is known as a fish of rivers rather than of sloughs and isolated lakes, but is associated with sluggish waters rather than with swift current. In 1890 Meek reported that it was less common in the Mississippi than in former years.

Unlike the Fulton cat, the goujon gives no sign of such a migratory habit as would be significantly affected by a barrier across the Mississippi River. In 1926 reports received at Montrose and Keokuk were to the effect that the goujon was increasing in numbers in the lake; while at Dallas City, across the lake, and at Burlington, near its upper limit, it was alleged that this catfish, especially in the larger sizes, was becoming increasingly scarce. Above the lake the species is apparently maintaining itself, except in the region of Lake Pepin and below to Lynxville, where it is reported to have declined in recent years. The yellow cat was never abundant in that region.

Other species of the family observed at Keokuk were the little stone cat, *Noturus flavus* (Rafinesque), of which a single example was taken from the stomach of a sauger on the lock gate; the yellow bullhead, *Ameiurus natalis* (Le Sueur), taken in Larry Creek and in Keokuk Lake just above the lock; and the black bullhead, *Ameiurus melas* (Rafinesque). The last mentioned is locally known as the "bullpouch" (a corruption of bullpout), the name "bullhead" being unfortunately applied to large spotted catfish. They are taken in the river from time to time, being particularly common in 1916, owing, in the opinion of fishermen, to the high stages of water connecting the sloughs with the river. While addicted to "deep and muddy streams with slowly moving current," it seems not to occur abundantly in the larger rivers. (Call, 1892; Forbes and Richardson, 1908.) An example taken near Warsaw, Ill., on April 7 was 12.5 inches in total length and weighed a pound. Its stomach contents consisted of centipede (10 per cent), May-fly nymphs (Hexagenia, 80 per cent), and débris (10 per cent).

COMMERCIAL FISHERY FOR CATFISHES

The seasonal abundance of catfishes in the region of Keokuk, as reflected by the reports of the local markets gathered by Stringham, is shown in Figure 17. It is evident that the periods of greatest catch of catfish did not coincide with the spawning season, which is in June and July, but rather began when that season was half over and continued for about six weeks. The only known factor that changed synchronously with the rise and decline of the fishery was the temperature of the water, which first passed 71° F. (21.5° C.) on June 25, rose until July 30, and then declined. In this connection, reference may be made to Evermann's report (1889, p. 292) that in Louisiana there is little fishing for catfish in summer (beginning in May) when the fish are supposed to run farther upstream or to retire to deeper water.

An increasing abundance of catfish in Lake Keokuk is well attested, by the market reports obtained by Stringham in 1916 and by the statistical surveys. (Coker, 1929.) The market receipts of catfish in summer at certain points on the lake are given in the following table, in which comparison is made with the total receipts at the same points for the whole year of 1914, the figures for that year being obtained from manuscript sheets of statistical agents conducting the survey for 1914:

TABLE 5.—*Market receipts of catfish*

Markets	1914, whole year	1916, summer months
	Pounds	*Pounds*
Montrose, Iowa (and Nauvvo in 1914)	4,800	9,000
Fort Madison, Iowa	6,900	25,400
Burlington, Iowa	11,130	7,200

The growth of the fishery, as evidenced by the reports of the statistical survey conducted by the bureau, is very pronounced—from 72,000 pounds in 1914 to 110,000 in 1917, 184,000 in 1922, and 140,000 in 1927. In Lake Pepin there was a very

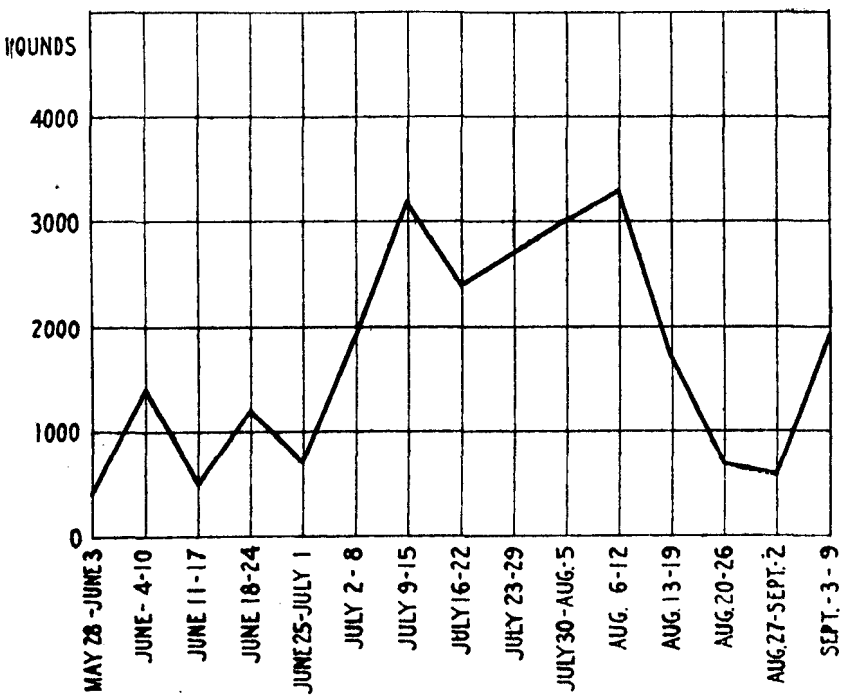

FIGURE 17.—Quantities of catfishes taken near Keokuk, Iowa, by weeks, May 27 to September 9, 1916

marked increase in yield from 1914 (27,000 pounds) to 1917 (254,000 pounds), but a reduced yield in 1922 (127,000 pounds), and a still smaller yield in 1927 (53,000 pounds). The catches in the three years last mentioned were, however, much greater than in 1914. In reference to the catch reported for 1927, it must be considered that a new factor, apparently pollution, had come to have a markedly disastrous effect upon nearly all fishes of the region of Lake Pepin.

SUMMARY AND CONCLUSIONS REGARDING CATFISHES

The catfishes are among the most valuable of the commercial fishes of the region of the Keokuk and of the Mississippi Basin generally. Three of the four important species of the river evidently breed both north and south of Keokuk and are not adversely affected by the dam. The Fulton catfish finds the dam near the limit of its range and is prevented from passing northward; but it is probable that it never extended northward of this point in substantial numbers.

No evidence was found of special abundance of catfishes at Keokuk before or during the early part of the breeding season, such as would be expected if they engaged in extensive northward migrations for purposes of spawning. It is probable that they tend to move upstream during warm weather in compensation for downstream drifting in cold weather.

The great increase in the yield of catfish from the lake apparently applies chiefly to the channel cat and the niggerlip. Reports regarding the flathead in the lake are not consistent. At any rate, the fishery for catfishes in Lake Keokuk showed marked and consistent development up to 1922, at least. Oral reports in 1926 indicate a continued upward trend for catfish in the lake, but this was not evident from the statistical report for 1927.

THE SUCKERS (Catostomidæ)

One of the most striking characteristics of the fish fauna of the whole Mississippi Valley, as Forbes and Richardson (1908) remark, is the prominence of the sucker family; and these fishes offer us one of the most difficult of problems, for the very reasons of their abundance and importance and their variety of kinds, together with the lack of distinctions between species in all statistical reports. In such statements the sucker fishes are lumped under two categories—"suckers" (covering probably a half dozen genera) and "buffalo fishes" (covering 3 species of one genus). Excluding buffalo fishes of the genus Ictiobus, we might find in the vicinity of Keokuk the blue sucker (Cycleptus, 1 species), the carp suckers (Carpiodes, 4 species), the chub sucker (Erimyzon, 1 species), the spotted sucker (Minytrema, 1 species), the fine-scaled suckers (Catostomus, 3 species), the redhorse (Moxostoma, 3 species), the pavement-toothed redhorse (Placopharynx, 1 species), and the rabbit-mouth sucker (Lagochila, 1 species). Some would be rare, if present; but of these 15 species possibly 4 or more may be of significance, and 10 were actually observed near Keokuk.

Blue sucker. *Cycleptus elongatus* (Le Sueur)

BLUEFISH; MISSOURI SUCKER

The blue sucker, the only species of its genus, is distinctive in appearance and habits, estimable for its qualities as a food fish, and in the past, at least, abundant enough to be caught in quantity at certain seasons. Its characteristic appearance, with strikingly reduced head, is well shown in the accompanying illustration. In distribution it seems to be largely restricted to two or three of the greater streams of the Mississippi Basin, in which it has been taken most abundantly in regions of swift water. It is generally rated, where known, as the best of the suckers. As to its past abundance, we have, on the one hand, the statement of Forbes and Richardson (1908, p. 66) that it "is not common in the Mississippi above the latitude of Quincy," and the remark of Meek (1890, p. 72) that it was not common in Iowa; we have, on the other hand, the oral reports of fisherman at many points on the Mississippi, as far north as Wisconsin, that until 10 or 15 years ago there were important spring runs and lesser fall runs of blue suckers. There is no occasion for surprise at the conflict of reports if it is borne in mind that it was the habit of the blue sucker to assemble in considerable numbers only for brief seasons and in the swiftest waters of the river, where, in the absence of effective protective legislation, it was comparatively easy to take them; while in other seasons they had retired to places unknown, probably the deeper parts of the river, from which they were taken only occasionally. The fish could, therefore, be known to commercial fisher-

men as abundant while regarded by scientific collectors as rare, unless by chance the collections happened to be made at the right season and in the right place. According to Forbes and Richardson (1908) it was reported to be abundant at Pittsburgh, far up the Ohio River.

At Keokuk, although few examples were seen during 1915 and 1916, one or more were observed in each month (except March) from February to September, inclusive. Only the market at Warsaw then handled more than an occasional sucker. Mr. Jackson, the proprietor of that market, said he had received as much as 500 pounds at one time during the winter of 1915–16; that he had about 500 pounds during the first half of June, 1916, about a dozen fish from then to September, and about 200 pounds in the first week of September. In former times, according to Mr. Jackson, speaking in 1926, blue suckers could be taken all the winter in the deep water below the rapids.

The blue sucker attains a length of about 30 inches and a weight of 15 pounds (or, as some say, of 25 pounds). It may be caught on set lines, in fyke nets, or in seines;

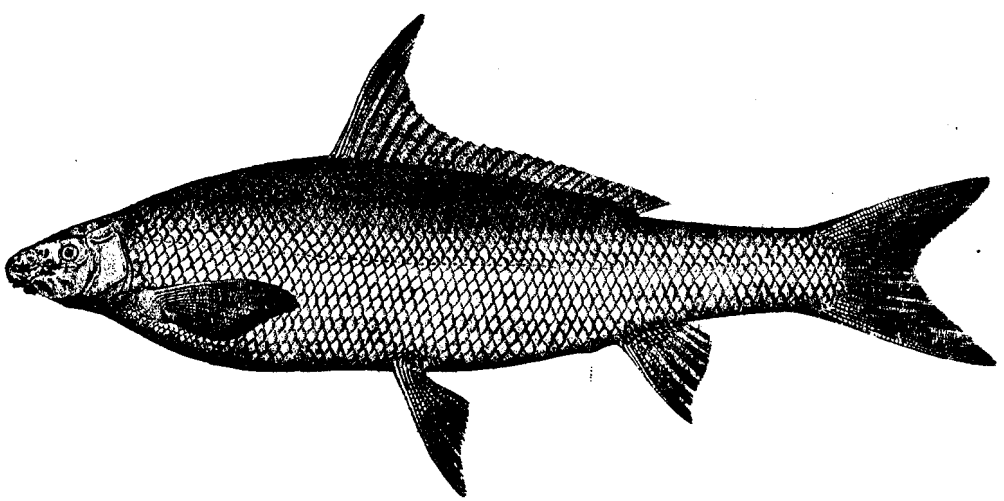

FIGURE 18.—Blue sucker or bluefish, *Cycleptus elongatus*

a favorite method of capture during the spawning migration was with the use of floating trammel nets drifted at night over the rapids; catches (with the trammel net) of 800 or 900 pounds in a night are mentioned.

Eggs are said to be deposited in May and June. (Forbes and Richardson, 1908.) Shira (1917a) mentions successful experiments in the hatching of eggs of the blue sucker at Fairport.

There was, in 1926, almost complete unanimity of opinion among fisherman as to the virtual disappearance of this fish from the upper river, although reports differ as to the manner of disappearance—whether it was gradual or sudden. It seems clear that in the region above the dam the blue sucker is only a memory. In all this region, which includes places where the fish once appeared seasonally in significant runs, practically no fisherman was encountered who reported the appearance now of more than two or three blue suckers each year.

That suckers, exclusive of buffalo fishes, have for long been of declining importance in the commercial fishery of the Mississippi Basin is indicated by the following figures from reports of statistical surveys, compiled by Sette (1925, p. 209) to show

the production of suckers from commercial fisheries of the Mississippi River and tributaries for various years.

	Pounds
1894	2, 178, 608
1899	2, 243, 934
1903	1, 109, 276
1908	892, 000
1922	699, 539

Since the general decline was more marked between 1899 and 1903 and again between 1903 and 1908 than in the longer period between 1908 and 1922, the dam built in 1913 can not be held primarily accountable for the general depreciation of the sucker fishery. As regards Lake Pepin, the yield was little less in 1917 than in 1914 but much greater in 1922. (See Table 7, Coker, 1929.) In Lake Keokuk, however, the small sucker fishery of 1914 (4,640 pounds) had almost disappeared in 1917 (700 pounds) and was not found at all in 1922. This local decline is very likely due to the changed conditions in the area covered by the lake, but its significance does not seem great.

At first thought it would seem clear that the dam has been responsible for the loss of the blue sucker from the upper river, either directly, by preventing the upward passage of fish from the lower river, or indirectly, by destroying favored schooling and breeding grounds in the rapids. Against this conclusion it may be argued that the blue sucker has largely disappeared from the lower river as well. This is a question of fact that should be determined more definitely. The limited information that we have regarding the river far below Keokuk points to that conclusion. We know that the fish is no longer common in the river from Keokuk to Canton, well below the dam. It is decidedly important that its occurrence in the Mississippi and its tributaries far below Keokuk should be investigated carefully.

River quillback. *Carpiodes carpio* (Rafinesque)

CARP SUCKER; SILVER CARP

While other carp suckers or quillbacks are occasionally found at Keokuk, the "river quillback" (*carpio*) is the only species constituting a notable fishery product. Forbes and Richardson (1908) report that the blunt-nosed carp sucker (*difformis*), common throughout Illinois, prefers the shallow waters of small streams; another species (*velifer*) is most abundant in northern Illinois; and the fourth species (*thompsoni*) is characteristic of the Great Lakes region.[18]

The river quillback is small and of minor value as a food fish. Forbes and Richardson (1908) say, regarding this species (*C. carpio*): "It is said by Mississippi River fishermen sometimes to reach a weight of 10 pounds. It is sold for food, but is flavorless and soft." In summer it is shipped irregularly from Keokuk, being said to keep badly in warm weather; in winter it constitutes a low-priced fishery product. Some fishermen say that other fish will not eat the river quillback, and it is a fact that they have not been found in stomachs of other fish during the present investigation. Forbes (1888a, p. 480) found them in the food of other fishes, but to what extent does not appear. The explanation of their not being found as food fishes at Keokuk may lie in the fact that the stomachs examined were from fish collected in the river, where young quillback are rarely found. In the fall of 1916 some were found along the

[18] Call (1892) says of *C. velifer*: "This is, beyond doubt, the most abundant of the buffalo fishes [sic] in Iowa." He also says that it is found in rather deep but muddy waters, which is not in agreement with the observations of some others.

