A STUDY OF THE AFRICAN CICHLID, *Tilapia heudeloti* DUMERIL, IN TAMPA BAY, FLORIDA

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ABSTRACT

Ecological observations of the African cichlid, *Tilapia heudeloti,* are reported from the Tampa Bay estuarine system. Hydrological and biological data were compiled during 1963 and 1964. Specimens as large as 237 mm. (standard length) and weighing 487 grams were caught. Breeding appeared to begin in April or May and continue until December. Spawning occurred in brackish waters with an average salinity of 13.06‰. In the study area, *T. heudeloti* was tolerant of water temperatures as low as 49.3°F. (9.6°C.) and as high as 89.6°F. (32°C.). Its food consisted of bottom detritus and phytoplankton. Attempts to catch tilapia in Tampa Bay with artificial or live bait were not successful. Economically, *T. heudeloti* offers some promise of becoming a commercially important estuarine species in Florida waters.

INTRODUCTION

In recent years, cichlid fish of the genus *Tilapia* have received attention as food, game, and bait fish in Africa, southeastern Asia, Hawaii, and the United States (Chimits, 1955, 1957; Uchida and King, 1962; and Swingle, 1960). The biology of some tilapias and their culture in ponds and rice paddies has been studied by many scientists. Fish (1955) and LeRoux (1956) worked on feeding habits, and Lowe (1955) on fecundity. Zaneveld (1959) and Brock (1954) reported on spawning of *Tilapia mossambica* in salt water and Baerends and Baerends-Van Roon (1950) recorded the social organization, care for offspring, and courtship of some other cichlid species. Aronson (1949) and Shaw and Aronson (1954) described the reproductive habits and oral incubation of *T. macrocephala.* Aronson (1949) stated that *T. heudeloti* may be a subspecies or variety of *T. macrocephala.*

The first record of the African mouth-breeder, *T. heudeloti*, in Hillsborough Bay, Florida was reported during the summer of 1959 between Mangrove Point and the Alafia River (Springer and Finucane, 1963). By 1962, the species became firmly established as a resident, and a small commercial fishery was developed.

Little was known of the life history and environmental requirements of *T. heudeloti* and its association with native species in the United States. This study was initiated in 1962 as part of the East Gulf Es-

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tuarine Program dealing with the ecology of estuarine biota in the Tampa Bay area.

T. heudeloti was captured consistently at only two collecting sites (fig. 1). These locations were considered representative of the ecological habitats where *T. heudeloti* has become established. Station A is in a man-made channel connecting with Hillsborough Bay via Dug Creek. Station B is in Dug Creek, a stream receiving overflow drainage from fresh-water springs in an adjacent hatchery. The hydrology of both stations is influenced by tidal exchange throughout the year and by fresh-water inflow during the summer and fall. Water depth averaged 4 to 6 feet at Station A and 2 to 3 feet at Station B, although deep holes in both locations are 8 to 10 feet in depth. No attached bottom vegetation of any type was found at either location. Bottom composition at Station A consisted mainly of detritus and a fine sand-mud mixture. Station B had essentially the same bottom composition with a lower detrital content. Station A is surrounded by high grassy banks with some Australian *(Casuarina equisetifolia)* and longleaf pines *(Pinus palustris)*. The main emergent vegetation at Station B is the mangrove*(Rhizophora mangle)*.

