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IMPORTANCE OF FORAGE FISHES

The extent of game fish production in our natural waters is determined mainly by two factors, the supply of young, and the amount of food which is available for them to eat. The amount of shelter, genetic potentialities of the stock, predators, parasites, diseases, the more indefinite "space" factor, etc., may be of importance in some localities, but on the whole they are probably relatively less important than food in limiting the production. If then any body of water continually receives a sufficient supply of young game fishes suited to its physical environment, the production will, in general, depend upon the food supply.

Most of the larger species of fresh-water game fishes of North America feed more or less upon fish. The extent to which these various species feed upon other fishes varies considerably, and the extent to which any one species feeds upon fish varies greatly with size and age and possibly with season and geographical range.

Forage fishes include those species whose chief economic importance to man is their contribution to the diet of the game fishes. Most important of the forage species are the daces, shiners, chubs and minnows of the family Cyprinidae. Others of considerable importance are the darters of the family Percidae, some of the suckers (Catostomidae), the top-minnows (Cyprinodontidae), and the silversides (Atherinidae). The muddlers (Cottidae) are of especial importance as food for trout. While the young game fish are not included in the category of forage fish, they too play an important role in the diet of adult game fish. In many lakes in Michigan the northern pike feeds to a considerable extent upon bluegills, sunfish and ciscoes;

in trout-rearing ponds in Michigan the writer has found brook, brown and rainbow trout feeding upon young sunfish and bluegills; it has been suggested that the land-locked salmon in eastern lakes depends almost entirely upon smelt; lake trout are recorded as eating smelt in Adirondack lakes, and cannibalistic tendencies have been noted among the black basses, the perch, the walleyed pike, the northern pike, the trouts, and probably many others. It is conceivable that adult game fish feed upon their own young as readily as upon any other kind of fish, and that the extent to which any particular kind of fish is eaten depends upon size, abundance and availability.

The value of forage fishes may be considered under at least three main categories: (1) their role in the diet of the game fishes in natural waters, (2) their use as bait for game fish, and (3) their use as forage in game-fish rearing ponds. In actual value as a natural resource the first is probably by far the most important. The ultimate goal of the writer would be to completely evaluate each of the various species of forage fishes according to these three categories. Through this evaluation scientific methods of fisheries management, lake and stream improvement, and fish culture, with respect to the forage fishes, could be advanced. Unfortunately so little is known concerning the life histories and ecologies of these fishes that a complete evaluation of any one species is as yet impossible. It is possible at this time to give some of the important features in the life histories of many of the forage fishes found abundantly in the Great Lakes region and to state in a general way the type of water in which each species is found most abundantly. In the following discussion, the species are considered somewhat in order of their general abundance.

SOME IMPORTANT FORAGE FISHES

Common shiner (Notropis cornutus)

The common shiner is one of the most abundant minnows of eastern North America. So far as known, it spawns only over gravelly riffles in streams, and this fact probably accounts for its abundance in streams and its almost total absence in lakes. The

rather limited spawning season extends from the latter part of May into June and spawning rarely occurs at water temperatures of less than 60 to 65 degrees Fahrenheit. In diet it is omnivorous and thus only partially competitive with the majority of game fish which are carnivorous. The common shiner reaches a length of about two inches at the end of its first year of life. Males grow faster than females and reach a larger size, the maximum length being 8 inches or more. Attempts to propagate this species in ponds have thus far been unsuccessful, and it is doubtful if further attempts would ever be successful due to the breeding habitat required. The large size, hardiness, and abundance of this species have made it an important and popular bait minnow.

Blunt-nosed minnow (Hyborhynchus notatus)

The blunt-nosed minnow is very abundant throughout most of interior North America, both in lakes and streams. It deposits its eggs on the under surface of submerged objects; these objects may be boards, logs, rocks, or almost anything if of a suitable size. The male guards the eggs during the incubation period. The blunt-nosed minnow is omnivorous, feeding in about equal amounts on plant and animal materials; thus in food habits it is only partially competitive with young game fish. Due to its long spawning season (May through August), there is a great variation in size of the young at the end of their first year of life. Young hatched in early spring spawn early in their second summer; young hatched late in summer do not spawn until late in their second summer or probably not until their third summer. The maximum total length is about 4 inches for males and 3 inches for females. Due to its abundance in lakes, this minnow is a very important forage fish for the warm water game species such as the pikes, perches, and basses. It has been propagated in a small pond in Michigan at the rate of over 100,000 per acre, and it has been propagated most successfully in rearing ponds at hatcheries as forage for young bass. It is a popular bait minnow, although the writer has found that when crowded into a minnow pail during warm weather, it is especially sensitive to low oxygen.