Illinois shore between Hamilton and Warsaw, but young were not taken in the river at any other time, although they occurred in several of the few collections that were made from creeks.

The river quillback was extremely common at Keokuk. As reported in a previous paper (Coker, 1929), it constituted 48 per cent of all fish taken in the trammel net operated on the lock gate in 1915. Its general abundance relative to other species was certainly not as high as might seem indicated by that figure, but it is believed to have been the commonest fish about Keokuk in that year, except possibly one or two minnows.

In 1916 the German carp and short-nosed gar were present in greater numbers than the year before, but the quillback was still very abundant, constituting 42 per cent of the product of 34 catches that chanced to be observed. Again the per-

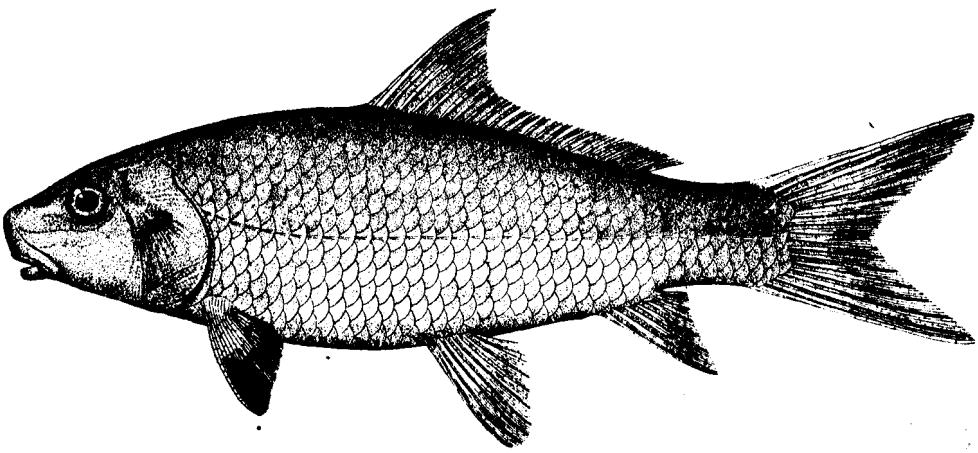

FIGURE 19.—River quillback or carp sucker, *Carpiodes carpio*

centage figure is probably somewhat misleading, but it is believed that the quillback was exceeded in numbers by no large species except the German carp.

The habits of the fish seem to be unknown. It was found everywhere about the plant as well as in other localities, but never in any aggregation suggesting an interference with migratory movement. Examples were noted each month except December, during which no observations have been made. It appears to be unharmed by the dam.

In some localities fishermen distinguish "white carp" (*carpio*) and "quillback," in others "quillback" and "spearback," but the applications of the names to the respective species is not clear and is probably much confused. It is evident that there is a carp sucker most abundant in slack water (*difformis?*) and regarded as trash, and another more valuable kind (*carpio*). We must call attention to the fact that the distribution and relative abundance of the several species of carp suckers in the Mississippi River and outlying waters has not been made known but offers a promising field for study. In nearly all parts of the river the fish of one species or the other are extremely abundant. Those of substantial size (above 4 pounds) are of commercial value, usually selling as No. 1 fish, some others selling as No. 2 fish, and still others being thrown away. It is not even clear that all of the carp suckers have an indirect economic value as food of other fishes.

In the river as a whole the report is general that white carp and quillback are present in undiminished abundance; one might almost say that there is general complaint of excessive abundance, since fishermen would prefer that there should be a relatively higher degree of abundance of the more esteemed fishes, such as buffalo fishes, catfishes, sturgeon, and paddlefish.

Other suckers

The only examples of the spotted sucker or striped sucker, *Minytrema melanops* (Rafinesque), that were seen by Stringham near Keokuk were a female of 37 centimeters (15 inches) total length and a male of 36 centimeters taken in 1916 on April 18 and April 20, respectively. Both were captured in fyke nets placed in the river opposite Keokuk. They were approaching sexual maturity, the eggs being 1.3 millimeters in diameter.

But two specimens of the common sucker or fine-scaled sucker, *Catostomus commersonii* (Lacépède), were observed at Keokuk, and these were taken in the same place and way as the spotted suckers just mentioned, but on earlier dates, March 18 and 23. Each contained eggs 1.4 millimeters in diameter.

Stringham has single records for the hog sucker, *Hypentelium nigricans* Le Sueur, taken, as reported, on April 21, 1915, in a trammel net near the Illinois shore a little below Warsaw; and the white-nose sucker, *Moxostoma anisurum* (Rafinesque), found in the market of Warsaw on April 21, 1916.

The common red horse or "Des Moines plunger," *Moxostoma aureolum* (Le Sueur), is taken occasionally about Keokuk, particularly in the Des Moines River. Forbes and Richardson (1908) speak of its avoidanee of turbid waters and mud bottoms and its preference for swiftly flowing streams. It is said to breed in April and May in this latitude, ascending the smaller streams and spawning on riffles. (See Hankinson, 1919, and references there cited.) The species is apparently not well adapted to the Mississippi River. As a food fish it is perhaps one of the best of the suckers.

A female from the Mississippi examined on May 1, 1915, had a total length of 16 inches and contained eggs 2.3 millimeters in diameter. Another example from the Mississippi, examined April 19, 1916, contained 2 cubic centimeters of food materials consisting of dipteran larvæ and pupæ (Simulium, 30 per cent), caddis-fly larvæ (Hydropsyche, 10 per cent), May-fly nymphs (Heptagenia, 40 per cent), dragon-fly larvæ) Gomphus, 5 per cent), and débris (15 per cent). The material was determined by Dr. R. A. Muttkowski.

The short-head red horse, *Moxostoma breviceps* (Cope), according to Forbes and Richardson (1908), has a more general distribution than the preceding species and shows a less marked preference for clear and swiftly flowing waters. At Keokuk, where the fish is called simply "red horse," it is taken in substantial numbers during the spring but very little at other seasons. The fish are captured chiefly in fyke nets placed among the willows on the Illinois side, but some are caught in trammel nets. Examples were seen in each month from January to October (except August).

In both years of observation spawning occurred during the latter half of April. Several observed on May 1 were spent fish. The eggs of mature fish 15½ and 20½ inches, respectively, in length measured 1.8 and 2.1 millimeters in diameter. Other observations of fish, mature or nearly so, revealed eggs of various diameters from 1.4 to 2.2 millimeters.

As a food fish the short-head red horse is of about the same grade as the river quillback, but it is much less abundant. It is believed that it is present about Keokuk at all times, and we have no evidence that it is significantly affected by the dam.

In general, the red horsefishes (Moxostoma) have little commercial importance in the Mississippi River, although one or more species are common in many parts of the course of the river. They are present all the year but because of poor keeping qualities are never sought in warm weather. In the cold weather of fall and spring they were frequently taken in considerable numbers in floating trammel nets or in seines. Being addicted to flowing water, they are now (1926) hardly known in the lake above the dam, although they were once abundant in the rapids at this place. It is said that before the dam was built red horse or "redfin" could be taken in quantity in winter from the Mississippi about the mouth of the Des Moines River. It was assumed that that part of the river was the winter resting place for the red horsefish that summered in the swift waters of the rapids above Keokuk and of the Des Moines River. The origin of the name "Des Moines plunger" is apparent. Although a fair food fish and saleable in season, the red horse is not highly valued; it is not large and can be sold only as No. 2 fish, as are undersized carp and quillback.

SUMMARY AND CONCLUSIONS REGARDING SUCKERS

Excluding the buffalo fishes, the suckers of most potential importance in the river are the blue sucker, the carp sucker or river quillback, and the short-head red horse. The blue sucker is a valuable food fish, lending itself to artificial propagation, and it should, if possible, be preserved as a national resource and a basis of commercial fishery. In comparatively recent years it has virtually disappeared from the upper portion of the Mississippi River, and, according to all present indications, it has largely passed from the lower river as well. There is the possibility that the dam has contributed to its loss from the upper river, but when consideration is given to the evident diminution of blue suckers below Keokuk and to the very drastic decline of the sucker fishery of the basin between 1899 and 1908, before the dam was built, the actual part played by the dam can not be fixed with any assurance.

The river quillback is probably the most abundant of all fishes in the vicinity of Keokuk and elsewhere, but it is of little economic importance. None of the suckers (disregarding the blue sucker) appear to be unfavorably affected by the dam, except in so far as the slackened current of the lake makes that particular region an unfavorable environment for fish that prefer regions of strong current.

Since 1899 the sucker fishery in the Mississippi Basin as a whole has shown a strong decline. An exception to the general trend has recently been shown in Lake Pepin, where there appeared a marked increase in the yield of suckers in 1922.

Buffalo fishes. *Ictiobus* Rafinesque (all species)

The buffalo fishes are among the most important commercial fishes of the Mississippi Basin. The value of the product to the fishermen in 1922 was over $1,000,000 (Sette, 1925, p. 208); in that year, indeed, buffalo fishes ranked above the German carp and the catfishes, the next most valuable species. In weight, the catch of buffalo fish in 1922 was a little less than that of carp.

The apparent uniformity in the catch of buffalo fish in the basin as a whole over a long period of years is quite remarkable. The figures that follow are from Sette (1925, p. 209):

	Pounds
1894	15, 924, 810
1899	14, 215, 975
1903	11, 491, 663
1908	15, 040, 000
1922	15, 488, 765

The species are not separated in statistical reports, and, indeed, it has not been practicable to do so. Some fishermen think that they distinguish five or six kinds of buffalo fishes. The majority of them name three, as do the systematic treatises. After examining many specimens, Stringham recognized the three known species but concluded that the published descriptions did not afford a satisfactory test for distinguishing between *urus* (Agassiz) and *bubalus* (Rafinesque); the ratio of depth to length was so variable as to be of little use for diagnostic purposes, but the degree of

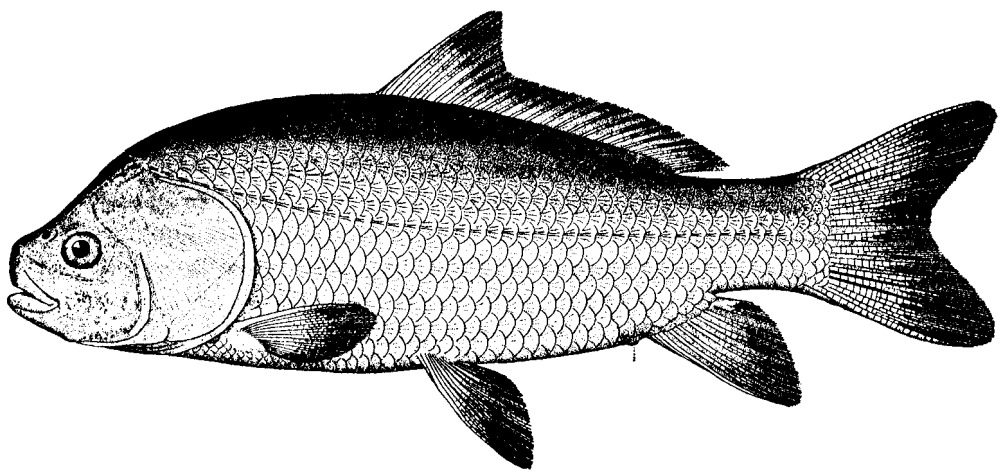

FIGURE 20.—Large-mouth buffalo fish or stubnose, *Ictiobus cyprinella*

transverse rounding of the anterior dorsal region offered a more satisfactory point of distinction.

For the reason that field identifications were sometimes doubtful, and because all statistical data and much of the information received from others was without value for application to particular species, it is not attempted in the following discussion to treat the species separately. Certain essential facts regarding the several species were established, and these will be reported first.

The two common species, the big-mouth buffalo fish, *cyprinella*, and the small-mouth buffalo fish, *bubalus*, are about equally abundant at Keokuk, while comparatively few of the "mongrel" buffalo fish, *urus*, were identified. They are all present at Keokuk practically all the time. During 1915 and 1916 *bubalus* was recorded each month except December, when no observations were made; *cyprinella*, each month except January and December; *urus*, each month except January, November, and December.

The spawning season of the large-mouth buffalo fish at Keokuk in 1916 extended from early in April to the middle of May. The small-mouth buffalo fish may have begun spawning as early, but no "ripe" fish were noted until April 21, and

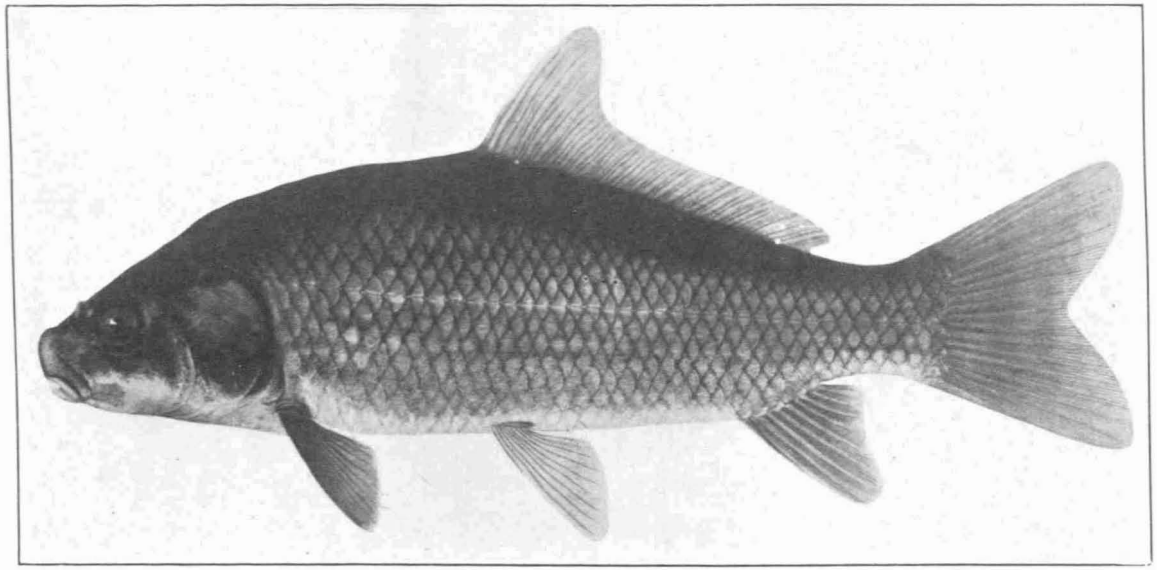

FIGURE 22.—Small-mouth buffalofish or roachback, *Ictiobus bubalus*. (Photograph from a color plate by Forbes and Richardson, 1908.)

spawning evidently concluded in the second half of May. The only ripe example of the "mongrel" buffalo fish noted that year was taken on May 17. On June 1, 1915, in a little creek then having perhaps 7 feet of water but which had been less than knee-deep a couple of months earlier, 17 buffalo fish were taken and identified in the field as *urus* and *bubalus*. All were big fish, the largest measuring 32 inches (81 centimeters) in length. Several examples, believed to include both species, were pressed and found to be "ripe." The presence of the fish in spawning condition in a small creek suggests that they sometimes ascend small streams to spawn.