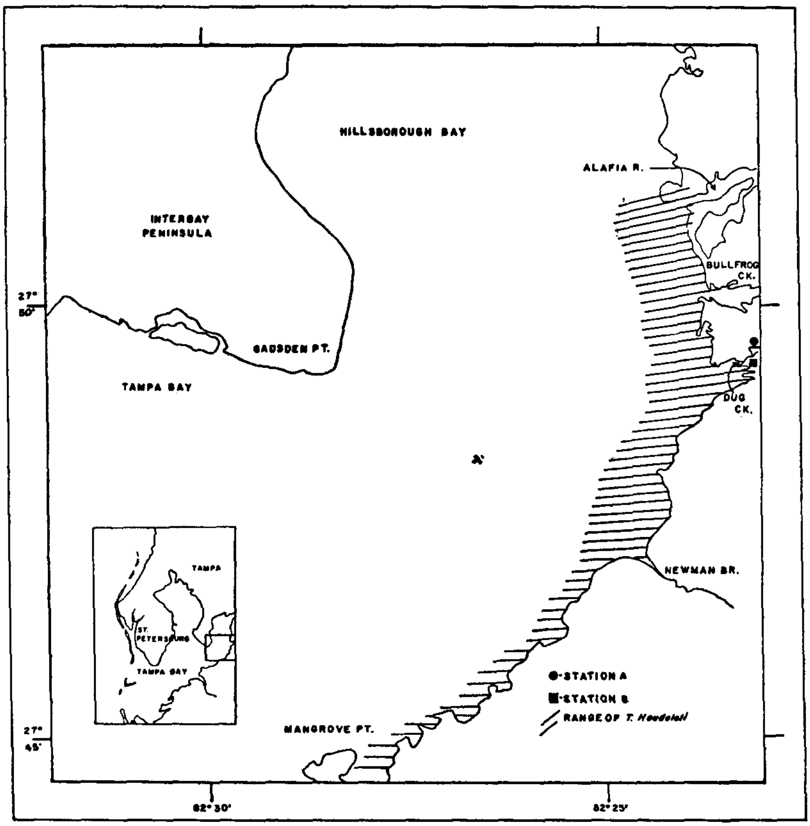

Figure 1.--Sampling stations and range of Tilapia heudeloti in the Tampa Bay estuarine system.

METHODS AND EQUIPMENT

Monthly seine hauls were made at each station with a 70-foot bag beach seine having ½-inch stretch mesh in the wings and ⅛-inch mesh in the bag. Tilapia retained for length-weight analyses were stored on ice and later frozen in polyethylene bags. The remainder of the specimens were preserved in 10 per cent formalin for later laboratory analysis.

Fish were measured to the nearest millimeter in standard length (SL) with a rule and Vernier calipers. Length-weight relationships were calculated according to the method of Lagler (1956). Selected specimens were weighed to the nearest tenth of a gram on a Mettler balance and checked for gonodal development and parasites. Age was determined from scales removed in an area between the dorsal fin and lateral line.

Small blue crabs *(Callinectes sapidus)*, caridean and penaeid shrimp, earth worms, artificial jigs, flies, and spoons were used as bait with fly and spinning rods to determine the catchability of the fish with sport gear.

Water samples were taken from the surface at each station to determine salinity, oxygen, and hydrogen concentration (pH). Water temperature was measured with a mercury thermometer to the nearest tenth of a degree centigrade. All salinity samples were collected in 120 ml. prescription bottles. The pH was determined from samples taken in 25 by 200 mm. pyrex glass culture tubes, fitted with polyethylene-lined screw caps. All oxygen samples were taken with modified Van Dorn bottles (Van Dorn, 1957) and treated immediately by the Windler method in 250 ml. glass-stoppered reagent bottles. Chlorophyll samples were collected in Erlenmeyer flasks and treated with magnesium carbonate to eliminate bacterial action. The complete methods used in chemical analyses have been described (Saloman, Finucane, and Kelly, 1964). Estimates of phytoplankton production were made according to the methods of Ryther and Yentsch (1957).

Sediment samples were taken with a manual coring device which extracted a core 2½ inches in diameter by 6 inches in length. Sand-size particles were separated by mechanical sieving, and silts and clays were determined by a soil hydrometer pipette method. An approximation of plant detritus was obtained by ignition (Moore and Gorsline, 1960). Per cent shell, sand, and detritus of each grain-size fraction was determined through particle counts on selected grids under low magnification by the method of Goodell[1].

RESULTS

Hydrology and Bottom Sediments

During 1963, monthly hydrographic parameters were measured at each sampling site (fig. 2). Water temperature was similar at both locations, averaging 23.3°C. at Station A and 24.3°C. at Station B. The lowest temperature occurred during February (14.3°C.) at Station A and the highest during September (32° C.) at Station B.

