SUMMARY

The chemical and physical properties and phytocidal activities of diquat (1:1'-ethylene-2:2'-bipyridylium cation) and paraquat (1:1'-dimethyl-4:4'-bipyridylium cation) are discussed.

Data on evaluations of herbicidal activity from controlled laboratory and plastic pool experiments indicate there was no difference in herbicidal effects of the various salts of these 2 quaternary bipyridyls on the aquatic species under observation. The results indicate that many submersed as well as emergent species of aquatic plants may be controlled for several weeks to several months by 0.2 to 0.5 ppm cation concentration of either diquat or paraquat.

Diquat appears to be safe to many fresh-water fishes at concentrations up to 10 ppm cation, and paraquat appears safe to many fishes at concentrations greater than 5 ppm cation.

Observations made in plastic pools and ponds treated with 0.5 ppm diquat or paraquat cation have indicated no harmful effects upon the fish or fish-food organisms from these herbicides.

From 80 to 100 percent kill of 15 species of aquatic weeds present in the pools and ponds has been obtained by a concentration of 0.5 ppm or less cation of either diquat or paraquat.

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STATUS OF Tilapia Nilotica LINNAEUS IN FLORIDA

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ABSTRACT

The Florida Game and Fresh Water Fish Commission's Fishery Division obtained 3,000 *Tilapia nilotica* fingerlings from Auburn University on August 30, 1961. These were used as brood fish and were stocked in a 3-acre naturally fertile mined-out phosphate pit in Central Florida at the rate of 1,000 per acre. From time of stocking until May, 1962, there was an estimated 7 inches of growth. During the latter part of May this pond appeared to go into an overcrowded condition. Twelve ponds totaling 65 acres have been stocked with tilapia from the brood pond. Stocking rates have varied from 2 adults to 1,000 fingerlings per acre. Minimum water temperature at the blood pit last winter was 53°F. Apparently no mortality occurred from this cold. It was estimated that 1,810 pounds of tilapia were produced per acre in the brood pit during a 369 day period. The fish were not fed and the pond was not fertilized. Tagging results to date from 100 bluegill and 100 tilapia show a return of 23 tilapia and 21 bluegills. The tilapia is thought to have great potential value in Florida as a sport and food fish.

INTRODUCTION

The exotic cichlid, *Tilapia nilotica* (Nile tilapia) was brought to Auburn University by S. Tal from Israel in 1957. Experiments were conducted at the

Unversity comparing the value of this species as a pond fish with an earlier arrival, *Tilapia mossambica* (Java tilapia) (Swngle, 1960). It was found that the tilapia could withstand somewhat colder weather than the Java tilapia (Kelley, 1957; McBay, 1962).

The Florida Game and Fresh Water Fish Commission became interested in the possibilities of the Nile tilapa for introduction as a species which should have high public acceptance for food and sport fish purposes. This fish should also be able to occupy the highly productive niches used chiefly at present by low-value fishes (Benson, 1961). The Florida Game and Fresh Water Fish Commission's Fishery Division obtained 3,000 fingerlings of *T. nilotica* from Auburn University on August 30, 1961 for experimental purposes.

This report will describe the progress of Florida's Nile tilapia studies since their first stocking as brood fish in a completely enclosed pond in Central Florida.

DESCRIPTION OF THE BROOD POND

The pond in which the tilapia were stocked is one of a number located in a 505 acre mined-out phosphate pit area 20 miles southeast of Tampa in Hillsborough County. This land was leased to the Commission for managed public fishing by The American Agricultural Chemical Company and by Mr. Wayne Thomas. There are 30 ponds in this area. They are inherently fertile, and range in size from one-half to 17 acres, and in maximum depth from 6 to 28 feet.

The brood pond may be taken as representative of these water-filled pits. Designated as T-4, this pond has an area of 3 acres and a maximum depth of 10 feet. The shoreline slopes off rather abruptly and depths range from 8 to 10 feet in the mid-section. High spoil banks, present on the two long sides of the pit, have resulted in deposit of deep, soft, grayish silt on the bottom. The few shallow areas in T-4 support a scattered growth of maidencane (*Panicum* sp.). The entire shoreline, next to the water's edge, is covered with maidencane and intermingled clumps of southern wax-myrtle (*Myria cenfera* L.) and water primrose (*Jussiaea* sp.).

Fertilization was found to be unnecessary in Pit T-4. The pond supported a phytoplankton bloom comparable to that found in fertilized ponds described by Swingle (1952). Secchi-disc readings ranged from 12 to 18 inches throughout the year except for brief periods, not longer than 7 days in length, when the water was clear.