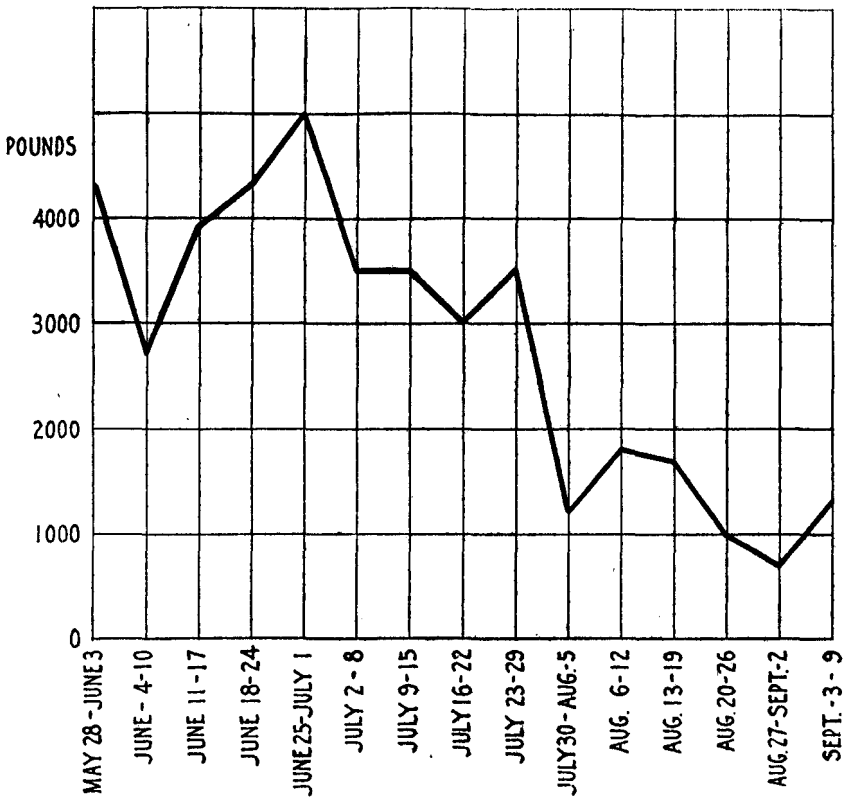

FIGURE 21.—Quantities of buffalo fishes taken near Keokuk, Iowa, by weeks, May 27 to September 9, 1916

Some indication of the relative abundance of buffalo fishes at different seasons at Keokuk may be had from Figure 21, based upon reports from the local markets received by Stringham each week during the period covered.

Considerable fluctuation in weekly catches appear, as would be expected; but in a general way the weekly catch oscillated around 3,750 pounds as a mean from about the end of the breeding season (when the record began) until the end of July. The drop about the latter date seemed in no way related to the stage of the river, which had been declining since the middle of June and continued to do so; and it was thought not to be explainable by any change in intensity of fishery, for no change was observable. It may have been related to changing water temperature, which was at its maximum just then and which declined gradually but irregularly. Possibly it was referable to the flights of May flies, the large ones of which ended at this time, although smaller flights occurred later. (See Needham, 1920, p. 272.) There is, of course, the

possibility that the fishery had depleted the local stock. In any event, the slump in catch occurred some weeks (being most noticeable at two months) after the end of the spawning season. The conditions might conform with the supposition that at some time after the spawning season the fish tend to recede down the river, so that the local spawners pass away from Keokuk, while their places are not taken by fish from the river above, since these are checked in their downward course by the slack water of the pool above the dam.

The information gained by the author in 1926 is best included at this place. It is remarkable that fishes so familiar to the fishermen of all parts of the river and so economically valuable to them should be known by such a diversity of common names. One of the chief difficulties in obtaining information regarding the buffalo fishes arises from the multiplicity of names. A special effort was made to clear up the local nomenclature, and in this I was materially helped by H. L. Canfield, whose practical knowledge of Mississippi River fishes and fishermen was invaluable. The common names applicable in one place or another to the three species of buffalo fishes severally are given below in tabular arrangement. Out of all the diversity it is apparent that the common names of *cyprinella* nearly all refer to the form of the head or the mouth, those of *bubalus* to the form of the back, and those of *urus* either to the very extensible mouth ("bugler") or to its habit of rooting in mud in the shallow waters ("rooter," "reefer," "prairie buffalo"). Names that are rarely encountered are placed in parentheses; contrasting names are placed in the same block.

TABLE 6.—*Common and scientific names of buffalo fishes of the Mississippi River* [1]

	I. cyprinella	I. bubalus	I. urus
Names referring to head or mouth.	Roundhead buffalo. Goardhead. Bullhead buffalo. Bullmouth buffalo. Bullnose buffalo. Stubnose buffalo. (Chubnose buffalo.) (Pug.) (Bigmouth buffalo.)* (Redmouth buffalo.)*	(Smallmouth buffalo.)	Buglemouth buffalo. Bugler. Rooter. Blue rooter. (Chucklehead buffalo.)
Names referring to form of back.		Roachback buffalo. Razorback buffalo. Humpback buffalo. Quillback buffalo.	Round buffalo.
Names referring to habitat.	Slough buffalo. (Mud buffalo.)	Channel buffalo. (River buffalo.)	Reefer. Prairie buffalo. Kicker.
Other names.	(White buffalo?.)	(Black carp.) Baitnet buffalo. (Southern buffalo.)	Blue buffalo. (Bastard buffalo.) (Mongrel buffalo.) (Pumpkinseed buffalo?).

[1] Some other names were encountered but were not definitely identified with a particular species. It has been said that some fishermen or dealers distinguish more than three kinds of buffalo fishes, but nearly all well-informed fishermen recognize three chief kinds, which apparently correspond with the three species known to science. The names marked with an asterisk are from Forbes and Richardson (1908).

The names used in the following paragraphs for the several species are, respectively, stubnose, roachback, and bugler. The names "roundhead" and "bullhead" are probably more generally employed for *cyprinella* than is stubnose, but either of these names invites confusion, for "round" is a very familiar name for *urus* and "bullhead" is, of course, applied to several species of catfishes.

The stubnose buffalo fish is not generally common in the river proper, being characteristically an inhabitant of the bays, sloughs, and lakes. They are less esteemed than the roachbacks and are not generally so large. Forbes and Richardson

(1908) say that the stubnose is the largest buffalo fish of the Illinois River, but conditions in that relatively sluggish stream are very different from those in the Mississippi. In the upper river, generally, the stubnose is thought to be less abundant than the roachbacks, but this may be partly because it is less sought after. It is said that in recent years the stubnose has come to supersede the other species in the river just below Keokuk, where it is taken mostly in the slack waters below the Government-built wing dams. It is the common buffalo fish of the Illinois River. (Forbes and Richardson, 1908.)

The roachback is a more migratory fish, in the opinion of fishermen. At any rate, it lives more in the current of the river and is lither in form and swifter in action. Fishermen in the region of Lake City, Minn., and Lynxville, Wis., complain of the great diminution of "humpbacks" since the dam was built. On the other hand, at all points from Fairport, Iowa, to Keokuk, this was said to be easily the most abundant species of buffalo fish; the only report to the contrary was heard at Oquakwa, where buglers were said to be equally abundant with roachbacks and at New Boston, where comment was made on an unusual predominance of the "roundheads" in that year.

The bugler is chiefly southern in distribution. It is never abundant now in the river above Muscatine but appears rather prominently in the region of New Boston and southward and just below Keokuk seems to take rank with the roachback. Mr. Canfield says that this species is much more abundant in Arkansas, where it attains a very large size.

There are several points upon which nearly all fishermen of the Mississippi River above Keokuk are in agreement. One is that buffalo fishes of very large size, 20 to 40 pounds, once common in the upper Mississippi as they are now in Arkansas (Canfield), are now very infrequent. This would be attributed more plausibly to the results of continued intensive fishery or to conditions affecting food supply (such as pollution) than to the dam. Another point of agreement is that the years 1925 and 1926 were poor years for buffalo fishes, due to stages of low water at the wrong seasons, but there was a relatively heavy catch of buffalo fishes about 1924.

The buffalo fishes and carp from Lake Keokuk command a much higher price in the large markets than do those of any other portion of the upper river. The higher value is due to the form and fatness of the lake fish.

There is in print little definite information regarding the spawning habits of the buffalo fishes. For a long time reference could be made only to a letter of A. A. Mosher to Commissioner Baird, written from Spirit Lake, Iowa, on April 24, 1885, and published in the Bulletin of the United States Fish Commision for 1885, p. 190. His vivid account is worth quoting, although the species is uncertain (it was probably *cyprinella*):

> When the water begins to grow warm after the ice goes out, these fish are around the shores in immense quantities; they are in bunches of from 3 to 7 or 8; the female is in the center, and when she sinks to the bottom to deposit her eggs, the males crowd around and under her, pushing her to the top of the water, until their tails and fins are out; then they make a tremendous rush, causing the water to foam, and with a noise which can be heard on a still evening a mile they go ahead for a few rods, then sink, and the same performance is done over. The people call it "tumbling"; in fact, it is a sight which once seen will never be forgotten.

Mosher conducted an experiment in propagation by placing the mature fish in a small basin grown over with cane grass, about 15 feet square and 18 or 20 inches deep. He removed the adult fish after spawning and recovered a large number of small fish in the fall. Nothing further seems to have been done along this line until the fish-

eries biological station at Fairport, Iowa, conducted the experiment mentioned in a following paragraph. Meantime, however, unsuccessful attempts had been made at various places to propagate the buffalo fish artificially by the mixing of eggs and sperm and the application of indoor hatchery methods. The difficulties entailed in this sort of propagation were solved by Supt. H. L. Canfield at the Fairport station in the spring of 1915, and since that time the buffalo fish has been extensively propagated by the Bureau of Fisheries in various places. The methods, which have been fully described by Canfield (1918), involve the use of special methods to avoid agglutination of the eggs, as by the use of corn starch and by brushing the eggs through bobbinet screens at different times. He tells of the taking of spawning fish in fyke nets set over inundated lands, and of the great diminution of catch whenever the water recedes, suggesting that the fish return to the river with falling water. This is a point of interest, as we shall see.

The Fairport station had also attempted to promote natural propagation of buffalo fish in ponds, but met with no success until the spring of 1917, when the conditions were varied by keeping the pond about half full of water in the early part of the season and allowing it to fill gradually early in May. A few days after the production of this artificial flood stage the splashing of buffalo fish was observed (May 11 and again May 17, 18, and 19) in overflow regions along the margins of the pond, and propagation was found to have been successful. (Shira, 1917.) The methods have been more fully described by Canfield (1922), who found that in artificial ponds it was necessary nicely to time the artificial rise of water level to the rising temperature of the water. The rise should begin when the temperature of the water is 56° F. and should be so controlled that it is completed in 10 to 15 days, with the water at 62 to 64° F. Spawning begins at 56 to 58° but is more active at 60 to 62°, so that the fish have spawned out when the rise is concluded. The large-mouthed buffalo fish (*cyprinella*) may be bred without the artificial rise, but the smallmouth (*bubalus*) does not do well without it. The rise is found desirable for both species, as the weathered grounds seem to offer a more favorable environment for the eggs during incubation. It has also been the experience of fish culturists propagating buffalo fish in the field that a normal rise in the river is beneficial (Canfield, 1918: Fisheries Service Bulletin [Culler], 1922), although it may lead to scattering of the fish and thus hamper the collectors who are seeking the spawners.

This account of the conditions of propagation has been given because the facts are not readily available and also because, in appraising the effect of the formation of a lake on the reproduction of buffalo fishes, it is important to know whether or not a normal spring flood, the effect of which would be diminished under lake conditions, is favorable or unfavorable to the multiplication of these important fishes. Apparently a rise of the river in spring, causing the water to flow out over previously exposed ground, is a positively favorable factor; but it may be that there will still be, in a pool of the nature of Lake Keokuk, a rise sufficient to meet the needs of the buffalo fishes.

From the fact that buffalo fishes are frequently taken in the current, it has been thought by some that they are migratory; a prominent fisherman in Lake Pepin spoke of "southern buffalo" as being less common than before the dam was built at Keokuk. Although buffalo fish move upstream at times, and doubtless drop back at others, and the upstream movements may normally be more vigorous when the fish are seeking spawning grounds, there seems to be no evidence at all

that any of the species are strongly migratory or that conditions at Keokuk could have any effect whatever upon the abundance of buffalo fishes at a place several hundred miles distant.

The statistics of the commercial fisheries for the years 1914, 1917, 1922, and 1927 (Coker, 1929) show a steady increase in the catch of buffalo fish in Lake Pepin—an increase, however, that is not so marked as to require any special explanation. In 1926 there was general complaint of scarcity of buffalo fishes at all places visited in Minnesota and Wisconsin, but the years 1925 and 1926 had been poor for buffalo fishes in all parts of the upper river, and apparently the same condition prevailed in 1927. The catches for the several years of report were as follows in pounds: 261,000 (1914), 301,800 (1917), 340,000 (1922), and 33,000 (1927).

The story as regards Lake Keokuk is quite different. The yield of buffalo fishes took an enormous upward jump in 1917 and showed a tremendous slump in 1922 and 1927. The figures in pounds in round numbers, are as follows: 250,000 (1914), 697,000 (1917), 114,000 (1922), and 68,000 (1927). Comment on this remarkable series of facts has already been made in a previous paper. (Coker, 1929.) We had supposed after 1917 either that the creation of the lake had made most favorable conditions for the reproduction and growth of buffalo fishes or that fish, dropping down from the upper river, collected in the lake because of the slackened current. It was naturally presumed that a permanent high level of catch in the lake was assured. It has not turned out so. It may be instructive to record some of the physical changes in the lake that occurred between 1917 and 1922.

In 1917 the lake extended out over the broad Green Bay bottoms on the western side between Montrose and Fort Madison, and these were known to be most productive fishing grounds and reputed to be the spawning ground of buffalo and other fishes. Later this whole region was formed into a drainage district and leveed, the levees, 21 miles in length from near Fort Madison to Skunk River, being closed in the winter of 1918–19. It does not appear that there are, along the whole course of the lake, any other outlying breeding grounds of adequate area. We may well question if the recovery of the overflowed lands and the old Green Bay for purposes of agriculture can yield any public benefit sufficient to compensate for the sacrifice of its value to the fisheries of the river as a whole.

In the body of the lake in 1917 there were many submerged islands still covered with the trees they had grown prior to the formation of the lake. By 1922 nearly all of the trees had disappeared, partly, perhaps, from decay, but chiefly, it is said, from being cut away in winter when they could be made into firewood and carried over the ice to the near-by villages. The flats corresponding to the islands are now almost fully exposed and open to wave action. Local informants say that buffalo fish and carp are seen abundantly in spawning activities over some of the "islands," and give it as their opinion that the nests are destroyed by the strong wave action that prevails when high winds sweep across the broad open expanses of the lake.

It may be significant that it is the catfishes that seem consistently on the increase in the lake. These are fish that can dig into banks and find or make protected places for breeding.

If a later growth of trees that endure submergence of the bases or the further growth of strongly rooted aquatic plants should give these regions protection from too vigorous wave action, probably two good purposes would be served—favorable breeding places for fish might be provided and a reduction might be effected in the

turbidity of the lake water generally and consequently in sedimentation. In any event the results of future statistical surveys may be awaited with special interest.

SUMMARY AND CONCLUSIONS

The buffalo fishes, including two or three species of the most valuable food fishes of the basin, breed far north and far south of Keokuk, and their migratory movements are presumably very limited as to length of journey along the course of the river. We find no evidence that the dam has any effect on the abundance of buffalo fishes in distant parts of the river, as in Lake Pepin, nor any marked effect on the abundance of them in the river just below the dam. The conditions as concerns these fishes in the lake above the dam seemed baffling at first. A very marked and encouraging upward trend of the fishery, as revealed by statistical data for 1917, was followed by a very discouraging decline shown in 1922. Between these dates the most extensive areas evidently suitable for spawning and nursery purposes had been reclaimed from the water for purposes of land farming, and changes had also occurred over the submerged islands away from the mainland shores, which would seemingly prevent their serving as substitute spawning grounds. The sequence of events gives the strongest reasons for assuming that the very recent decline of the commercial fishery for buffalo fishes and carp in the lake is attributable to the loss of breeding grounds. That it is lack of effective reproduction rather than of food that accounts for the decline in numbers of buffalo fish taken is further attested by the fact that the fatness of the fish from the lake gives them a notably higher value in the biggest markets. Evidently there is food enough for the fish, if not fish enough for the captors.

