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NOTES ON THE LIFE HISTORY OF THE MINNOWS GAMBUSIA AFFINIS AND CYPRINODON VARIEGATUS

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INTRODUCTION.

The observations and experiments upon which the present paper is based were made in the Beaufort, N. C., region, partly in the laboratory and partly in the field, from April, 1914, to October, 1915. Only living fishes are considered and the experiments in aquaria have probably afforded the most interesting data. While some of the observations here recorded are in general harmony with the published statements of previous investigators, yet they are found to present such essential points of difference as to make it advisable to include them in the present paper. The fact that these and other minnows are now so highly esteemed as agents for the destruction of mosquito larvæ in ponds and reservoirs lends a timely interest to the publication of any data relating to the habits and propagation of the species.

GAMBUSIA AFFINIS (Baird and Girard). THE TOP MINNOW.

NATURAL HISTORY.

This top minnow is known on the Atlantic coast from Delaware to Mexico and in the Mississippi Valley from Illinois to Louisiana. It inhabits both fresh and brackish water, while an occasional straggler is taken in strictly salt water. Locally it is the only viviparous teleost known. It may be found in nearly all shallow streams or ponds of brackish or fresh water, and it is particularly abundant in certain very shallow and muddy arms of the Mullet Pond on Shackleford Bank. Nowhere, however, was it found to grow so large as it does in a small fresh-water pond on Gallants Point. Females taken from this very shallow and extremely dirty pond, visited daily by both cattle and hogs, are from 60 to 65 mm. in length, while the largest specimens obtained elsewhere do not exceed 45 mm. The males, as is well known, are much smaller than the females. The largest male observed in this vicinity was 33 mm. in length, which is probably 6 mm. above the average.

This fish is one of the hardiest known to the writer. It flourishes in very stagnant water, providing, of course, that the proper amount of food is available; it thrives in the aquarium; and it lives equally as well in salt as in fresh water. It may be plunged directly from the one into the other without any apparent harm. If placed in a battery jar and left without change of water it will usually survive until a green scum forms on the walls of the container; thereafter no more attention need be given it, except to add a small quantity of water from time to time to compensate for evaporation. Care must, of course, be exercised not to give the fish more food than it can consume. Probably more aquarium fish of all kinds are lost through overfeeding than from any other cause. Both old and young have been kept in the aquarium at the laboratory for one and one-half years, and were still in good condition at the expiration of that period.

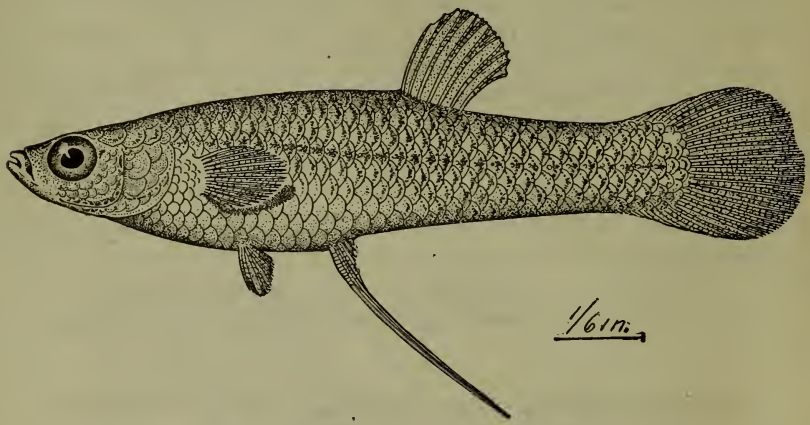

FIG. 1.—*Gambusia affinis*. Top minnow. Male.

Gambusia becomes inactive and ceases to feed even during moderately cool weather. It is at its best in water of a relatively high temperature. The shallow water in which it is usually found in abundance during the summer reaches a temperature, during the day, which is above that of the human body. It is never a very active swimmer, and when it ventures out into water inhabited by larger fishes it becomes an easy prey. Its habit of swimming at or near the surface is well known, and this has caused it to be known everywhere throughout its range as the top minnow. When in very stagnant water it projects its mouth above the surface at frequent intervals, making a sucking noise each time. It is presumed that this is done because there is an insufficient supply of free oxygen in the water, but if this is the case the deficiency of oxygen does not appear to interfere with the health and welfare of the fish. The large size attained by the minnows in the stagnant pond on Gallants Point may be cited as evidence.

