The Resources Agency of California
Department of Fish and Game

PROGRESS REPORT OF THE CULTURE OF TILAPIA M___BICA (PETERS) HYBRIDS IN SOUTHERN CALIFO

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SUMMARY

In December 1963 we initiated a study of the culture of Tilapia mossambica hybrids (Zanzibari x Javanese subspecies). The purpose of the study was to gain knowledge concerning the following: production of all-male hybrids, cultural and rearing requirements, growth rates, fecundity, temperature tolerances, optimum stocking size, catchability by anglers, and control of insects and plant nuisances.

We have developed successful techniques for culturing all-male hybrids. Hybrids held in holding ponds at the Chino Fisheries Base grow 1.0 to 2.4 inches per month.

It appears the hybrids can tolerate brief periods of temperature as low as 40° F., but normally cannot survive when low temperatures prevail.

Maximum production potential is yet to be determined. However, we believe under suitable hatchery conditions with a basic breeding unit of five females per male, 20,000 hybrids can be produced per unit per year.

Fingerlings should be stocked in the spring at a length of 2 to 3 inches, thereby obtaining sufficient growth to provide catchable-sized 6 inches or longer fish for the late summer and fall months. No problems are anticipated concerning cat chability although angler acceptance is yet to be ascertained.

It appears the hybrids would not control midges but may control aquatic plants in small ponds through nest building activities.

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INTRODUCTION

The many scientists who are now fostering the culture of tilapia for protein or sport are participating in an ancient practice. Hickling (1963) states, "The earliest known representation of a fish-culture pond in history -- a bas-relief from an Egyptian tomb dating from before 2000 B.C. -- shows a pair of small fish that can be identified as Tilapia nilotica a species still abundant in the Valley."

It is not unlikely that when Simon, called Peter, and his brother Andrew cast the nets into the Sea of Galilee, their catch included tilapia. Gill (1907). mentions, referring to tilapia, "The same species and closely related. ones are inhabitants of Palestine and undoubtedly were the chief products of the fisher disciples of Jesus Christ ..."

Another species, T. mossambica (sometimes called the large-mouthed kruper, bream, or African mouth breeder), is an ancient resident of MozaMbique and the east coast of Africa.

Schuster in 1959, according to Vaas and Hofstede (1952), described a new species collected from the Serang River of East Java and named it ikan <u>mudjair</u> after its discoverer, Pak Mudjair. Other authorities later recognized the species as T. mossambica.

During World War II, the Japanese army of occupation disseminated the species throughout Java. Since that time, it has become an important source of protein in most of Indonesia and Malaysia. The fish is also popular in Taiwan and comprises a substantial proportion of the harvest from certain lakes in Ceylon according to Vaas and Hofstede (op. cit.).

Tilapia are now common in some countries of South and Central America. Granados (1964, personal correspondence) reported that the species is present in Mexico and that Auburn University, Auburn, Alabama, supplied them with stock of T. mossambica T. <u>nilotica,</u> and T. <u>melanopleura.</u>

American workers in various southern states including Alabama, Texas, and Arizona have been culturing tilapia for experimental purposes, but have been generally cautious in respect to introduction in natural waters.

Hickling (op. cit.) and his associates obtained fertile, but exclusively male offspring from the crossing of two subspecies of T. mossambica. The intriguing development arose from the pairing of females from Java with males of a subspecies indigenous to the brackish swamps of Zanzibar. Their experiments were originally intended to develop sterile hybrids for use in the culture of tilapia in small ponds and rice paddies.

T. <u>mossaMbica</u> are maternal brooders, the eggs and fry being reared in the female's mouth. Spawning *begins* with the male building a nest or, if no bottom material is present; he will clean a particular area for the nest site. According to Simpson (1954) and Hickling (op. cit.), the female lays the eggs in the nest or spot' designated by the male. After the male has fertilized the eggs they are collected by the female and held in her mouth. We have not seen the actual spawning act. The female holds the eggs, and subsequently the young fry, in her mouth continuously until they become free swimming.

Free swimming tilapia fry return to the mother's mouth upon being frightened. The fry swim near the mother who then picks them up. It is a cooperative action. The common conception is that the female opens her mouth and passively allows the fry to enter, and according to McConnell (personal communication), the fry into an artificial (dummy) mother fish's mouth.

Most authorities agree that tilapia do not thrive at water temperatures below 50^{o} *F.* Swingle (1957) experienced a total loss of tilapia at 41^{o} F. during cold-room tests at Auburn University. Although tilapia could probably survive and prosper in many waters of southern United States, American fisheries workers have not been too enthusiastic about its future as a sport fish.

The fecundity of tilapia, combined with under. harvest or insufficient predation, can result in rapid [illegible] populations. E[illegible] ([illegible]) experiences suggested to us that the use of the male tilapia hybrids might be of worth in some of the warmer waters of [illegible] California.

In 1963 we learued that the Arizona Game and Fish Department had introduced T. mossambica (males and females) into canals and ditches tributary to the Colorado River. Region 5 personnel reported that the tilapia has survived. Roger Lame, California Department of Fish and Game, as observed tilapia spawning activity in the Yuma Valley East Drain, three miles [illegible] Y[illegible]. I[illegible] appeared likely that the species could, eventually, appear in the Colorado River and some of its California distributaries. The rapid spread of the threadfin shad, Dorosoma petenense, throughout the canals and wasteways of Imperial County, as well as [illegible] appearance in the Salton Sea, suggested the possibility of a similar experience with tilapia.

Therefore, [illegible] seemed essential [illegible] we prepare for management of the species if, and when, it appeared in California waters. We required a source of tilapia for controlled investigations which would enble us to study the adaptability of the species and to determine its possible effect upon the established ichthyofauna of southern California. We could, at the same time, explore the possibility of production and beneficial utilization of the male hybrids for sport, forage, and aquatic vegetation and insect control.

On November 12, 1963, the California *Fish* and Game Commission authorized the importation of T. mossambica (Javanese and Zanzibari) for experimental purposes.

St. Amant (1966) subsequently reported that T. mossambica (Javanese) are established in a tributary of the Salton Sea, Imperial County, California.