THE CARP AND MINNOWS (Cyprinidæ)

The minnow family is not always thought of as representing one of the chief economic assets of our waters. Yet the family is most important for two reasons: first, because it includes the carp, esteemed by some, hated by others, but always held significant; and, second, because it includes the real minnows—those "young fishes which never grow up." "It is not too much to say," we quote Forbes and Richardson (1908), "that the number of game fishes which any water can maintain is largely conditioned upon its permanent stock of minnows."

It might be supposed that, since there is such a large number of species of minnows of such varied adaptation to all sorts of ecological conditions, there could be no minnow problem in connection with a water-power development. Such a supposition would be ill founded. The author has made observations on a series of lakes resulting from a water-power development in western North Carolina, where the waters were almost entirely open, the shores and bottoms having been effectively cleared of trees and brush in almost all parts, and where, unfortunately, the conditions were unfavorable for the growth of submerged vegetation. The small streams tributary to the lakes contained minnows, but in the open waters, stocked with game fishes, there was virtually no chance for a minnow to survive and reproduce. It was reliably reported that in the first years of the lakes there had been great swarms of minnows hugging the shores and strenuously preyed upon by the game fish, which developed in numbers most gratifying to the angler. At the time of these observations practically no minnows could be found; many seine hauls in the lakes brought only the young of game fish. (Coker, 1926.) The sport-fishing in the lakes had shown a lamentable decline, doubtless because the game fish could prey only upon each other.

As regards Lake Keokuk, the conditions are quite different from those just described. Even had the trees and brush been cleared away, there are great areas sufficiently shallow and constant enough in depth to permit of the growth of submerged plants that afford the necessary shelter for minnows and other small fish. In giving special attention to other fishes we have made no adequate observations on minnows in the lake. As will appear later, two species constitute the chief minnow fauna of the river below the dam.

Carp. *Cyprinus carpio* Linnæus

"GERMAN" CARP

Despite a widespread prejudice against the carp, it remains one of the most valuable food fishes of the United States. According to statistical reports, the value of the carp product exceeds that of any other of the river fishes.

More than two-thirds of the carp product of the United States comes from the Mississippi Basin, and of this share about one-third is from the Illinois River and more

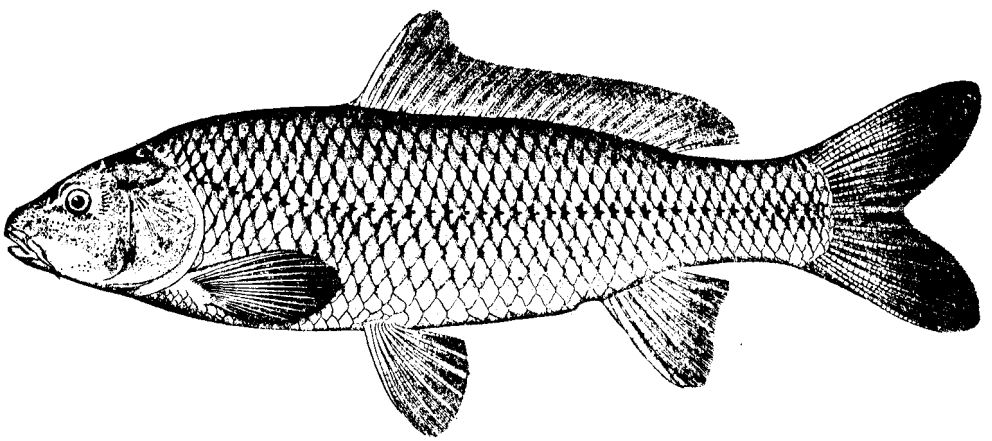

FIGURE 23.—Carp, *Cyprinus carpio*

than half from the Mississippi River itself and its minor tributaries. (See statistics in Sette, 1925.) Thus, in 1922, 9,374,073 pounds of carp were obtained from the Mississippi River itself and such tributaries as were not sufficiently significant to be named separately.

The question of the relation of carp to other fishes is one upon which so many opinions have been held and so much has been written that it would be superfluous for us to enter into a discussion of the matter, especially as we have no original contribution to make to the subject. We accept the carp as it is, standing with the buffalo fishes as paramount commercial fishes of the river.

The carp, which is supposed to have originated in Asia and which was introduced into this country from Germany, is perhaps the most adaptable of all fishes. It is found in the far south and is an important fish of the Great Lakes, especially of Lake Erie. It thrives and reproduces in rivers, lakes, and small ponds, and is, therefore, evidently without the need for extensive migrations for purposes of breeding. It is hardly necessary to ask whether the dam as an obstruction is injurious to such a fish, but the pool, with its enlarged water area, might be supposed to promote the multiplication of carp.

The statistics of the carp fisheries for Lake Pepin and Lake Keokuk since the erection of the dam are somewhat difficult to interpret. Let us first see what has been the general history of the carp fishery of the basin over a considerable period of years. (Sette, 1925, p. 209.) The product of the carp fisheries of the Mississippi River and tributaries for various years was as follows:

	Pounds
1894	1, 294, 843
1899	11, 868, 840
1903	12, 270, 346
1908	[19] 30, 670, 000
1922	[20] 18, 338, 371

There is noted a progressive increase in the carp fishery of the basin up to 1908 and a marked decline in 1922, even after discounting the figures of 1908 and 1922 because of the unusual conditions prevailing in the Illinois River about 1908.

Coming now to the consideration of recent statistics of the carp fishery of Lake Keokuk, there is found a great increase from 1914 to 1917 (from 302,000 to 762,000 pounds[21]), and a decrease of even greater proportions in 1922 (276,000 pounds), with a comparable yield in 1927 (291,000 pounds). The story is very similar to that of the buffalo fish in the same waters, except that the decline of the carp fishery was much less notable. Reference is made to the discussion of this question in connection with the buffalo fishes, page 193 above. It is the story in Lake Pepin that seems phenomenal. From 238,000 pounds in 1914 to 468,000 pounds in 1917 is not astonishing, but an increase to 2,579,000 pounds in 1922 seems to require explanation, especially as the catch in 1927 was but 615,000 pounds.

It is always proper to inquire into the validity of such statistics, and, as the story told by the records of the carp fishery of Lake Pepin appeared almost incredible on its face, a special effort was made to check it by inquiries of fishermen and dealers. The information obtained was convincing as to its essential truth. Zack Nyhart, of Lake City, Minn., informed the author in 1926 that there had been great runs of carp in 1921, 1922, 1923, and 1924, but few since. The crest of the run was, he thought in 1923. The last great haul of carp made by him was on July 30, 1924. Mr. Deschneau, of Reed's Landing, spoke of the "droves and droves" of carp of about 2½-pound weight seen in 1921 and immediately following years. He spoke of a single haul of 40,000 pounds taken in the lower end of the lake several years before (about 1922). He told also of seeing from his garden one afternoon, a great mass of carp "breaking" the water between wing dams and moving upshore. Seines were gotten ready as soon as possible, but the carp had disappeared before he and his partner were ready. Other fishermen were more successful and made large hauls from the school. From these and other reports, it appears that for some unknown reasons

[19] 15,400,000 pounds from Illinois River.

[20] 6,434,539 pounds from Illinois River.

[21] That the greatly increased yield of carp in Lake Keokuk for 1917 was not peculiar to that year is indicated by data secured from certain markets in 1916 and given below. The data of the column headed 1914 were obtained from manuscript records of the statistical agents who conducted the canvass for 1914.

Locality	1914, whole year	1916, June, July, August
	Pounds	*Pounds*
Montrose, Iowa (and Nauvoo in 1914)	22,475	92,000
Fort Madison, Iowa	63,700	132,000
Burlington, Iowa (at upper limit of lake)	81,775	50,000

there were about 1922, runs of carp on a scale that was probably unprecedented for the region.

As a commercial fish the carp possesses (along with the bowfin) two great advantages over other commercial fishes. It is easily kept in large numbers in pens or other forms of inclosure; consequently the fish that are caught in summer when the market is poor can be held until winter, when they can be shipped more safely and sold at a better price. They can be shipped alive at little extra expense; thousands of pounds of carp are readily shipped in cars fitted with tanks and equipped with a motor-driven pump to force air into the tanks. The motor need be employed only when the car is still, for while the train is moving the pump may be driven by a connection with the axle of the car. Live carp are, of course, in special demand in certain markets.

In 1915 carp were very numerous in the river in the vicinity of Keokuk; the only species that compared with it in abundance were the river quillback, short-nosed gar, and one or two minnows. In 1916 carp were still more numerous, those taken in the commercial fishery exceeding in weight all other kinds of fish combined. The breeding season was ascertained by Stringham's examination of about 150 examples between the middle of May and the middle of July; the first certainly mature male was found on June 2 and the last on July 13. This gives a late season, as compared with the observations of others,[22] and it may be that breeding began before June; or the breeding season may have been comparatively late because of the sl w rise of water temperature, which did not pass above 63° F. (17° C.) until May 25.

Figure 24 represents the seasonal fluctuations in catch for 1916, as determined from reports received currently from local markets. The greatest abundance in the markets coincided closely with the breeding period, occurring from about the middle of June to the middle of July, undoubtedly because the fish, as is well known, move out into shallow waters for spawning (Richardson, 1913), giving the fishermen better opportunities for capturing them. Carp were seen at Keokuk in each month except December, when no observations were made.

The observations on the carp with reference to the physical structure of the dam are significant. Owing to the habit of coming frequently to the top, and because of the brilliant yellow or orange color of the fish, it is relatively easy to observe them in the water. In the power-house inclosure, described in a previous paper (Coker, 1929) carp were seen by Stringham from time to time in 1915 from May 16 to September 24, when observations at this point were interrupted. They were also noted near the junction of the power house and the dam, and some were captured below open spillways. Among these were a ripe male taken on June 5 and two others, apparently ripe, taken on June 12. The next year, 1916, the species was phenomenally abundant in the entire vicinity of Keokuk. From May 30 until the interruption of observations after September 15 carp were usually or always to be found in the power-house inclosure. An enormous quantity was present there from about July 6 to July 15; some diminution in numbers occurred from that time onward, but there were still thousands in the inclosure by the middle of September. An extraordinary aggregation of carp near the lock is described in a following paragraph. Along the bank, between the lock and the bridge, many persons were commonly engaged in catching them with hook and line. In this short stretch 60 fishermen with hook and line were counted on the

[22] "Carp spawn in the northern United States in May and June. The eggs are small and exceedingly numerous, 400,000 to 500,000 being a common number in a 4 or 5 pound female." (Forbes and Richardson, 1908.)

evening of August 23. This fish was particularly conspicuous among the fish taken on the lock gate, constituting 90 per cent (by record) of all fishes taken that year.

The accumulation of fish in the power-house inclosure and near by seemed to indicate that the fish, at least many of them, while seeking spawning grounds, move in a generally upstream direction and so at Keokuk are checked by the power house and dam. This seemed further evidenced by the fact that the fish seen in the inclosure and near the junction of the power house and dam were frequently jumping where the water fell, as where it leaked through stop logs. Some of the leaping fish cleared

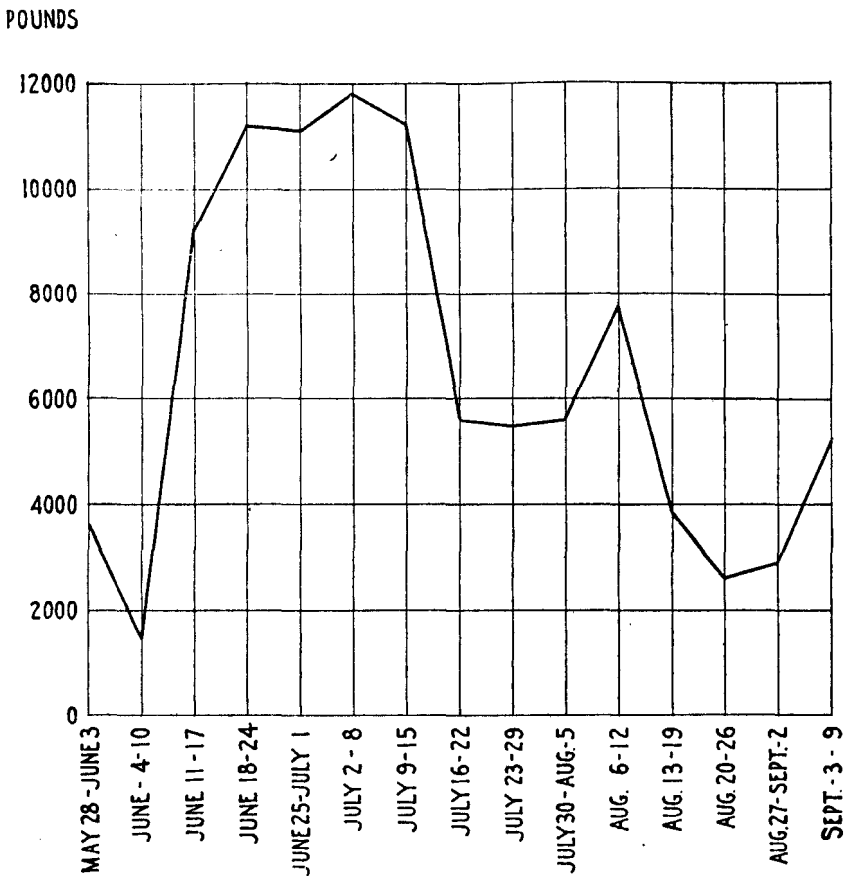

FIGURE 24.—Quantities of carp taken near Keokuk, Iowa, by weeks, May 27 to September 9, 1916

the surface of the water by a distance estimated at 1½ meters (5 feet). However, the demands of breeding could not account for the presence of fish after the middle of July, when they were generally present in somewhat reduced numbers.

The most striking accumulation of fish near Keokuk after the spring of 1914 (river herring, p. 167) was shown by carp near the lock in the middle of July, 1916. Mr. Huele, the lock master, stated that the aggregation of carp began July 16. Observations by Stringham were first made on the 17th from 2 to 5 p. m. The fish were gathered about the bottom of the chute for driftwood, situated between the lock and the lower end of the power-house structure. The number of fish in view at any given moment in this small area was variously estimated by several observers at from 4,000 to 50,000. Such estimates are significant only as indicating that the fish were seen in extraordinary numbers.

The cause of this remarkable aggregation of fish was fairly obvious. On July 13 and 14 there had occurred a great emergence of May flies, *Hexagenia bilineata*,[23] and millions were floating dead on the surface of the lake. On the 15th the prevailing wind, as shown by records of the local office of the Weather Bureau, was from the southeast, but on the 16th it came from the north and on the 17th from the northeast, driving the surface drift toward the lock and the chute, below which the carp were seen. At the time of the observation (May 17) an enormous and noisome mass of bodies of May flies, mingled with casts and with duckweed, had accumulated near the lock, and a steady stream of this matter was flowing through the chute. The carp were evidently snapping at the generous food supply. Nine carp were dipped up for examination, and although two had empty stomachs the remaining seven were found to contain duckweed and remains of adult May flies, chiefly the latter. Early the next morning, after the accumulated mass of May flies and weed had been forced out through the chute by the lockmen, both May flies and fish had disappeared. Observations could not be continued by Stringham, but the following notes made by Mr. Raber, lockman on duty from midnight to 8 a. m., are significant:

July 19. Wind *southwest*. Not more than a dozen fish visible at one time.
July 20. Wind *north*. Several hundred fish, mostly by spillway (chute).
July 21. Wind *north*. Couple of dozen fish visible at a time when there was food.