Salinity at both locations ranged from fresh to brackish. At Station A the lowest salinity occurred in December (1.62‰) and the highest during November (20.01‰).

The pH concentrations were essentially alkaline at both stations, ranging between 6.90 in June and 8.23 in September. The average at A was 7.60, and at B, 7.47. With the exception of January and February, the pH values at Station A were higher than at Station B.

[1] H. G. Goodell (personal communication), Florida State University, Tallahassee, Florida.

Oxygen values at both locations ranged from 1.70 in June to 6.47 ml./1. in January. The averages were 4.12 ml./1. at Station A and 4.44 ml./1. at Station B. The percentage oxygen saturation ranged from 34.4 per cent in June to 131.3 per cent in September.

Chlorophyll measurements at both stations gave productivity values of 0.65 and 0.35 g $C/m^2/day$ at Station A and 0.36 and 0.16 g $C/m^2/day$ at Station B in July and August 1964. Chlorophyll a for these same periods was 12.29 and 22.4 mg/m^3 at Station A and 4.52 and 10.01 mg/m^3 at Station B.

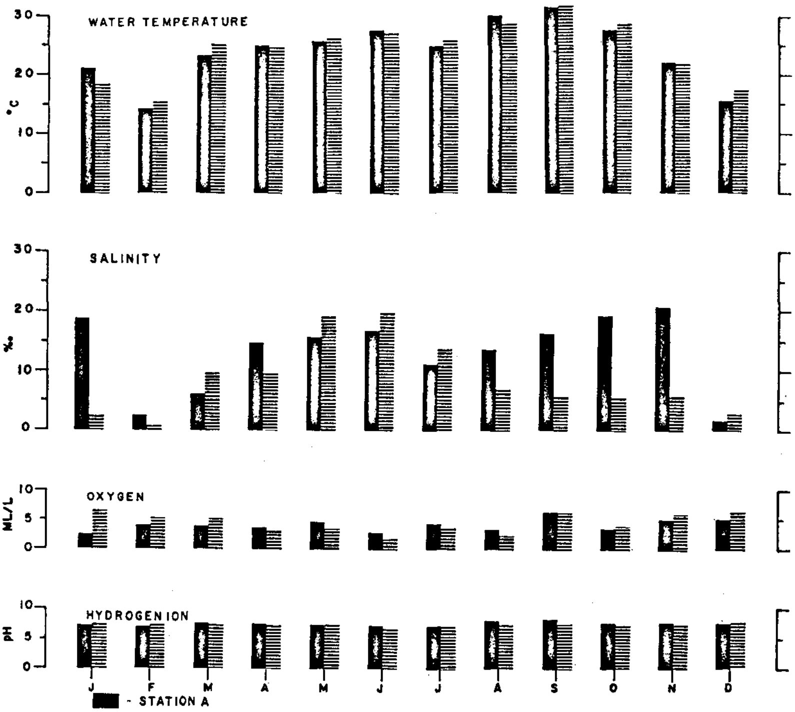

Figure 2.--Hydrological properties of the Dug Creek area for 1963.

Bottom sediment from Station A consisted of 67.36 per cent sand, 31.98 per cent detritus, and 0.67 per cent shell. Station B had 87.91 per cent sand, 11.97 per cent detritus, and 0.11 per cent shell. Clay and silt at both stations were negligible.

Natural History of Tilapia

Length-frequency data for 364 tilapias were determined for the period December 1962 to January 1964 (Table 1). The size range was 28 to 237 mm. (standard length). Examination of length-frequency and scale data revealed that the tilapia population consisted solely of fish in age groups O and I.

Representative length-weight relationships were plotted for 177 tilapias from the Dug Creek area (Fig. 3). Weight ranged from 5.1 grams for a fish of 46.7 mm. (SL) to 497.1 grams for one 220 mm. (SL). Most of the larger mature fish weighed more than 250 grams and were caught during January and March 1963. This indicates that weight increases rapidly in relation to length after length exceeds

100 mm. (SL). The logarithmic formula for the expression of this relationship is $\log W = \log a + n \log L$, where W is the weight in grams, and L is the length in millimeters. The values for log a and n were found to be —3.848 and 2.772 respectively.

