THE BIOLOGY OF *TILAPIA NILOTICA* LINNEAUS

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ABSTRACT

Studies concerning the reproductive behavior, spawning temperatures, fecundity, period of egg formation, food habits, and lower lethal temperatures of the exotic cichlid, *Tilapia nilotica*, were conducted in aquaria and in earthen ponds at Auburn University, during the period of April 1959 to June 1960. These studies suggest that the spawning behavior of *T. nilotica* is typical of that of many cichlids and consists of schooling by the females, territorial establishment by the males, an intricate prespawning courtship, spawning, and parental care by the female. During this period of parental care, the eggs are carried in the buccal cavity until they hatch, and the fry remain there for about five days thereafter.

T. nilotica spawned in aquaria at a constant temperature of 74° F. Spawning occurred in ponds in late April when diurnal temperatures ranged from 70° to 84° F.

The fecundity was found to vary considerably with the size of the brood fish and on a seasonal basis. Relatively lighter broods were produced at the initial spawning. Mean seasonal values for 5-, 6-, and 7-inch fish were calculated at 160, 261, and 462 eggs per spawn, respectively. In aquaria kept in the Fisheries Building, Auburn University, spawning occurred at 5 to 8 week intervals. Egg formation began at a relatively early age. Fish from ponds receiving supplemental feeding were found to form eggs when they were 4 inches in length and about 50 days old.

T. nilotica was omnivorous with greater concentrations of zoo-organisms, primarily Entomostraca and Chironomids, being utilized by smaller sizes of fish. *T. nilotica* of the 6-and 9-inch groups, in a *Pithophora* infested pond, utilized the alga quite extensively, whereas it comprised only a negligible part of the diet of smaller sizes of fish.

Temperature induced mortality occurred in ponds at 48° F. and was limited to fish less than 6 inches in length. Mortality in the larger inch-groups occurred progressively with decreasing water temperature. Some 9-, 10-, and 11-inch fish tolerated 37° F. for a short period of time; however continued exposure to temperatures below 55° F. cumulatively affected these larger fish and resulted in mortality. The last survivors of these larger inch groups were observed on January 13, after 32 days of water temperatures below 55° F.

INTRODUCTION

Tilapia nilotica Linnaeus is a member of the family Cichlidae. This family consists of over 600 species distributed mostly in Africa and in Central and South America. The Rio Grande Cichlid *Cichlasoma cyanoquttatum* (Biard and Giard) and the Velvet Cichlid, *Astronotus ocellatus* (Agassiz) are inhabitants of some fresh water areas of the United States. The Rio Grande cichlid reaches a length of about 7 inches and its natural range is the Rio Grande River drainage of Texas.

Ben-Tuvia (1960) quotes Trewavas as stating that *T. nilotica* is distributed over most of the African continent. It is also found in almost every lake and river of Israel (Ben-Tuvia, 1960). *T. nilotica* was introduced into the Southeastern United States in 1957 as a prospective pondfish and fish to control various types of noxious aquatic vegetation.

Although this species of tilapia is used quite extensively as a food source in Israel and Northern Africa where it has been studied by Ben-Tuvia (1960), Yashouv (1958), and Boulenger (1908), details relevant to its use in the Southeastern United States are lacking.

This study was conducted with *T. nilotica* to determine its spawning behavior, minimum spawning temperature, egg production per spawn, frequency of spawning, period of egg formation, food habits, and lower lethal temperature.

REPRODUCTION

Spawning Behavior

Ethological studies conducted with *T. nilotica* in the spring of 1959 in a relatively shallow pond on the Auburn University Experiment Station and observations of fish in aquaria suggested that, in general, spawning activities consisted of schooling, territorial establishment, prespawning courtship, spawning, and parental care.

Apparently *T. nilotica* is a gregarious species. Brood fish stocked in ponds early in April were observed in schools prior to spawning and females were observed to be in schools after some spawning activity had begun. Males being reared in mono-sex culture were observed in schools in mid-summer when water temperatures were favorable for spawning.

Cichlids are noted for their intricate and elaborate patterns of courtship. Aronson (1949) gives an extensive account of their reproductive behavior in which he reports that as long as they are immature, or when the conditions are unfavorable for reproduction, they live in schools; but as soon as reproductive activity begins, they establish themselves in territories which they defend against intruders. The females, upon maturing, visit these territories and pair off with the males until after spawning has taken place. The female takes the eggs and adhering milt into her mouth and leaves the male, which again begins his courtship activities. In some species of cichlids the males remain with the females as long as they are caring for the young.