OBSERVATIONS ON FEEDING.

The habit of surface swimming in this species is correlated with the fact that it seeks and acquires most of its food at or near the surface of the water. It feeds very largely upon the larvæ of insects when these are available; accordingly, it has been found to be of great value as an eradicator of mosquitoes, and herein lies its greatest economic importance. For this reason, also, it has been planted in many places where it is not native, and the results have been gratifying. While aquarium feeding does not, as a rule, teach us much about a creature's habits of feeding in nature, a few experiments in this connection are nevertheless worthy of mention. An adult female, about 43 mm. in length, had been held in a battery jar since early spring and regularly fed with finely minced fish. On August 2, 1914, she was fed 140 mosquito larvæ between 11 a. m. and 12.15 p. m. The larvæ were all of large size and nearly ready to pupate, being from 6 to 8 mm. in

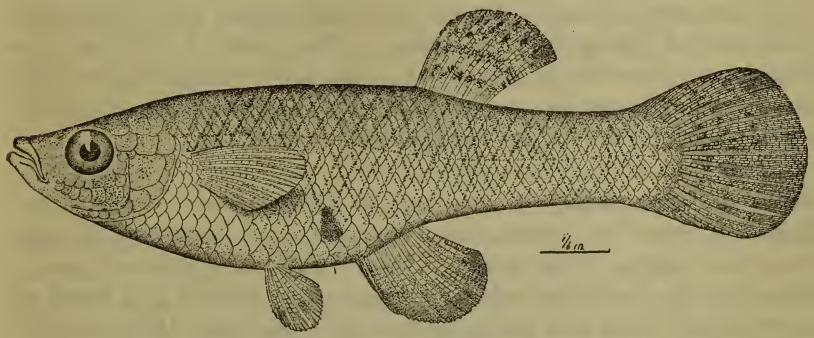

FIG. 2.—*Gambusia affinis*. Top minnow. Female.

length. All except four were eaten by 12.30 p. m. When observation was made again at 5.30 p. m. all the larvæ had been consumed. At 6 p. m. 25 additional larvæ were supplied. Nearly all of these were immediately eaten, and all had disappeared by 9 p. m. It was clear, however, that her appetite was satisfied. The abdominal walls were greatly distended and it was evident that she had eaten all that she could hold.

That its service in the destruction of mosquito larvæ probably begins on the day that the fish is born is evidenced by the fact that fish only a few hours old devoured larvæ that were fed to them. At this early age they were unable to swallow large larvæ, but the writer has seen them swallow larvæ more than half the total length of the fish itself. Considerable difficulty is apparently encountered in swallowing a morsel of this size, and a portion of the larva is often visible 1 minute after the process of swallowing is begun. It was sometimes observed that one such morsel did not satisfy the appetite and that a second one was taken.

While this fish in captivity will readily eat dead food, such as minced fish, oysters, clams, corn bread, the yolk of hard-boiled egg, etc., it shows a preference for living food. Mosquito larvæ were killed and introduced along with live ones, and in each instance no attention was given to the dead larvæ until the live ones had been consumed. It is probable that this fish has a preference for insects as food, but it is evident that it is by no means dependent upon these for subsistence. Apparently it devours nearly anything of suitable size, whether animal or plant. It is well known that in the aquarium *Gambusia* will eat its own young, but this cannibalistic habit is certainly not restricted to aquarium life, since the writer has captured specimens in nature which contained in the stomachs fish of their own kind.

OBSERVATIONS ON BREEDING.

In the Beaufort region this fish delivers its first young of the season some time during May, or in some years possibly as early as the latter part of April, depending largely upon the temperatures which prevail during the early spring. The spring of 1915 was somewhat cooler than the spring of 1914, and the breeding season, therefore, began at least two weeks later. It continues to breed throughout the summer and as late as October.