Mr. Raber's notes were found, upon inquiry from others, to be representative of the conditions throughout the period. During the remainder of the month a few carp were occasionally seen below the chute.

These observations, we think, are of real importance, because it is so generally assumed, when fish are congregated below falls or dams, that they are necessarily endeavoring to pass upstream, whereas there may be various conditions at the bases of falls to attract fish that have no decided migratory urge. Of such conditions are the exceptional degree of oxygenation of water below falls and, as in this case, the presence of food in unusual quantity.

The nomadic tendencies of carp have been commented upon by Cole (1905, p. 556–561). Another series of observations is pertinent. In 1916 carp were taken on the lock gate principally in August. The height of the movement was between August 6 and 12, but during each week of the month there were taken from three to ten times as many carp as were taken during any other week of the year. Stringham saw 300 carp shoveled from the gate on August 26. The spawning season was certainly closed before August. It should be noted that the abundance in the lock was very local, not being reflected in the catches brought to near-by markets; even the inclosure of the power house had, as already said, fewer fish in evidence during August.

From information obtained personally in 1926 it appeared that the reduced abundance of carp in Lake Keokuk, indicated by the statistical survey of 1922, still prevailed. There was general complaint along the shores of the lake of the relative scarcity of small carp. Most of the carp taken were very large. The carp of the lake, like the buffalo fishes, brought relatively high prices in the New York market. According to a reliable informant, when carp taken below the dam must be sold at 5 cents a pound those from the lake might bring 22 cents. The relative scarcity of small carp, as reported, and the fine condition of those taken in the lake bear out the supposition that the reduction in abundance of carp in the lake is attributable

[23] For details see Needham, 1920, p. 272, quoting observations of Stringham.

to unfavorable conditions for breeding rather than to lack of food supply. The fact that carp seemed to have suffered less than buffalo fishes agrees well with the fact that carp are known to be more adaptable than the other fishes. It may be added that in 1926 the reports of diminution of carp were also heard at Muscatine and Fairport. The carp taken immediately below the dam and as far as Warsaw are said to be very poor; the carp found near Canton are variable—some very good and some very "slim."

SUMMARY AND CONCLUSION

The carp, or so-called "German carp," ranks with buffalo fishes and catfishes as the most important food fishes of the Mississippi Basin as a whole and of the region of Keokuk, both in the lake and in the river below the dam. Although manifesting a tendency to move from place to place, and probably working upstream when in search of spawning grounds, its prosperity is evidently independent of *extensive* migrations, and there is no reason to suppose that the fishery can be unfavorably affected by the Keokuk development.

Up to 1917, at least, a marked increase in the abundance of carp in the lake was evident, but the statistics of 1922 (as well as those of 1927) indicate that the increased abundance was not maintained, although in 1922, and just before and after, there were notable runs of carp in the northern portion of the river. The marked decline in abundance of carp has apparently been due to changes in conditions affecting the breeding of carp and buffalo fishes. The carp and the buffalo fishes taken in the lake are said to be exceptionally fat and well flavored, so that in the large markets they command prices higher than are paid for the same species of fish from any other parts of the river. Fishermen generally complain of a relative scarcity of young carp in the region. A recent general decline in abundance of carp in the river is indicated.

Remarkable catches of carp in the region of Lake Pepin were made in 1922 and about that year, but we are not able to relate this to the presence of the dam.

There is described a most striking aggregation of carp at the dam, occurring just after the middle of July, 1916, and an obvious explanation for the condition is furnished in the mass emergence of May flies self-propagated in the lake above.

Minnows. *Notropis atherinoides* Rafinesque;[24] *Notropis jejunus* Forbes

SHINERS

About 15 species of minnows were taken in the vicinity of Keokuk in the course of the investigation, but only the two species named above were found to be present in sufficient numbers to be of evident significance in the economy of fish and man. These appeared to constitute the chief food of fish-eating fishes inhabiting the river at this point and are the principal bait fishes used by anglers. In 43 hauls of the minnow seine made from May 3 to September 2, 1916, including some from each side of the river and all being within 2 miles below the dam, there were taken 299 *jejunus*, 455 *atherinoides*, and 4 specimens of other cyprinids. Both species were found in February and in each month from April to September, inclusive. No effort was made to secure them in the other months. *Jejunus* comprised about one-third of the minnows taken in the river at Keokuk, and it was also found in the lake near Montrose

[24] Following Forbes and Richardson (1908), *N. argo* and *N. dilectus* are treated as synonyms of *N. atherinoides*. *N. rubifrons* (Cope) was looked for but not found. Changes of nomenclature suggested by Hubbs (1926) were not available at the time of our field observations, and the modification of our nomenclature at this time would be at the risk of confusion rather than clarification in our records.

and in Larry and Sugar Creeks and in the Des Moines River. More than half of the minnows taken from the river were of the species *atherinoides*, which was also found in the lake and the other waters just mentioned.

One of the methods by which minnows are captured at Keokuk shows the tendency of these fish to swim upstream, at least on some occasions. In shallow water, where the current is strong, a miniature dam is built with large stones loosely piled in a row. Near the middle of this little dam an opening is left. A conical wire net with wooden handle is then held in the opening, the open end of the net downward. If the minnows are active they will soon be striking the inside of the net, and the blows can be felt in the handle. In a little while the net is raised, emptied of its catch, and put back. Quantities of both species are caught in this way.

Minnows are found close to the power dam and were seen jumping from the water when pursued by herring. They were seen in the tailrace on May 14, 1915.

The facts noted show that minnows are probably sometimes checked by the dam and accessories while moving northward, but the observations are not extensive enough to justify conclusions. There is no evidence that the interference is of consequence.

The stomachs of eight examples of *atherinoides* were examined by Doctor Muttkowski—four contained only fragments of midges; two, fragments of May flies; one, an adult caddis fly, *Leptocella;* and one, a trace of insect débris. Stomachs of six examples of *jejunus* were also examined, with the following report: (1) Trace of débris; (2) chironomus adult fragments; (3) Probezzia sp. pupa; (4) May fly at metamorphosis, fragments; (5) May fly nymph fragments, 60 per cent, midge pupa fragments, 40 per cent; (6) caddis worm (*Leptocella*?), 50 per cent and *Lumbriculus* sp., 50 per cent.

The other species of cyprinidæ that were observed by Stringham may be listed with notes regarding their occurrence:

Campostoma anomalum (Rafinesque), stone-roller: Larry Creek, August 12–14, 1915 (2); Keokuk Lake or a tributary, September, 1915 (4 collected by Henry McAdams); Cheney Creek, March 13, 1916 (3 distended with eggs).

Hybognathus nuchalis Agassiz, silvery minnow: Mississippi River near Keokuk, September 2, 1915.

Pimephales promelas (Rafinesque), blackhead minnow: Sugar Creek, June 2, 1915 (1); Price Creek, on Iowa side, about 2 miles above the dam, April 20, 1916; Mississippi River, near Warsaw, May 6, 1916 (2).

Pimephales notatus (Rafinesque), blunt-nose minnow: Sugar Creek, April 30, 1915 (several); Larry Creek, August 12, 1915 (1).

Semotilus atromaculatus Mitchill, horned dace: Received from an angler who had caught it in a back water (or Mouth of a creek) near Hamilton, April 16, 1915 (1, length 26 centimeters, or 10¼ inches).

Notemigonus chrysoleucas (Mitchill), golden shiner: Occasionally taken in minnow seines in river. A mature female taken April 28, 1916, had a length of 15.5 centimeters, and a mature male of the same date a length of 9.3 centimeters.

Ceratichthys vigilax (Baird and Girard), bullhead minnow: Sugar Creek, April 30 and June 2, 1915; other examples received from fishermen were said to have come from the river and from Price Creek.

Notropis blennius (Girard), straw-colored minnow: After comparison with material in the collections of the bureau of Fisheries and the National Museum about 3 dozen fish, collected in Sugar Creek and the Des Moines River, have been referred to this species in spite of the fact that an inner pharyngeal tooth was found in some examples.

Notropis lutrensis (Biard and Girard), redfin: The redfin seems to be generally distributed in small numbers, having been collected in the lake at Montrose, in Larry Creek, the river below the

dam, the Des Moines River, and more abundantly in Sugar Creek. Some small specimens are slender enough to be called *N. whipplii* but are assumed to be of the same species as the larger examples.

Phenacobius mirabilis (Girard), sucker-mouthed minnow: Sugar Creek, about 2.5 kilometers from its mouth, March 22, 1916. The largest measured 7.7 centimeters (3 inches) over all and contained an earthworm in its stomach.

Hybopsis hyostomus (Gilbert): Mississippi River at Keokuk, September 2, 1915, May 25 and June 7, 1916 (3).

Hybopsis storerianus (Kirkland), Storer's chub: Several collected in the river (identification confirmed by Lewis Radcliffe); one example, 10.8 centimeters total length, taken from stomach of a goujon, April 24, 1915; Sugar Creek, March 21, 1916 (small, identified by Dr. W. C. Kendall); Mississippi River, May 19, 1916 (1).

Hybopsis kentuckiensis (Rafinesque), river chub, horny-head: Sugar Creek, March 21, 1916 (4, identified by Dr. W. C. Kendall).

THE SUNFISHES AND BLACK BASSES (Centrarchidæ)

The keenest interest of nearly all persons except commercial fishermen and market men is, of course, in the game fish, which are included chiefly in this and the following family; but, for reasons that will readily be understood when given, we have the fewest notes of direct observations to submit in reference to these fish. The natural histories of the game fishes are relatively so well known that it seemed inadvisable to give special attention to their study, except in so far as certain specific questions relating to the dam were involved. There were just two leading questions: First, does the dam as an obstruction act as an injurious barrier to upstream movements of game fish; and, second, does the lake offer them a favorable or unfavorable environment? The observations bearing upon the former question were negative and therefore are stated briefly. As to the second question, quantitative data are difficult or impossible to secure because of the general mode of taking game fish, while an effective answer to the question in terms of common information seems so clear as to admit of brief presentation.

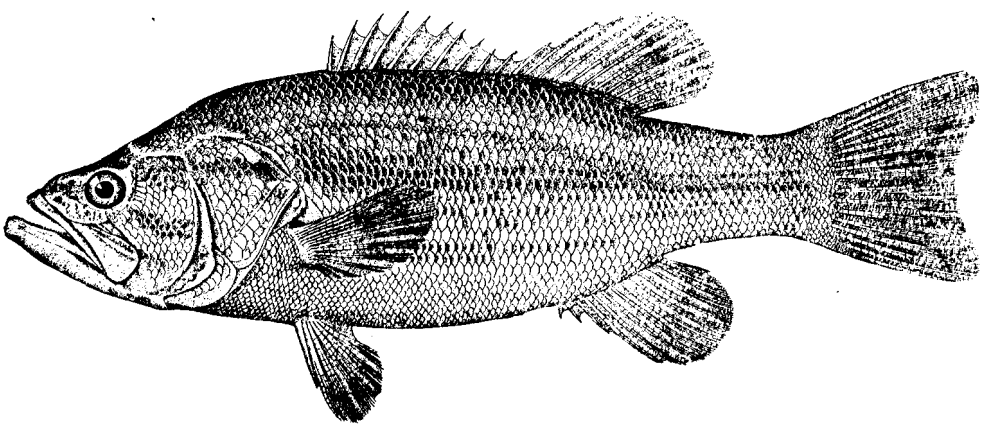

FIGURE 25.—Largemouth black bass, *Micropterus salmoides*

The species of this family that are chiefly involved are the following: The white crappie, *Pomoxis annularis* (Rafinesque); the less common black crappie, *P. sparoides* (Lacépède); the bluegill or blue bream, *Lepomis incisor* (Mitchill); and the largemouth black bass, *Micropterus salmoides* (Lacépède). The white crappie was apparently about three times as abundant as the black crappie. The common sunfish of the region, large enough for table use, were practically all bluegill. Other species were

collected, chiefly the little blue-spotted sunfish, *Lepomis cyanellus* (Rafinesque), and the small orange-spotted sunfish, *L. humilis* (Girard).[25] The common black bass of the region is, as would be expected, the large-mouth; but at least two examples of the small-mouth black bass, *Micropterus dolomieu* (Lacepède), were observed. All of these are undoubtedly present all the year.

The first question stated above was this: Does the dam at any time obstruct essential upstream migrations of the members of the sunfish family? Because of the conspicuously anadromous habit of certain kinds of fish, such as the shad and the salmons, and possibly because of the fact previously referred to that other fishes sometimes congregate at the base of falls, there exists a widespread general feeling, if not a faith, that all fish must engage each year in extensive upstream migrations. We know not a single observation of any kind to suggest that such extensive migrations are an essential feature of the life history of any of the fish of this family. Crappie, sunfish, and bass are at home not only in rivers but also in lakes and in ponds, both large and small, where they thrive and reproduce year after year without the possibility of long migrations. When in rivers, no doubt, there is some downstream drifting during periods of relative inactivity and a compensatory upstream trend at times of active life in the current. There may, in many cases, be a certain leakage, as it were, from the fish supply of the upper water as fish drift unintentionally over the dam, and the leakage may require compensation.

Persistent observations failed to give any ground for the supposition that there is any considerable drainage of fish over the dam. (Coker, 1929, p. 95.) Such observation could not, of course, be continuous, and it is possible that fish pass over the dam. We would think it a desirable condition, indeed, that there should be some overflow into the river below of the game fish reared in the lake above. The most diligent observation and inquiry during a period of two years failed also to reveal any evidence of aggregation of bass or sunfish below the dam or other signs of notable upstream movement. The dam as an obstructive factor for sunfish and bass may be disregarded.

Regarding the lake as an environment for bass and sunfish, extended discussion would seem superfluous. Everyone knows that these fishes are adapted to life in lakes and ponds, and there could not well be any other expectation than that an increased area of water, much of which would be without strong current and fairly stable in level, would bring increased numbers of such fish. Bass were locally reported to have been particularly abundant in parts of the lake about 1916, a condition that is not uncommon in new lakes when young. Reference may be made to discussions in a previous paper (Coker, 1929, p. 126.)

As seen from the statistical data presented in the paper just cited, a commercial fishery for crappie and bass has been developing in the lake, but as the commercial fishery for these species is generally discouraged [26] no great development in this line is to be expected. Many persons living about the lake have testified to the author of the better fishing for such fish since the lake was formed.

A factor that will mitigate seriously against the full development of the fish-cultural possibilities of the lake is the reclamation of outlying submerged lands for purposes of agriculture. Not only is the area of the lake being thus greatly reduced

[25] The warmouth and some other species escaped notice but could undoubtedly be found.

[26] A recent act of the Congress restricts the shipment of black bass in interstate commerce. Iowa and Illinois limit the areas in which game fish may be taken in nets.

but the bottoms reclaimed are probably among those that are best adapted as breeding grounds for the common fishes. It was generally reported in 1926 that black bass were notably less abundant than in the years before the development of the Green Bay drainage district in 1919, that crappie and bluegills were apparently less affected by this development, and that warmouth or goggle-eye were never very abundant.

SUMMARY AND CONCLUSIONS REGARDING SUNFISHES

The dam as an obstruction to hypothetical upstream migrations of bass and sunfish may be disregarded. No evidence is found either of any harmful leakage of the fish supply of the upper river by the drifting of fish over the dam. The lake obviously offers a favorable environment for the reproduction and growth of bass, crappie, and bream, but its advantages in this regard are being diminished by agricultural developments involving the organization of drainage districts with the construction of levees and reclamation of submerged lands.