In December 1963 we obtained 111 tilapia from Dr. William J. McConnell of the Arizona Cooperative Wildlife Research U[illegible] at the University of Arizona in Tucson (Table 1).

We divided the tilapia study into three separate phases: laboratory, holaing pond, and experimental stockings. The laboratory studies stemmed from the need of initial stocks of tilapia hybrids and the development of culture methods which, if warranted, could be expanded into hatchery production. The pond studies were an essential extension of the laboratory phase. The stocking of hybrids under natural conditions was required to provide information on their [illegible] our waters.

TABLE 1

Tilapia Acquired in Arizona for Use in Region 5 Studies

Strain	Sex	Number	Total weight in ounces	Average weight in ounces
T. mossambica (Javanese)[1]	Male	7	6.2	0.88
T. mossambica (Javanese)	Not determined	9[6]	5.9	0.06
T. mossambica (Zanzibari)[2]	Male Female	4 4	3.5	0.44

[1] The *T. mossambica* (Javanese) were obtained by McConnell from the Tishomingo National Fish Hatchery, Oklahoma.

[2] The T. mossambica (Zanzibari) were obtained by from the Tropical Fish Culture Research Institute, Malacca, Malaysia.

ACKNOWLEDGMENTS

Marvin J. Whalls initiated the study. Robert G. Hulquist and Ira L. Sharp fabricated the aeration equipment utilized in the laboratory experiments and participat in other phases of the study.

Other Chino Fisheries Base personnel who took part in the study included Larry Puckett, John Dienstadt, Richard Jones, Robert Carr, and Robert Andrews. Lee Mille: assisted in supervision of the Santee Pond Test.

Dr. Ernest Bay, University of California, Riverside, conducted the pond tests held at the U. C. R. experimental ponds.

Dr. McConnell, University of Arizona, supplied the original test fish and provided valuable suggestions.

Whalls and Paul Giguere gave editorial assistance.

LABORATORY STUDIES

Equipment

We converted a small storage room at the Chino Fisheries Base into a heated tilapia laboratory. Our original fish tanks consisted of a modified wooden hatchery trough and two 20-gallon glass aquaria. We soon encountered a need of additional small tanks for separation of sexes and subspecis.

We then improvised additional tanks from discarded refrigerator liners made of sheet steel. They were lined with polyethelyne sheets to prevent leakage and corrosion. Their usable capacity varied from 46 to 58 gallons. We also borrowed a supply of 60-gallon polypropylene tanks from the University of California, Riverside, which appear to be ideal from the standpoint of resistance to leakage, breakage, and corrosion.

A Model X-2 Quincy air compressor with a 1 HP electric motor, pressure control valve, oil filter, and bleed valve provides sufficient air for all tank water. The manifolds and supply lines are of plastic tubing. Aeration stones are of the conventional type. Salt accumulation necessitated frequent replacement of the aeration stones. On one occasion, the dissolved oxygen in the various tanks ranged from 3.2 to 6.4 ppm. The lowest readings were associated with tanks having the stones in longest use.

Filtration and Cleaning of Tanks

In time we were able to avoid most of the tank cleaning chores and water replacements associated with the methods utilized by the Arizona workers. We maintained satisfactory water clarity and purity with activated charcoal aquarium filters.

Fish Cover

We prepared artificial cover, as recommended by McConnell,by cutting sheets of black polyethelyne film into 1-inch wide strips and tying them together at one end to form mop-like bundles. When the bundles are weighted and placed in a tank, the free ends become loosely dispersed in an excellent simulation of natural vegetation.

Food Studies

The tilapia would not consume guinea pig pellets which were recommended by McConnell. We found that both rabbit and guinea pig feeds disintegrated rapidly. Only the smaller fish utilized the fragments. The use of rodent feeds originated in a belief that tilapia prefer and thrive on vegetable diets rather than feeds containing animal proteins.

We have since experimented with a variety of feeds which included filamentous green algae, Cladophora; frozen daphnia; mosquito larvae; cooked fish; chopped liver; hamburger; chicken; turkey; and canned dog food. Adults and juveniles accepted all of the above items. The adults would devour live mosquitofish, Gambusia affinis, and guppies, Lebistes reticulatus. The fingerlings also consumed fresh fish when they were small enough to be ingested. The Zanzibari and the hybrids are more piscivorous than the Javanese.

For convenience and economy, we finally adopted a standard diet of dry trout meal (crumbles or pellets) with occasional supplements of filamentous algae and frozen or live daphnia.

The particle size of the dry meal fed to tilapia of various size groups appears in Table 2. A typical analysis is presented in Table 3.

Uchida and King (1962) demonstrated that there was a significant difference in the growth rate of tilapia subsisting on livestock feed (white wheat middlings) and those living on dry trout feeds of high quality. The growth of tilapia on the trout meal surpassed that of the fish on the middlings diet. The authors, however, intimated that prolonged use of the higher quality diet might impair the spawning potential of brood stock. Our tilapia have been on the trout meal diet for approximately 18 months. Their growth has been excellent. As yet, we have not detected any impairment in maturation or fecundity which could be attributed to diet.

Normally, we feed the tilapia fingerlings and adults once a day at a rate equivalent to 3 to 5 percent of their body weight. Feedings in excess of 5 percent usually result in unutilized residues and consequent reduction in dissolved oxygen and water clarity.

As with most fry, the first 10 to 14 days is a critical period. The tilapia fry readily consume fine tropical fish meals, but we found that pulverized trout meal was a satisfactory substitute. There should be at least two, preferably more, feedings per day for fry less than 14 days old. Our feeding schedules represented a compromise with operating conditions rather than an effort to obtain maximum growth.

Tilapia

The immediate objectives of our tilapia culture were: (1) development of a broodstock reserve, and (2) production of sufficient hybrid fry for future investigations.

We obtained the first Javanese fry on February 11, 1964. The 19 fry were transported to a nursery tank. They were about 0.2 inches long. Their first food consisted of the fine meal, and gradually the diet was changed to coarser food (crunibles). We measured a sample of five fish on February 29 and all 19 on March 19. They had grown about 1 inch by the 18th day and 2 inches by the 38th day.

