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Notes on the Life History and Ecology of Gambusia Patruelis

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TROXEL

GAM-
BUSIA
PAT-
RUELIS

NOTES ON THE LIFE HISTORY AND ECOLOGY OF *GAMBUSIA PATRUELIS*

A Thesis

Presented to

the Faculty of the Department of Biology

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In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Robert B. Troxel

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CHAPTER I

THE PROBLEM

Statement of the problem. It is the purpose of this thesis to present information on the life history of Gambusia patruelis. The study is the combination of data collected by a number of writers on this subject, as well as observations taken of this species from the Rio Grande and Conservancy ditches surrounding Albuquerque.

Importance of the problem. The problem is important from a biological and ecological standpoint. In accordance with the present scientific methods, the life habits of a species must be known before its economic value can be accurately determined. If its habits are known, we can more easily increase or decrease its numbers. It is important to increase the numbers because of their importance in mosquito control. Gambusia have been distributed through the combined efforts of the United States Bureau of Fisheries, the League of Red Cross Societies, and other Governments, practically throughout the world where ever climatic conditions were favorable.

In 1926, Carl Hubbs[3] investigated the problem further and has determined other distinguishing factors, whereby they may be separated.

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[3] Hubbs, Car L., "Studies of the Fishes of the Order Cyprinodontes," Occasional Papers of the Museum of Zoology, University of Michigan, Miscellaneous Publication 16, 1926, p. 3.

CHAPTER II

EARLY HISTORY

Heterandria patruelis was first described by Baird and Girard in 1854, Proceedings of the Academy of Science, of Philadelphia,/ but at present is Gambusia petruelis. According to Poey, the generic name, Gambusia, is from the Cuban word Gambusino which signifies nothing with the idea of a joke or farce. These people say that one "fishes for Gambusinos" when he catches nothing.[1]

Regan, 1913, has held on general anatomical grounds that there are three species, Gambusia affinis, G. patruelis, and G. holbrookii, within the territorial limits of the United States. The evidence was based on the microscopic structure of the gonopodium. But many of the later writers did not agree as to the distinctness of the species and up to 1926 it was generally accepted that the Gambusia in the United States were included in one species, Gambusia affinis.[2]

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[1] Jordan, David Starr, Manual of the Vertebrate Animals of the Northeastern United States Inclusive of Marive Species (New York: World Book Company, 1929), p. 103.

[2] Geiser, S. W., "Notes Relative to the Species of Gambusia in the United States," The American Midland Naturalist, 8:160, 1922-1923.

CHAPTER III

SPECIFIC CHARACTERS

Adults. Body moderately elongate, becoming deep in the adult female; head flat above; mouth moderate; lower jaw projecting; both jaws with bands of pointed teeth; dorsal and anal fins rather short and small, the anal more or less in advance of the dorsal and in the male much advanced and modified into a long intromittent organ.

> Length 13 mm. to 69 mm. (total length); body robust and not much elongate, considerably compressed; depth 3.7 to 4.3 in length, greatest width of body about 3/5 of its depth; depth ofcaudal peduncle 2.1 to 2.4 in its length. Color light olive, each scale edged with darker; a very narrow dark streak along sides; top of head dusky; a more or less distinct triangular bluish-black bar below eye; sides and belly anteriorly dusky with dark dots; a black blotch on each side of belly, caused by the black internal organs showing throught the skin. Head short, broad, and flat above, 3.7 to 4 in length; width of head 1.4 to 1.6 in its length; interorbital space 2 to 2.5 in head; eye 2.6 to 3.2; nose 2.8 to 3.6; maxillary 2.8 to 3.4; mandible equal to eye; lower jaw slightly longer than upper; teeth in broad villiform bands. Dorsal rays 6 or 7, the fin inserted behind ventrals; anal rays 8 (females) or 6 (males); anal fin of males inserted nearer muzzle than base of caudal (vice versa in females), its anterior rays modified into a long, blade-like intromittent organ; ventrals reaching to vent; pectorals past front of ventrals, 1.2 in head. Scales 28 to 30; transverse series 9 or 8; top and sides of head covered with large scales.[1]

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[1] Forbes, Stephen Alfred, and Robert Earl Richardson, The Fishes of Illinois (Springfield, Illinois: State Printer, 1920), p. 215-217.

Young. Young uniformly transparent yellowish; head rounded; eyes large and black and close to the anterior end because of the short snout. A dark pigmented line extending from the dorsal line, mid-dorsally forward, forming a bi-lobed area, the lobed areas coming forward to the eye; and there is a dark pigmented line between the anal fin and the caudal. Lateral line quite prominent; pigmented spots below the eye and around the lips; fins finely spotted along the rays. The young at the time of birth are from 8 mm. to 10 mm. in total length. The average measured length of 10 newly born young was 7 mm. standard length; 9 mm. total length.

Sexual differences and characteristics. According to Hildebrand, 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 became evident when the fish was 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. 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 25 mm.[2]

From Collier's paper[3], who further studied the mechanism in more detail, we find that the short first and second rays of the fin have a normal appearance. The third, fourth, and fifth rays are elongated to about one third the standard length of the body, and are characteristically armed with recurved spines, serrae, and hooks at the extreme distal end. A less conspicuous but probably significant modification is exhibited by the sixth and seventh rays and sometimes the eighth ray, which are deeply bowed and separated by an unusually broad expanse of fin membrane to form a broad, deep concavity into which the sperm masses are probably transferred. Complex anatomical specializations are developed to allow the complete reversal of the fin. Some of the special anal fin and osteological modifications of the male Gambusia are represented in vestigal or rudimentary condition in the female. The anal fin of the female shows a distinct approach toward that of the male, especially

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[2] Hildebrand, Samuel F., "Notes on the Life History of the Minnows, Gambusia affinis and Cyprinodon variegatus," Bureau of Fisheries, Document 857:7, 1917.

[3] Collier, Albert, "The Mechanism of Internal Fertilization in Gambusia," Copeia, No. 1:52, May, 1936.

in the third, fourth, and fifth rays. These rays are broadened near their proximal ends and otherwise approach the corresponding rays of the male, but they are only about half as long and bear no trace of hooks or spines. The second haemal spine of the female shows a slight bending of the lower portion of the spine. The third spine also shows bulgings.

Relative size and length. Hildebrand, who took Gambusia holbrookii which is the species found in North Carolina according to the latest classification, found females taken from a very shallow and extremely muddy pond to be from 60 mm. to 65 mm. in length. The males were considerably smaller than the females. The largest male observed by Hildebrand when he studied Gambusia in this region was 33 mm. in length[4].

The smallest male observed in the collections taken from the local conservancy ditches which had the gonopodium developed was 13 mm. in length. The largest males taken from these collections were two specimes both of which had a standard length of 38 mm. and a total length of 48 mm. Two other large males were 30 mm. standard length, 37 mm.

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[4] Hildebrand, Samuel F., "Notes on the Life History of the Minnows, Gambusia affinis and Cyprinodon variegatus," Bureau of Fisheries, Document 857:1, 1917.

total length; 31 mm. standard length, 39 mm. total length. The largest female had a standard length of 57 mm. and a total length of 69 mm. The average total length of the females is about 35 mm. to 55mm. Pietro Parenzan, who worked with Gambusia in Istria in northern Italy, also observed a female 69 mm. in total length.[5]

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[5]Parenzan, Pietro, "Biological Study of Gambusia holbrookii," Atti. Accad. Sci. Veneto-Trentino-Istriana, I9:I09-I23, 1928. Abstracted by F. Lamonte, Biological Abstracts, 1934. p. 553.

CHAPTER IV

DISTRIBUTION

General. Of the genus Gambusia there are numerous species in warmer parts of America. Most of them belong to coast streams of eastern Mexico. Two of them, very much alike, range through our south Atlantic and Gulf States. The one considered in this paper, Gambusia patruelis, is found from Florida to Texas in sluggish streams of the Gulf States and northward to southern Illinois and south to Tampico, Mexico. Another, Gambusia holbrookii, extends from Georgia northward, in lowland streams, swamps, and rice ditches in the south Atlantic States and ranging to the Lake of the Dismal Swamps in Virginia. A third, Gambusia affinis, of the San Antonio-Guadalupe system in eastern Texas,[1] is now regarded as distinct from Gambusia patruelis; another, Gambusia nobilis, is found in the springs of the Pecos valley in New Mexico and western Texas; although the structural differences are small, and in their habits and food all these are doubtless alike.[2] California introduced Gambusia

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[1] Hubbs, Carl L., "Studies of the Fishes of the Order Cyprinodontes," Occasional Papers of the Museum of Zoology, University of Michigan, Miscellaneous Publication 16, 1926, p. 3.