THE PERCHES (Percidæ)

The true perches of general interest in the Mississippi River are the yellow perch or ringed perch, *Perca flavescens* (Mitchill); the wall-eye pike, *Stizostedion*

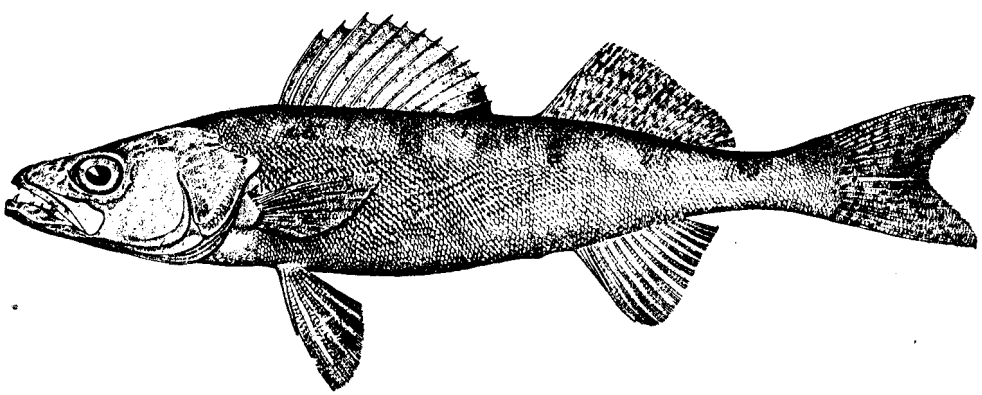

FIGURE 26.—Wall-eye pikeperch, *Stizostedion vitreum*

vitreum (Mitchill); and the sauger, *Stizostedion canadense griseum* (DeKay). The yellow perch was apparently not at all common in the vicinity of Keokuk, but, as it is "essentially a lake fish," it might become more abundant in Keokuk Lake. This had not occurred up to 1926.

The pike perches are locally but inappropriately known here, as in many other places, as "salmon" or "jack salmon." The sauger is evidently much the more common of the two pike perches. It was seen at Keokuk each month from February to October, but "salmon" of one kind or the other are known to be taken frequently in winter, probably more frequently then than at any other season. It is believed that most of the winter-caught "salmon" are saugers. Winter fishing is prosecuted with hook and line, minnows being used for bait.

In fact that pike perches are common below the dam in winter suggests the possibility of a northward migration. On the other hand, it must be kept in mind that the river just below the dam is open in winter when frozen over above and below, and also that feeding conditions are possibly better there than elsewhere. It is said, however, that "salmon" were taken most frequently in winter even before the

dam was built. We lack the information necessary to answer the question of the migratory habits of these species.

Remarks of Evermann and Clark (1920, p. 420) that are illustrative of the habits of the walleye pike in lakes may be quoted:

> The walleye bites almost any time during the year, but the best season is in June and during October and November. They are occasionally taken through the ice. * * * During the warmer weather they keep in deep water. When the weather first gets cold in the fall they come inshore in some numbers at night, doubtless to feed on other fishes. * * * They do not appear to stay near shore or in shallow water during the winter, for they are not seen through clear ice, and it is not known whether they go in schools or not. From the fact that only one or a few are taken at a time it would seem that they are rather solitary.

The only mention of the breeding of sauger that has been found in the literature refers to two examples taken in Lake Champlain, N. Y., April 25. (Evermann and Kendall, 1896, p. 602.) The authors state that this indicates an earlier spawning season for sauger than for walleye. At Havana, Ill., the walleye spawned from April 1 to 15. (Forbes and Richardson, 1908.) At Keokuk six saugers taken at various dates from March 27 to May 29 were examined, and none were found advanced in sexual development; it is possible that these were spent. In 1916 an example taken on March 15 emitted milt on pressure. The breeding season and habits of the sauger offer a problem for study.

In the vicinity of Keokuk the pike perches have not been of sufficient abundance to be of commercial importance, although the beginning of a market fishery is indicated by the statistical survey for 1922, in which year 2,280 pounds were reported. Locally they are the most esteemed of the game fishes. The walleye is much the larger of the two and is of predominantly northern distribution, being a most important fish in some of the Great Lakes. It is the common "pike" of the region just south of Lake Pepin, where it is sought in the swift clear waters. It is also extensively propagated by artificial means. It is reported to be diminishing in numbers in that region where the waters are becoming less clear.

The walleye is said to attain a length of 3 feet and a weight of 25 pounds, while the sauger rarely exceeds a weight of 2 pounds. Some writers refer to the sauger as inferior in quality to the walleye, a conclusion evidently based upon observations in the north. The Missouri Fish Commission (1887, p. 118), clearly referring to the sauger, said:

> The smaller and more numerous variety rarely exceeds 3 pounds; this is the better table fish of the two. As a food fish he has no superior in our waters. His flesh is white, firm, and flaky, and of most delicious flavor.

The pike perches and the yellow perch offer most unhappy examples of valuable fishery resources that during a long period of years have shown a remarkable decline in commercial importance in the Mississippi Basin as a whole. The story is plainly told in the following figures taken from Sette (1925, p. 209):

TABLE 7.— *Yield of yellow perch, pike perch, and sauger fisheries of the Mississippi River and tributaries for various years*

Year	Yellow perch	Pike perch and sauger	Year	Yellow perch	Pike perch and sauger
	Pounds	*Pounds*		*Pounds*	*Pounds*
1894	177,909	910,057	1908	36,000	133,000
1898	65,006	249,435	1922	22,250	29,395
1903	73,447	398,668			

The only break in the steady decline is found in the returns for 1903 in each case. State laws for conservation of game fishes have, no doubt, had a marked effect on the commercial fishery for these species. We can offer no other explanation for the decline except as it may be found in the changed conditions of our streams in consequence of the development of the country.

SUMMARY

Of the perches, only the sauger (locally known as "salmon") has any evident significance in the river at Keokuk. It is the most prized of local game fishes and is taken most frequently in winter by hook and line just below the dam. There is slight evidence of a developing commercial importance for the sauger in the lake. We have no adequate information regarding the possible migrations of either of the pike perches or regarding the breeding habits of the sauger. The pike perches and the yellow perch have shown a remarkable decline in commercial importance in the Mississippi Basin as a whole during the past 30 years. Other representatives of the perch family collected by Stringham in the vicinity of Keokuk were identified as follows:

Hadropterus phoxocephalus (Nelson), darter: A few samples were caught in minnow seines at and near Keokuk in both years.

Cottogaster shumardi (Girard), darter: Several specimens taken at Keokuk were secured during 1915.

Boleosoma nigrum (Rafinesque), Jonny darter: Among fish collected near Sandusky, Iowa, in Keokuk Lake and its tributaries by Henry McAdams during September, 1915, there was one Johnny darter measuring 4 centimeters total length.

Ammocrypta pellucida (Baird), sand darter: On September 2, 1915, somewhere in the river between Keokuk and Hamilton, Luther McAdams collected an example of this species 4.9 centimeters in length.

Pœcilichthys (*Etheostoma*) *cœruleus* (Storer), rainbow darter, soldierfish: On July 29, 1915, at Cheney Creek, a specimen 4.4 centimeters in length over all was taken bulging with eggs. In September, 1915, another, 4.8 centimeters long over all, was taken in or near Keokuk Lake, near Keokuk. On March 13, 1915, in Cheney Creek, the following specimens were taken: 1 fish 5.4 centimeters long, with chironomid larvæ, mostly Chironomus, and insect débris in the stomach; 1 specimen, 5.3 centimeters in length and highly colored when fresh, containing the same kind of food; and 1 specimen, 5.3 centimeters long over all, and also brightly colored, containing chironomid larvæ, diatoms, and Mougeotia (alga) in the stomach.

A fish caught by Henry McAdams near Keokuk about June 28, 1916, belongs to this genus. It was submitted to Dr. W. C. Kendall, who reported that it was near to *E. cragini* Gilbert, but might be an undescribed species.

THE SEA BASSES (Serranidæ)

Of the great family of sea basses there are a few representatives in fresh waters, including two species in the Mississippi River. The distributions of the two species are distinct, the white bass, *Roccus chrysops* (Rafinesque), occurring northward and the yellow or striped bass, *Morone interrupta*, occurring southward; but their respective territories overlap to a considerable degree. Only the former species occurs in Lake Pepin; but the lower part of Iowa, at least, is well within the region of overlapping. Speaking of the white bass (the northern species), and with reference to the region of Quincy, Ill., a little south of Iowa, Garman (1890) wrote: "This fine species was more abundant than the striped bass [meaning *Morone interrupta*] and ranged in a greater variety of situations. I saw it caught from the swiftest current of the river." His observations referred to conditions in August, 1888. Regarding the yellow bass, he said: "Young were frequent in certain of the sloughs and lakes, but were not seen elsewhere."

At Keokuk the yellow bass, the southern species, is infrequently taken, and fishermen do not distinguish it from the other. The white bass is common although not found in great numbers. It is highly esteemed as a game fish. One fisherman

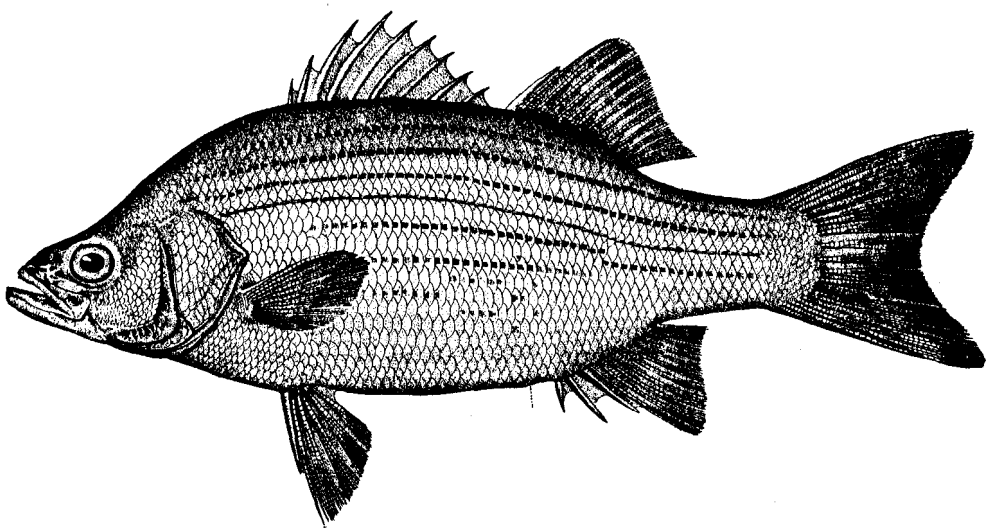

FIGURE 27.—White bass, *Roccus chrysops*

caught about 30 with hook and line on April 29, 1915. Regarding the white bass in Lake Pepin, Wagner (1908) wrote: "A common form, almost daily seen in our seines, although always in very small numbers. Many young specimens were caught with

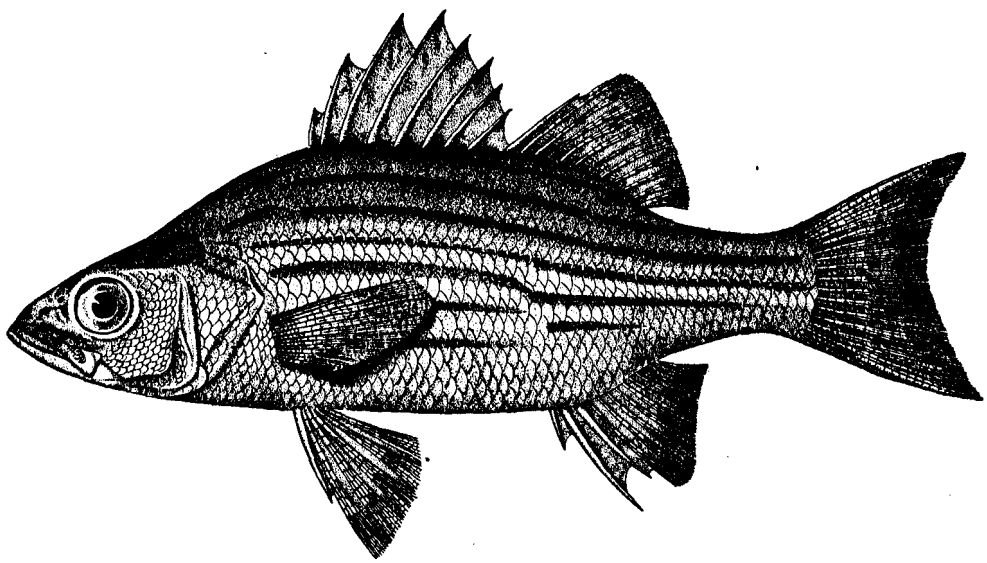

FIGURE 28.—Yellow bass, *Morone interrupta*

the minnow seine. Of all the game fishes of Lake Pepin, this one most readily takes the hook."

The white bass breeds in Michigan. (Michigan Fish Commission, 1893, p. 26) and Arkansas (U. S. Commissioner of Fisheries, 1910, p. 9.) It was seen at Keokuk

each month from March (24) to November (1), except September. During 1915 they were recorded only in spring and (once) in the fall; it is possible that they are commoner before the spawning time, but this is doubtful. At present there is no reason to consider the power development an injury to the fish. Keokuk is somewhere near the southern limit of its range, but it has been well established below the dam. Forbes and Richardson (1908) found it in Illinois "from the Mississippi near Cairo, more than 300 miles below Keokuk, to extreme northwest Illinois and thence to the Calumet River." While "its center of abundance is in the Great Lakes region * * *, it is also distributed widely over the Ohio Basin and the northern part of the Mississippi Valley." They record, however, that it was formerly much more abundant than at the time of their writing (about 1908).

So far as the information obtained orally in 1926 can be depended upon, the following conditions now apply: The white bass, formerly quite abundant in the upper part of the river, has almost disappeared within the past two or three years. In the region from Fairport to Keithsburg, above the upper limit of Lake Keokuk, the two species are about as abundant as they have been within the memory of local fishermen. From Keithsburg to Keokuk both species occur, but in comparatively small numbers. Below Keokuk white bass appear in undiminished numbers, or perhaps in increased abundance; they are taken chiefly in late fall and early spring. Yellow bass are not plentiful near Keokuk.

The history of the basses during recent decades is evidently another of the now familiar tragedies connected with the fishery resources of the Mississippi Basin. The conditions are possibly obscured a little by the fact that not only are the white and yellow basses placed in one statistical category, but there is lumped with them the rock bass, a fish of very different relationships—one of the sunfishes, in fact. The figures that follow, showing the yield of rock, yellow, and white bass from the Mississippi River and tributaries, are again those assembled by Sette (1925, p. 209).

	Pounds
1894	510, 763
1899	278, 457
1903	104, 557
1908	83, 000
1922	74, 862

SUMMARY

The white and the yellow basses occur at Keokuk, but the former is the more common species. We have no evidence of ill effect of the dam on either species and as yet no information regarding the effect of the lake. The combined yields of white and yellow basses and the rock bass (a sunfish) have shown an apparently uninterrupted decline during the past 30 years.

THE DRUMS (Sciænidæ)

The family of drums is another large group composed chiefly of marine species. The name drum is directly applicable only to those members of the family that make a croaking or drumming sound, but it fits with obvious aptness our only American species of fresh waters—the drum, sheepshead, or so-called "white perch" of the Mississippi. The equipment and method by which the drumming sound is produced in many representatives of the family is well described by Smith (1907, p. 307).