During these observations of spawning behavior, the males separated from the schools when the water temperature approximated 68° F. In the experimental ponds the establishment of territories by the males began with the construction of a spawning nest. The nests were usually located in the shallower regions of the pond where the water was approximately 2 feet deep and the substrate sandy. Nest construction began with the "excavation" of a shallow, narrow depression in the substrate. At this time the fish were observed in a position vertical to the substrate. The detritus was loosened with the mouth and an accompanying revolving motion of the body. This loosened detritus and plant material was taken into the mouth and carried to the perimeter of the nest where it was deposited. These activities were continued until the nest was of a desired size. After nest construction was completed, the males kept all intruders out of the surrounding territory. Early in the spawning season, and where the nests were concentrated, the territory of each male consisted of only the nest and its immediate surroundings, whereas later in the season the larger males dominated the area and each fish defended a 2 to 3 yard radius around his nest. During the nesting period each male, at the approach of another, manifested an elaborate frontal display in which the dorsal fin was raised and the mouth opened wide. Closely nesting males in display were observed to advance frontally with a series of continuous, swift, short movements. This activity occasionally resulted in contact between the two.

As the schooling females moved through the water near the nests, the males swam out into the schools and back to their nests attempting to lure the females to their territory. A small female was observed to enter three nests before spawning with one of the larger males.

When a female "paired" with a male, the behavior pattern exhibited by the pair became one of lateral display, which consisted of tail flapping and nipping by both sexes. Following this display, spawning occurred. During the spawning act, the pair were oriented in opposite directions in the deepest part of the nest. The male was observed to initiate a circular movement of the pair by pressing against the lower abdominal region of the female with his forehead. This effort, which was apparently an attempt to induce the female to spawn, resulted in the deposition of 10 or 12 eggs. As the eggs were deposited the male passed over them spraying the milt. This circular movement occurred throughout the spawning act, with the female immediately picking up in her mouth each batch of fertilized eggs. After spawning was completed, the female swam into the deeper waters of the pond, and the male began his prespawning activities again.

All incubation duties were carried out by the female, whereas in some species of *Tilapisa* the male, or both seves, incubate the eggs. Boulenger (1908) states that *T. nilotica* is a member of the buccal-

incubating group and that this task is relegated to the females. Aronson (1949) states that, with four probable exceptions, all of the species of *Tilapia* are mouthbreeders. There four exceptions are: *T. quinasans, T. sparmanii, T. zilli,* and *T. melanopleura.*

In aquaria experiments, the length of the incubation period varied with temperature. At a temperature of approximately 81° F., fry were 9 millimeters in length 8 days after the eggs began to develop. At this time, remnants of the yolk sacs were present; and, the yolk sac was completely absorbed in 13 and 14 day old fry that had been held at 78° F. and 77° F. respectively.

With the approach of danger, the hatchlings swarmed to the head region of the female and were retrieved into the buccal cavity through the mouth and gill clefts. The duration of this parental care varied with the brood fish and individual fry. After the third day, the fry were less willing to re-enter the mouth of the female, and the number retrieved thereafter gradually decreased. Usually this relationship did not exist after 5 days.

Spawning Temperature

For the determination of the minimum spawning temperature, twenty 40-liter aquaria, 10 of which contained a pair of *T. nilotica* each, were maintained in a thermostatically controlled room. At weekly intervals the fish were transferred to the second group of 10 aquaria. This procedure was used to avoid subjecting the fish to sudden temperature changes while the aquaria were being cleaned and refilled with fresh water. Fish for these tests had been wintered in troughs maintained at 70° F. in the Fisheries Building at Auburn University. During this period, they were fed Auburn No. 2 pelleted fish feed (35 percent peanut meal, 35 percent soybean meal, 15 percent fish meal, 15 percent dry distillers dried solubles) at the rate of 1 percent of their body weight per day.

The fish were subjected to an initial temperature of 57° F. for 15 days and to consecutive temperatures of 67° F., 71° F., 74° F., and 77° F. for 15 day periods. The females were examined daily to see whether or not they were carrying eggs, and observations relative to patterns of behavior at these various temperatures were made.

Fish stocked into aquaria to determine the minimum spawning temperature were relatively inactive at 57° F. and feeding was not evident. With an increase of 10° F. the males were observed to exhibit their courtship patterns and food placed in the aquaria was utilized. The first spawning occurred on the second day of the 74° F. exposure. A second spawn was observed on the seventh day, whereas the third fish did not spawn until the water temperature was increased to 77° F. These spawns occurred during the month of July.