[2] Jordan, David Starr, "The Mosquito Fish (Gambusia) and its Relation to Malaria," Annual Report of the Smithsonian Institution, 1926, p. 363.

patruelis from Texas in 1922. From there it was introduced to Hawaii and from Honolulu it was taken to Formosa by Masamitu Oshima. From here it was taken to Singapore, Mandalay, and Bangkok. It is now distributed to southern Japan and China. It has been introduced into Mexico, South America, Asia, and Europe.[3]

Dulzetto,[4] who worked with Gambusia in Italy, mentioned Gambusia holbrookii, indicating that the species was introduced into that area. Boettger,[5] however, stated that the killifishes introduced into Italy, by way of Spain for malaria control, hitherto regarded as Gambusia holbrookii proved to be Gambusia patruelis. Shipments have been made from California to the Near East, and it would be logical to conclude that the species was Gambusia patruelis as this is the species found in the California region.

Local. Gambusia patruelis was introduced into New Mexico in 1928 and was distributed in the conservancy

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[3] "The Use of Fish for Mosquito Control," International Health Board of the Rockefeller Foundation, 1924, p. 13.

[4] Dulzetto, Filippo, "Structure of the Ovary of Gambusia holbrookii," Boll. Zool. (Naples) 5(3):83-85, 1934. Biological Abstracts, 1935, p. 2181.

[5] Boettger, Caesar R., "Uber die Artzugehorigkeit des in Italien zur Malariabekampfung Einegefuhrten Zahnkaspflings," Zool. Anz., 105(½):9-14, 1933. Biological Abstracts, 1934, p. 1619.

ditches of the Rio Grande drainage and irrigation system. These fish were brought to this area from Mississippi to aid in the mosquito control work which was begun at that time.[6] They are quite abundant in the ponds and sluggish ditches in and around Albuquerque. They are also present in the Rio Grande. The ditches where most of the collections were made were west and south of Albuquerque. Those ditches selected were about 12 feet wide, about two feet deep, and the current slow, as the top-minnow can not live in fast water. The bottom is very muddy and there is an abundance of vegetation of algae, Characeae, and other submerged vegetation. Along the sides are emergent vegetation such as cattails and water cress. The banks as a rule are steep as they have been dug out and form an artificial system.

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[6]Barber, M. A., H. W. Komp, and C. H. King, "Malaria and the Malaria Danger in Certain Irrigated Regions of Southwestern United States," United States Public Health Report, 44:1312, May, 1929.

CHAPTER V

FEEDING

Food of young. The young are very active when born and, according to Samuel F. Hildebrand, they are ready to begin the work of destroying mosquito larvae at once, for he observed them attacking and eating small and even medium sized mosquito larvae in an aquarium before they were a day old. At this early age, they were unable to swallow large larvae, but he watched them swallow larvae more than half the total length of the fish itself. Considerable difficulty is apparently encountered in swallowing a particle of this size and a portion of the larva was still visible one minute after the process of swallowing was begun. It was sometimes noticed that one such morsel did not satisfy the appetite and that a second one was taken.[1]

From the stomach contents of 10 young which were less than 20 mm. in standard length, six contained Ostracoda and four had Diptera larvae. But one of these had a small percentage of plant food which was an alga . Because of their advanced development at birth they are equipped to feed on materials similar to that of the adults.

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[1] Hildebrand, Samuel F., "Notes on the Life History of the Minnows, Gambusia affinis and Cyprinodon variegatus," Bureau of Fisheries, Document 857:3, 1917.

Food of adult. The habit of swimming at the surface, which is the reason for the name top-minnow, is correlated with the fact that it seeks and acquires its food at or near the surface of the water. Due to this fact it was found to be a great eradicator of mosquitoes, and in this respect lies its greatest importance. For this reason it has been planted in many places where it is not native and the results have been gratifying. Laboratory experiments are not very good evidence to prove the feeding habits as they occur in nature, but will be considered because of the outstanding results.

Hildebrand took an adult female, about 43 mm. in length, which he had held in a battery jar since early spring and which he had regularly fed minced fish. On August 2, she was fed 140 mosquito larvae between 11 a.m. and 12:15 p.m. The larvae were all of large size and nearly ready to pupate, being from 6mm. to 8 mm. in length. All except four were eaten by 12:30 p.m. At six p.m., 25 additional larvae were added. Nearly all were immediately eaten and by nine p.m. all had dissappeared. He also observed that one adult female ate 165 large larvae in less than 12 hours.[2]

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[2] Hildebrand, Samuel F., "Notes on the Life History of the Minnows, Gambusia affinis and Cyprinodon variegatus," Bureau of Fisheries, Document 857:4, 1917.

Seale, working with this fish in the Phillipines, reported that one pair of half grown Gambusia ate 5,041 mosquito larvae, by actual count, between December 9, 1915 and February 25, 1916.[3]

Kalandadse and Mtscheldlidse observed under laboratory conditions that an adult female consumed 300 mosquito larvae in five minutes. They also observed them eating mosquito eggs, particularly those of Anopheles. Larvae, eggs, and pupae were all devoured if enough Gambusia were present and the vegetation did not too greatly hinder the swimming. The males and young do not eat pupae because they cannot swallow them. Males eat far fewer larvae than females.[4]

The fish kept in captivity became quite tame after a short period of time and would feed on the prepared fish foods and would touch and pull on the green algae that was placed in the aquaria. When small clumps of algae were placed in the aquarium, the largest female would feed first, driving the others away, until she had her fill. Sometimes,

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[3]Seale, Alvin, "The Mosquito Fish, Gambusia affinis (Baird and Girard) in the Philippine Islands," Philippine Journal of Science, 12:67, May 1917.

[4]Kalandadse, L., and J. Mtscheldlidse, "Materialien zur Biologie des Fishes Gambusia," Arch. Schiffs,-U. Trop. Hyg., 36(10):539-544, 1932. Citation from Biological Abstracts, 1936. p. 262.

the next largest in size would follow her and bump her in the sides. The males did not fight back as was characteristic of the larger females, but they would watch their chance and get some algae while the others were chasing each other about. Frog eggs, Rana pipiens, were hatched in the aquarium and the tadpoles were soon eaten by the Gambusia.

Hildebrand[5] took some dead mosquito larvae and introduced them with live larvae and in each instance no attention was paid the dead larvae until the live ones had been consumed. It is quite probable that this fish has a preference in food, but it is evident that it is by no means dependent upon live food for subsistence. Apparently it devours anything suitable in size, whether animal or plant. It is well known that in the aquarium Gambusia will eat its own young, but this cannabalistic habit is by no means restricted to the aquarium, since Hildebrand has captured specimens in nature which contained in the stomachs fish of their own kind.

Although, 21 kinds of food are listed in the tables for the period between October and June, only a few of these were important from the standpoint of bulk and occurence in the 130 fish stomachs that were examined. Fifty-three contained Ostracoda, all of which were taken from the

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[5] "Transaction of the Second Annual Antimalaria Conference," Public Health Bulletin Number 115:39, January, 1921

conservancy ditches. Twnety-five were empty, 18 of which were collected during the winter months when the top minnow is inclined to be less active. Thirty-four of 105 contained plant material, indicating that animal material is most frequently chosen, if we can draw conclusions from this small number examined.

Kind of food preferred. Griffiths observed that Gambusia came up and actually touched the mosquito larvae and did not devour them until some motion was perceived. According to Hildebrand, Gambusia does not seem to have a good eyesight. The range of sight seems to be limited to about 3 inches, and it is essential that there is not much vegetation to hide the motion of the "wigglers".[6] Movement is one of the determining factors in the selection of food, but the fact that they eat prepared fish foods is evidence that movement is not entirely necessary.

Abundance of food at different seasons. In the ditch west of the Rio Grande from the Central Avenue Bridge, food was not the factor that it was in the ponds. In this ditch, which is fed by seepage, the temperature did not slow up the activity in winter and food was more abundant. Ostracods

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[6]"Transaction of the Second Annual Antimalaria Conference," Public Health Bulletin Number 115:39, January, 1921.

were the most abundant food in the seepage fed ditch. In the other ditches, there was more vegetation and a greater variety of animal life. Diptera and Ostracods were most frequently chosen in spring and fall. More empty stomachs were found in the ponds.