Drum. *Aplodinotus grunniens* Rafinesque

SHEEPSHEAD

Conspicuous for its abundance, its appearance in the water, and its frequent vociferous announcement of its presence, the drum is well known to all concerned with fishing in the Mississippi and its tributaries. As Wagner says (1908), writing of the drum in Lake Pepin, the peculiar sound it produces is a characteristic feature of every twilight boat ride. Its distribution is very broad: "Throughout the Great Lakes Basin and the Mississippi Valley, between the Alleghanies and the western plains, ranging from Lake Champlain to the Red River of the North, and through the Ohio Basin to Alabama, Louisiana, Arkansas, Texas, and Mexico." (Forbes and Richardson, 1908.) It is unfortunately often known and marketed as "white perch," the name perch, properly applicable to fishes of a single family, being at almost any

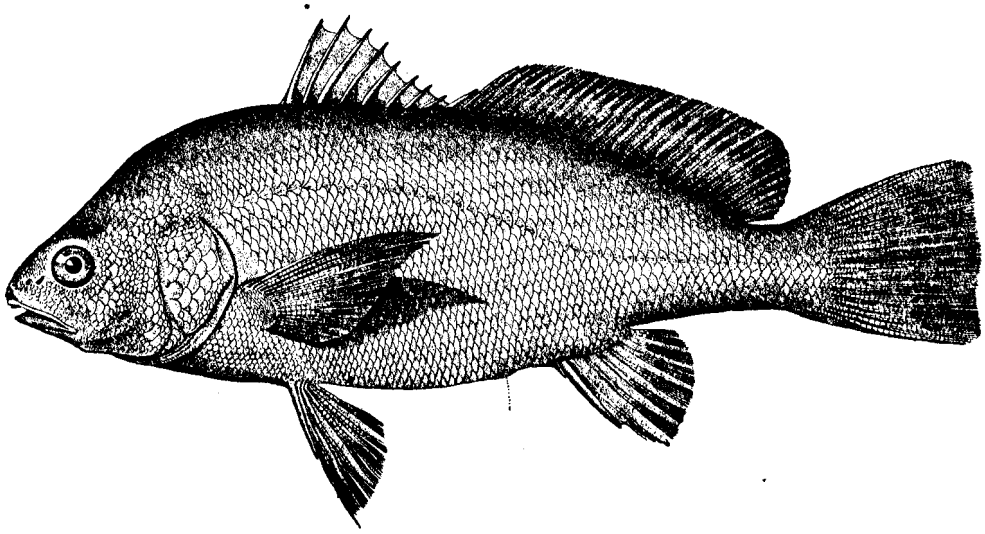

FIGURE 29.—Drumfish or sheepshead, *Aplodinotus grunniens*. (Locally but erroneously, called "perch")

place generally fitted to whatever fish seems most abundant. In many southern localities of original French influence it bears the distinctive and euphonious name of "gaspergou."

It is notable not only for its drumming sound but also for the powerful grinding apparatus (pharyngeal teeth) it possesses in the back part of its mouth and with which it may grind up the thinner-shelled mollusks that seem often to constitute the bulk of its food. Its relation to the pearly mussels that it devours is not altogether one-sided, for it thus exposes itself to infection with the glochidia (larval stages) of mussels; so that, of all fishes, it commonly carries the heaviest load of young mussels to be fostered, transported, and planted on the river bed, and then to grow up to become the food of other drumfishes. The drum is the only known fish that systematically, if unintentionally, grows its own food.

Not all of the mussels that it carries are directly valuable to man, but at least one useful species, the butterfly mussel, appears to owe its continued existence to the drum; and another, the washboard mussel, is aided by it and by other species. The drum is to be accounted a resource of double value—first, as an abundant food fish and, second, as an agent in the natural propagation of commercial fresh-water mussels, from which are made so staple an article as pearl buttons.

Although caught sometimes with hook and line and crawfish bait (Forbes and Richardson, 1908), it is primarily a market fish. In 1922 more than 5,000,000 pounds were marketed from the Mississippi River and tributaries, including the connecting Atchafalaya, and about 2,500,000 from the Great Lakes, mostly from Lake Erie, with a small quantity from Lake Huron and a much smaller amount from Lake Michigan.

As to the qualities of the fish as food there are diverse opinions. Following are some of the testimonials: Wagner (1908), Lake Pepin: "Decidedly mediocre in quality." Meek (Iowa): "A food fish of inferior quality." Woolman (1892), Kentucky: "A much valued food fish." Evermann (1902), Ohio River, Louisville, Ky.: "This fish is highly prized and meets with a ready sale." Garman (1890), Mississippi River, Quincy, Ill.: "It is considered one of the best of foodfishes." Jordan (1884): The flesh often has "a disagreeable sharklike odor, particularly in the Great Lakes, where it is never eaten." The flesh of partly grown fish is better, he says, than that of the adults. Forbes and Richardson (1908): "Thirty years ago the sheepshead was universally rejected by Illinois fishermen as worthless, but at the present time all except the largest ones are commonly dressed and sold. * * * It becomes tough and strong with age, but is at its best when weighing from three quarters of a pound to 3 pounds." Patterson (fish dealer of Dallas City, Ill.): "The perch (sheepshead) is a fine fish in Lake Pepin, but not in the Great Lakes, where it is tough; here it is soft and flaky."

The inference from these reports is that the quality of the drum as a food fish varies with its size and, perhaps, with the locality where it feeds; that only the smaller fish are good, and that those from Lake Keokuk (where the larger sizes are not yet common) are estimable fish.

Information obtained in Wisconsin and Minnesota indicates that drumfish from inland lakes are almost invariably poor and often worthless as food fish. They are said to be thin and high-backed. Thousands of pounds taken in the seines of contract fishermen are not infrequently hauled away and buried. Those from the river are usually good, and sheepshead from Lake Keokuk are considered particularly good. Very large drumfish, wherever found, are said to be quite inferior in quality.

The drum is unusually variable as to size. We have the authority of Jordan (1884) and of Forbes and Richardson (1908) that specimens of 50 or 60 pounds are not unusual; yet in the Mississippi it is not ordinarily a large fish. Garman found the largest at Quincy to be about a pound in weight. In Iowa, said Meek, it attained a length of 2 feet or more. Evermann and Kendall mention specimens from Lake Champlain that were, respectively, 28 inches long and 12.5 pounds in weight, and 19 inches long and 3.75 pounds in weight. Apparently drum 50 pounds in weight have a length of approximately 4 feet. About Keokuk it is uncommon to find drumfish weighing more than 2 pounds. One was seen on May 23, 1915, weighing 6.5 pounds dressed, and Stringham was informed of a specimen in the market on June 11 weighing 7.5 pounds dressed.

One to two pounds is the usual weight of drumfish at Fairport; less frequently examples 10 to 15 pounds in weight are found. At Lynxville it was said that most of the drumfish were 2 to 4 pounds in weight; that some of 15 to 35 pounds were taken; and, strangely enough, that drumfish between 4 and 15 pounds were extremely rare.

Regarding the natural history of the drum, more is known of its feeding than of its breeding habits. It is a fish of the larger rivers and the Great Lakes, not commonly found in the smaller streams. Jordan (1884) says: "It is apparently not at all

migratory." It thrives in the slack waters of Lake Pepin and of Lake Erie, and, according to Garman, "It seems quite at home in the swiftest current, and was caught with minnow bait from banks upon which the current strikes with a force which it would seem no animal could withstand." [27]

References to the breeding habits of the drum are almost none. Furthermore, no fisherman was found who had any information to offer on the subject. It is hardly to be supposed that a fish of such broad distribution and adaptability as to environment is geographically localized as to spawning grounds, unless it ascended small streams, such as are available from lakes or large rivers as well; but it is not found in small streams. Wagner found that in Lake Pepin "many females with ripe spawn occur by June 15." Forbes and Richardson (1908) concluded, from the condition of specimens examined by them, that in Illinois the drum "probably spawns in the latter part of May or the first of June." Circumstantial evidence indicates that it breeds in the south. Young fish 2.5 to 4.5 inches in length were frequently found in sloughs and lakes of Mississippi bottoms near Quincy, Ill., in August, 1888. (Garman, 1890.) The drum was taken at Vicksburg, Miss., in July (Hay, 1882, pp. 58, 64), not long after the probable season of spawning, and at Arthur, Tex., and Fort Smith, Ark., in May (Meek, 1894, pp. 341, 344). These last records show that the drum were present in these southern localities some time near the season of spawning. Two small drumfish, with respective lengths of 9.1 and 9.8 centimeters (3.6 and 3.9 inches), were collected by Henry McAdams in or near Lake Keokuk in September. About Keokuk in 1916, as indicated by examination of approximately 150 fish in May, June, and July, the breeding season was chiefly in the second and third weeks of June. Most of these were taken in nets placed in the unfinished half of the power house. Evidently the fish breeds in the north and in the south, but the particular places and habit of spawning of one of the commonest fishes of a large part of the country seems to be quite unknown.

Because of the dark shade of the back and the distinctive form of the tail of the drum, one can soon learn to recognize it in the water. In 1915 the drum were frequently visible near the junction of power house and dam (below spillway No. 119) from June 7 to September 13. Some were seen in the inclosure of the unfinished part of the power house on May 27 and September 5 and 7. On July 3 the power company had a large number of drum removed from this inclosure, and of four examined three contained eggs, in one instance well-developed eggs. In 1916 four small fyke nets used in that inclosure during June took 135 drum, constituting 54 per cent of the total catch of fish in the nets. None was seen from the surface near the dam until July 10, but they were thereafter noted occasionally until September. Drum ranked about fifth in abundance among the fish stranded below the dam in July, 1913. (Coker, 1914, p. 10.)

Our attention was more than once arrested by the presence of drumfish in the lock. Both in 1915 and in 1916 they ranked next to buffalo fishes and quillbacks in the numbers stranded on the lock gate. They were found there most abundantly in the former year from July 4 to 10 and September 5 to 11, and in the latter year from September 17 to 23. In the catches in the trammel net on the lock gate the drum was exceeded in 1915 by the river quillback, the spotted cat, and the Ohio shad, and in 1915 only by the two species first mentioned.

[27] It would appear that Garman either exaggerated the force of the current or underestimated the swimming abilities of many kinds of fish.

Lock Master Huele reported that when the lock was first partly filled with water and then emptied in 1915 a large number of drum were carried out; a few days later, on March 5, the first complete operation of the season was witnessed, and many drum were swept out and caught in hand nets. The fish moved their fins very feebly but appeared to be uninjured; the most likely guess is that they were hibernating and were unable quickly to resume full activity. It seems improbable that the temperature in the lock and culverts would be substantially lower than that in the river. In 1916, either because the lock had been pumped out during the winter or because the first operation was not made until March 24, only a couple of dozen drumfish were seen floating. These made frequent efforts to submerge, and some of them disappeared, while others quickly floated again to the surface. Fourteen drum taken in the lock on this day were dissected and all had the alimentary canals empty. No other species was observed to be affected by the filling of the lock.

Although particularly abundant in the neighborhood of the hydroelectric plant, the species is taken in the river generally and by all sorts of tackle. Examples were seen each month except December, when no observations were made.

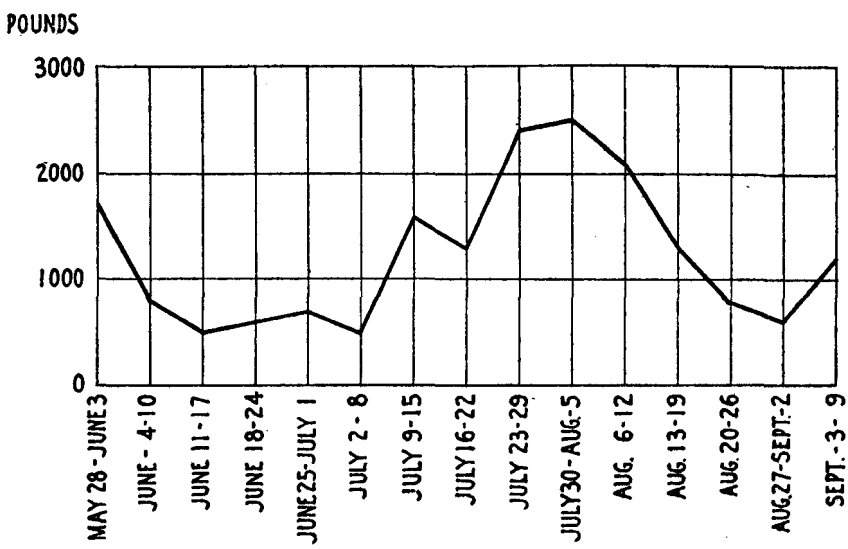

FIGURE 30.—Quantities of fresh-water drumfish taken near Keokuk, Iowa, by weeks, May 28 to September 9, 1916

A dealer at Dallas City, Ill., on the lake, spoke with assurance of spring and fall runs of drum, the fall run being then (September 29) expected to occur soon. As shown by the reports of local markets, the chief catches during the summer months were made in 1916 between July 22 and August 12. The reports, unfortunately, did not continue beyond September 9. The story for the summer is told by Figure 30. With this species, as with some others previously discussed, there was no unusual abundance during the spawning season, which evidently occurred in June.

In Lake Pepin, Minn., and Wis., the catch by the seining crew of the United States Bureau of Fisheries greatly declined in 1915 and still more in 1916, as appears from Table 8. Austin F. Shira, who had charge of the work during a part of the period, stated that special efforts were made to secure the fish in 1913 and 1914, but the decline was so great as to lead us to suspect that there must be another

cause—possibly the Keokuk Dam. The statistics of the commercial fisheries indicate, however, that there was no enduring diminution of the species of the lake. The yield of the commercial fisheries of Lake Pepin in 1914 was 132,000 pounds; in 1917, 118,000 pounds; in 1922, 396,000 pounds; and in 1927, 114,000 pounds, using even thousands. As previously mentioned, the catches of all fish in 1927 and a year or two preceding were very poor in the region of Lake Pepin.

TABLE 8.—*Quantities of drumfish taken by Bureau of Fisheries seining crew, 1913–1916, Lake Pepin*

Year	Hauls made	Fish taken	Year	Hauls made	Fish taken
1913	438	32,977	1915	476	8,005
1914	377	32,998	1916	384	4,860

About Keokuk Lake no complaints were heard of the disappearance of the drum. Information gained in 1916 indicated marked increase in the catches of drum about Montrose and Fort Madison and the approximate maintenance about Burlington (at the head of the lake) of the conditions of 1914. The bureau's statistical reports show a marked development of the drum fishery from 1914 (26,860 pounds) to 1917 (160,554 pounds), but a decline in 1922 (65,040 pounds), which was very distinct although not approaching closely the lower stage of 1914. In 1926 the general report from Fairport, Iowa, to Canton, Mo., both above and below the dam, was that drumfish were as plentiful as ever; yet the statistical report for 1927 showed a decline practically to the level of 1914 (27,538 pounds).