TABLE 2

Tilapia Feed Particle Size

Size of tilapia	California Department of Fish and Game standard numbers	U. S. standard screen size
Fry	Starter	
Advanced fry (2 weeks old to 2 inches long)	No. 1 crumbles	All through No. 16, all retained on No. 26
Fingerlings (2 to 3½ inches long)	No. 4 crumbles	All through No. 12, all retained on No. 16
Fingerlings (3½ inches long through large adults)	3/32-inch pellets	

TABLE 3

Typical Analysis, Dry Trout Feed

Constituent	Percent
Protein	37.0
Carbohydrate	35.0
Fat	5.0
Ash	9.0
Fibre	2.86
Moisture	10.0
Miscellaneous, additives such as vitamins	1.14

W observed another group of Javanese fry on February 24 in a 20-gallon aquarium which contained five females and one male. The young were prematurely released by the mother. We use the term premature to indipate that the yolk sac was still visible. Normally, the mother does not release the fry until after yolk sac absorption.

Four fry, placed in a 1-ounce jar of unaerated, unchlorinated tapwater, survived without feed or aeration for four days. They were still alive after seven additional days of similar conditions in a 1-quart jar. Such hardiness appears to be a characteristic of young tilapia.

Initial Production of Zanzibari Fry

We noticed the first sign of spawning by the Zanzibari on February 10, when a male prepared a nest by removing most of the sand from one end of the aquarium bottom. By February 20, the buccal cavity of the female was fully enlarged and contained eggs. We then removed the male from the tank. We discovered fry in the female's mouth on February 27. Two days later we removed 299 young. The female was about 5 inches long. The fecundity of tilapia becomes apparent when we consider that T. mossambica can spawn monthly.

Initial Hybrid P[illegible]

On March 13, 1964, following daily checks, we observed the first hybrid fry. T[illegible] appeared in a tank containing four females Javanese and one male Zanzibari. There were only four fry in the tank. Two days later there were three. Later observations showed that insufficient cover was available to prevent cannibalism, resulti[illegible] in the poor fry survival.

Tilapia Production: Improvements

For our next tilapia breeding studies, we employed the modified hatchery trough, which is 3 feet wide, 8 feet long, and 18 inches deep, with abundant [illegible] cover. We divided the trough into two parts with a net screen in order to prevent parental predation. We reasoned that the screen would permit escape from adults.

On April 1, 1964, we placed a male Zanzibari and four females Javanese in one portion of the trough. On April 22 we found fry in the mouth of a female. We ther placed 2 inches of sand on the bottom of the trough to provide nest material. The male constructed a nest within a few days.

We observed no other evidences of breeding activity until June 29 when we again noticed fry in the mouth of a female. On August 13 we drained the tank and found 50 hybrid fingerlings of several size groups. It was obvious that we had failed to detect several spawnings. It further appeared that the adults had consumed most of the fry.

We decided that visual inspection alone in the trough would not insure prompt recognition of egg-carrying females. In addition it appears necessary to remove the mother holding the fry or the fry from the mother's mouth prior to the free-swimming stage to prevent parental predation. It is possible that predation could be minimized by increasing the feed during this time.

We then utilized the converted refrigerator liners for breeding **tanks.** The females were inspected in hand every 10 days. If eggs were present, **the** female was placed in a separate incubation tank. When the mother's mouth **contained fry,** we transferred the young to a nursery tank. The extraction of fry **from** the buccal cavity is a simple **process.** We merely hold the female just under the water surface of the nursery tank, open her mouth, and shake the fry free into the water.

The method of periodic in-hand inspection of females and early separation of fry and mother appears to be the most practical means of **obtaining maximum** survival of fry. Under the temperature conditions in the **Chino** [illegible], a 10-day inspectior period would allow detection of eggs or captive fry. A larger [illegible] schedule with more uniform water temperatures [illegible] require daily inspection of females **in** incubator tanks to **permit** prompt removal of fry.

Further simplification for detecting eggs can be [illegible] the use of glass aquaria for breeding tanks where females carrying eggs or fry can [illegible] readily **observed.**

Other Tilapia Production Methods

We found that we could **successfully** hatch tilapia eggs in aerated jars. We had a 99 percent survival with one batch of 120 eggs. Although the Arizona workers (personal communication) experienced **an** average mortality of about 50 percent **in similar** tests, we believe tilapia eggs can be incubated in egg jars or hatching trays with circulating warm water and **aeration.** We made no effort to strip eggs from gravid females for hatching experiments, because we did not care to **subject** our limited brood stock to injury.

We began the study with 103 Javanese and 8 **Zanzibari.** The latter comprised half of the known **stock** in the **United** States. In **December** 1965 we had the following on hand at Chino Fisheries Base.

	Adult male	Adult femal e	Fingerling	
Javanese	5	33	27	
Zanzibari	7	5		
Eybrid	250		319	1 450

Since March 23, 1964, the date of the first hatch of hybrid **fry,** we have produced over 5,000 young hybrids, none of which were females.

We were unable to maintain a satisfactory uniformity of water temperatures. Therefore, diurnal and tank-to-tank fluctuations did not permit accurate laboratory tests of food **consumption,** growth rates, and breeding **or** incubation periods. Boom temperatures ranged from 73 to 118^{o} F. Tank water **temperatures** ranged from 65 to 102^{o} F. The highest room and water temperatures resulted from a **maladjustment** of the manual gas heater controls on February **11.** The tilapia showed no evidence of distress during their brief exposure to the higher **temperatures.** Actually, their activity and food **consumption increased temporarily** and then declined as the water became cooler. In contrast, there was a mortality of about 90 percent of the guppies held as tilapia food in the same room.

Despite the variations, our crude equipment did allow us to produce additional brood stock and to obtain a sufficient supply of hybrids for future work. In addition, our experiences are helpful in the planning of improved facilities.

There can be no question that temperature is an extremely important factor in the production of tilapia. North Viet Nam workers, L[illegible], Giay, [illegible] Vinh (1961) concluded that 300 C. (86 P.) is the optimum water temperature for tilapia rearing. The upper lethal temperature is 43° 0. (108 F.); the upper sublethal temperature is 37° C. (98.8° F.) to 38° C. (100.4° F.) and higher. The lower sublethal temperature is 16° C. (60.8 F.) to 20 C. (68° F) and lower; the lower lethal temperatures is 6° C. (42.8° F.).