Creek chub (Semotilus atromaculatus)

The creek chub is a very abundant fish, especially over the northern part of the interior region. It lives almost entirely in streams and spawns during late spring and only over gravel beds near riffles. It is carnivorous in diet. Large creek chubs occasionally feed on crayfish and small fishes. Thus it is entirely competitive with game fish. Since it lives mainly in smaller streams, its food competition with game fish is confined mostly to the trouts. The creek chub reaches a length of 2 to 3 inches by the end of its first summer and 4 to 7 inches by the end of its fourth summer. The maximum age has been recorded as 7 years; the maximum length as approximately 11 inches. Since this minnow seldom occurs abundantly in the same habitat with the warm-water game fishes, it is probably not fed upon to any great extent by them. Where they occur in trout streams, small creek chubs are probably eaten to some extent by trout. There are no records of the species being propagated in ponds, and it is doubtful if this would be possible due to the spawning habitat requirements. However, one author has recorded success in propagating the creek chub by stripping the fish and hatching the eggs on hatchery troughs. The creek chub is a very good bait minnow, large individuals making an excellent pike bait and an attractive decoy for spearing pike through the ice in winter.

Black-nosed dace (Rhinichthys atronasus)

The black-nosed dace is another very abundant species to be found mostly in small streams and rarely in lakes or ponds. It spawns over gravel beds in the riffles of streams during the latter part of spring at water temperatures of approximately 70 degrees Fahrenheit or warmer. This minnow is ommivorous in diet but feeds more upon insects than upon the microscopic plants. The maximum length of this species is approximately 3 inches. Since the black-nosed dace is found abundantly in trout streams, it is probably a serious food competitor with trout, but it is also eaten to some extent by the larger trout. Being a stream spawner, it is doubtful whether it could be propagated in ponds. Due to its abundance in many warm-water, non-trout streams, from which it can be legitimately seined, it is an important bait minnow.

Golden shiner (Notemigonus crysoleucas)

The golden shiner occurs over the eastern half of the United States, where it is abundant in lakes, ponds and the stillwaters of the larger rivers. It spawns from May into late summer and deposits its eggs throughout masses of filamentous algae. Its diet is mainly carnivorous, consisting mostly of micro-crustaceans. On the average this species reaches a length of 3 inches by the end of its first summer of life, 4 inches by the end of the second summer, and $5\frac{1}{2}$ inches by the end of the sixth summer. A maximum age of 9 winters and a maximum length of approximately 1 foot have been recorded for the species. The golden shiner occurs abundantly in lakes along with many warm-water species of game fish, and as a natural food for bass and pike. It is undoubtedly one of the most important of the forage fishes. This species has been propagated in small ponds at the rate of 100,000 to 250,000 per acre, and it is also a valuable minnow in bass-rearing ponds as forage. It is one of the more desirable of the bait minnows.

The fat-headed minnow (Pimephales promelas)

The fat-headed minnow is found quite commonly in the North and the Southwest. Toward the Northeast it is generally less abundant than the blunt-nosed minnow, the common shiner, the golden shiner and the creek chub, and is usually found most abundantly in the smaller lakes and ponds and in boggy or sluggish streams. Its general life history is much like that of the blunt-nosed minnow already discussed. It lays its eggs on the under surface of logs, boards and rocks, the males guarding the nest. It has a long spawning season from May throughout most of the summer. The most intensive study on the food of this minnow has indicated that it feeds chiefly upon algae. It is quite probable, however, that animal food is taken to a considerable extent. During experiments at the U. S. Fisheries Station at Fairport, Iowa, Mr. Markus has observed the fat-headed minnow to grow to maturity and spawn in its first summer of life. In the colder waters of the Great Lakes region growth is less rapid and the species does not mature until the second summer. The maximum length

of this species is approximately 3 inches. In natural waters the fat-headed minnow is probably not important as a forage fish because it lives mostly in the smaller waters. It has been propagated in small ponds at the rate of over 200,000 fish or 328 pounds per acre, and has been successfully propagated in bass-rearing ponds as forage.

Northern red-bellied dace (Chrosomus eos)

The northern red-bellied dace is found quite abundantly throughout the northeastern part of the United States (New York, Michigan and Wisconsin) and throughout much of the southeastern part of Canada. It inhabits mainly the smaller lakes, the bog ponds and the sluggish streams. In Michigan the spawning season has been found to extend from May into August. The eggs are deposited in masses of filamentous algae. Those young which hatch early in spring reach maturity early in their second summer. The species has a maximum length of approximately 3 inches. It has been recorded that this minnow is mainly herbivorous, feeding upon algae. It therefore does not compete to any great extent with trout for food. In the small lakes and ponds and in the sluggish streams of the northern parts of New York and Michigan this minnow is probably an important forage for trout. The writer has propagated this species in a small spring-fed pond at the rate of over 125,000 per acre. It unquestionably has possibilities as a forage fish to be propagated in trout-rearing ponds. It is an extremely hardy minnow and a good bait for the smaller game fishes such as the rock bass, the crappies and the perch.