Ovary development and length-frequency data indicate that spawning starts in the spring and extends through the summer and fall. Mature ovaries were found in fish collected during March. Nest sites were also seen along the banks of Station A during the spring and summer. No nest sites or other evidence of spawning was noticed at Station B.

Stomach analyses showed that *T. heudeloti* is primarily a detritus and phytoplankton feeder. Contents of the intestional tracts (in descending order of magnitude) consisted of detritus, sand, diatoms, armored dinoflagellates, filamentous algae, and insects. The predominant phytop-

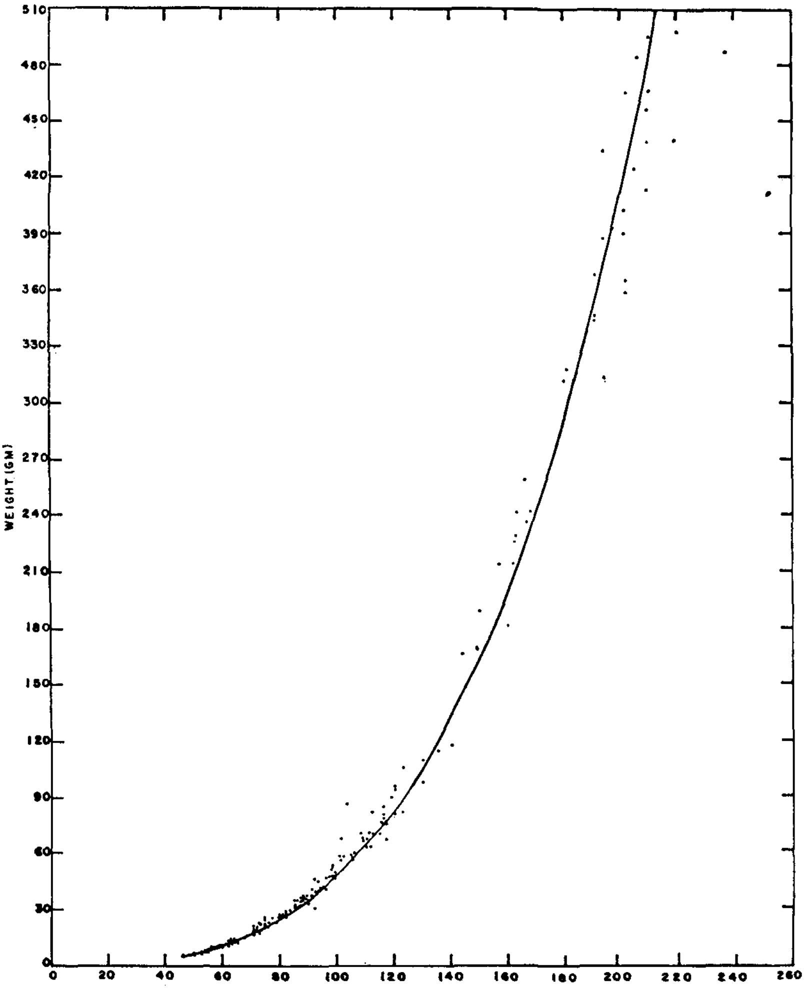

Figure 3.--Length-weight relationship for Tilapia heudeloti.

Table 1.--Length-frequency distribution of Tilapia heudeloti measured from the Dug Creek area

Mid-class (mm.)	1962 Dec	1963 Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	1964 Jan	Mar
20															
25															
30									11				1		
35									11			1	1		
40	1								3		1		2		
45			2							1			7	1	
50	2	1	4	1									5	3	
55	2		7	1								1	3	4	
60	2		5	1							1		2	3	
65	3		5	1							1	1	4	11	
70	2	1	4									1	2	8	
75		3	4										1	12	
80	1	3	3	1								1	5	16	
85		4	4										1	8	
90	1	5	7											6	
95	1	5	3									1	2	7	
100		4	3	1								1		7	
105		3			2							5		5	
110		7				2						3		2	
115	1	2			1	6							1	1	
120						4									
125		1				1						1			
130						2									
135		1													
140		1													
145															1
150						2							1		
155													1	1	
160														1	
165		2	1			2									
170		1								1				1	
175	1														
180	2	2													
185															
190	1												1	1	2
195	2	2		1										1	
200				1									1	1	3
205	2													2	
210													1	3	1
215												1			
220													1		2
225										1			1		
230	1													1	
235	1			1											
240															
Monthly total	26	48	52	9	3	19	0	0	25	3	3	17	44	106	9
Size range	40-235	48-197	46-163	50-237	103-116	110-167	-	-	28-42	47-225	42-64	36-215	32-223	46-230	144-220