A[illegible] Noble (1964) found the upper lethal temperature was 38° C. (100.8° F.

We found the upper temperature tolerance limit to be about 108° F., and the lower limit about 42° F.

Our laboratory is now equipped with thermostatic controlled natural gas heat. We will now be able to maintain our breeding and rearing temperatures near the desired 86° F. mark.

Mortality

Several female Javanese have been killed [illegible] Zanzibari males. The deaths occurred during comparative testing of spawning conditions in two 20-gallon aquaria. We had placed a 2-inch layer of sand on the bottom of one aquarium. The other contained no sand. There was a male Zanzibari [illegible] female Javanese in each tank. Four days after nest construction, the female, 3.8 inches long, in the sand-bottom tank displayed various injuries including lost scales and caudal fin damage. The male was approximately 5 inches long. We separated her from the male, but she soon died.

We then replaced the female with another which was 4.2 inches long. The male killed her within five days. The same behavior occurred in the tank without sand, but we saved the female by prompt removal. I believe the mate killing behavior occurred because the females were not ready to spawn, the male was larger, and there was no cover for the female. We have had no difficulty since we began providing an abundance of cover in the form of plastic strips.

Most other fish losses occurred because of escape from tanks [illegible] out, from handling, and by predation. We have covered all aquaria and tanks with polyethelene film mounted on wooden frames. Although we installed the covers [illegible] prevent the fish from jumping out of the tanks, we discovered that the semi-opaqueness of [illegible] film reduced alarm activity caused by movements of personnel about the laboratory. Normally, the Zanzibari and hybrids are more subject to fright than the Javanese.

D[illegible] tests, two broods of tilapia were infected with fungus (*Saprolegia*. One from handling during seinings. The other, presumably, resulted from poor conditions [illegible] temperatures. A[illegible] recovered completely after two dips of 30 to 60 seconds duration in a 1:15,000 [illegible] malachite green. Their prompt recovery indicated that a single treatment might have sufficed.

Deformities

We have observed only seven deformed fish in our entire production of hybrids. The malformations were confined to two batches of fish and amounted to less than 1 percent of each lot. The deformity appeared to be a curvature or shortening of the spine in four of the fish. Two fish lacked the right eye and one had no caudal peduncle or caudal fin.

Our experiences with T. mossambica indicate they are not readily susceptible to diseases and parasites. Chimits (1955) referring to the genus Tilapia in general states, "So far no serious diseases or parasites of Tilapia have been recorded." We have not encountered fungus outbreaks during warm water periods. Tilapia, it appears, are more susceptible to fungus attacks at the colder temperatures.

As yet we have not held the tilapia with other warmwater fishes to determine how susceptible they are to transmission of diseases and parasites.

Incubation and Fecundity

Under temperature conditions in the Chino laboratory, fry normally hatch between 7 to 10 days after egg deposition. The fry become free swimming 3 to 5 days later. The water temperatures generally ranged from 66 to 82° F. The maintenance of uniform optimum temperatures would undoubtedly shorten incubation and fry development periods.

Fecundity of Javanese Females

Our present brood Javanese females produce an average of about 200 fry per spawning, but the nuMber varies considerably in relation to the size of the [illegible].

We are now recording the length, weight, and fry production of all brood females. Table 4 provides data on production of individual fish. Note the difference in size and production of fish numbers 2 and 7.

Spawning Behavior in Unisexual Populations

R[illegible] J[illegible] manifest typical maturation charactieristics of mouth pouch development, oviposition, and storage of eggs in the buccal cavity even when males are absent. Under these conditions, the eggs are retained for a considerable period. We assume that the female [illegible] infertile eggs, for we have not observed discarded eggs or [illegible] during such behavior.

Mature male hybrids exhibit spawning characteristics including coloration and nest building despite the absence of females. Although other workers, Vaas and Hofstede (op. cit.) and Uchida and King (op. cit.), cite rare instances of male T. mossaMbica holding eggs and fry in their mouths, we have not observed such behavior.

Determination of Sex

We have utilized the external features illustrated in Figure 1 as a means of identifying the sex of tilapia. A[illegible] a check upon our method, the author and a seasonal employee independently determined the sex of 87 young tilapia which ranged in size from 2.7 to 4.0 inches. Our determinations were in total agreement When the [illegible] group of fish became sexually mature, we repeated the process. The diagnosed number of males and females coincided with our initial determinations.