Before the Nile tilapia were stocked the existing fish populations of the pond were eliminated by use of toxaphene. Eventually eastern mosquito fish (*Gambusia affinis*) made a reappearance, but this is the only other species present.

GROWTH, REPRODUCTION AND PREDATION

The fingering tilapia were stocked at the rate of 1,000 per acre on August 31, 1961, and ranged in total length from 2 to 5 inches. The first sign of reproduction was two and one-half months afterstocking. On Nevomber 14, 1961, 80 tilapia fingerlings ranging from 2 to 3 inches in length were taken from the pit by a seine. Since it had been previously determined that it took approximately 50 days for recently hatched fry to attain a length of 4 inches in Alabama (McBay, 1962), it is believed that the fingerlings caught in the seine had been hatched in late September or early October. The first observation of reproduction in the spring was on April 16, 1962, when numerous clusters of recently hatched fry were seen. It is possible that young had been produced several weeks before this date but had escapd notice.

Samples of fish in the pond were collected by use of baited wire traps during the months of February through May of 1962. These traps were selective for size, in that fish smaller than 5 inches were seldom caught. The mode of the length-frequency curve advanced from 3 inches at the time of stocking to 8 inches in February, to approximately 9 inches in March, and into the 10 inch class in April, 1962. This represents an estimated growth of 7 inches for the 8 month period. Fish measuring 5 inches in total length began to appear in limited numbers in samples taken in March, and in greater numbers in April and May. These latter groups undoubtedly represent the hatch in fall of 1961 (Table 1).

TABLE 1. LENGTH-FREQUENCIES OF *Tilapia nilotica* BY NUMBERS AND PERCENT DURING FEBRUARY THROUGH MAY, 1962

	At Time of Stocking		*Caught in Baited Traps*							
	Aug. 31, 1961		*Feb., 1962*		*March, 1962*		*April, 1962*		*May, 1962*	
Size	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
1"	..	..	..	..	..	..	..	..	..	..
2"	2	2	..	..	..	..	..	..	..	..
3"	77	61	..	..	..	..	..	..	..	..
4"	43	34	..	..	..	..	..	..	..	..
5"	5	4	..	..	2	5	62	33	28	11
6"	..	..	..	..	..	..	75	40	83	33
7"	..	..	13	6	..	..	8	4	24	9
8"	..	..	114	56	13	32	6	3	2	1
9"	..	..	66	33	13	32	7	4	23	9
10"	..	..	9	4	13	32	26	14	70	28
	WHEN STOCKED IN BROOD POND AND AS CAUGHT IN BAITED TRAPS									
11"	..	..	1	1	..	..	2	1	21	8
TOTAL	127	101	203	100	41	101	186	99	251	99

The modal peaks for May remained essentially the same as in April, and were at the 6 and 10 inch classes. Spawning beds and schools of recently hatched fry were extremely abundant during April and early May. In the latter part of May no beds or fry were observed, and at the time of writing, spawning beds and fray are still absent from the pond. However, McBay (1962) reported that a 5 and a 6 inch female tilapia were observed to spawn 6 and 5 times respectively during a study period from April 22 to October 31, 1959 in Alabama. The presence of a repressive factor which prevents repoduction is suggested by the cessation of nomal spawning activity (Swingle, 1960) in T-4. Swingle (1958) moreover indicated that tilapia stocked in the absence of a predator tend to overpopulate. It is believed that the population of tilapia in the brood pond had reached the point of overcrowding by May, 1962.

Fifty of the 80 fingerling *Tilapia nilotica* caught from the brood pond, ranging in size from 2 to 3 inches in total length, were stocked on November 15, 1961 in the Girl Scout Pond at Ft. Lauderdale. This pond is 0.8 acres in size and was fertilized. However, its waters are similar in fertility to the unfertilized waters of the T-4 pit. At the time of stocking with tilapia it contained two or more adult largemouth bass.

Nine and one-half months later, on August 31, 1962, this pond was poisoned out with rotenone. A total of 12 tilapia, ranging in size from 10.8 to 11.8 inches, were recovered. Two more large fish were found on the second day, but they were not picked up. No small tilapia were seen. Two adult and numerous young largemouth bass were picked up dead. On the same day, August 31, 1962, twelve large Nile tilapia, ranging from 9.2 to 12.0 inches in size, were captured in baited traps from the T-4 pond.