TABLE I

RESULTS OF STOMACH ANALYSES

Palmer's Slough (Ditch) October 18, 1938

SL	TL	Sex	Stomach empty	Plant material unidentified	Algae	Lemna	Animal material unidentified	Debris	Snail	Nauplius	Ostracoda	Eubranchipus	Locustidae	Zygoptera larvae	Aphididae	Coleoptera	Diptera larvae	Diptera pupae	Chironomidae	Culicidae larvae	Culicidae adults	Formicidae
11	14	F					100															
14	18	F		X							100											
15	19	F									100											
20	24	M																				
22	27	M		X																		
27	33	F					85									15						
31	39	F														100						
30	38	F																		100		
27	33	F		X																		
24	31	F												60							40	

Northwest of Alameda, October 29, 1938

26	34	F									100											
28	35	M		50							50											
32	40	F									100											
35	43	F	X																			
37	45	F									100											
40	50	F									100											
45	56	F									100											
47	57	F												100								
48	60	F									100											
50	62	F									30			70								

TABLE II

RESULTS OF STOMACH ANALYSES

Palmer's Slough (Ditch) November 5, 1938

SL	TL	sex	Stomach empty	Plant material unidentified	Algae	Lemna	Animal material unidentified	Debris	Snail	Nauplius	Ostracoda	Eubranchipus	Locustidae	Zygoptera larvae	Aphididae	Coleoptera	Diptera larvae	Diptera pupae	Chironomidae	Culicidae larvae	Culicidae adults	Formicidae
20	25	F	X																			
22	28	M		90	10																	
23	29	F	X																			
24	30	F		100																		
27	35	F	X																			
24	30	M		5	95																	
32	40	F		85	10																	
33	40	F		5	95																	
35	42	F		10	10								40	20		20						
36	43	F	X																			
Palmer's Slough (Pond) December 2, 1938																						
21	26	M		25													75					
22	29	F		100																		
22	27	M	X																			
23	29	M		100													100					
24	30	M																				
25	31	F	X																			
27	34	F	X																			
28	34	F														100						
32	40	F					50															50

TABLE III

RESULTS OF STOMACH ANALYSES

1st Ditch West of Rio Grande January 24, 1939

SL	TL	Sex	Stomach empty	Plant material unidentified	Algae	Lemna	Animal material unidentified	Debris	Snail	Nauplius	Ostracoda	Eubranchipus	Locusitdae	Zygoptera larvae	Aphididae	Coleoptera	Diptera larvae	Diptera pupae	Chironomidae	Culicidae larvae	Culicidae adults	Formicidae
22	27	M					25				75											
22	28	M	X																			
[illegible]	[illegible]	[illegible]		25												5	20			50		
31	37	F					80	20														
32	38	F									100											
33	41	F		5							95											
39	47	F									20						80					
40	49	F									50								50			
41	51	F									10		45				45					
45	52	F									100											

Palmer's Slough (Ditch), January 28, 1939

23	29	M															100					
25	32	F												50			50					
28	35	F															25		75			
31	37	F															60	30	10			
37	46	F		10													60				30	

Palmer's Slough (Pond), January 28, 1939

22	28	M	X																			
25	32	F	X																			
25	32	F		100																		
26	32	F						100														
35	44	F	X																			

TABLE IV

RESULTS OF STOMACH ANALYSES

North of Central Bridge, West of Rio Grande February 26, 1939

SL	TL	Sex	Stomach empty	Plant material unidentified	Algae	Lemna	Animal material unidentified	Debris	Snail	Nauplius	Ostracoda	Eubranchipus	Locustidae	Zygoptera larvae	Aphididae	Coleoptera	Diptera larvae	Diptera pupae	Chironomidae	Culicidae larvae	Culicidae adults	Formicidae
22	27	M															100					
25	31	M		75			25															
26	[illegible]	F	X																			
28	35	F	X																			
32	39	F	X																			
35	43	F									100											
35	43	F	X																			
36	45	F															100					
38	48	F	X																			
40	50	F															100					

North of Central Bridge, West of Rio Grande, March 17, 1939

21	27	M		60			40															
22	28	M					100															
27	33	F	X																			
27	33	F					100															
31	39	F									100											
33	42	F									100											
34	42	F									100											
34	42	F									100											
34	42	F									100											
38	47	F									100											

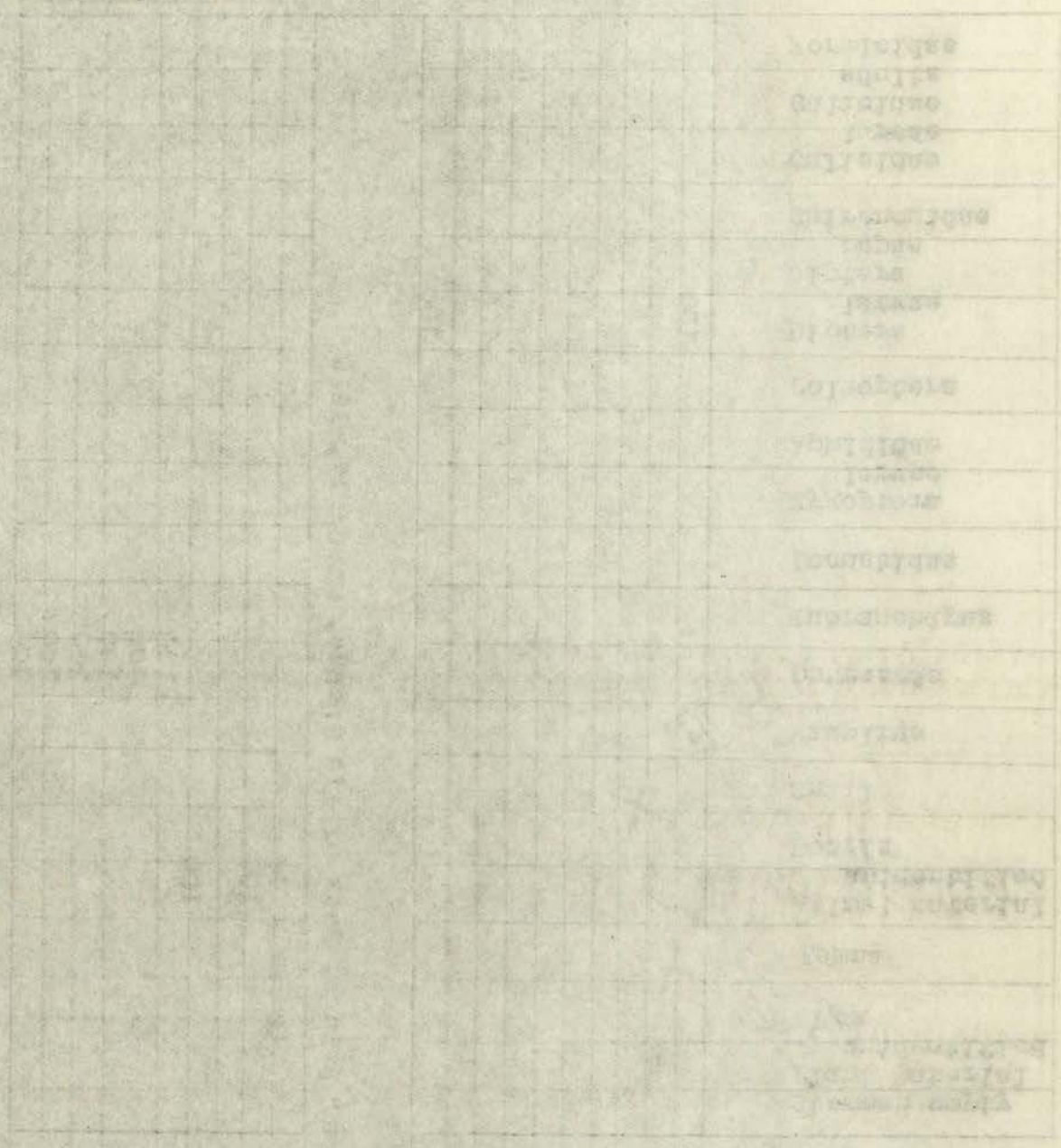

TABLE V

RESULTS OF STOMACH ANALYSES

½ Mile West of Alameda
April 22, 1939

SL	TL	Sex	Stomach empty	Plant material unidentified	Algae	Lemna	Animal material unidentified	Debris	Snail	Neuplius	Ostracoda	Eubranchipus	Locustidae	Zygoptera larvae	Aphididae	Coleoptera	Diptera larvae	Diptera pupae	Chironomidae	Cuilcidae larvae	Cuilcidae adults	Formicidae
15	19	F			25						10						45	75				
18	23	F			45						100											
19	25	M									80						20	100				
21	25	M																				
23	29	F									100											
24	30	F									30						20			50		
24	31	M									50											
25	31	F					50				40											
27	33	F					60				100											
32	41	F									50								50			
35	41	F									10									90		
34	42	F									90						10					
35	42	F																				
36	45	F															100					
37	46	F									100											
40	49	F				5					95											
44	56	F		20							80											
45	56	F							10		80							10				
47	59	F									100											
48	58	F		25							75											