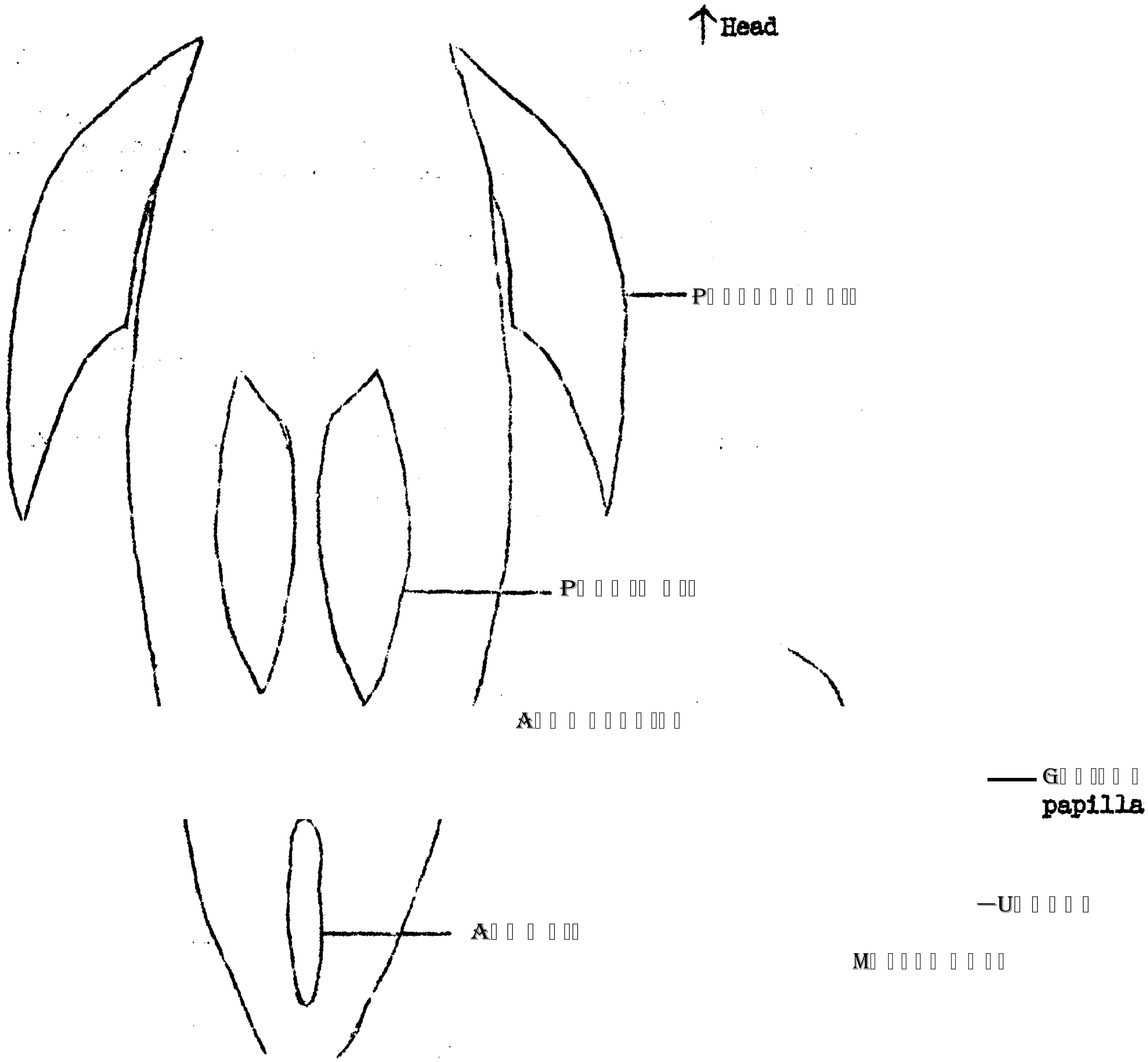
TABLE 4

Individual Hybrid Fry Production of Javanese Females

Number	Total length in inches	Weight in ounces	Number of fry
1	4.0[a]	0.39	65
2	4.5	0.53	304
3	4.6	0.62	153
4	4.7	0.62	293
5	4.9	0.62	235
6	5.4	0.75	281
7	6.1	1.2	95

Average number of fry per female = 203

[a] The 4.0-inch female was measured before spawning; the others after the fry were released.



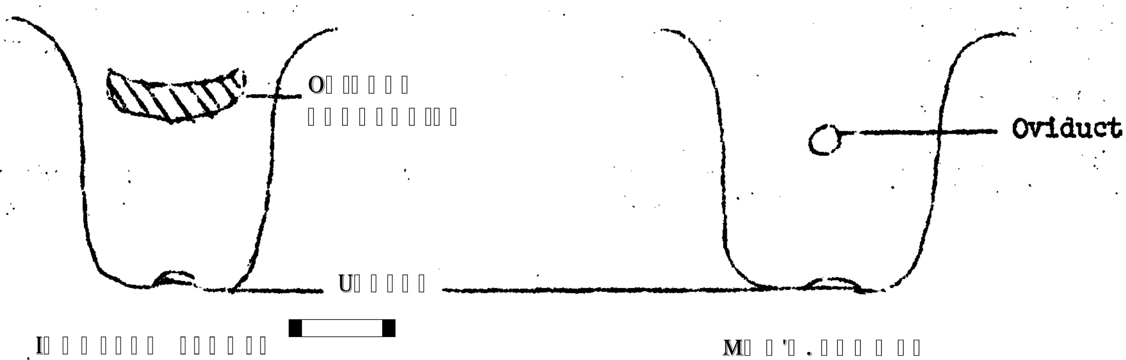


FIGURE 1. S[illegible] *T. mossambica*.

In 1964 we chemically treated a small pond and tributary stream in Riverside Count which contained tilapia. The tilapia are believed to have become established following unauthorized introductions (St. Amant, op. cit.). During the treatment, we examined a sample of 100 tilapia of varying sizes. Three members of our staff independently determined the sex of each fish. We were in complete accord.

We then examined each fish internally in the same order as the external inspection There were no disagreements in the results of the two examinations. The determina tion of sex is difficult when the tilapia are smaller than 2.5 inches.

Visual Difference Between the Subspecies of T. mossambica: Zanzibari and Javanese

According to Lowe (1955), T. mossambica can be distinguished from other species by the following key characteristics:

1. Dorsal fin 27-29 (rarely 26 or 30) spiny and soft rays.

2. Anal fin 12-15 spiny and soft rays.

3. Gill rakers 14-19 (rarely 20).

4. Outer teeth in jaws of mature male are unicuspid.

5. Lateral line series approximately 29-32 (rarely 33).

6. Variable color, dark brown, grey to silver grey, sometimes with about six vertical dark bars.

To prevent breeding the wrong combination of subspecies (i.e., Javanese male x Zanzibari female) it would be helpful to be aware of the visual differences between the two subspecies.

Dr. Prowse, Director of the Tropical Fish Culture Research Institute, Malacca, (personal correspondence) related some of the work conducted by Chen Foo Yan on the differences between the Zanzibari and Javanese subspecies. He states, "Coloration does differ but is not consistent. The yellowish color in the cheek and chin of the Javanese fish is usually slightly more intense and there is usually a spectacle mark across the nose of the fish. In the Javanese strain the vertical black bars of the female are usually more prominent. These color differences vary however, with food, light, etc." He further mentions that the pectoral fins of the Javanese placed horizontally reach the base of the third anal spine. The Zanzabari pectoral fins reach only to the genital papilla. Also the Javanese appear to have fewer gill rakers than the Zanzibari (14 to 16 and 21 to 33, respectively).

When a sufficient supply of both subspecies is available, we will examine these fish for additional differences and develop a key to the two subspecies.

POND STUDIES

We selected four ponds in which to conduct studies: Chino Fisheries Base holding ponds; Indio City Golf Course Pond; University of California, Riverside experimental ponds; and pond number two of the Santee County Water District.