Gizzard shad (Dorosoma cepedianum)

The gizzard shad occurs very abundantly in the larger rivers of the Mississippi Valley, and less abundantly along the Atlantic coast and in the southern part of the Great Lakes drainage. According to Mr. M. B. Trautman, the shad is very prolific and spawns in open water in the spring. The shad feeds to a large extent upon plankton and therefore competes only with the very young of the game species for food. It reaches a maximum total length of approximately 18 inches. The excellent bass fishing

in certain lakes in Ohio and Kentucky has been attributed to the abundance in these lakes of the gizzard shad which constitutes the chief food supply of the bass. The shad has been successfully propagated in bass rearing ponds in Ohio as food for young bass. The young shad are so delicate and difficult to transport that they are of little or no value as bait.

Other important forage fishes

The black-chinned shiner (Notropis heterodon) and the black-nosed shiner (Notropis heterolepis) are abundant lake species occurring throughout much of the Great Lakes region. Both species have a maximum length of approximately 3 inches. Little has been published relative to their general life history and ecology. Both species are very important forage fishes for bass and other game fish of weedy lakes. While no attempt has been made, to the writer's knowledge, to propagate these two species in ponds, both are probably suitable for pond propagation.

The lake shiner (Notropis atherinoides) is one of the most, if not the most abundant species of fish in the Great Lakes. It is probably the most important item in the diet of the fish-eating fishes in these waters. Each winter it congregates at the mouths of many of the larger rivers in Michigan in enormous numbers, and at this time dealers seine up great quantities and transport them to the inland lakes where they are sold as bait.

The Menona killifish (Fundulus diaphanus menona) occurs in many lakes throughout the Great Lakes region, where its abundance suggests that it is an important item of food to the game species. It spawns during late spring or early summer, depositing its eggs in masses of filamentous algae. It grows to a maximum length of 3 inches. The writer has been able to propagate this species in a small pond at the rate of approximately 80,000 per acre. It is a promising species for propagation as bait and as a forage in bass-rearing ponds.

The lake chub sucker (Erimyzon sucetta) occurs commonly in weedy lakes and in the quiet, weedy sections of streams. It has been found to scatter its eggs throughout masses of filamentous algae, over beds of aquatic moss and over submerged plant roots. The maximum length of 10 inches is reached in about 5 years. It occurs commonly in warm-water lakes along with bass, perch and pike, and it has been propagated successfully in trout rearing-ponds where it was an important forage for the trout. Thus far in pond propagation, the chub sucker has given a rather low production in number of fish but the relatively few fish grow rapidly. The species is very hardy and the large individuals are popular as bait for large game fish. It might therefore be a profitable business to propagate this species for sale as bait.

The darters, a group of small fishes related to the perch and walleye, are probably of more importance as forage fishes in our natural waters than has generally be recognized. The Johnny darter (Boleosoma nigrum), the log perch (Percina caprodes), and the Iowa darter (Poecilichthys exilis) occur abundantly over part or all of the Great Lakes region. All occur quite abundantly in many lakes. Their habit of remaining near the bottom most of the time probably accounts for the fact that many sportsmen do not even know of the existence of this group of fishes. During recent studies on the food habits of bass from Michigan lakes, the writer has found the Johnny darter and log perch to be important forage fishes. The Johnny darter is well suited to pond propagation but whether or not such a venture would be justified by the returns can not be stated at this time.

FORAGE FISHES AND CONSERVATION

The most important function of forage fish research, as it pertains to the conservation of the sport fisheries, is the development of methods to increase the supply of these fish food organisms in our natural waters; the most important task of forage fish management is to put these methods into practice. These methods are embodied in three main categories: (1) a control of the removal of minnows and other forage fishes from waters where they are of considerable importance as food for game

species, (2) environmental improvement to favor their reproduction in natural waters (a subject which is being discussed during this conference by Mr. Tarzwell), and (3) the introduction of species of forage fishes into waters where they have not previously existed, or from which they may have been exterminated by the severe predation of game fish or by other causes (a subject which is being discussed by Dr. Hubbs). The beneficial results of increasing the forage fish supply in any body of water are two-fold: a greater supply of food is furnished for those game fishes already present, and the increase of forage organisms relieves the predation pressure on the young game fish many of which would otherwise be eaten by adults of the game species. Each of the methods, here mentioned, of promoting fish conservation through management of the forage fishes has been in practice, to a limited degree, for some time. Perhaps the most severe, justified criticism of current forage fish management is that these methods have not been put into practice to the extent to which the expected results would seem to justify.

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Most of the larger species of freshwater game fishes of North America feed mainly upon fishes. The cyprinids are, as a group, the most important of the forage fishes; others of considerable importance are the darters, suckers, top-minnows and muddlers. The program of game fish conservation should include a program of forage fish management embodying: (1) a control of the removal of minnows and other forage fishes from waters where they are of considerable importance as food for game species, (2) environmental improvement to favor their reproduction in natural waters, and (3) the introduction of certain species of forage fishes into waters where they now do not occur. Increasing the forage fish supply furnishes more food for the game fishes present and relieves the predation pressure on the young game fish many of which would otherwise be eaten by adults of the game species.