In experiments conducted to determine the fecundity of various sized females, the first spawning occurred on May 5, 1959, when the water temperature had reached 76° F., and continued at intervals until October 10, 1959, when the temperature of the water in the aquaria had dropped to 77° F. These fish were stocked on April 22, 1959, when the aquaria water temperature was recorded at 73° F.

Similar observations were made in a 1-acre farm pond in which a Simpson electric thermometer was used to measure the temperature at three locations. The metal probes of the thermometer were located to measure the air temperature and the water temperature at a depth of 6 inches and at the pond bottom (5 feet) at 7 a.m. and 1 p.m. daily.

Brood fish were stocked in the pond on April 14, 1960, and samples of these fish were removed for examination at 6-day intervals by seining. The fish caught were carefully removed from the seine, the mouth forced open and examined for the presence of eggs or fry. The fish were then returned to the pond. The pond was also seined for fry with a 6-mesh, 10-foot seine on these days. On the intervening days the shoreline was examined for their presence.

In the farm ponds the first brooding female was taken in the periodic seine checks on April 27, 1960, from fish that had been stocked 13 days prior to this date. The eggs were eyed and approximately 5 days old; therefore it was assumed that spawning had occurred on April 22 Temperatures recorded at this date in 6-inch water were 70° F. at 7 a.m. and 84° F. at 1 p.m. An average of the 7 a.m. and 1 p.m. readings for

a week prior to the spawning date was 76° F. at the 6-inch depth and 71.8° at the pond bottom. The lowest temperature recorded during this week was 68° F. at the pond bottom.

Apparently the temperature necessary to stimulate prespawning activity in the males is somewhat lower than the spawning temperature of the females. Bed preparation by the males was observed 10 days before spawning occurred. The mean daily temperatures during this period was approximately 70° F. In the aquaria experiments, males were observed to exhibit their courtship patterns at 67° F.

In the fish ponds of Israel, *T. nilotica* spawned first in late April or early May when the temperature of the water reached 72° F. (Yashouv, 1958). Huet (1955) states that the temperature plays an important role in the reproduction of *Tilapia* and that the average daily temperature must be at least 68-70° F. before spawning is initiated.

Fecundity

Fifteen 40-liter aquaria were used in an experiment to determine the number of eggs produced per spawn and the frequency of spawning by various sized brood fish. Each of these aquaria was stocked on April 22, 1959, with a pair of *T. nilotica*. The temperature of the water in these aquaria at this date was 73° F. The aquaria were stocked with fish that had been wintered as those previously discussed and during the experiment they were fed Auburn No. 2 pelleted feed at the rate of 2 percent of their body weight every other day. The aquaria were cleaned at 4-day intervals. The females were checked daily for eggs. During incubation the branchiostegial membrane was expanded, the respiratory movements were weak, and the fish refused to take food placed in the aquaria.

Feeding was discontinued and the male removed when a female was observed to be incubating or in distress as a result of pre-spawning activities of the male. The eggs spawned in the absence of a male were removed from the aquaria or the mouth of the fish and counted. Eggs fertilized prior to the removal of the male were allowed to hatch and the fry subsequently counted. The number of eggs and/or fry produced, the size of the brood fish, the spawning date, the hatching date, and the water temperature were recorded for each spawn during the period April 22 to October 31, 1959. The number of eggs found in the mouth of incubating females removed from the ponds on various occasions were counted and the size of the fish recorded.

The egg and/or fry production for each spawn of the 15 brood females used in this experiment varied considerably with the size of the female and as the spawning season progressed. The brood females used

TABLE 1.

EGGS AND/OR FRY PRODUCED IN AQUARIA BY VARIOUS SIZED BROOD FISH DURING THE PERIOD MAY 2 TO OCTOBER 10, 1959.

Size of Female At Stocking (Centimeters)	*Number of Eggs and/or Fry produced per spawn*					
	1	*2*	*3*	*4*	*5*	*6*
12.8	78	246	64	...	...	...
13.2	114	195	...	...	...	...
13.2	...[1]	182	139	...	...	...
13.4	94	141	229	...	...	...
13.5	...[1]	192	89	407	...	...
13.6	86	137	196	362	291	421
13.6	...[1]	...[1]	...[1]	411	...	...
13.9	73	...	...	...	...	...
14.3	304	198	...	...	...	...
14.4	261	292	...	...	...	...
14.6	159	...	...	...	...	...
15.3	320	...	...	...	...	...
15.4	276	84	219	558	655	...
15.5	124	...	...	...	...	...
15.5	308	...	...	...	...	...
15.1	437	...	...	...	...	...
16.8	142	415	...	...	...	...