lankton were diatoms and dinoflagellates (table 2). No evidence of fish-remains, crustaceans, or mollusks was noted. In nature, the species is essentially a herbivore, although in the laboratory it is omnivorous.

Twenty-eight species of fish appeared in catches with *T. heudeloti* (table 3). The dominant species were as follows: *Anchoa mitchilli, Menidia beryllina, Eucinostomus argenteus, Mollienesia latipinna,* and *Diapterus plumieri.* The majority of these fish were young-of-year and used the areas sampled as nursery grounds. No evidence of predation by tilapia was noted.

DISCUSSION

The ability of *T. heudeloti* to survive in waters of abnormally low temperature has been shown by Springer and Finucane (1963) when a

Table 2. Diatoms, dinoflagellates, and algae utilized as food by *Tilapia heudeloti.*

Genus Species	Genus Species
Achnanthes curvirostrum	Navicula cryptocephala
Achnanthes hauckiana	Navicula hungarica
Amphora ovalis	Nitzschia palea
Bacillaria paradoxa	Nitzschia closterium
Bellerochea malleus	Nitzschia filiformis?
Caloneis formosa?	Opephora sp.
Cocconeis sp.	Peridinium sp.
Cyclotella striata?	Pinnularia sp.
Diploneis ovalis?	Pleurosigma sp.
Gonyalax sp.	Skeletonema costatum
Gyrosigma spencerii?	Stauroneis sp.
Melosira nummuloides	Synedra ulna

Table 3. Species of fish collected with *Tilapia heudeloti* during 1963 at both sampling stations.

Genus-species	Common Name	Number Collected	Per Cent Total Collections[1]
Eucinostomus argenteus	Spotfin mojarra	694	100.0
Diapterus plumieri	Striped mojarra	336	84.6
Mollienesia latipinna	Sailfin molly	560	76.9
Centropomus undecimalis	Snook	20	69.2
Menidia beryllina	Tidewater silverside	971	69.2
Fundulus grandis	Gulf killifish	74	61.5
Anchoa mitchilli	Bay anchovy	3529	53.8
Archosargus probatocephalus	Sheepshead	9	46.2
Floridichthys carpio	Goldspotted killifish	84	38.5
Eucinostomus gula	Silver jenny	20	30.8
Trinectes maculatus	Hogchoker	7	30.8
Cyprinodon variegatus	Sheepshead minnow	27	30.8
Fundulus similis	Longnose killifish	9	23.1
Mugil trichodon	Fantail mullet	63	23.1
Leiostomus xanthurus	Spot	3	23.1
Cynoscion nebulosus	Spotted seatrout	6	23.1
Oligoplites saurus	Leatherjacket	12	23.1
Lutjanus griseus	Gray snapper	3	15.4
Lagodon rhomboides	Pinfish	21	15.4
Cynoscion arenarius	Sand seatrout	2	15.4
Lucania parva	Rainwater killifish	21	15.4
Gambusia affinis	Mosquitofish	1	7.7
Dorosoma cepedianum	Gizzard shad	1	7.7
Sciaenops ocellata	Redfish	2	7.7
Adinia xenica	Diamond killifish	5	7.7
Fundulus confluentus	Marsh killifish	1	7.7
Strongylura timucu	Timucu	4	7.7
Harengula pensacolae	Scaled sardine	4	7.7