TABLE VI

RESULTS OF STOMACH ANALYSES

½ Mile Northeast of Alameda
May 13, 1939

SL	TL	Sex	Stomach empty	Plant material unidentified	Algae	Lemna	Animal material unidentified	Debris	Snail	Naupilus	Ostracoda	Eubranchipus	Locustidae	Zygoptera larvae	Aphididae	Coleoptera	Diptera larvae	Diptera pupae	Chironomidae	Culicidae larvae	Culicidae adults	Formicidae
15	19	F									25						75					
15	19	F															100					
17	20	M								100												
17	21	F														100						
25	33	M									40	60										
22	26	M	X																			
20	25	M	X												60	40						
23	29	F													60							
24	30	F									40											
27	34	F									100						100					
28	32	F																				
32	38	F									100											
33	40	F									100						10					
35	43	F			60						30											
43	52	F				70					15			15								
43	53	F	X																			
45	55	F									100											
45	55	F									100											
46	58	F									100											
46	58	F									100											

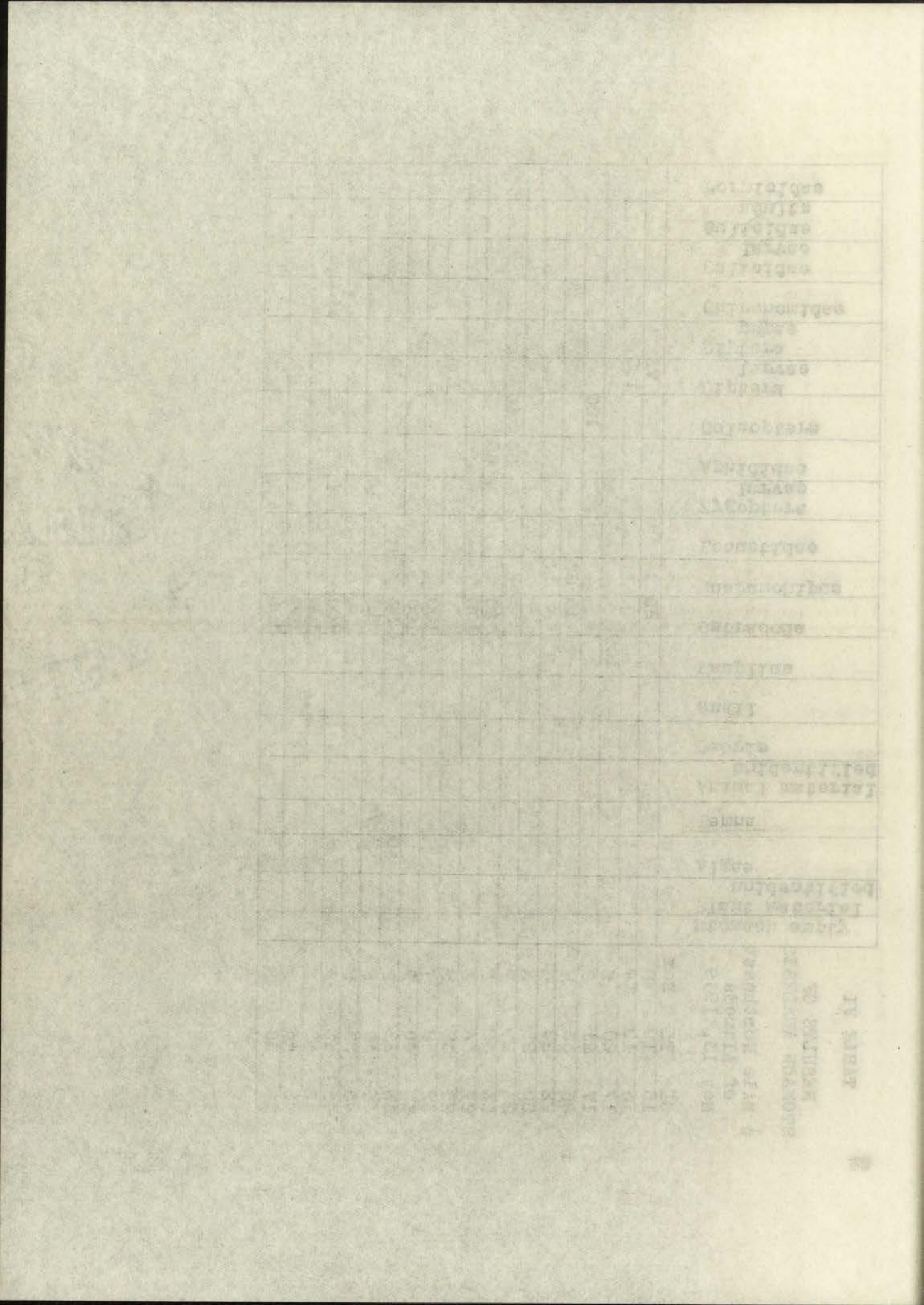

TABLE VII

RESULTS OF STOMACH ANALYSES

Rio Grande
Sandoval County
June 9, 1939

SL	TL	Sex	Formicidae	Culicidae	Culicidae adults	Culicidae larvae	Chironomidae	Dipter. pupae	Diptera larvae	Coleoptera	Aphididae	Zygoptera larvae	Locustidae	Eubranchipus	Ostracoda	Nauplius	Snail	Debris	Animal material unidentified	Lemna	Algae	Plant material unidentified	Stomach empty
20	25	M																	100				
24	29	M					50														50		
28	35	F					30					70											
25	32	M																				100	
28	35	F																				100	
31	37	F					30			20											50		
36	45	F										100											
37	46	F								70									30				
39	48	F										50							50				
40	50	F									10										90		

CHAPTER VI

REPRODUCTION

Age and size at maturity. In some specimens, the specialized form of the fin became evident when the fish was only 13 mm. in length and less than three months old; in others it was not apparent at the age of five months or at a length of 17 mm. 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 any later stage until it attains its maximum normal growth of about 25 mm.[1] In fact a few male fish 28 mm. in length had it undeveloped, but none above that size.[2]

From the work of Dulzetto, the various stages of the gonopodium are correlated with the 10 stages in the development of the testicle. They are characterized by the different stages of spermatogenesis and by the development of the testicular canals and the vasa

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[1] Hildebrand, Samuel F., "Notes on the Life History of the Minnows, Gambusia affinis and Cyprinodon variegatus," Bureau of Fisheries, Document No. 857, 1917, p.7.

[2] _____, "Sex Ratio in Gambusia", Biological Bulletin, Marine Biological Laboratory, 53:390-404, 1927. Citation from Biological Abstracts, 1928, p. 967.

deferentia.[3] From this we can infer that there is a correlation in growth and development between the testicle and gonopodium, and as the gonopodium develops the fish is reaching maturity.

It is interesting to know that the early broods of the season reach maturity 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 are only about 23 mm. in length and the first brood consists of only two or three young.[4]

From a number of fish observed here in New Mexico, the smallest female with embryos was 28 mm.

Dominance of sex. 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 appears that the abundance and prolificness varies locally and also seasonally; and considered from the

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[3] Dulzetto, Filippo, "Structure of the Testicle of Gambusia holbrookii and its Evolution in Relation to the Development of the Gonopodium," Arch.-Zool. Ital. 19:405-437, 1933. Citation from Biological Abstracts, 1935, p. 2181.

[4] Hildebrand, Samuel F., "Notes on the Life History of the Minnows, Gambusia affinis and Cyprinodon variegatus," Bureau of Fisheries, Document No. 857, 1917, p. 6.

standpoint of possible mosquito larvae control with Gambusia as the active killing agent, it indicates the desirability of a knowledge of the changing sex-ratio of the top-minnows and the factors responsible for the difference.

Using[5] two closely related species, G. holbrookii of the Atlantic drainage and affinis (or patruelis) of the Mississippi valley, 1o3,150 individuals of 21 mm. (using eye measurements) and over in length were sexed, principally on the basis of the anal fin, if the anal fin had become changed into an intromittent organ, gonopod, the fish was classed as male, if not, female. Later, 1945 fish, 20 to 30 mm. long, with unmodified anal fins and showing no dark abdominal spots, as in gravid females, were sexed by examination of the internal sex organs. Finally, 2593 immature fish (from birth about 8 mm. to 20 mm.) were sexed by examination of internal sex organs. Among the adults (21 mm. and upward in length), a seasonal variation was found. The ratio in midsummer (August) was one male to 11.31 females; during early summer, (June) one male to 2.54 females. The results confirm those of earlier investigators (Barney and Anson). The explanation of these authors, however, is rejected. From the examination of specimens 20.5 to 30 mm. long which could not be sexed from external characters, it was found that a portion of the males had not developed the intromittent organ when 21 mm. long. In fact a few male fish 28 mm. long had it undeveloped, but none above that size. Results show that the number of males from examination of external sex characters is somewhat below the actual, but the error is too small to account for the large differences in sex ratio obtained. In the young (20 mm. and under in length), the sex ratio was nearly one to one (1298 males and 1295 females). Evidence is adduced that the males are the weaker sex, that they possess less resistance to unfavorable environment, and that they are probably also more extensively preyed upon, because of the abundance

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[5] Hildebrand, Samuel F. "Sex Ratio in Gambusia," Biological Bulletin, Marine Biological Laboratory, 53:390-404, 1917. Citation from Biological Abstracts, 1928 p. 967.

of Gambusia in favorable environments and their very rapid multiplication under such conditions and because recopulation between the broods of a female during one season is not necessary, apparently enough males for reproductive purposes are always present.