[1] Fish spawned but eggs were not counted.

ranged in size from 12.8 to 16.8 centimeters and the related egg number was found to vary from 64 to 655 per spawn (Table 1).

The number of eggs and/or fry produced at the first spawn by 5-inch fish (12.8 to 13.9 centimeters) ranged from 73 to 114, whereas the 6-inch females (14.3 to 15.5 centimeters) produced from 124 to 437 eggs and/or fry. The number produced by the 5-inch fish increased from a mean of 89 for the first spawn to 182 for the second. The mean for the following spawns in general increased, but an exact comparison could not be made because the number of brood fish was reduced periodically. The total length of these brood females had increased from .25 to 1.0 inch by October.

At the cessation of the experiment, two of the original 15 brood fish remained alive. The two females remaining alive, a 5-and 6-inch fish, spawned six and five times respectively. The 5-inch fish produced a total of 1,493 eggs and/or fry as compared to 1,796 for the 6-inch fish.

The number of eggs spawned by *Tilapia* varies according to the species and size of the females. Huet (1955) states that in *T. mossambica, T. macrochir,* and *T. melanopleura* the eggs produced per spawn may number in the hundreds and often in the thousands. Ben-Tuvia (1960) found the egg number of six female *T. nilotica* of the length of 22 to 31 centimeters to vary from 120 to 730. According to Ben-Tuvia (1960) Leibman counted 1,300 eggs in a female and Worthington found a female with 2,000 eggs in her mouth.

A 6.7- and a 6.4-inch incubating female were taken from the brood ponds on June 25 and July 21, 1959 respectively. The larger fish was incubating 314 eggs and the smaller 358. In late April of 1960, a 9.0-inch female in the wintering troughs was found to be incubating 1,359 eggs.

The duration between the periods of spawning in these laboratory studies was found to range from 33 to 59 days, with 87 percent of the females used in the fecundity studies completing this cycle within 43 days. Spawns occurring where males were absent were not considered in determining the duration between spawns, since the eggs were not incubated. The average period of incubation and parental care was approximately 20 days. Where males were absent from the aquaria and the eggs removed, second spawns occurred from 5 to 49 days later.

Huet (1955) states that the spawning frequency of tilapias varies with their geographical location. In tropical waters *T. macrochir* and *T. melanopleura* spawned every 5 to 7 weeks, or an average of eight times a year. Pickford and Atz (1957) in summary of the works of Aronson state that the West African mouth-breeder, *T. heudeloti,* bred throughout the year in his laboratory at the American Museum of Natural History in New York City, but that two peaks were exhibited that corresponded to the vernal and autumnal equinox.

Ben-Tuvia (1960) states that Lowe assumed *T. nilotica* of East Africa had three, four, or more batches of young in succession, while Yashouv (1958) reported three spawns in the ponds of Israel during the period of May to October.

Maturation of Eggs

Five specimens of each inch-group represented in S-5, a *T. nilotica* brood pond receiving feeding, were taken during the second week of August, 1959, for studies of ovary development. The ovaries of these fish were carefully removed and placed in a 20 percent formalin solution to harden. A compound dissecting microscope, with an installed ocular micrometer graduated into tenths of a millimeter, was used to measure the eggs from each specimen at the various stages of maturation. The diameters of the eggs in the more mature ovaries were recorded along with the ovary weight, body weight, and body length for each specimen.

The ovaries of *T. nilotica,* unlike many species, contained eggs of various sizes when the females were sexually mature. With favorable environmental conditions, a portion of these eggs progressively enlarged and were released at each successive spawn. The eggs examined were opaque, and at maturity averaged approximately 2.0 x 3.0 millimeters in size.

The first evidence of egg formation appeared in 4-inch fish (9.6 to 11.3 centimeters). The ovaries of all specimens examined in this inch-group were in a similar stage of development. The eggs measured 0.1

millimeter or larger in three of the specimens and were evident in the remainder. The egg size advanced progressively with the higher inch groups.

The exact age of the 4-inch specimens is unknown, although it can be estimated with sufficient accuracy from the specimens taken for food habit studies. These samples indicate that *T. nilotica*, under the prevailing conditions, attained a growth to 4 inches in approximately 50 days. Seven-inch specimens were taken in late July or approximately 90 days after hatching.