The two ponds were equivalent in fertility, but differed in that predators (largemouth bass) were present in Girl Scout Pond and were absent from the T-4 pit. A comparison of body weights and lengths shows that the Nile tilapia from the pond with largemouth bass predation were in better condition and were growing faster than those from the T-4 pit (Table 2). However, the tilapia population undergoing predation had been greatly reduced from the original number stocked.

This is in agreement with the work of Swingle (1960) who found that largemouth bass stocked with Tilapia reduced their numbers by as much as 75 percent; while bass predation increased the AT value he found that it often reduced the total production of the pond. These findings have a possible significance in that they imply that bass predation might prevent tilapia from becoming the nuisance fish carp and other carelessly introduced exotics have sometimes turned out to be.

MINIMUM WINTER TEMPERATURES AND SURVIVAL

In general Florida's coldest weather occurs in December, January and February. At Plant City, 11 miles from the T-4 pond, the minimum air tempera-

TABLE 2. COMPARISON OF LENGTHS AND WEIGHTS OF *Tilapia nilotica* COLLECTED ON AUGUST 31, 1962 FROM TWO PONDS OF EQUIVADENT FERTILITY, ONE OF WHICH (GIRL SCOUT POND) CONTAINED LARGEMOUTH BASS AS A PREDATOR

	T-4 Pond		*Girl Scout Pond*	
Weight in Pounds	*Number of Fish*	*Mean Length in Inches*	*Number of Fish*	*Mean Length in Inches*
0.6	3	9.8	None	...
0.7	2	10.5	None	...
0.8	1	10.8	2	10.8
0.9	2	11.3	2	10.6
1.0	1	11.4	4	11.2
1.2	2	12.0	1	11.5
1.3	1	11.9	3	11.6
Total Numbers of Fish and Mean Lengths	12	10.9	12	11.2
Mean Weights (Pounds)		0.88		1.04

tures recorded were 25°F in December, 1961 and 26 and 41°F, respectively in January and February, 1962 (U. S. Department of Commerce: 1961, 1962). Maximum air temperatures for these months at the above location were 88, 86 and 91°F, respectively. Minimum water temperatures taken 3 feet below the surface of the T-4 pit with a maximum-minimum recording thermometer were 54, 53 and 63°F, respectively, during the same months. In the Girl Scout Pond at Ft. Lauderdale lowest water temperatures in December and January were 60 and 57°F, respectively. Cold weather in Florida comes in snaps, seldom lasting more than one week, with warm weather intervening.

Frequent checks were made in each of the ponds for tilapia dead or in distress both during and following all the cold snaps. None were ever found.

In Alabama mortalities were found among tilapia measuring less than 6 inches at a temperature of 48°F. Progressive mortality among larger fish occurred with decreasing water temperature, although some 9, 10 and 11 inch fish tolerated 37°F for a short period of time. But continued exposure (up to 32 days) to temperatures below 55°F cumulatively affected these larger fishes and resulted in mortality (McBay, 1962).

POND PRODUCTION

On September 4, 1962, 369 days after original stocking, a 0.57-acre section of the T-4 pit was sealed off from the rest of the pond with polyethylene film, and the tilapia inside were poisoned with sodium cyanide briquettes at a concentration of 3.3 parts per million. From the dead and anaesthetized fish picked up during this operation, and from records of number and weights trapped and removed through preceding months it was estimated that the total production of T-4 pond for the year was 1,810 pounds of Nile tilapia per acre.

STOCKING ACTIVITIES

To date stocking of the Nile tilapia in other bodies of water has been limited to the numbers that could be collected from the brood pit T-4. Collection methods have mainly been by baited screen and wire traps. Because of the condition of the bottom of the brood pond, seines are not dependable. Twelve ponds, totaling 65 acres, have been stocked to date with tilapia. Rates have varied from 2 adults to 1,000 fingerlings per acre. Some have been stocked with wild fish populations, others with largemouth bass alone, or with combination of largemouth bass, bluegill and redear sunfish. It is planned to maintain one or two regular hatchery ponds for tilapia in the future.

TILAPIA AND BLUEGILL TAG RETURNS

In order to compare the sportfishing values of tilapia and bluegill, 100 tilapia from the brood pit and 100 bluegill were marked with red Petersen disc tags and introduced during April 15-28, 1962 at a number of points into a 17-acre pond in the phosphate pit area. This pit had been previously stocked with bass and bluegill and was sustaining a considerable sportfishery. Rewards rang-

ing from three dollars to $500, offered by the Joseph Schlitz Brewing Company, motivated the return of sportfisherman-caught tagged fishes. Because both tilapia and bluegill were caught with worms, the fishing pressure is believed to have been identical on each species.