Barney and Anson[6] worked on male frequency, and said:

> In the prosecution of this study, 18,780 Gambusia of all ages have been examined. Of the fish 1.5 cm. and more in length, 14.7 percent were males. In 1919, 18.2 percent were males. The largest percent of females came in November, 1918, and February, 1919, when there were 34.8 and 34.0 percent respectively. The lowest monthly percent of males came in July, 1918, and August, 1919, when there were 11.1 percent and 10.4 percent respectively. Between the period from January to July or August, there appears to be a general decrease in the ratio of males to females, even though the actual Gambusia frequency continually increases throughout this period.

They found that the frequency increased rapidly from late April to July. In late summer, there was also a decreasing production of young.

A table of collections taken from October 13 to June 9 was tabulated to illustrate the difference in number between males and females. Quite consistently the sex ratio was about three females to one male. The differences here are not as great as have been given by other writers because mature and immatures were considered. In the immatures, the ratio was one to one, and the fact that the two were counted reduced the ratio.

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[6] Barney, R. L., and B. J. Anson, "Seasonal Abundance of the Mosquito Destroying Top-minnow, Gambusia affinis, Especially in Relation to Male Frequency," Ecology, 2:69, 1921.

Some of the reasons considered for the difference are that the males are smaller and are lost in manipulating the net. Some have used mosquito netting and still found a large difference in number. This then does not seem to be related too closely to the truth. Another reason advanced by Barney and Anson for the difference is that in summer and fall, because of the high evaporation, the water level is lower which would diminish natural protection. Winter temperature, however, produces a high death rate during the colder months.

There is also a percentage of error in the late development in the male of the secondary sexual characters.

It would be quite difficult to determine the number of females fertilized by one male in natural conditions. Jordan stated that about ten females were born to one male.[7] Although there is a consistent shortage of adult males, the fact that the female is capable of producing young throughout the season by coming in contact with the male only once overshadows the fact that there might be a reducing effect on the species. From observations in the aquarium it was quite apparent that the males were not monogamous.

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[7] Jordan, David Starr, "The Mosquito Fish (Gambusia) and its Relation to Malaria," Annual Report of the Smithsonian Instituion, 1926, p. 361.

Fighting of males and females. From observations in the aquarium, the female frequently dashes at the male and causes him to dart into a corner. The male was not observed to dash at the females. Fighting was frequently noticed especially among the females, and particularly those of similar sizes, when food was placed in the aquarium. That some of these fights are quite serious was evidenced by the fact that a female which was confined in a small rectansular tank, killed and partly devoured three males that were introduced for breeding purposes. An article in Science mentioned how frequently the females attack and kill the males, which seem to be too timid to fight back[8].

Courtship. Copulation was seen rather frequently, however, observations were limited to an aquarium in the Biology building.

In the transfer of sperm, the male swims up from behind and under the female, moving the gonopodium excitedly. He swims to the side of the female, tilting slightly on his side and facing forward. He moves the gonopodium forward to an angle of about 145 degrees. The female pauses just long enough for the brief sexual contact. The fish from which

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[8]"The Mosquito Fish", Science, 67, January, 1921.

these observations were made, were collected from Palmer's Slough, December 2, 1938, from a pond on which there was a slight shell of ice and the temperature was four degrees centigrade. On the fifth of December, the temperature of the water in the aquarium was 21 degrees centigrade. Copulation could be observed rather frequently for several days.

Season of reproduction and frequency. Jordan[9] listed the season of Gambusia holbrookii in Georgia, where there are four or five broods, between March and September, and in California, he listed Gambusia patruelis with two or three broods in a season. However, in a bulletin used by the California Department of Public Health, they gave from six to eight broods a year.[10]

From Hildebrand's observations, a single female may produce as many as six broods of young during a single season. This was demonstrated through an aquarium experiment. In one instance, a medium sized female, about 40 mm. in length, was placed in a jar early in the spring of 1914. She gave birth to the young as follows: first brood, May 20;

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[9] Jordan, David Starr, "The Mosquito Fish (Gambusia) and its Relation to Malaria," Annual Report of the Smithsonian Institution, 1926. pp. 361-368.

[10] "Mosquito and Malaria Control", State of California Department of Public Health, Bulletin No. 44:25, 1927

second brood, July 2; third brood, July 18; fourth brood, August 9; fifth brood, August 30; and sixth brood, October 5. This fish did not receive the direct rays of the sun. Presumably the effect of aquarium life would be to reduce rather than to increase the number of broods.[11]

From observations in Albuquerque, the exact number of broods in a year was undetermined because this study extended only during the school term between October and June. However, gravid females were collected every month but February. These collections were made from a Conservancy ditch west of the Central Avenue bridge, and the first ditch west of the Rio Grande. The source of the water for this ditch was a series of springs and here the temperature did not fall much below 15 degrees centigrade. The ditch was 15 feet wide, about two feet deep, with a sandy bottom.

The number of gravid females taken during the cold months was quite small but never the less they were present. On December 23, a gravid female was brought into the office and on the 24th at four o'clock, she began to bear young, one at a time (while observed) and all tail first. Only a few were alive and these soon died after birth. The

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[11] Hildebrand, Samuel F., "Notes on the Life History of the Minnows, Gambusia affinis and Cyprinodon variegatus," Bureau of Fisheries, Document No. 857:1-15, 1917.

TABLE VIII

PERCENTAGE OF MALES AND FEMALES COLLECTED BETWEEN OCTOBER 1938 AND JUNE 1939, TO ILLUSTRATE SEX RATIO
(Both matures and immatures were considered)

Location	Date	Number of females	Number of males	Number of unknown	Percent of females	Percent of males	Percent of unknown
South of Alameda (ditch)	Oct.13-38	17	7	2	65	27	8
Parson's Slough (ditch)	Oct.18-38	137	80	12	59	36	5
Parson's Slough (ditch)	Oct.19-38	70	29	1	70	29	1
Alameda	Oct.20-38	293	75	9	69	29	2
Total	October	517	191	24	62	25	3
Palmer's Slough (ditch)	Nov. 5-38	539	198	51	69	25	6
Palmer's Slough (ditch)	Dec. 2-38	74	30	1	61	28	1
North, Central Bridge; West, Rio Grande	Jan.24-39	132	42	19	70	21	9
Palmer's Slough (ditch, pond)	Jan.30-39	464	154	63	69	22	9
North, Central Bridge; West, Rio Grande	Feb.26-39	153	81	13	63	32	5
North, Central Bridge; West Rio Grande	Mar.17-39	102	38	2	73	26	1
South, Alameda	Apr.22-39	410	140	2	74	25	4
South, Alameda	May 13-39	210	42	0	84	16	0
Rio Grande	Jun. 9-39	68	37	10	60	32	8

abortion was probably caused by two factors: the sudden change in temperature, or injury from handling; the latter is probably the more logical. The total number of young collected was 54,but this may or may not be the total number of young produced, since she continued the process over a four day period. The temperature of the water was 21.5 degrees centigrade.

Again a female was collected, January 24, 1939, and aborted February 11, 1939. Some of the young, that were alive, died shortly after birth, while others were in various stages of development.

From Dulzetto's work, we learn that the sperm of Gambusia do not lose their power of fecundation in a few months when retained in the female as was formerly thought. On May 13, 1927, six Gambusia females were taken from a reservoir and segregated. Three of these died. In April, 1928, specimens D and E showed the nuptial color patterns. On May 17, 1928, specimen D gave birth to 21 fry, and on May 18, specimen E yielded 33 fry. From this it is evident that the sperm in this species retain their power of fecundation for at least a year within the body of the female.[12]

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[12] Dulzetto, Filippo, "Preliminary Note on Sexual Life of Gambusia holbrookii," Atti. R. Accad. Naz. Lincer. Rend. Cl. Sci. Fis. Mat. e Nat., 8(½):96-101, 1928. Citation from a translation by R. A. Huttkowski, taken from Biological Abstracts, 1930, p. 402.