Copulation, although carefully looked for, was not satisfactorily observed. Apparently it is a very quick process[a] and is accomplished during what appear to be frequent fights in which the opposite sexes engage. That some of these fights are quite real was evidenced by the fact that a female which was confined in a small rectangular jar killed and partly devoured three males that were from time to time introduced for breeding purposes. In order to protect the male from this ferocious female it became necessary to place in the jar a partition of wire netting, with mesh large enough to permit the male to pass through, yet small enough to keep the female back. The male continued to venture out from his compartment quite frequently, and notwithstanding that he was obliged to make many hasty retreats he survived and successfully fertilized the eggs for the future broods.

That a single female may produce as many as six broods of young during a single season was demonstrated through aquarium experiments. In one instance a medium-sized female, about 40 mm. in length, was placed in a small rectangular jar early in the spring of 1914. She gave birth to young as follows: First brood, May 20;

[a] The act of copulation in *Gambusia holbrookii* and *Heterandria formosa* was observed and described by Seal (1911). *Gambusia holbrookii* is now considered a synonym of *G. affinis*. This process was also observed and described by Philippi (1908) in *Glaridichthys januarius* and *G. decemmaculatus*. (The first of these fishes according to Henn (1916) was *Phalloceros caudomaculatus* (Hensel) and the other is placed in the genus *Cnesterodon* Garman by the same author following Eigenmann.)

second brood, July 2; third brood, July 18; fourth brood, August 9; fifth brood, August 30; and sixth brood, October 5. It is probable that some females produce an even greater number of broods during a single season, for it was noted that several females in the aquaria gave birth to young during a period of two to three weeks after the individual just cited had concluded for the season; some also began bearing at an earlier date than this one. Presumably the effect of aquarium life would be to reduce rather than to increase the number of broods. As the temperature of the water seems to determine the time of beginning of the spawning season, it probably influences, to some extent at least, the rapidity with which the later broods are developed. The aquarium in which the above-mentioned female lived was kept in the writer's office, where it was protected from the direct rays of the sun. The water in it, therefore, never reached the luke-warm temperature of that usually occupied by these fish in nature, and for that reason it may be supposed to have exercised a retarding influence upon the development of the successive broods.

The number of young comprising a single brood appears to bear a direct relation to the size of the female. If the female is small, a small brood results. If the female is large, a more numerous brood may be expected. That the earlier broods are larger than the later ones, as suggested by Dr. H. M. Smith (1912, p. 224), could not be verified. A large number of dissections of specimens obtained at various times during the season revealed no differences that would substantiate that suggestion. In the same paper Dr. Smith states that the average number of embryos contained in the ovary of a limited number of fish dissected or observed by him at the aquarium of the Bureau of Fisheries in Washington was 100. Dealing with specimens from the Beaufort region, the largest number found by the present writer in any single ovary was 63, and the average among the largest females obtained did not exceed 40. Dr. Albert Kuntz (1914, p. 183), working with fishes from the Beaufort region, found 76 to be the maximum number produced by a single female. The fish examined by Dr. Smith were from the Potomac River and measured from 45 to 50 mm. in length. They were, therefore, not so large as some of the specimens under observation at Beaufort, the largest of which are 64 mm. in length. The number of broods of one season produced by a single female in a more northern latitude are probably fewer in number, owing to the shorter period of warm weather; but since the observations of Dr. Smith suggest that the broods may be larger, it is possible that the number of young produced during a single season is not materially smaller in the higher latitude.

It is an interesting fact that females separated from males even before the first spring brood is born continue to produce young

throughout the season in a perfectly normal way.[a] A female kept under close observation produced five broods after she had been separated from all other fish. To determine if fish that were separated from males in the spring would continue to produce young the following season without again coming in contact with males, a number of females were kept in aquaria through the winter. In the following spring large eggs, of yellowish appearance, were produced instead of young. Other females that had been with males during the entire summer were separated from them late in the fall and also carried through the winter. This lot, too, produced eggs instead of young. In each case the eggs appeared when young would normally have been produced. These experiments show that this fish is able to carry the sperms throughout the breeding season, but indicate that it can not carry them through the winter.