Chino Fisheries Base Ponds

Reproduction

We tested the use of a spawning cage placed in a 1/8-acre [illegible]. T[illegible] consisted of a modified live car including a solid bottom for holding spawning material (sand). In this cage we placed one male Zanzibari and three female Javanese, the sex [illegible] Uchida [illegible] K[illegible] ([illegible].). B[illegible] the parent stock in a cage, the possibility of [illegible] parents would be eliminated. Also the fry could escape predation.

The three females were placed in the cage on May 22, 1964. The male was placed in the cage on May 27. Water temperature in the pond during the test period May 22 to June 19 ranged from 70 to 79^{o} F. Periodic examinations of the cage were made to [illegible] for indications of [illegible]. No signs of reproduction were found, so the fish were released into the pond on June 22 and the cage removed.

The failure of the tilapia to breed in the cage was probably due to low water temperatures. There is no other obvious reason why reproduction should not occur in this type of situation. It is doubtful that this method would be practical in the production of large numbers of hybrids because it is difficult to determine the number of fry being produced, and cannibalism might result because of differen sized hybrids being in the same pond.

To determine the production of the brood fish released in this pond, it was drained on August 24 and we attempted to recover all of the fish. Those recovered were as follows:

Parent stock	Size planted		Size August 24	
	Inches	Ounces	Inches	Ounces
Male Zanzibari	6.1	1.2	8.8	3.7
Female Javanese	3.5	0.28	3.8	0.39
Female Javanese	3.7	0.30	4.0	0.50
Female Javanese	4.0	0.35	7.1	2.0

In addition, 56 hybrids averaging 1.76 *inches* long were recovered. They were not the total production, since some fish were lost in aquatic plant growth and mud during the process of draining the pond. However, even if large numbers could be produced in ponds, this method lacks the control necessary to consistently produce significantly large numbers of hybrids.

Growth

To determine the best size for stocking to obtain maximum survival, we stocked four holding ponds with various sized fry and fingerling hybrids (Table 5). As would be expected, larger, older fry had a higher survival rate than smaller, younger fry.

The largest hybrids we have obtained to date were fish measuring 8.7 inches. These fish were held in a pond for 5.7 months. Most of the growth was obtained in the first 3 months. Little growth was made in October or November due to low water temperature. Growth of fish held in the other ponds ranged from 1.0 to 2.4 inches per month. The best growth rate was obtained when the fish were held in ponds when the temperatures were the highest.

TABLE 5

Results of Stocking Various Sized Hybrid Fry in the Chino Fisheries Base Holding Ponds

Pond	Size acres)	Date planted	Number planted	Size of fry	Date recovered	Number recovered	Percent survival	Pounds recovered	Average length (inches)
21	1/8	5-27-64	206	Large[1]	11-13-64	163	79	50.9	8.05
Si.	1/8	6-6-64	66	Large	8-3-64	55	83	34.74	4.52
L3	1/4	7-20-64	841	Small[2]	10-30-64	426	51	36.76	5.23
L4	1/4	7-31-64	275	Small[3]	10-9-64	53	19	5.31	5.29
L1	1/4	8-24-64	297	Small[2]	10-15-64	145	49	0.78	2.08

Large fry indicates fry are free swimming and maternal care has ended.

[2] Small fry indicates fry are free swimming but maternal care has not ended.

[3] Indicates fry are not yet free swimming.

It appears that temperature is the main limiting factor for growth. Allason and Noble (op. cit.) found that T. mossanbica do not feed extensively at temperatures below 60° F. Our observations are that feeding slows down when the water temperature is in the low 70's. Conversely, the higher the temperature the more active the fish become, within specified limits.

Hybrids held in a pond for 59 days with an average water temperature of 76.5° F. averaged 2.4 inches per month while hybrids held in a pond for 87 days, but with an average temperature of 71° F. averaged only 1.0 inches per month.

Pond Survival

The recovery of fish stocked in the Chino Fisheries Base ponds varied from 19 to 83 percent (Table 5). The fish were stocked as fry at different times and stocked at different rates in each pond. The highest recovery rates, 83 and 79 percent recovery resulted from ponds stocked with large fry. The lowest recovery rates, 1[illegible] 49, and 51 percent recovery occurred in ponds stocked with small fry. The lowest recovery, 19 percent, occurred in the pond where the fry were taken directly from the female's mouth and released into the pond. It appears that it is best to hold the young hybrids to at least the size of free swimming fry before stocking to obtain maximum survival.

Catchability

We did not conduct any catchability tests as such. However, on September 22, 1964, while spin fishing with worms as bait in the S3 pond, I captured the following fis[illegible] within a few minutes:

Total length in inches	Weight in ounces
8.4	3.9
8.0	3.1
7.9	3.0

The water temperature was 74° F. and the fish readily took the bait.

An earlier attempt to hook tilapia with artificial flies failed to produce any strikes. The water temperature was not recorded.

McConnell (personal communication) found in Arizona that the tilapia hybrid readily accept both artificial flies and worms.

University of California, Riverside Pond

We conducted a test from September 17 to November 16, 1964, using the experimental ponds at the University of California, Riverside. Sixteen hybrids were placed in each of three ponds, 1/150 acre, 18 inches deep, eclual to a stocking rate of approximately 205 pounds per acre. Controls consisted of three similar ponds without fish.

The purpose of the test was to obtain data on the effects of the hybrids in controlling insect populations. Larval midge (predominantly Chironomus californicus) populations were sampled twice weekly by removing two 1/4-square-foot bottom samples from each pond.

During the week prior to November 16, water temperatures dropped to lows of 42 - 43 °F. and all of the fish died. Dr. E. Bay, who supervised this test found the hybrids did not appreciably reduce the number of midge larvae (Figure 2).

Although measurements of larval mosquito populations were not made, gene:al observations indicate the tilapia did control these insects.

Measurements of the tilapia when stocked and at the termination of the test are as follows:

Size range when stocked September 17	Size range at termination of test. November 16
- 5.0 inches	6.25 - 7.75 inches
0.57 -2.3 ounces	1.6 - 2.8 ounces

Range of growth 2.15 - 3.65 inches.