[1] Per cent of total collections was based on the number of times these species were taken in 13 seine collections with *T. heudeloti.*

water temperature of 9.6°C. (49.3°F.) was recorded in the Tampa Bay area for a short period in December 1962. Some mortality of larger tilapia did occur, but there was no evidence of a massive fish kill. Crittenden[2] reported that experimental stocks of *T. nilotica* in a Florida State Management Area of Hillsborough County were also exposed to a water temperature of 8.9°C. (48.°F.) during this same period with no apparent mortality. The Java tilapia, *T. mossambica,* is more sensitive to low temperature and has been reported by Kelly (1957) to die at about 48°F. The mortality was limited to fish less than 6 inches in length, although some larger fish to 11 inches tolerated 37°F. (2.8°C.) for a short time. Aronson[3] believed that *T. marcrocephala* would not survive temperatures much below 60°F. (15.6°C.)

Low water temperature in the Tampa Bay area appears to inhibit the spawning of *T. heudeloti* from December to February. During these months, no spawning behavior was observed, and no nests were seen along the banks at either station. Our observations indicate that a minimal water temperature of 25°C. must be reached before spawning begins. Aronson (personal communication) stated that his experiences with laboratory specimens of *T. macrocephala* indicated optional temperature for breeding to be between 80 and 90°F. (26.7 and 32.2°C.).

Our attempts to spawn *T. heudeloti* in aquaria were not successful when salinity was greater than 34‰. Aronson (personal communication), however, reported successful breeeding of *T. macrocephala* in a sea-water aquarium and collection of the species in natural habitats where the salinity was nearly that of sea water. Zaneveld (1959) spawned *T. mossambica* in aquaria with running sea water at 36.2‰. Additional spawning took place at this same salinity at intervals of 28 to 50 days. The number of young produced never exceeded 25. Brock (1954) reported that Java tilapia also spawned in running sea water having a salinity of about 34.85‰ and a pH of 7.95.

Aronson (1949) and Shaw and Aronson (1954) reported extensively on the reproductive behavior, oral incubation, and embryology of *T. macrocephala* in laboratory aquaria. They found that oval nests were built having an average diameter of 13.2 cm. and an average depth of 2.6 cm. Of 76 observed spawnings, the male alone picked up the eggs in his mouth 81.8 per cent of the time, usually within one minute (average time 1 minute, 3 seconds). Incubation by the male ranged from 6 to 22 days with a mean of 14 days. Eighty females with a mean weight of 7.2 grams deposited an average of 50 eggs. The unfertilized mature ova are asymmetrical (Breder, 1943). They range between 2.0 and 3.5 mm. in length and 1.5 and 2.5 mm. in width. There is considerable variability in egg size within the ovary, although Shaw and Aronson (1954) stated that within each hatch the size was uniform.

Mature ovaries of *T. heudeloti* were recorded during March. Spawning of this fish probably first occurs during the spring. Two male specimens examined by Springer and Finucane (1963) were carrying eggs in their oral cavities as early as April. In laboratory experiments, Aronson (1951) found that *T. heudeloti* exhibited two peaks of reproductive activity: a major peak in March coinciding with the vernal equinox and a lesser one in October roughly coinciding with the autumnal equinox. In the natural West African habitat of *T. heudeloti,* spawning reaches its peak during December and January and tapers off during February, March, and April (Aronson, personal communication).

The youngest juvenile occurring in our study were caught in August, 1963 and ranged from 28 to 38 mm. (SL). The exact age of these fish is unknown, although specimens of *T. nilotica* from a local

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2 Edward Crittenden (personal communication), Florida Game and Fresh Water Fish Commission, Leesburg, Florida.

3 Lester R. Aronson (personal communication), American Museum of Natural History, New York, New York.

hatchery in this same size range were approximately one month old. McBay (1962)also reported that young *T. nilotica* measuring 4 inches (100 mm.) were approximately 50 days old, while 7-inch (195 mm.) specimens were 90 days old. Scale analysis of the larger tilapia (to 200 mm.) showed that most were still in their first year or early part of the second year. Annual rings on the cycloid scales were not distinct. No fish greater than 237 mm. (SL) was caught, however, indicating that in Tampa Bay *T. heudeloti* seldom lives longer than two years.