Ova in various stages of development are present in the ovary at one time. When one brood is born the eggs of the next set are already well developed, being about 1 mm. in diameter, and several smaller eggs are also present. When the fertilization of the different sets of eggs occurs is not known. With regard to *Phalloceros caudomaculatus* and *Cnesterodon decemmaculatus*, two viviparous forms belonging in the same family with *Gambusia affinis* (the family Pœciliidæ), Philippi (1908, p. 22) found that the sexual product of the male consists of numerous milk-white bodies which stick fast to the first available object. Microscopic examination showed that these bodies consist of closely crowded spermatozoa. The whole mass is held together by a sticky substance, which probably causes the sperm bodies to fasten themselves to the genital papillæ of the females. He found also that these bodies were quickly dissolved when they came under the influence of the ovarian fluid, and the individual spermatozoa were set free. Within the folds of the lining of the oviduct the sperms were found in great numbers, even after the birth of young. It is probable that the sperms are retained there throughout the breeding season and that the eggs are fertilized as soon as they are sufficiently mature.

The fact that the female is capable of producing young throughout the breeding season without coming in contact with the male leads one to look with suspicion upon the many notices of "hybrids" produced by crossing species of viviparous fishes. In order to obtain true hybrids of *Gambusia affinis* with another species, if such cross-breeding will occur at all, it would be necessary to begin the experi-

[a] "Zolotnisky (1901, p. 65) observed that a female of *P. caudomaculatus* which had been separated from males after the appearance of a brood of young pro luced another within six weeks and a third brood four weeks after this. This occurred although copulation subsequent to the first parturition had not taken place. Philippi also isolated females at, or slightly before, parturition. In every instance the females became pregnant for a second time, and one specimen produced a third brood 46 days after the appearance of the second. Poey noted these facts many years ago." (Henn, 1916, p. 102.)

ment during the fall or winter or to rear young for the purpose, in which case the sexes must be segregated at a very early stage.

As the embryos develop within the ovary a black spot appears on each side of the abdomen of the parent above and in front of the vent, and these spots gradually become larger and larger. When they become so large that they are about to meet at the ventral surface, the period of parturition is at hand. The process of extrusion of the young was observed repeatedly. There is no uniformity in the manner of birth. They may appear singly or by twos and threes at a time. Some come head first, some tail first, and others are delivered in a coiled position. Extrusion may occur quickly and with some apparent force; at other times it is a slow and deliberate process. Some females under observation delivered nearly the entire brood in one position, but others did not. It appears that the young are most frequently born tail first and one at a time. The process invariably takes place during the day. The entire brood may be delivered in the course of an hour or two, or the process may consume an entire day or a portion of two days. During this period the adult swims about as usual and eats food when it is supplied. If hungry, she devours her own young as rapidly as they are born. In many instances in the aquarium the mother eats her entire brood on the day they are born.

The young at the time of birth are from 8 to 10 mm. in length. They are very vigorous, and, as previously indicated, they come into the world with an appetite and well prepared to enter upon an independent career. The average rate of growth is rapid, but, as is the case with other forms of animal life, each lot has its "runts." The largest female among a lot born in May, 1914, and reared in the aquarium had reached a length of 25 mm. by the middle of September. The recognizable males were somewhat smaller, although the difference in size was not nearly so great at this age as it is among fish that have attained their full growth. The smallest individuals in this lot were only 13 mm. in length. In the field, by about July 30 it became difficult to distinguish the first young of the season from the adults. The largest specimens taken at this time and identified as young of the season were 25 mm. in length. From this it would appear that the young in natural habitats grow faster than those in captivity. Fish born and reared in the aquarium now nearly one and one-half years old have not quite reached the maximum normal size of their parents.

The external character distinguishing the sexes is the modified anal fin of the adult male, which is developed into an intromittent organ. In the young, however, the anal fins are similar. The modification of this fin in the male is a gradual process and can not be said to become evident at a stated age or length of the fish. In some

specimens the specialized form of the fin becomes evident when the fish is only 13 mm. in length and less than 3 months old; in others it is not apparent at the age of 5 months or at a length of 17 mm. For example, a lot of 43 young born in May, 1914, the smallest of which was 17 mm. in length, was examined on October 15, 1914, and was thought to comprise females only; but on June 3, 1915, 6 of the 39 fish surviving were easily recognized as males. It may, therefore, be stated that the modification of the anal fin into an intromittent organ may take place when the fish reaches a length of 13 mm., or at any later stage until it attains its maximum normal growth of about 25 mm.