Santee Pond

To obtain information on growth rates in an effluent pond, we introduced fingerling hybrids into one of the Santee ponds. The pond used in the study is one of five ponds managed by the Santee Water District in Sycamore Canyon, San Diego County. The ponds are being developed as recreational lakes using effluent water originating from the Santee sewage treatment plant. We selected Pond No. 2 since it is closed to angling and supposedly was devoid of fish (pond drained during the winter of 1964). All of the ponds at Santee are enclosed with a fence and the area is patrolled by Water District personnel. The test pond ranges in depth from 3.5 to 12 feet and covers 1/2 acre.

On June 7, 1965, we planted 1,140 fingerling hybrids. We collected samples of the hybrids monthly by seining and recorded the growth (Table 6).

A fish kill occurred on August 25, 1965, and again on September 8, 1965, in the test pond. An observer at the pond reports that on August 25 he found about 15 dead tilapia; several red-ear sunfish, *Lepomis microlophus*; threadfin shad; and a largemouth bass, *Micropterus salmoides*, 11 inches long.

A second kill occurred in September which apparently resulted in the complete elimination of all fish. A heavy bloom of the algae *Microcystis* was noted during both kills.

A qualitative stomach analysis revealed the hybrids had been feeding on dragonfly and damselfly larvae; water boatmen adults; Ephemeroptera mayfly larvae; and unidentified amphipods. A portion of the stomachs also contained unidentified adult insect parts.

Indio City Golf Course Pond

To obtain data on temperature tolerances, we began a [illegible] at the Indio City Golf C[illegible] [illegible]. T[illegible] [illegible] [illegible] 3-surface-acre pond with a maximum depth of 14 [illegible]. A[illegible] agreement was reached with the City wherebywe bad control of angling, fish introduction and removal, and chemical use. On November 2 we placed 30 tilapia hybrids from 5.0 to 5.6 inches long in a live car in the pond.. On November 21 we released [illegible] [illegible] into the pond and placed 20 additional hybrids from 2.2 to. 8.3 inches long in [illegible] [illegible] [illegible]. T[illegible] [illegible] terminated on December 23, 1964, when

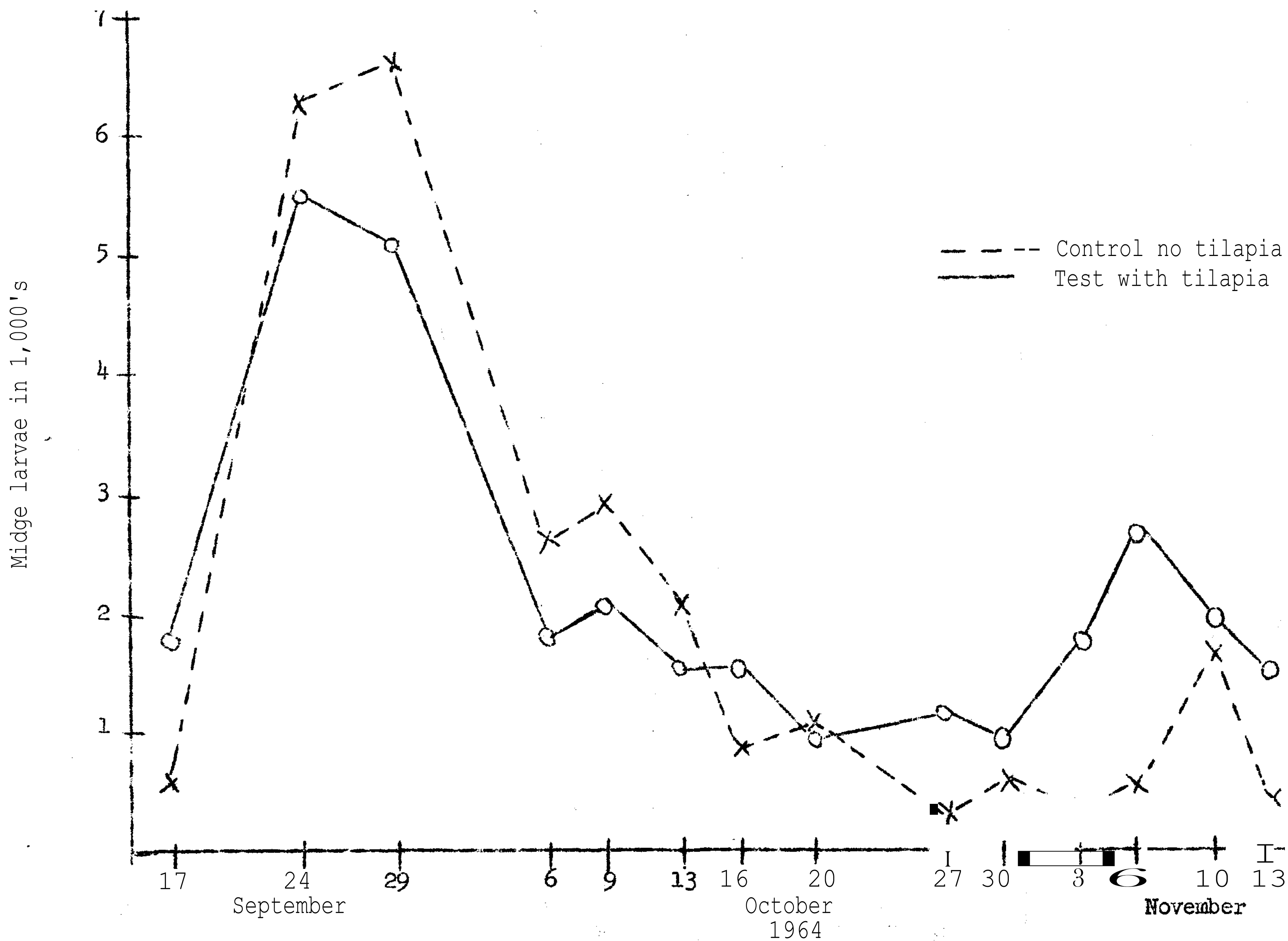


FIGURE 2. **Results** of test with **tilapia** in control of midge larvae.