By May 27, approximately one month after introduction, 21 tagged bluegill and 16 tagged tilapia had been returned by sportfishermen. No more tagged bluegill were subsequently reported, but by September 29, seven additional marked tilapia have been turned in. From limited information available, apart from the tagging returns, Nile tilapia appear to be gaining favorable recognition among Florida's bream fishermen.

POSSIBILITIES OF TILAPIA IN FLORIDA

When stocked at the rate of 1,000 or more per acre there is a possibility that tilapia might control duckweed (*Lemna* sp.) in ponds. The brood pond T-4 was two-thirds covered with duckweed when stocked with tilapia and the duckweed was reduced to a thin, foot-wide margin around the shore 4 months later. At present duckweed is limited in the pond to a few individual plants scattered over its surface.

If the Nile tilapia can successfully survive Florida's winters it might prove to be a valuable addition to the ichthyofauna. Tilapia wintering under natural conditions should provide good sportfishing in early sprng when the fishing load is heavy and the supply is moderate. This fish should attain a greater size in Florida than elsewhere.

The tilapia has a short food chain. All size groups of this species were found to utilize plankton primarily, and to a lesser degree insects, chiefly of the families Chironomidae and Ceratopogonidae, in Alabama ponds (McBay, 1962). Since gizzard and threadfin shad are also primarily phytoplankton feeders (Miller, 1960), and are so abundant in Florida's fresh waters as to constitute an ever-increasing problem, but are of low economic value, it would seem that their replacement by tilapia should be highly desirable. Experiments in ponds with tilapia and shad combinations are being planned.

Other relatonships to be investigated on a long-range basis in Florida are stocking tilapia in combination with channel catfish, laregmouth bass, and largemouth bass-bluegill-redear complexes. It has been stated that tilapia stocked in state lakes of Alabama "had no visible effect on established bass-bream populations", but they added 13,156 pounds of fish to the creel in these lakes in 3 years. Thus tilapia have been used with considerable success as a supplemental fish in lakes subjected to unusually heavy fishing pressure in Alabama (Rogers, 1961).

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RETURN RATES OF STRAP TAGS AND PETERSEN TAGS

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During January, February and March, 1962, a total of 1,593 Florida Largemouth Bass were tagged in five lakes of central Florida with Monel metal strap tags and Petersen disc type tags.

The strap tags (sizes 3 and 4) were applied to the jaws of 745 bass in the same manner described by DeQuine (1949). Eight hundred and forty-eight red Petersen disc tags were attached by the insertion of a .0359" gauge 3" nickel pin between the first and second spinal rays of the dorsal fin through the fish's back.

High value awards were offered for return of the tags to sport fishermen through a Joseph Schlitz Brewing Company sponsored fishing derby (Copeland, 1962).

A summary and totals of the numbers and percents of tag returns as of September 14, 1962 occur in Table I.

TABLE I

COMPARISON OF RETURN RATES OF STRAP AND PETERSEN TAGS FROM FLORIDA LARGEMOUTH BASS

	Strap Tagged			*Petersen Disc Tagged*			*Total Tagged*		
Lake	*No. Tagged*	*No. Returned*	*% Returned*	*No. Tagged*	*No. Returned*	*% Returned*	*No. Tagged*	*No. Returned*	*% Returned*
Apopka	172	3	1.7	84	4	4.8	256	7	2.7
Dora	150	16	10.7	200	47	23.5	350	63	18.0
Eustis	132	23	17.4	202	23	11.4	334	46	13.8
Griffin	68	5	7.4	164	21	12.8	232	26	11.2
Harris *	223	60	26.9	198	48	24.2	421	108	25.7
TOTAL	745	107	14.4	848	143	16.9	1.593	250	15.7

* Two recaptured fish without tag numbers were not included in the figures.

The rate of return of the Petersen type tag from Lake Apopka was 4.8%, Lake Dora 23.5%, Lake Eustis 11.4%, Lake Griffin 12.8%, and Lake Harris 24.2%.

Returns of strap tags was 1.7%, 10.7% 17.4% and 26.9% for each of the lakes in the order mentioned.

A summary of all tag returns for the lakes indicated the Petersen tags were returned at a rate of 16.9% whereas the strap tags were returned at a 14.4% rate.

Although variations occurred from lake to lake, it could be concluded that the Petersen type was returned at a slightly greater rate. However, the differ-