The proportion of males to females in this species has been discussed by various writers. In collections the males are generally much in the minority. It has been argued that this is due to the small size of the males, which permits them to pass through the meshes of nets and thus to escape capture. However, when the writer has collected the minnows with mosquito netting of a mesh so small that not even the tiniest male may pass through, the disparity in the numbers of the sexes has remained evident. Among the lots grown in the aquarium, the inequality is quite as great as it seems to be in nature. For example, on June 2, 1915, 60 of the young of the previous season had survived, and of these only 7 were males. The indications are that in the broods of 1915 the sexes are just as unequally represented, although, as shown above, the sexes can not be positively determined at this time (October, 1915). Owing to the rather heavy loss during the early stages of life in the aquarium, the results as stated above may not afford a reliable criterion, although there is no apparent reason why aquarium life should not be as well suited to the male as to the female. Among the adults there is much fighting between the sexes and the males often suffer severely, but among the young these disastrous conflicts have not been observed. It seems entirely probable that the normal ratio of males to females is about 1 to 8 or 9.

The extreme prolificness of the species has already been the subject of comment. It is particularly interesting to know that the early broods of the season reach sexual maturity[a] and some of the fish begin to breed before they are four months old. During both seasons that the young have been observed and grown in the aquarium the oldest and largest females among the broods have delivered their first young during September. At this time the females are only about 23 mm. in length, and the first brood consists of only two or three young. In the fall of 1914 two of the largest females hatched

a Seal (1911, p. 95) observed that the young of *Gambusia holbrookii and Heterandria formosa* began to breed during the season in which they were born.

in the spring of the same year even succeeded in producing two small broods before the arrival of cool weather.

A female that produced 6 broods during one season, averaging 40 young to a brood, would have 240 descendants of the first generation by the end of the season, assuming that all survived. Now, if the sexes in the first brood occurred in the apparently normal proportion of 5 males and 35 females, and if each female produced three young in September, the total number of young of the second generation resulting from this brood would be 105. It appears that by the end of the season the original female would have given rise to a family of 240 offspring of the first generation and 105 offspring of the second generation. There are few, if any, fishes whose output of eggs does not outnumber the young of *Gambusia,* but the chances of survival for young delivered alive as compared with eggs and young hatched from them, are probably 1,000 to 1. It seems reasonable to conclude, therefore, that under natural and normal conditions no native fish multiplies more rapidly than *Gambusia affinis.*

SUMMARY.

1. *Gambusia affinis* usually inhabits shallow, stagnant waters, whether fresh or brackish, and it thrives under conditions of relatively high temperature if the proper amount of food is available.

2. It is a very hardy fish, adapting itself readily to many different natural conditions as well as to life in the aquarium.

3. Its food consists largely of the larvæ of insects, but it feeds also upon a variety of other animal and plant substances. It sometimes eats its own kind, even its own offspring, especially in the restricted environment of an aquarium.

4. One medium-sized female may destroy as many as 165 large mosquito larvæ in a single day.

5. In the region of Beaufort the fish produces its first brood of young for the season during the month of May and continues to breed throughout the summer until as late as October. It may produce during a single season six or more broods, averaging 40 young to a brood.

6. Females separated from males in the spring shortly before the first brood is born continue to produce young throughout the season. If separated from the male even during late fall no young will result the following spring, but infertile eggs will be deposited.

7. Young are delivered during the day, one, two, or three at a time. Some come head first, some tail first, and others in a coiled position. The period of labor may comprise an hour or the greater portion of a day or even portions of two days.

8. The modified anal fin of the male, which is the external character that distinguishes the sexes, may be fully developed when the fish

is less than 3 months old or not until the fish is 1 year old; it may appear when the fish is 13 mm. in length, or be delayed until a length of 23 mm. is attained.

9. The proportion of males to females appears to be about 1 to 8 or 9.

10. Some of the individuals of the early broods of the season become sexually mature and produce small broods of young late in the season in which they themselves were born.

CYPRINODON VARIEGATUS (Lacépède). THE VARIEGATED MINNOW.