Hildebrand, who also experimented on this problem, gives the following information:

> A female kept under close observation produced 5 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 the males, a number of females were kept in aquaria throughout the winter. in the following spring, large eggs, of yellowish appearance, were produced 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 indicates that it cannot carry them through the winter.[13]

The evidence from Dulzetto's and Hildebrand's experiments is conflicting. To offer an explanation would be q uite difficult, but it would seem logical to attribute the cause to some limiting factor as could only be determined by further experimentation.

Temperature of water and relation to breeding season. Temperature of the water seems to be the determining factor as to the beginning of the breeding season. If based on the kind of food, temperature would still be an important factor since the plant foods, such as algae, etc., are dependent to some extent on temperature, and the animal life is directly

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[13] Hildebrand, Samuel F., "Notes on the Life History of the Minnows, Gambusia affinis and Cyprinodon variegatus," Bureau of Fisheries, Document 857:8, 1917.

or individually dependent on plant life. A difference of five degrees centigrade has been seen to produce a decided change in activity, in the top-minnow.

Effect of breeding instinct in feeding. From examination of the stomach contents of gravid females, there is no evidence of breeding effect on feeding. The fact that they are more sluggish at this time did not change the type of food taken, and usually the stomach was gorged with food.

Seasonal variation in the adult testis. The testis shows a periodicity in volume, the number of contained spermatozeugmata, and in the volume of the longitudinal testicular canal. During the spring and summer, which is the breeding season, this testis increases in size. The increase is not great compared to other species of fish, as it averages only 60 percent, while the maximum is only a six-fold volume increase. During the late autumn and winter and very early spring, the testis is filled with spermatozeugmata. which greatly distends the longitudinal testicular canal. After the great spring wave of copulation, the testis shows very few spermatozeugmata, and in June and July the testis is filled with early stages of spermatogenesis. Active

spermatogenesis occurs only at this time.[14]

This work was not completed on Gambusia patruelis, but on G. holbrookii, however, these two species are very closely related and are difficult to distinguish and occur in similar habitats.

Time required for young to develop. Using circumstantial evidence from this point of discussion and taking the time between different parturitions, observed by different men is from 16 to 43 days. However, there are usually embryos in the same ovary in different stages of development and this may or may not be the time required for the young to develop.[15]

Description and activity of gravid females. As the embryos develop within the ovary a black spot appears on each side of the abdomen of the female 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 surfaces, the period of parturition is not far distant. She remains with the group at this period although

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[14] Geiser, S. W., "Sex Ratios and Spermatogenesis in the Top-minnow, Gambusia holbrookii," Biological Bulletin, 47:175-212, 1924.

[15] Hildebrand, Samuel F., "Notes on the Life History of the Minnows, Gambusia affinis and Cyprinodon variegatus," Bureau of Fisheries, Document 857:6, 1917.

she is a great deal more sluggish and not able to get about as quickly and is very easily picked up with a seine or net.

Position in which young are produced. Hildebrand observed the extrusion of the young repeatedly and stated that 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 be quick and with some apparent force; at other times, it is slow and deliberate. Some females under observation delivered nearly the entire brood in one postition, but others did not. It appears that the young are most frequently born tail first and are born one at a time. The process invariably taking place during the day. The entire brood may be delivered in 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.[16]

From observations on four specimens in an aquarium here in Albuquerque, the young were always produced one at a time, tail first. These notes were taken when there were abortions. It being an abnormality, the process was extended over a four day period.

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[16]Ibid., p. 8.

Care of young by the female. After birth there is apparently no further interest on the part of the female, unless her appetite is unsatisfied, and then she will use her young for food for herself.

Number of young born correlated with the size of female. 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 as would be expected.

Kuntz,[17] 1914, working with fishes from the Beaufort region found 76 to be the maximum number produced by a single female. Smith[18] examined some fish 45 to 50 mm. in length, which were killed, and counts of fully developed young were made. The numbers ranging from 84 to 134, the average for all fish examined was 100.

Twenty-four gravid females were examined from collections taken throughout the year. Those with a total length less than 40 mm. had an average of 35 embryos, and the females between 40 and 50 mm. had an average of 64 embryos,

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[17] Kuntz, A., "Notes on the Habits, Morphology of the Reproductive Organs and Embryology of the Viviparous Fish, Gambusia affinis," Bulletin, US Bureau of Fisheries, 33:138, 1913.

[18] Smith, Hugh M., "The Prolificness of Gambusia," Science, August, 1912, p. 224.

while those over 50 mm. from a random selection of 10 females which were nearing the time of parturition had an average of 108 embryos. This average is high because only the heavier ones were selected and this would give the evidence as to how many they would bear. The largest number of embryos contained in one female, with a standard length of 55. mm. was 152, and one 52 mm. in standard length contained 151 embryos. In both of these females, the embryos were all of the same size and had the eyes developed.

Rate of growth of young. Barney and Anson state that the disparity of the rate and growth between male and female takes place chiefly after the first six weeks when all Gambusia will be at least 15 mm. in length.[19] From this point the females in early stages, for the first one and one half to two months, grow in length and weight faster than the males.[20]

Age at which males and females can be distinguished. Some of the males can be distinguished in six weeks while in

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[19] Barney, R. L., and B.J. Anson, "Seasonal Abundance of the Mosquito Destroying Top-minnow, Gambusia affinis, Especially in Relation to Male Freq uency," Ecology, 2:53-69, 1921.

[20] Geiser, S. W., "Observations on Sex in the Top-Minnow, Gambusia affinis," Anatomical Record, 23:112, January, 1922.

others it has been found to be five month before the gonopodium develops. This is the only external character by which we can identify the males and females, but we are not able to distinguish the females by the position of the anal fin until the intromittent organ is developed.

CHAPTER VII

GENERAL BEHAVIOR

Migration from one depth to another. Migration is not so well promounced inthe life cycle of Gambusia, as is characteristic of many of our native fish. However, there is a noticeable change in this connection, and that is when the water becomes cold due to the low temperatures. The warmer water is at the bottom in winter and is also influenced by the heat of the earth. Gambusia are not very active at this period and remain on the bottom of the pond. Their movements at this time are quite laborious and heavy. This short movement is correlated with temperature and it was only in standing water or ponds where this change occurred.

Schooling at different seasons. From observations in the local ditches there are always a number of fish together forming a school, and apparently at all seasons. However, one finds a large female or several away from the others, and occasionally a number of small ones are collected and usually of the same size. But usually we find a number of large and small ones in schools.

Winter habitat. The winter habitat does not change except the temperature drops to freezing and then the

top-minnows remain at the bottom as was referred to in migration and in the preceeding heading.

Character of water and ground preferred. The fact that the top-minnow is able to thrive under a wide range of conditions and especially in water suitable for the mosquito larvae, has made Gambusia so successful in mosquito control.

The little fish make no objection to sewage in the water and flourish in the gutters of Vera Cruz and other filthy cities where open ditches take the place of sewers. It is indigenous to the extracantonement zone and can withstand the higher water temperatures.[1]

Source of water. Most of the collections made during this study were taken from the conservancy canals that drain the excess underground water from agricultural lands that are located in the middle Rio Grande valley. In the drainage canals which have become a part of the reclamation projects the flow is fairly constant throughout the year.[2] They have become one of the principal sources for a number of the native fish and several that have been introduced.

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[1] Jordan, David Starr., "The Mosquito Fish (Gambusia) and its Relation to Malaria," Annual Report of the Smithsonian Institution, 1926, p. 361.

[2] Clark, John D., and Hillard L. Smith, "A Chemical Study of the Waters of the Middle Rio Grande Conservancy District, as Related to Fish Culture," University of New Mexico Bulletin No. 270, July, 1935, pp. 1-36.

The source of the water in the ditch, when gravid females were collected in winter, was mainly from seepage and because of its contact with the earth, the water seldom if ever dropped below 12 degrees centigrade.

In the ponds of Palmer's Slough, collections were also made. The source of the water is seepage as these ponds were formed when ground was taken to make banks to prevent flooding. The diggings were lower than the water table and filled with water; however, they are not entirely permanent.

Manner of resting. At night when the lights were turned on, the fish could be seen resting on the bottom of the aquarium or up in the algae and were perfectly quiet; but during the day they are almost continually moving. They often made short darts like a pike, curve in the dorsal and anal fins and also the caudal fin; then stay in one position and move the pectoral fins and the caudal fin, but more frequently the caudal fin is not moved when at rest.