FOOD HABIT STUDIES

Food Habits: Food habit studies were initiated during May, 1959. Samples of *T. nilotica* were taken for stomach analyses periodically during the period of May 18 to September 27, 1959 from a 2.2-acre pond (S-12) and a 3.5-acre pond (S-9) which contained largemouth bass and *T. nilotica*. Samples were taken from a 0.25-acre (F-4) and a 1.6-acre pond (S-5) stocked with *T. nilotica* only. During the period of study, S-5, S-9, and F-4 were fed with Auburn No. 2 pelleted fish feed. All ponds used in the experiment were fertilized and the higher plants available to fish were limited almost exclusively to a few marginal species of *Eleocharis* and *Juncus*. Specimens were also taken from a 9.75-acre pond (S-3) which was infested with the filamentous alga, *Pithophora*, and which received no feeding. In the *Pithophora* infested pond, pens were constructed of chicken wire in selected areas along the shoreline. The pens were constructed so as to have a surface area of 9 to 225 square feet and a maximum depth of approximately 3 feet. These pens were stocked with 3 to 20 fish of various sizes depending on the size of the pen. The stocking rates were considered to be low enough that they would not alter the diet of the fish in any way. The pens contained *Pithophora* in quantities similar to those found in other areas of the pond. Some of the fish were removed from the pens periodically by seining. The contents of the digestive tract of these fish were analyzed and other fish were subsequently added to the pens to replace those removed.

Laboratory procedures employed in the food habits studies were similar to those given by Lagler (1952). In order to provide a basis for intraspecific comparisons, the contents of the stomach and anterior one-third of the intestine of each specimen were examined. The material therein was placed in a vial containing approximately 20 milliliters of water, agitated lightly, and emptied into a petri dish to be examined macro and microscopically. The percentage of the total due to each type of food organism was estimated.

Plankton samples were taken with a plankton net from each of the fish sampling areas at the time the fish were removed. These organisms were preserved in a 10 percent formalin solution and from each sample a 1 milliliter subsample was examined macro and microscopically. The organisms present were counted and identified and the number per liter of pond water subsequently calculated.

Stomach analyses conducted on *T. nilotica* revealed that they were primarily plankton feeders and that all sizes utilized phytoplankton to a large extent. Insects, primarily Tendipedidae and Ceratopogonidae, were utilized also by all size groups. A comparison of the quantities of various organisms consumed by the fish of each inch group suggests that some selectivity existed at various stages of their life history.

The average quantity of insects consumed by fish during the period May 18 to August 19, 1959 was 4.1, 14.3, and 5.6 percent of the total food-take in the 1-inch fish removed from ponds S-5, S-9, and S-12, respectively. A sharp decrease in the quantity of insects consumed by 2-inch fish was detected. Insects were utilized extensively by 3-, 4-, and 5-inch fish and usually comprised only a negligible part of the diet of the larger specimens (Table 2).

Small crustaceans were a more important item in the food-take of 1-inch fish only. Ostracods occured frequently in the gut of all sizes of fish. Rotifers, caddis fly larvae, water mites (hydrocarinae), Annelids, Formicids, remnants of higher plants, and fish remains were relatively unimportant items in the diet and occurred in very low quantities. (Table 2 and 3)

TABLE 2.

FREQUENCY OF OCCURENCE AND AVERAGE PERCENTAGE OF VARIOUS FOOD ITEMS FOUND IN THE DIGESTIVE TRACT OF SPECIMENS OF *Tilapia nilotica* TAKEN FROM PONDS S-5, S-9, AND S-12 PERIODICALLY FROM MAY 18 TO AUGUST 19, 1959.