The food of both young and adult *T. heudeloti* consisted primarily of bottom detritus and phytoplankton (table 2). Most of the phytoplankton were diatoms and armoured dinoflagellates of the genera, *Peridinium* and *Goniaulax.* In laboratory aquaria, however, these tilapia readily consumed sailfish mollies *(Mollinesia latipinna),* caridean and penaeid shrimp. Stomach analysis conducted on *T. nilotica* by McBay (1961) showed that they were primarily plankton feeders and all sizes utilized phytoplankton to a large extent. Fish less than one inch in length (25 mm.) ate some small crustaceans (ostracods) while 3-5 inch fish (75-125 mm.) utilized insects, primarily Tendepedidae and Ceratopogonidae. Uchida and King (1962) and McBay (1962) reported some cannibalism by the larger, faster-growing individuals (20 mm. or larger) of the Java and Nile tilapias on other smaller juveniles.

From the types of fish species found to be associated with *T heudeloti,* it appears that little direct competition for food exists. The dominant species (table 3), such as the Bay anchovy, *A. mitchilli,* and the tidewater silverside, *M. beryllina,* are primarily plankton feeders but are reported to eat zooplankton principally. For example, Darnell (1959) found that the anchovies generally consumed rotifers and calanoid, and cyclopoid copepods when young. When mature, the diet consisted of fish and small shrimp. Larval silversides lived on copepods. Those 40 to 54 mm. fed primarily on isopods and those 55 to 79 mm. on amphipods. The sailfish molly, *M. latipinna,* is a herbivore, and the mojarras, *E. argenteus* and *D. plumieri,* are listed by Springer and Woodburn (1960) as eating ostracods, copepods, polychaetes, pelecypods, and insect larvae. The diet of cyprinodontids is similar to that of the mojarras but is more varied. Few of the young-of-year fish appear to need large amounts of phytoplankton as a primary food source. On the other hand, *T. heudeloti* is dependent on an abundant supply of phytoplankton such as that produced at Station A. The chlorophyll a values at Station A are approximately 10 to 22 times greater than those reported by Ryther and Yentsch (1957) from 14 tropical Atlantic stations. The higher rate of chlorophyll a and phytoplankton production at Station A probably is partially responsible for the greater abundance of *T. heudeloti* there than at Station B. The greater detritus content at Station A also appears influential in the support of comparatively large tilapia populations.

The practicability of developing *T. heudeloti* as a sport species is questionable. Attempts to catch this species with artificial or live bait were not successful. Swingle (1960) and Crittenden (1965) stated that both *T. mossambica* and *T. nilotica* could be caught on worms, although the Nile tilapias were more difficult to catch.

The greatest potential for the West African tilapia lies in its development as a commercial species. It has been marketed in Tampa on a limited scale by gill net fishermen during the winter and spring (Springer and Finucane, 1963). It is difficult to catch during the breeding season, although cast netting is sometimes successful. Since 1957, its range appears to have been confined chiefly to an area extending from the Alafia River to Mangrove Point along the eastern shore of upper Tampa and Hillsborough Bays (fig. 1). Other similar habitat types appear to be suitable for the species in Old Tampa Bay and in parts of lower Tampa Bay. Over three years of extensive field sampling throughout the Bay area have shown no further extension of its range. Since it appears to be essentially a euryhaline species, any of the major drainage areas along the southwest coast of Florida would seem to offer a suitable environment.

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MAN'S ALTERATION OF ESTUARIES BY DREDGING AND FILLING A GRAVE THREAT TO MARINE RESOURCES

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ABSTRACT

Despite the recognized importance of estuaries to the well-bing and economy of our Nation, these areas are being unwisely exploited to develop water-front real estate by dredging and filling operations. Accumulative adverse effects of these activities threaten the precarious balance of nature. The Fish and Wildlife Service, working closely with appropriate state agencies to conserve estaurine areas, has made little headway. The power of public opinion, suppored by sound scientific data concerning the importance and continuing value of estuaries, offers hope for success.

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In today's era of precise terminology and classification the term "estaury" is an exception in that definitions are modified as estaurine