Manner of swimming. When starting from a resting position, there is a flap from the two pectoral fins and an undulating movement of the body and caudal fin, all apparently taking place at one coordinated movement. When moving rapidly, the only fin that moves is the caudal, but when not moving so rapidly the pectoral fin aids in the movement. In

some movements, both pectoral fins are moved together, while in other movements, they will first move to one side and then the other.

Peculiar movements. Occasionally, one can see a fish come within several inches of the floor of the aquarium, stop, and make a sudden dart, rubbing his side on the bottom, or moving over almost entirely on the dorsal side; sometimes the movement is repeated several times. The fish may also move up to an object, stand, and then make a sudden dart, and seem to catch something and then bounce away. Another movement, which is merely the opening of the mouth and swimming along, is often observed. This expression reminds one that the fish is yawning.

Respiration. Respiration takes place in the gills. During respiration the walls act like a pump. In inspiration, the oral cavity is enlarged by raising of the opercular apparatus, and water is therefore drawn into it through the mouth. Folds of mucous membrane, branchiostegal membranes, prevent water from entering through the opercular aperture. Expiration results from the contraction of the opercular apparatus. The branchiostegal membrane is opened and water passes out through the gill slits. The exit of water by way of the mouth is prevented by valves of mucous membrane.[3]

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[3] Hegner, Robert W., College Zoology (New York: Macmillan Company, 1932), p. 445.

CHAPTER VIII

EMBRYOLOGY

Fertilization. The ovaries are united into a single sac and before each gestation period the yellowish eggs are produced. The eggs do not leave the follicular sacs in which they are developed; these follicles instead of bursting the ovary, merely form a small opening in their walls, and through this opening sperms enter and fertilize the egg which goes on developing within the follicle.[1]

Development. The formation of the blastoderm and the differentiation of the embryo takes place in a manner which is quite typical for teleosts. The blastoderm appears as a small, almost circular cap of cells which is slightly elevated above the surface of the yolk. While the embryonic area is becoming differentiated, the blastoderm spreads rapidly over the yolk until the latter is completely covered. After the embryonic area is formed the embryo soon becomes well outlined. The tail bud grows out and the neural axis is apparent throughout the length of the embryo. The optic vesicles are present when three to four somites are formed.

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[1] Cunningham, J.T., Ed. Reptiles, Amphibians, and Fishes. (London: Methnen and Company, 1912), p. 333.

The auditory vesicles are present when the embryo has from twelve to fourteen somites, and at this stage the heart is also differentiated, which soon begins to pulsate. As development advances, the ovarian follicle becomes highly vascular, increases in size, and is filled with a transparent fluid in which the embryo is constantly bathed. The gills of the developing embryo apparently become functional comparatively early. The young are born in an advanced stage and show nearly all the diagnostic characters of the species except sex. They undergo no marked metamorphic changes after birth.[2]

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[2] Kuntz, A., "Notes on the Habits, Morphology of the Reproductive Organs and Embryology of the Viviparous Fish, Gambusia affinis," Bulletin, Bureau of Fisheries, 33:187, 1913.

CHAPTER IX

PARASITES

Parasites. From observations made here in Albuquerque and from the literature which has been examined, there was no information given on the parasites of Gambusia. Sterility and belated development of the gonopodium were thought to be caused by some abnormal condition which might be caused by a parasite.

CHAPTER X

MORTALITY

Mortality. The Gambusia is a warm-water fish but is indigenous to areas where there are mild winters. Although it is able to adapt itself to a wide variety of condition, the low temperatures in winter probably has the most effect on the mortality of the top-minnow in this area.

However, the effect of water temperature, its influence upon the growth or decay of water plants and upon the content of various dissolved gases in the water, may also become of grave importance. In general, fish can tolerate comparatively wide ranges of acidity and alkalinity. So here the principal effects on the death rate are indirect. They are not as harmful as they might appear to be, because of the amount of alkalinity present in these areas.[1]

The mortality is probably due to several factors, but most important, probably, are the low temperatures and the cannabalistic tendencies of this species.

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[1] Clark, John D. and Greenbank, John, "A Cause of Death of Fish in the Southwest," University of New Mexico Bulletin, Number 294, September, 1935. p. 10.

CHAPTER XI

ENEMIES

Enemies. The top-minnow is not a very active swimmer, and becomes easy prey for predatory fish. As to the enemies of Gambusia, Jordan[1], 1926, stated that he noticed but one especially destructive. This was the large water beetle, Dytiscus, about an inch long and of a shiney brown color and very voracious.

The predators were discussed at the Antimalaria Conference and the worst enemy of Gambusia was thought to be the large mouth black bass, when it is from three to four inches in length. Water snakes are probably next in importance, but pike and pickeral are quite harmful, as well as a number of the wading birds.[2]

Their cannibalistic tendencies must also be considered under this heading, as they are their own enemies.

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1 Jordan, David Starr, "The Mosquito Fish (Gambusia) and its Relation to Malaria," Annual Report of the Smithsonian Institution, 1926, p 365.

2 "Transaction of the Second Annual Antimalaria Conference," Public Health Bulletin, No. 115, January, 1921, p. 39.

CHAPTER XII

ECONOMIC VALUE

Importance in mosquito control. The use of larvivorous fish in mosquito control work, to supplement drainage, oiling, and other methods, is of somewhat recent origin; yet it cannot be considered an innovation. For hundreds of years similar procedures have been studied and advocated in closely allied fields.

The introduction of a predacious fish may result also in the elimination of more choice kinds of fish and do more harm than good. This is the reason the United States Bureau of Fisheries declines to furnish any type of fish unless they known their habits.

Objection to the attempt to control mosquito production by use of fish has been made on the ground that nature tends to establish a balance between mosquito larvae and fish. The evidence indicating that in some regions fish and larvae have lived together naturally, for a long period of time and that the fish have not succeeded in destroying all the larvae.

But objection of this sort is answered by the fact that fish have been successfully used not only against the yellow fever, but also against malaria mosquitoes. The experience of many independent investigations shows that within certain definite limits, excellent results can be obtained

by applying the biological method to mosquito control.[1]

The malaria mosquito, Anopheles, makes malaria a distinct menace, as it is common throughout the southern states, and wherever it exists unmolested, with suitable biological conditions, the disease will probably flourish. Its importance and inseparability from mosquitoes justify a discussion of the disease and its relation to the mosquito.[2]

Malaria is caused by a microscopic parasite which attacks and lives in the red corpuscles in the blood of human beings. Its beginning, in all cases, dates from the bite of an infected mosquito. In biting, the mosquito injects a small amount of saliva into the victim before sucking up its blood meal. With this saliva, one or more parasites are injected into the blood stream, where they immediately attack and enter the red corpuscles. The further development in the human system is then by division. As each division takes place a quantity of toxin or poison is also released into the blood stream.[3]

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[1] "The Use of Fish for Mosquito Control", International Health Board of the Rockefeller Foundation, 1924, p. 11.

[2] Jordan, David Starr, "The Mosquito Fish (Gambusia) and its Relation to Malaria," Annual Report of the Smithsonian Institution, 1926, pp 361-368.

[3] Howard, H. H., "An Indigenous Fish Used in Combating Malaria," International Health Board, Reprinted from Nations Health, 4:Nos. 2,3, February, March, 1922.

Careful experimentation has definitely shown that the transmission of malaria from one human to another is absolutely dependent upon a cycle of man to mosquito to man. If this cycle can be broken, the spread of malaria can be absolutely controlled. Malaria mosquitoes are the only ones to be controlled, but forms of Culex are also of economic value because they are a nuisance to man, and summer resorts, otherwise desirably located, lose large amounts of tourist trade because of the persistance of these mosquitoes.[4]

Mosquitoes of all species pass through four distinct stages: egg, larva, pupa, and imago or adult insect. The first three are aquatic stages, during which the mosquito may be most effectively attacked. During these stages the insect lives in a fixed, accessible, and easily located habitat where it may be most easily destroyed on a large scale. It is almost necessary to rely upon destruction of immature stages, as destruction of the winged form counts for relatively little. During their aquatic stages, mosquitoes encounter fish as one of their natural enemies, a great many larvae being destroyed by cetain fish that depend on the food they find on or near the surface of the water.

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[4] "Mosquito and Malaria Control," State Department of Public Health, California, 1927. p. 6.

The advantages of fish over oil are in places such as ponds and lakes where a continuous film of oil cannot be maintained because of frequent rains, emerging vegetation, or where frequent winds break up the film. In places where the water is used for drinking, oil would not be desirable. Fish control is more permanent in its results and less expernsive. Oil is not only expensive, but there would be an added cost of distributing and spraying.[5] Oil is also advantageous in temporary ditches, pools, and swamps. There are also many places which would not be suitable to fish life and where other methods must be used.