This variegated minnow occurs on the Atlantic coast from Cape Cod to the Rio Grande, inhabiting brackish waters and ascending streams. Stragglers are also taken in strictly salt water. Locally

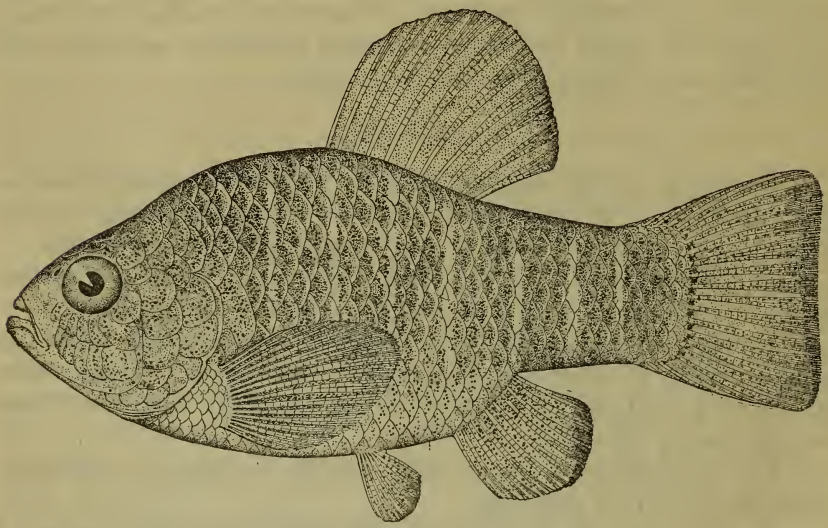

FIG. 3.—*Cyprinodon variegatus.* Variegated minnow. Male.

it is very abundant in the shallow brackish ponds, but it does not appear to attain as large a size as it does in some other localities. The usual length of the adult female is only about 45 mm.; the adult male is somewhat larger, averaging about 48 mm. in length and being notably deeper in body than the female. The sexes appear to occur in equal proportion.

The fish is an active swimmer and very ferocious. In captivity it will kill and devour fishes of other species much larger than itself. Even such species as *Fundulus heteroclitus* (Linnæus) and *Fundulus majalis* (Walbaum), which are ordinarily quite aggressive, are unable to withstand its attacks. Its sharp, tricuspid teeth afford a very effective weapon. It makes its attacks by darts, inflicting a wound here or there, and then quickly turning for defense. After a brief

period another attack is made, and this is kept up until the victim is exhausted or disease attacks the wounds. In several instances it was noticed that a number of individuals made a concerted attack upon one common victim. Where the prey is large and can not be devoured whole, the flesh is ripped from the bones with the sharp teeth and eaten a bit at a time. Cyprinodon does not limit its attacks to fishes of other species. When a number of them are placed in an aquarium, fighting soon ensues among their own kind and cannibalism prevails.

It is apparently a voracious feeder, with a varied diet. In nature it appears to subsist largely upon vegetable matter. The stomachs that were examined were found to be distended with plant stems, algæ, and mud. The nature of the digestive tract, which is much convoluted and equal to about two and one-third times the length of the fish, indicates that plants form the principal natural food.

In 1914 it was noticed that this fish spawned throughout the summer, so that ripe females could be obtained at nearly any time from April, when the observations were begun, until October. It was also found that there were several sizes of eggs present in the ovary at one time. These facts suggested that this fish produced more than one set of eggs during a single season. In order to obtain more definite information in regard to this matter, the following experiments were undertaken: A rectangular box was constructed with four legs and with a hole in the bottom near one end. Beneath the hole there was tacked a piece of wire netting, the meshes of which were too small to permit the escape of the fish to be used in the experiment, but large enough to allow the eggs to pass through, should any be produced. This box was placed in a compartment of a hatching table provided with an overflow and connected with drain pipes. Underneath the hole in the bottom of the box a small basket of wire gauze was placed. The opposite end of the box was somewhat elevated. A small stream of salt water was allowed to flow in at the elevated end, thus creating a current directed toward the opening in the bottom at the opposite end. The purpose of the current was to carry the eggs through the screened opening and cause them to be deposited in the small gauze basket. On April 10 a large female was placed in the box, where she lived until September 20. Eggs were produced on the following dates: April 28, May 28, June 14, daily from June 24 to July 3; July 16, 17, 19, 22, and daily from July 24 to 31; August 9, 11, 13, and 16. The first three sets consisted of from 18 to 24 eggs each and the remainder of only from 2 to 6 each. When the female died on September 20 she was completely "spawned out." It is, however, probable that all of the eggs that were produced did not reach the retaining basket, as dissections indicate that the early sets at least are usually much larger. It is possible that the parent may have eaten