We have recorded the lamentable story of the diminution of several of the most important fishery resources. It is pleasant to note that the drumfish, like buffalo fish, catfish, and some others of minor importance, appears to be holding its own in the Mississippi Basin generally, as shown by the records of catch that follow (figures from Sette, 1925, p. 209):

	Pounds
1894	4,478,620
1898	3,149,232
1903	2,748,743
1908	4,737,000
1922	4,539,165

SUMMARY AND CONCLUSIONS REGARDING THE DRUM

The drum, a low-priced food fish of the larger rivers in the Mississippi Valley and of the Great Lakes, is of best quality when of small size, and only the small sizes are common in the vicinity of Keokuk. It is valuable not only for itself but for the commercial mussels for which it serves as host. The fish evidently breeds north and south of Keokuk, but the extent to which it occurs close about the power plant suggests that this, to some extent, blocks the normal movements of the fish; these movements seem not to be related to spawning, and the fish is not generally regarded as having a pronounced migratory habit. The drum appears in the vicinity of Keokuk to hibernate and to be in greatest activity when the water is warmest. There is no evidence of diminution in abundance of drum in the river above the dam, and possibly the reverse is the case in the region covered by Keokuk Lake. On the whole, the indications are that the power plant has effected no serious injury to the drumfish in the Mississippi River. The drum is one of the few important commercial fishes that is now captured in the commercial fisheries of the basin in undiminished quantity as compared with conditions about 30 years ago.

CERTAIN FISHES OF MINOR IMPORTANCE

We may insert here some records regarding species that were rarely found.

Common pike. *Esox lucius* (Linné)

PICKEREL

Keokuk is evidently south of the common range of the true pike in the Mississippi River. The so-called "pike" of the river is, of course, the pike perch or walleye, another kind of fish (p. 204). In 1916 pickerel were recorded four times, the dates and lengths (in centimeters over all) being as follows: April 18, 49; April 25, 18.5; May 14, 29; June 19, 8.3. The last-mentioned example was brought as a curiosity to the Alexandria market and the others were caught near Keokuk and Hamilton. The fish taken April 25 was destroyed in the burning of the Fairport laboratory, having been doubtfully identified as *E. vermiculatus*. While ordinarily pickerel seem to be nowhere abundant in the Mississippi River, they were being taken in Lake Pepin in 1926 in surprising numbers, as compared with other species of fish that were very scarce.

Top minnow. *Fundulus notatus* (Rafinesque)

The only record of this species is based on a specimen caught somewhere in the vicinity of Keokuk and brought to Stringham on July 20, 1915.

Brook stickleback. *Eucalia inconstans* (Kirkland)

One stickleback, measuring 2.77 centimeters over all, was caught near the ice boom above the lock on July 11, 1916.

Brook silverside. *Labidesthes sicculus* (Cope)

Two examples were seined in Larry Creek, August 12, 1915, and in the following year, on August 22 again on September 2, single examples were taken in the river between Warsaw and Hamilton.

Eelpout. Lota maculosa (Le Sueur)

LAWYER

The eelpout, though not seen by Stringham or by the author, has been recorded from the Mississippi River. (Wagner, 1908, Lake Pepin; Forbes and Richardson, 1908, "occasionally taken in the Ohio and the upper Mississippi.") Luther MacAdams, at Keokuk, said that he has seen as many as a half dozen examples in the vicinity of Keokuk; the description of the fish that he offered gives credence to his statement. The species is not known to most of the fishermen of the river. Mr. Kayo, of Lynxville, Wis., said in 1926 that eelpouts or "lawyers" had not been known in that region until within the past few years, but that now a good many were taken in bait nets fished in cool waters in the fall, and that they ranged in length up to 30 inches.

THE LAMPREYS (Petromyzonidæ)

Silver lamprey. *Ichthyomyzon concolor* (Kirtland)

The lamprey, while not used as food, is of economic significance as an enemy of fishes. As matter of fact, lampreys are edible. The lampreys of Europe are esteemed as food, but those of America seem not to have come into the market in any significant way. They "attach themselves to the bodies of fishes by means of the sucking

mouths, rasping off the flesh and sucking the blood of their helpless victims, which swim about unable to dislodge them. The ring muscle of the mouth works all the teeth at once against the selected surface, and both scales and skin are soon bored through. The relentless voracity of these fearful pests of our fresh waters is shown by the deep holes which they make in the living bodies of their victims and by their own intestines gorged with blood and flesh. Their hold is probably seldom loosened by any fish, unless by accident." (Forbes and Richardson, 1908.)

The paddlefish, when more abundant, were conspicuously the favored hosts of lampreys, which are said to be common on all large fishes except the game fishes. They are now seen most frequently on catfish, sturgeon, carp, and buffalo fish.

They are taken most plentifully in spring and fall and are said to found on fish caught from beneath the ice. While there are reports that lampreys are seen less commonly in Lake Pepin in recent years, they are plentiful enough in the region from Fairport to Keokuk.

FRESH-WATER MUSSELS

The report would not be complete without reference to the fresh-water mussels, which are the basis of a very important industry of button manufacture. The mussels as adults are sedentary in habit, and they can be affected directly by the power development only in the region covered by the impounded water; but the larval mussels are, in a sense, migratory, for they are parasitic on fish, which move from place to place, unwittingly conveying the young mussels and distributing them more or less widely as they fall from the gills or other parts of the fish after completing the metamorphosis from larval to adult form of body. The mussels, then, are affected as the fish are affected. The relations of the several species of mussels to the several species of fish have been fully treated in another report (Coker, Shira, Clark, and Howard, 1921), and some specific cases pertinent to this study have been mentioned in earlier pages of this report. Since most of the possible effects of the dam upon mussels are conditioned upon the effects upon fishes, it would be a redundancy to discuss the effects of the second order in detail. We will, however, refer to a few significant facts that have not been brought out previously.

The old rapids above Keokuk was a famous place for niggerhead mussels of the finest quality. The change from rapids to bed of lake at once rendered bottom conditions in that region unfavorable to that particular mussel; the ensuing sedimentation probably destroyed what mussels were there and prevented their replacement by others of different habit. F. C. Vetter, of Muscatine, told the author in 1926 that he had recently had a diver go down over the old rapids to see if the niggerhead mussels still remained. The bottom was found deeply covered with fine silt, into which the diver sank so far that Mr. Vetter was afraid to permit him to continue the search. The mussel fauna of former times is gone from that region.

There is the possibility that in other parts of the lake there may be bottoms suitable for other kinds of mussels, such as the Lake Pepin mucket, which thrives so well and proves so valuable in Lake Pepin and Lake St. Croix. For several years the Fairport station had made attempts to introduce the Lake Pepin mucket in Lake Keokuk. Some mussels from a plant made near Fort Madison by Superintendent Hessen were seen in 1926, having been recently recovered from the lake. It is very desirable that these attempts be continued, but it is by no means to be assumed that the conditions of bottom in Lake Keokuk will permit of a population

of mussels at all comparable to the fauna of Lake Pepin. The conditions of sedimentation in Lake Keokuk seem entirely different from those in Lake Pepin and quite likely are far less favorable for mussels.

In 1926 the author was greatly impressed by what seemed a remarkable change in the aspect of the mussel fauna of the river as a whole between Lake Pepin and Keokuk. Twelve years before the niggerhead mussel had been the standard shell of button manufacture and was still abundant at many places in the river, although evidently in course of gradual depletion. It is a slow-growing species, and the mussel fishery was then pursued without check. There were many other species of commercial mussels occurring in varying abundance. One of these was the yellow sand shell, which was never found in abundance. Those that were taken along with other shells were sorted out on the banks if found in numbers to justify the effort. Those that reached the factories in mixed lots of shells were picked out there. The shell was considered too valuable for use in button manufacture and was generally shipped abroad to be used for the making of novelties, such as knife handles and ornaments for umbrella handles. Its high value was based in part upon its exceptional qualities among fresh-water shells, in both form and texture, and in part upon the fact that it was never available in relatively great quantities.

In 1926 the conditions had changed. Niggerhead mussels had become scarce in most parts of the river visited and very small shells of this species seemed especially rare. This information was gained by examination of many shell piles on the river banks (piles including all shells taken) and by inquiries of shellers and manufacturers. The evidence was strong that the niggerhead mussel is not reseeding itself successfully in the river. There may be presumed to be several responsible factors, of which overfishing may be one, for the mussel is one of the slowest growth. A second factor is undoubtedly the depletion of the river herring, formerly abundant in the upper river but now relatively rare; for this the dam might be responsible. (See discussion of river herring, p. 165.) There may also be other conditions that affect this particular mussel more unfavorably than others. We present the apparent facts; a definitive explanation of causes is out of the question in view of the complexity of the conditions involved.

On the other hand, the yellow sand shell, formerly relatively scarce, had become a very common mussel by 1926 and was extensively used in button manufacture. The shell is eminently adapted for the purpose, because it has the proper texture and is of such form as to yield a very high number of blanks per ton, although it lacks the qualities of fine irridescence possessed by the niggerhead shell in its hinder part. It is a very profitable shell to use when it is had in such abundance that the cutting machines can be set for it. Furthermore, it is a species of far more rapid growth than the niggerhead. To one who had known the conditions in former years it was an occasion for surprise when small boats were seen in 1926 containing *only* sand shells. At one factory the author was shown a single heap containing 200 tons of sand shells from the Mississippi River.

For the increased numbers of sand shells there may be several causative factors. A greater quantity of gars, if prevailing, would be one factor. The chief cause may, however, be the development of a condition of stability in the areas between wing dams. These have been constructed by the Government in great numbers along almost the whole course of the upper river, with the idea of restricting the channel and causing the river to scour its main course. Away from the channel and between

successive wing dams are broad areas of shallow water, which seem to be affording now, in many places at least, just the right conditions for the growth and reproduction of yellow sand shells. It is also easily practicable in these shallow waters to collect mussels by hand while wading, and this practice, known as "pollywogging," is more extensively practiced now than in former times.

What will be the ultimate fate of the areas between the wing dams or of the bottom in the channel can be known only with the lapse of time. It is to be hoped that the shallow areas will not become completely soil filled and waterless. Such areas may be productive not only of mussels but of many living things of microscopic size, or larger, to serve as food for fishes. It is very desirable that there should be made here and there careful biological studies of the conditions between wing dams and of the contributions made by these areas to the food supply for fishes in the river as a whole. The changing Mississippi offers significant problems for study.

SOME PROBLEMS SUGGESTED

Having encountered, and sometimes quite unexpectedly, unfortunate gaps in our knowledge of the fishes of the Mississippi River and of the conditions of their existence, it seems worth while to direct attention to some of the problems that are most promising of solution with useful results. We shall refer particularly to the fishes, but may cite a few problems of more general significance. The page references given relate to earlier parts of this or the companion report[28] where the problem is first discussed. Evidently some of these problems can be attacked most profitably by Government agencies. Others, however, are readily available for naturalists suitably located with reference to rivers in almost any part of the basin.

1. A study of the varying extent and rapidity of fluctuations of river level (Coker, 1929, p. 113) should be made for the full period for which data is available. Such a study might be made for several rivers and for several points on each river.

2. There is needed a better study of the multiplication of plankton in the flowing waters of large streams like the Mississippi, and of the effect of floods in depleting given sections. (Coker, 1929, p. 124.)

3. It is most desirable that there should be a thorough study of the productivity of the shallow areas of slack waters that form between wing dams built along the Mississippi in aid of navigation, and of the contribution of such areas to the general productivity of the river. The ecological significance of such areas with reference to the river as a whole constitutes an untouched problem of great interest and importance (pp. 216 and 217).

4. The breeding habits and breeding places of paddlefish, rock sturgeon, and shovel-nose sturgeon should be better known. The rate of growth and extent of migration should be determined, especially by tagging operations (p. 142, ff; p. 150, ff; p. 152, ff).

5. There is virtually no available information regarding the habits of either of the known species of mooneyes, although one of them has real commercial possibilities. The relative abundance of the two species is known for scarcely any part of the river (p. 164).

6. The breeding habits of the river herring offer an excellent opportunity for study. The places and conditions of breeding are now entirely unknown (p. 167).

[28] See Keokuk Dam and the Fisheries of the Upper Mississippi River, by Robert E. Coker (1929), Fisheries Document No. 1063.

This applies also to the Ohio shad, a fish of potential importance and evidently not uncommon in season, but actually recorded at only two or three places in the whole basin (p. 171). It should be sought in late spring and early summer in all large streams of the Mississippi Basin. Even records of its presence anywhere would be of importance.

7. Field studies should be made of the breeding habits of the larger catfishes. Practically nothing is known concerning the breeding of Fulton catfish, niggerlip, or goujon. What is known by direct observation of the breeding habits of the spotted catfish in fish-cultural ponds has been learned in very recent years (pp. 174, 176, 178, and 179).

8. A systematic study of the catfishes of the Mississippi, or any one of them, would be of great value. There are no adequate descriptons of any of the four larger and more important species—descriptions that give data as to change of color, form, and appearance with age, with season, or with habitat. Such information is particularly needed for the spotted catfish and the niggerlip (p. 178).

9. The condition of the blue sucker in the lower part of the river should be determined. Since it is by far the most valuable of the suckers, excluding the buffalo fishes, and since it was once very abundant and important as a commercial fishery product, further experiments in its propagation by artificial means should be made if brood fish are still obtainable anywhere. Experiments made at Fairport are suggestive of possibilities in propagation. A study of its habits in any tributary of the Mississippi would be worth while. Why is it so rapidly vanishing (p. 184)?

10. The distribution and relative abundance of the several species of carp suckers (genus Carpio) ought to be better determined; at least two species are generally obtainable in quantity in the Mississippi (p. 185).

11. The drumfish offers an excellent problem for study. It is remarkable that a fish that is so widely distributed, so very abundant, so large at times, and so valuable should be almost unknown in respect of breeding habits and natural history other than as regards its feeding habits. One may well expect to learn something of interest concerning a fish that loves the swiftest current but is at home in lakes; regarding a fish that in one place is known as a 30 to 40 pound fish, in another as almost invariably a 2 to 3 pound fish, in still another as a fish that may weigh up to 6 pounds or over 12 but rarely between; or regarding a fish that in many places is valued as a food fish and in others is discarded and burned by the ton at some expense (p. 209).

12. It is most desirable that there should be made a study of the conditions of occurrence of the yellow sand shell which is increasing in abundance in notable degree. This applies especially to the Mississippi River.

13. The conditions of the niggerhead mussel should also be ascertained more definitely—where can beds of mussels be found in the upper river, in which very young mussels of this species are present in such numbers as to promise the perpetuation of the species (pp. 166 and 216)?

14. The migration of fishes in the Mississippi River can readily be studied by means of tagging operations, such as were begun on a small scale a few years ago. The tagging and subsequent liberation of fish in large numbers is probably the most profitable method of inquiry that can now be applied to the fishes of a large river. The results should go far to settle disputed questions concerning migratory habits, besides throwing light upon rates of growth. Fishes of particular interest in regard

to migration are buffalo fishes, sauger, white bass, yellow bass, paddlefish, sturgeons, and Fulton catfish.

15. If practicable a study ought to be made of the winter habits of fishes in the Mississippi and the possible hibernation of fishes in the deeper parts at that time. Such an investigation offers considerable difficulty, however, in view of the heavy ice sheet that forms comparatively early in northern waters.

16. Strongly to be recommended is a study of the early life histories of fishes by the blanket method of towing and trawling for eggs and larval fishes and the patching together of the fragments of information gained at one time or another in different places. Such methods, applied in the sea, have been almost the chief reliance in gaining information regarding the life histories of marine fishes. Perhaps it is only by methods of this kind that the breeding habits of the paddlefish, herring, Ohio shad, drum, etc., will be learned.

17. Two suggestions regarding practical work may be repeated here. The occurrence of young eels at the base of the dam can be inquired into more particularly and consideration given to the possibility of trapping them in quantities and transplanting them to the waters above the dam, so that the upper river may be annually stocked with young eels. The transplanting of some Fulton catfish from the river below into Lake Keokuk may be worth while in the possible event that they might survive the winters in the deeper waters of the lake and replenish the river for a short distance above the lake. As the lake is about at the former northern limit of range of the species, favorable results from the experiment need not be expected with assurance.

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