The natural habits of both fish and mosquito larvae must be considered in selecting fish to be used for the destruction of larvae. As has been said, the problem of attacking Anopheles of which there are many species is particularly complex, because these mosquitoes breed in quiet as well as running water; they are almost completely hidden by the surroundings. For these reasons the fish used must be of a species that will search for food not only in the shallow water but amid vegetation as well.

Seal, formerly of the United States Bureau of Fisheries, lists a number of questions to be considered in choosing fish

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[5] "Transaction of the Second Annual Antimalaria Conference," United States Public Health Bulletin No. 115, January, 1921, p. 39.

for mosquito control:[6]

1. Do they swim amid aquatic and semi-aquatic vegetation?
2. Do they live in quiet or open water?
3. Are they slitary or gregarious?
4. Are they sluggish, lethargic, or active?
5. Are they carnivorous, herbivorous, or omnivorous?
6. Are they bottom-feeders, top-feeders, current-feeders, or variable?
7. Are they destructive of other fish?
8. Are they found where there are mosquitoes?

In pools, ponds, lagoons, and other natural bodies of water an adequate supply of food and the breeding habits of the fish become very important points for consideration. The fish must breed rapidly because large numbers of them must be kept in the water. Carnivorous fish are to be preferred to omnivorous, and surface feeders are usually best.

There are a number of fish that eat mosquito eggs and larvae or "wigglers" when they find them convenient, but what is needed is a kind of fish that makes mosquito killing its chief business, which enters on it with alacrity and which will not and cannot destroy more choice kinds of fish.

These desired traits are found in the top-minnow, Gambusia.[7]

> Gambusia was selected for the present tests because, first, it seeks its food at the surface, which appears to make it especially suitable for anti-malaria or anti-mosquito work; second, it lives and thrives under a variety of conditions and especially in water suitable for the support of mosquito larvae; third, it proved to be

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[6] "The Use of Fish for Mosquito Control," International Health Board of the Rockefeller Foundation, 1924, p. 13.

[7] Jordan, David Starr, "The Mosquito Fish (Gambusia) and its Relation to Malaria," Annual Report of the Smithsonian Instituion, 1926, p. 365.

quite common in the extracantonement Zone and adjacent territory; fourth, it is very prolific; fifth, its usefulness in destroying mosquito larvae in aquariums and fountains was well known. This fish does not lay eggs but gives birth to well developed and very active young. It, therefore, requires no special environment as most other fish do for depositing and hatching the eggs.

, the species in question,
Heterandria/was first described by Baird and Girard in 1853. As early as 1854, in Georgia, a certain Dr. Gort freed a tank of all its larvae by placing in it a dozen or more small fish. They were believed to be Gambusia.

About 1914, shortly after interest in fish as mosquito destroyers had been re-awakened in India, the United States Bureau of Fisheries participated actively in trials that were being made in the use of fish in the southeastern states.[8]

However, Hildebrand mentioned that the first practical test of this kind of control was made at Dallas, Texas, by Van Howenberg about 1916. In the spring of 1918, the request of the Public Health Service sent Hildebrand to Augusta, Georgia.[9]

Breeding Gambusia in the southern states of this country has been highly successful in small to modeate sized ponds or swamps. Heavy reproduction also resulted in shallow ponds or swamps containing an abundant growth of plants.

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[8] "The Use of Fish for Mosquito Control," International Health Board of the Rockefeller Foundation, 1924, p. 16.

[9] "Transaction of the Second Annual Antimalaria Conference," Public Health Bulletin, No. 115, January, 1921, p.39.

It is highly essential that such ponds should be free from fishes, snakes, and other animals that would prey on minnows. It is unfortunate that Gambusia are unable to endure the winters north of Deleware and therefore, can not be used in that section of the country except on a small scale.

Since 1918, when the value of Gambusia as a destroyer of mosquito larvae was first clearly demonstrated in the extracantonement zone. It has been distributed through the combined efforts of the United States Bureau of Fisheries, the League of Red Cross Societies, and other governments, practically throughout the world where ever climatic conditions were favorable. Shipments have gone to the Philippine Islands, to the Hawiian and Society Islands, and to many of the countries of Europe including Germany, Austria, and Russia, also to China, Japan, and Siam. The first successful shipment to Europe went to Spain, and from there Gambusia were distributed to points in Italy, and elsewhere in southern Europe. The United States Bureau of Fisheries has sent fish to Syria and Palestine, the West Indies, and the Argentine.

Nowhere has Gambusia multiplied so enormously as in Italy where it is reported that standing water in some places has become literally clogged with them, so much so that the peasants complain that the cattle refuse refuse to drink the water.

Pietto Parenzon also reports that Gambusia finds an over favorable environment, resulting in physiological excess. This is shown by a larger size and by a more frequent and prolific reproduction. This occurs in super-saturation, considering by saturation a content of 1000 per cubic meter.[10]

The success obtained in Austria and Italy in the control of mosquitoes through the use of Gambusia is reported to be most gratifying. In June, 1927, Dr. Maximus Sella reported that:

> After four and three years respectively, from the time of importation of Gambusia into Spain and Italy, we have to thank the United States for the precious gift which they made us, the value of which we no longer doubt.

In Palestine, unfortunately, it is said that Gambusia has encountered enemies with which it could not cope.[11]

The number of mosquito fish necessary for satisfactory work depends on a number of factors. The size of the pond or body of water that is subject to much wave action. The presence or absence of vegetation. The presence or absence of enemies and the presence or absence of a shallow shore line.

The general plan of anti-mosquito work should be the protecting Gambusia in the area in which the tests are to

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[10] Parenzon, Pietro, "Overpopulation of Waters by Gambusia and Effects of Overstocking on Gambusia," Arch. Zool. Ital., 16(½):538-544, 1931. Biological Abstracts, 1935, p. 19.

[11] "The Top-minnow, Gambusia, The Mosquito Destroyer," Bureau of Fisheries, February, 1935, p. 4.

be made, and to increase the number in the ponds in which the nuisance is to be abated. Usually, if the numbers are increasing, there is more competition for food and there will be more effective results. There should also be careful field observations, so that you can tell just how effective the method is you are using, and how it can be improved.

In the United States, there is a general consensus of opinion that various species of the top-minnow are adapted to mosquito control and that among these, Gambusia patruelis takes first place.

CHAPTER XIII

SUMMARY

The Gambusia are light greenish-brown in color. The fins are speckled, but no conspicous marking anywhere. The adult is marked by a black shade or bar under the eye, and the gravid females develop a black area on the side under the skin. The larger females were occasionally 60 mm. in length and the males 35 mm. in length. The young are born alive, transparent, with big black eyes, and are from 8 to 10 mm. in length. The sexes are distinguished externally by the presence of the gonopodium in the male which is used as an intromittent organ. It may appear when the fish is 13 mm. in length, or be developed due to delay at a length of 25 mm. in length.

Gambusia patruelis is indigenous from Florida to Texas, in sluggish streams of the gulf states, and northward to southern Illinois, and has now been introduced into practically every tropical and warm temperate climate country in the world.

Its food consists largely of the larvae of insects, but it feeds upon a variety of other animal and plant substances. It readily takes prepared fish foods. Sometimes, it eats its own kind, even its own offspring, especially in the restricted environments.

In a spring fed ditch, gravid females have been collected every month except February. More than 50 percent of the number of females taken from a collection in April were gravid. From all the collections taken, the sex ratio was about three to one.

Females separated from males in the spring, shortly before the first brood is born, continued to produce young throughout the seasons. Females that were killed and examined contained as many as 152 embryos.

Young are usually delivered tail first and one at a time. The parturition period may be from an hour to three or four days.

The young are born in advanced stages of development and show nearly all of the diagnostic characters of the species. There are no marked metamorphic changes after birth.

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.

They can withstand all kinds of water and great extremes in temperature. Winter is the season when there is the greatest mortality. At this season they remain on the bottom and activity ceases until the temperature rises.

The top-minnow is known primarily as a fresh water species, but is occasionally found in stagnant water. Gambusia is of great value in anti-mosquito work because the desired traits found in the fish fit this work to perfection.

It eliminates the "wigglers" completely from ponds which are fairly free of protective vegetation and debris, as the chief obstacles to the successful use of this fish are aquatic vegetation and floatage. They must also be protected from predators and must not be used as bait to catch other fish. But predators are not entirely harmful because they act as a check and keep them in the shallow parts where their work will be far more effective.

Because of its extreme prolificness, easy propagation, ability to adapt itself to different conditions, and to reach areas not penetrated by other species, exceptional devouring capacity, general habits, and living in identical areas with mosquito larvae, Gambusia affinis is the most valuable natural agent known for the destruction of mosquito breeding in the United States and many other countries, especially Italy.

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