		FOOD ITEM																												
						Insecta						Entomostraca																		
		Plankton algae		*Higher aquatic plants*		*Tendipedidae*	*Ceratopogonidae*	*Tricoptera*	*Formicidae*	*Unidentified*		*Copepoda*	*Cladocera*	*Ostracoda*		*Rotifera*		*Arachnida*		*Annelida*			*Unidentified eggs*		*Fish remains*		*Inorganic debris*		
Inch group	*Number sampled*	*Occurrence*	*Volume*	*Occurrence*	*Volume*	*Occurrence*					*Volume*	*Occurrence*			*Volume*	*Occurrence*	*Volume*	*Occurrence*	*Volume*	*Occurrence*	*Volume*	*Occurrence*	*Volume*	*Occurrence*	*Volume*	*Occurrence*	*Volume*	*Occurrence*	*Volume*	*Item total*
S - 5																														
1	25	25	73.1	5	0.8	4	6	0	0	1	4.1	9	7	3	16.9	0	0.0	1	T	0	0.0	1	1.3	0	0.0	14	3.7	99.9
2	20	20	96.1	3	T	4	4	0	0	0	T	2	4	3	T	1	T	0	0.0	0	0.0	0	0.0	1	T	16	3.2	99.3
3	15	15	94.2	7	0.5	7	10	0	0	0	1.9	2	0	1	T	2	T	0	0.0	0	0.0	0	0.0	2	T	13	3.2	99.8
4	14	14	94.0	8	T	6	6	0	0	0	3.3	1	4	3	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	10	2.3	99.9
5	10	10	97.5	7	T	8	7	0	0	0	0.9	1	0	1	T	1	T	1	T	1	T	0	0.0	1	T	9	0.8	99.7
6	2	2	98.2	2	T	1	1	0	0	0	T	0	0	1	T	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.7	98.9
S - 9																														
1	21	21	79.6	0	0.0	6	9	0	1	3	14.4	2	2	18	4.2	3	T	1	T	0	0.0	0	0.0	0	0.0	13	1.6	99.5
2	12	12	86.5	6	T	9	5	0	0	3	9.2	1	0	12	1.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	11	2.7	99.5
3	17	17	59.9	6	1.5	16	11	0	0	5	31.3	0	0	17	1.2	0	0.0	0	0.0	0	0.0	0	0.0	2	0.5	11	5.5	99.9
4	11	10	61.9	5	0.8	11	5	0	0	0	29.2	3	1	9	0.0	0	0.0	0	0.0	1	T	0	0.0	0	0.0	11	6.8	99.7
5	12	12	73.7	6	0.7	10	3	0	0	1	23.7	0	0	7	T	0	0.0	0	0.0	0	0.0	0	0.0	1	T	10	1.3	99.4
6	4	4	77.3	4	T	3	0	0	0	0	13.1	0	1	2	T	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	4	8.2	98.4
S - 12																														
1	18	18	39.2	0	0.0	3	7	0	0	1	5.7	13	5	5	40.2	7	10.1	0	0.0	0	0.0	3	2.9	0	0.0	2	1.2	99.1
2	9	9	81.3	3	0.5	1	1	2	0	1	2.4	0	0	8	1.0	4	7.7	1	T	0	0.0	0	0.0	0	0.0	6	6.9	99.8
3	12	11	44.6	9	3.4	11	9	0	0	2	28.3	1	0	11	0.9	1	T	0	0.0	0	0.0	1	T	2	1.9	9	20.7	99.8
4	15	15	72.4	5	0.6	9	7	0	0	1	20.4	0	0	15	1.0	2	T	0	0.0	1	T	1	T	5	1.2	11	4.0	99.6
5	7	7	91.7	1	T	1	5	7	0	1	6.0	2	0	5	0.9	0	0.0	0	0.0	0	0.0	2	T	3	T	4	0.7	99.3
6	4	4	97.5	3	0.7	2	0	0	0	0	T	0	0	3	0.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.6	99.6

[1] Includes filamentous forms and Auburn fish food in ponds S-5 and filamentous forms only in pond S-12.
[2] Expressed as average percentage of volume.
[3] Less than 0.5 percent.

The presence of fish remains in the gut of intermediate sized fish suggests some predation on the fry. In aquaria, adult brooding males and females were fed fry. The males fed upon the fry voraciously, while the recently incubated females would not feed upon them. Apparently this was associated with the recent spawning activity of the females, since at a later date, females which were not incubating were observed eating fry.

Concentrations of inorganic debris in excess of 40 percent were found in the digestive tract of some intermediate size fish; however, they were associated with the presence of caddisfly and chironomid cases. The occurrence of these substrate organisms and plankton in the intestine suggest that feeding occurs in all parts of their environment.

Quantitatively, filamentous algae and higher plants were minor items in the diet; in most ponds however, availability was probably a limiting factor since *pithophora* was eaten extensively when it was available. The higher plant concentrations in these fertilized ponds consisted of a few marginal patches of *Eleocharis* sp and *Juncus* sp. Filamentous algae, *Anabena* and *Anabenopsis*, were eaten frequently, in the ponds utilized which were not infested with *pithophora*.

A consideration of the organisms present in the gut during May to August, 1959, indicated that during this time there were no evident changes in the varieties of food organisms utilized. The quantity of each organism fluctuated considerably and was seemingly associated with the levels of availability. Peak concentrations of Entomostraca consumed by fish less than 1.5 inches in length corresponded to their availability in plankton samples. The concentration of insects occurring in the stomachs analyzed suggested that the type of plankton sampling used was inadequate for measuring the insects available; therefore, consumption and availability were not comparable on a seasonal basis. Chironomids and phytoplankton were the most important items in the diet. A comparison of the insects and phytoplankton consumed by various sized fish in each of the three ponds suggested that phytoplankton was substituted in the diet when insects were not utilized. Organisms represented in the plankton sample that did not appear at any time in the stomach contents were limited to the backswimmers, Notonectidae.