TABLE 6

Growth Rate of Hybrids in Santee Pond No. 2

Date	Total length in inches	Weight in ounces	Average length in inches	Average weight in ounces
6-7-65[1]	0.7 - 2.3	0.002 - 0.055	2.4	0.006
7-7-65	1.5 - 4.0	0.02 - 0.88	2.6	0.17
8-10-65	3.5 - 5.6	0.26 - 1.3	4.5	0.65
9-8-65[2]	3.8 - 7.7	0.57 - 2.71/	6.6	2.0

1/Date hybrid fingerlings were planted.

/Measurements of dead fish following fish kill.

/Weights are approximate since fish were in various stages of decomposition.

all of the live-car-held fish died and dead fish were found in the pond indicating all of the hybrids had succumbed to low water temperatures. Water temperatures during the test ranged from 70 to 42° F. Prior to the death of the fish in December, the minimum water temperatures stabilized between 50 and 55° F. The lowest temperature, 42° F., occurred on November 15 without affecting the test fish. Therefore, it appears the hybrids can survive low temperatures for a short time with no apparent harmful effects but cannot tolerate low temperatures of 50 to 55° F. for any extended time.

CONCLUSIONS

We have been successful in producing an all-male hybrid with the Zanzibari male and the Javanese female as has been reported by Hickling (op. cit.) and McConnell (1966).

The culture and rearing requirements have been determined using conditions available at our Chino laboratory. Of various culture methods tested, the following technique has proven to be the most efficient:

1. A Zanzibari male is placed in aquaria with one to five Javanese females. The number of females used is not critical as long as sufficient cover is available and the fish are not crowded. Aquaria, no smaller than 20-gallon capacity, are recommended. No bottom material is required for spawning.

2. Aquaria should be checked daily for females carrying eggs or fry although 10-day checks may suffice.

3. Females carrying eggs should be placed in separate tanks. If the female is carrying fry, these should be removed from the female and placed in a separate tank. It is possible to remove eggs from the female's mouth and achieve high survival. This method has application for hatchery production.

4. Fry should be fed at least twice a day on finely ground trout meal until advanced fry size, then larger food should be provided.

The only disease that occurred during the study was fungus resulting from exposure to low water temperatures. Malachite green effectively controlled the fungus.

Maximum hybrid size obtained to date was 8.7 inches. Growth rates ranged from 1.3 to 2.4 inches per month at the Chino ponds and averaged 1.4 inches per month at the Santee pond.

Well-fed hybrid fry, held in heated tanks, can attain 3 inches in 2 to 3 months.

To obtain maximum growth and survival, during the warm months, the hybrids should be stocked as fingerlings at a length of 2 to 3 inches. By stocking the fingerlings in April, catchable-sized hybrids should be available for the angler by June or July, depending on water temperatures and available food.

Temperature is a limiting factor in the use of Tilapia hybrids as a sport fish. Although they can tolerate lower water temperatures than previously believed for brief periods, they cannot tolerate temperatures below 57° F. for an extended time. However, it may be possible, by selective breeding, to produce hybrids that can survive through the winter in some of our reservoirs.

Results of tests [illegible] University of California, R[illegible], show [illegible] T. mossambica are not an effective biological control animal for larval midges.

Observations of the hybrids in controlling aquatic plants suggest they are no pore effective than carp. Aquatic plant control is realized mainly through their nest building activities.

No problems are expected concerning the angler catchability and acceptance of the hybrids *as* a sport fish. Spin fishing with earthworms for bait proved to [illegible] an effective method.

FUTURE PROGRAMS

The study will continue at least through 1966. Future investigations are planned to develop parent stock of both the Zanzibari and Javanese subspecies [illegible] breeding that can produce low temperature tolerant hybrids.

We have begun production of [illegible] supply 10,000 to 20,000 fingerlings for introduction into a southern California water that receives heavy angling pressure. This introduction, along with providing data on catchability, angler reception, and growth rates, should give information on the effects the hybrid has [illegible] Calif rnia ichthyofauna and how the hybrid is affected by other fishes.

REFERENCES

Allanson, B. R., and R. G. Noble
1964. The tolerance of Tilapia mossambica (Peters) to high temperatures. Amer. Fish. Soc., Trans., vol. 93, no. 4, pp. 323-332.

Chimits, Pierre
1955. Tilapia and its culture. 'AO Fisheries Bull., vol. VIII, no. 1, Jan.-March, pp. 1-33.

Gill, Theodore
1907. Parental care among fresh-water fishes. The Smithsonian Rep. for 1905, no. 16888, pp. 403-531. Gov't. Print. Off., Washington, D.C.

Hickling, Charles F.
1963. The cultivation of tilapia. Scientific American, vol. 208, no. 5 (Nay), pp. 143-152.

Long, Le Quang, Nguyen Dinh May, and Nguyen Quang Vinh
1961. First statement on the influence of temperature on Tilapia mossambica Peters acclimatized in Viet Nam since 1951. Russian Jour. of General Biol., vol. 22, no. 6, pp. 443-451.

Lowe (McConnell), Rosemary H.
1955. Species of tilapia in East African dams, with a key for their identification. East African Agr. Jour., vol. XX, no. 4, pp. 256-262.

McConnell, William J.
1966. Preliminary report on the Malacca Tilapia hybrid as a sport fish in Arizona. Prog. Fish-Cult., vol. 28, no. 1, pp. 4046.

Simpson, Donald A.
1954. The things that happen . . . (when you don't keep your mouth shut). The Aquarium Jour., vol. XXV, October, pp. 219-220.

St. Amant, James A.
1966. Addition of Tilapia mossaMbica (Peters) to the California fauna. Calif. Fish and Game, vol. 52, no. 1, pp. 54-55.

Swingle, H. S.
1957. Control of pond weeds by the use of herbivorous fishes. Tenth Ann. Meeting Southern Weed Conf., Proc., pp. 11-17.

Uchida, Richard N., and Joseph E. King
1962. Tank culture of Tilapia. U. S. Fish and Wildl. Sevr., Fish. Bull. no. 199, vol. 62, pp. 21-52.

Vaas, K. F., and A. E. Hofstede
1952. Studies on Tilapia mossambica Peters in Indonesia. Cont. Inland Fish. Res. Sta. Djakarta - Bogor, Indonesia, no. 1.