some of them before they reached the wire screen. Several dissections made on April 17 showed that the ovary of a large female contained about 140 well-developed eggs, fully half of which seemed to be of one size and generally nearly mature. To acquire more data on this point, artificial spawning was tried with a number of females. The process of stripping, however, involves more handling than the species endures, and none of the females lived to produce more than two sets of eggs.

Females of this species may be found in spawning condition as early as the middle of March and as late as October 1. Whether the early spawners continue to spawn as late as October or if these late spawners are those that began spawning later in the season is not known. Our aquarium specimen, which was an early spawner, had, under abnormal conditions, spawned out by August 16.

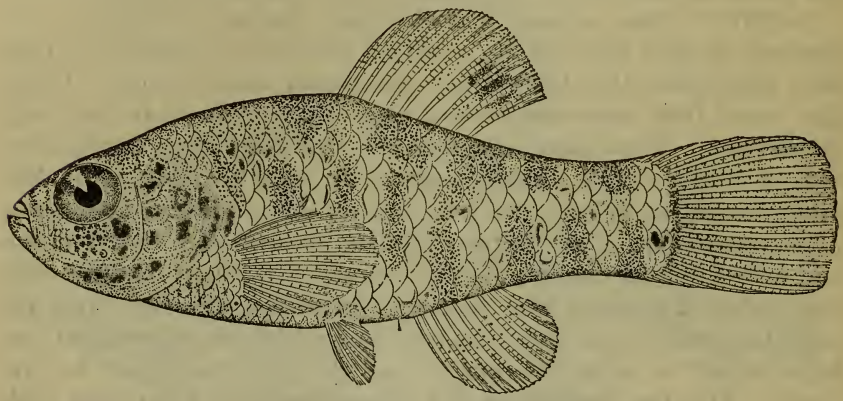

FIG. 4.—*Cyprinodon variegatus.* Varjegated minnow. Young.

The eggs of this species are somewhat heavier than salt water. They are spherical in form and about 1 mm. in diameter. Incubation at laboratory temperature occupies five to six days. The newly hatched young are 4 mm. in length (Kuntz, 1916, p. 414). They grow rapidly and by the beginning of August some of the largest are as much as 32 mm. in length. Up to this age the sexes are colored alike and resemble the adult female, but at about this time the young male assumes the adult markings and hereafter it can with difficulty be distinguished from an adult male.

My observations show that this is a very prolific species, and its fecundity may be held to explain in a measure its great abundance. It is said to be of some value as an eradicator of mosquito larvæ, but its greatest economic importance probably lies in the food it furnishes for larger fishes.

In this connection it may be mentioned that observations in the field and dissections made at various times during two seasons strongly

indicate that the following species, common in this vicinity, also produce more than one and perhaps several sets of eggs during a single season: *Lucania parva* (Baird and Girard); *Fundulus heteroclitus* (Linnæus); *Fundulus majalis* (Walbaum); *Fundulus ocellaris* (Jordan and Gilbert); *Fundulus luciæ* (Baird and Girard); *Menidia beryllina* (Cope); and *Menidia menidia* (Linnæus).

SUMMARY.

1. *Cyprinodon variegatus* inhabits shallow, brackish ponds and ascends fresh-water streams. Stragglers occur in strictly salt water.

2. Its principal food consists of vegetable matter, but it probably feeds also on many kinds of animal life. In captivity it is very ferocious and attacks and eats its own kind.

3. In the Beaufort region this fish spawns from March till October, producing eggs at intervals of varying length. Periods of 10 days or a month may intervene between occasions of spawning or eggs may be deposited daily for a considerable period.

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