In the *Pithophora*-infested pond, insects and crustaceans were utilized to a lesser extent by intermediate sized fish as compared to those in the ponds previously discussed. This change in the quantities of insects and crustaceans utilized may, in part, be due to competitive feeding or

TABLE 3.

FREQUENCY OF OCCURRENCE AND AVERAGE PERCENTAGE OF VARIOUS FOOD ITEMS FOUND IN THE DIGESTIVE TRACT OF SPECIMENS OF *Tilapia nilotica* TAKEN FROM POND F-4 ON JUNE 18, 1959.

Food item	*Inch Group* 1		2		3	
	Number Stomachs Examined 5		5		5	
	Occurrence	*Volume*	*Occurrence*	*Volume*	*Occurrence*	*Volume*
Insecta				3.6		1.2
Tendipedidae					1	
Ceratopogonidae			1		1	
Unidentified	2	14.2	1		3	
Plankton algae [1]	5	19.4	5	49.0	5	48.4
Higher aquatics						0.8
Entomostraca		66.4		47.4		49.4
Copepoda	5		4		5	
Cladocera	5		3		4	
Ostracoda						T[2]
Unidentified eggs					1	T
Inorganic debris					1	T

[1] Includes filamentous forms and Auburn fish feed.
[2] Less than 1 percent.

the availability of *Pithophora*. It is well known that these organisms are important items in the diet of bluegills, green sunfish, and channel catfish, which were also present. Algae comprised the major portion of the diet of the *T. nilotica* in this pond, and *Pithophora* was used quite extensively by the larger sizes of tilapia. *Pithophora* was absent in all 1-inch fish analyzed but occurred in 66.6 percent of the 2-inch fish and in all of the larger specimens. The average quantity occurring in the gut of 4-inch fish was 7 percent of the food-take and it increased to 18, 45, and 60 percent for the 5-, 6-, and 9-inch groups respectively (Table 4).

Lagler (1952) states that food habit studies based on the contents of digestive tracts merely show what an animal will eat. However, such facts when related to feeding habits and accompanied by ecological studies may constitute an important basis for resource management. Although these analyses show that large *T. nilotica* consume relatively large quantities of *Pithophora*, this serves only as a preliminary basis for testing this species for weed control.

The diversity in the food-take and relatively short food chain of *T. nilotica* apparently account, in part, for their high rates of production. Swingle (1960) reports of 4,003 pounds in 208 days, and growth of 6 to 8 inches in a 3-month period in ponds stocked with 80 brood fish per acre and fed on a limited basis.

LOWER LETHAL TEMPERATURE

Maximum-minimum thermometers were suspended at 6 inches, 6 feet, and 10 feet (bottom) in a 9.75-acre pond, and the temperatures at these depths were recorded from November 11, 1959, through January 23, 1960. Similar temperature data were recorded from November 16, 1959, to December 7, 1959, from thermometers placed in a 2-acre pond at a depth of 6 inches and 6 feet (bottom) and a 0.25-acre pond, with a thermometer at the 6-inch depth. All ponds were checked daily for the presence of dead fish and the larger pond was seined periodically after fish could not be seen in the shallow water areas.

Temperatures recorded revealed that 48° F. was lethal under certain conditions. This temperature was recorded in a 0.25-acre pond with a maximal depth of 5 feet (F-4). The pond contained fish of varying sizes under 6 inches in length and all of these sizes were affected. Mortality occurred in S-22, a 2-acre pond with a maximal depth of 6 feet, when the water temperature at a 6-inch depth was recorded at 47° to 58° F. Mortality due to these low temperatures was limited to the 2-, 3-, and 4-inch fish. The larger sizes of fish became visibly distressed when the temperature dropped to 37° F. on December 1, 1959. On this date they were observed in the warmer 6-inch waters and fungus infestations were evident on many fish. The low temperature recorded at 6 inches and at 6 feet for the previous 24 hours was 37° F. Temperatures for 7 days prior to this date ranged from 37° to 65° F. and an average of the mean daily temperature was 53.5° F. The larger sizes of fish in this pond had survived diurnal low temperatures of 47° F., 41° F., and 41° F. for 3 days prior to December 1, 1959.

Daily observations revealed that in the mornings the fish occupied the deeper waters of the pond, whereas in the afternoon, they could be seen in the shallow areas of the pond.

Temperatures recorded in S-3, which contained comparatively larger fish, also revealed that the larger sizes of *T. nilotica* were tolerant of colder water. The 9-, 10-, and 11-inch fish in this pond were first affected on December 4, 1959, when the temperature at the 6-foot depth was recorded at a low of 45° F. The lowest temperature tolerated by the larger tilapia for a short period of time was 37° F. which occurred on December 8, 1959. Temperatures recorded on December 5, 1959 ranged from 44° to 48° F., and on this date a few dead fish were observed. Fungus infestations became very heavy on many fish and mortality occurred continuously until January 13, 1960, the last date at which active fish were observed. Periodic seine checks for one week after this date failed to show the presence of surviving fish.

SUMMARY AND CONCLUSIONS

Experiments were conducted with the exotic cichlid, *T. nilotica*. Linnaeus, during the period April, 1959 to May, 1960. These experi-

TABLE 4.

FREQUENCY OF OCCURRENCE AND AVERAGE PERCENTAGE OF VARIOUS FOOD ITEMS FOUND IN THE DIGESTIVE TRACT OF SPECIMENS OF *Tilapia nilotica* TAKEN FROM POND S-3.

Food Item	*Inch Group*													
	1		*3*		*3*		*4*		*3*		*6*		*1*	
	Number of Stomachs Examined													
	2		*2*		*1*		*5*		*5*		*4*		*9*	
	Occurrence	*Volume*	*Occurrence*	*Volume*	*Occurrence*	*Volume*	*Occurrence*	*Volume*	*Occurrence*	*Volume*	*Occurrence*	*Volume*	*Occurrence*	*Volume*
Pithophora	0	0	2	0.6	1	1.0	5	7.0	3	18.3	4	45.0	1	60.0
Insecta	1	T [1]					1	2.0	2	T	2			
Entomostraca	1	T	2	T	1	T	5	T	3	T	3	T	1	T
Plankton algae	2	99.0	3	98.4	1	98.5	5	90.1	3	78.7	4	49.7	1	39.5
Higher aquatics							1	T						
Rotifera			1	T			1	T						
Inorganic debris							2	T	2	T	2	4.3		
Fish remains							2	1.0						
Unidentified eggs							1	T						

[1] 0.5 percent or less.

ments were directed toward acquiring a knowledge of the biology of this species and involved studies relative to spawning behavior, minimum spawning temperature, fecundity, period of egg formation, food habits, and its lower lethal temperature. The spawning behavior of *T. nilotica* was typical of that of many cichlids and varied mostly in that all incubating duties were performed by the female. This behavior consisted of schooling, territorial establishment by the males, prespawning courtship, spawning, and parental care.

From these studies it is suggested that the mature females will spawn at a constant water temperature of 74° F. In the farm ponds where the waters cool at night, diurnal temperatures must exceed this value.

The number of hatchlings per spawn of *T. nilotica* was comparatively smaller than those of most fish native to the United States. The size of the broods produced in the aquaria in this study varied with the size of the brood fish and seasonally. First spawns of 5-and 6-inch fish ranged from 73 to 114 and 124 to 437 eggs, respectively. Means for the 5-, 6- and 7-inch fish during the spawning season were calculated at 60, 261, and 462, respectively. In aquaria kept in the Fisheries Building, *T. nilotica* spawned at intervals varying from 33 to 59 days where water temperatures were 76° F. or higher.

The smallest fish forming eggs were 4 inches in total length and were reared in a brood pond receiving feeding. Growth to this length was attained in approximately 50 days.

T. nilotica was primarily phytophagous, however, there was extreme diversity in the food-take. Entomostraca were found frequently and voluminously in the stomachs of fish less than 1.5 inches in length. Chironomids were the second most important item in the diet of the 3-, 4-, and 5-inch groups and their occurrence decreased progressively in larger sizes of fish. *T. nilotica* in the 6- and 9-inch groups utilized the filamentous alga, *Pithophora*, quite extensively. The short food chain and diversity of food-take apparently account, in part, for the high production obtained with this species.

These studies indicated that *T. nilotica* of the smaller inch-groups (1 to 6) did not tolerate temperatures as low as 48° F. The 9-, 10- and 11-inch fish were affected less by the colder water and tolerated temperatures as low as 38° F. for short periods of time.

This study was conducted in conjunction with a research assistantship of the Auburn University. The author acknowledges the assistance of the Fisheries staff and students at the Auburn University. The author wishes to extend a special acknowledgment to Dr. E. W. Shell for his assistance in these studies and a review of this paper.

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