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Dawn P. Jennings
U.S. Fish and Wildlife Service

James D. Williams
U.S. Fish and Wildlife Service

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FACTORS INFLUENCING THE DISTRIBUTION OF BLACKCHIN TILAPIA *Sarotherodon melanotheron* (Osteichthys: Cichlidae) IN THE INDIAN RIVER SYSTEM, FLORIDA

Dawn P. Jennings and James D. Williams
U.S. Fish and Wildlife Service
National Fisheries Research Center
Gainesville, FL 32606

ABSTRACT: The blackchin tilapia, ***Sarotherodon melanotheron***, was first collected from the Indian River system, in Brevard County, Florida, in 1980. Since its introduction, this species has expanded its range northward along the coast approximately 37 km, to just north of Whites Point, Brevard County, and southward about 68 km to Vero Beach, Indian River County. Laboratory studies on salinity tolerance indicate an ability of this species to tolerate hypersaline concentrations of at least 100 ppt, and to reproduce in salinities of up to 35 ppt. The northern distribution of blackchin tilapia is almost certainly limited by cold temperature; however, the potential exists for extensive coastal, and possibly inland, invasion south of its present limits.

The blackchin tilapia in the United States is an exotic cichlid fish, native to estuarine areas of west Africa from Senegal to Zaire (Trewavas 1983). This species was originally imported as an aquarium fish, but was released or escaped into the wild and became established in open waters. It currently is established in Florida on the west coast in the Tampa Bay area in Hillsborough and Manatee counties, and on the east coast in the Indian River lagoon system in Brevard and Indian River counties.

Blackchin tilapia were first reported from Tampa Bay in 1959 (Springer and Finucane 1963). By 1962, the species was established and utilized as a small commercial fish (Finucane and Rinckey 1967). It continues to be exploited in the fishery today, from the eastern side of Tampa Bay southward to Cockroach Bay.

The first collection of blackchin tilapia in the Indian River system was in 1980 near Satellite Beach, Brevard County (Dial and Wainwright 1983). It is unknown whether this population resulted from the release of aquarium or aquaculture fish, or whether tilapia were transplanted from the Tampa Bay population for sport fishing and bait potential. The blackchin tilapia is commonly taken by commercial fishermen netting for mullet in the Indian and Banana rivers, and there is a local market for them.

Although the blackchin tilapia has been present in these estuarine systems for many years, little is known about its life history. Because it is a tropical species, cold temperature is considered a primary environmental factor restricting its dispersal northward (Courtenay et al. 1981.). Knowledge of its reproductive behavior and survival over a range of salinities is also important for predicting its potential distribution in estuarine areas.

We conducted field studies to determine the distribution and habitat requirements of blackchin tilapia in the Indian River system and to establish baseline data for monitoring the population at the extremes of its range. Laboratory studies were designed to investigate the primary factors influencing distribution in estuarine environments. These experiments were done following a previous study on temperature tolerance (Jennings 1991), to further enhance our knowledge of blackchin tilapia. This combined information will help predict potential range expansion of blackchin tilapia in the Indian

River and other estuarine systems.

MATERIALS AND METHODS

Study Area

The Indian River system is essentially a long narrow estuarine lagoon, with little freshwater inflow, situated on the east coast of Florida. It extends 253 km, from Ponce de Leon Inlet near New Smyrna Beach, Volusia County, south to Jupiter Inlet, Palm Beach Co. (Figure 1). It consists of 3 interconnected bodies of water — Mosquito Lagoon, Indian River, and Banana River. Lagoons are separated from the Atlantic Ocean by narrow barrier beaches and by the Cape Canaveral and Merritt Island land masses. Ocean connections consist of 5 inlets: Ponce de Leon, Sebastian, Fort Pierce, St. Lucie and Jupiter. The width of this system varies from only a few meters at Jupiter to 8.9 km near Titusville (Gilmore 1977). Average depth is approximately 1.5 m. Salinity varies with rainfall, evaporation and proximity to freshwater runoff sources or the inlets, but averages 25.6 ppt annually. Open lagoon waters may become hypersaline, with concentrations as high as 42 ppt. Surface temperatures average 11 °C in winter and 31 °C in summer. The lowest recorded water temperature was 6 °C from a lagoon in northern Brevard County (Snelson and Bradley 1978). Several small, low gradient rivers, creeks and canals flow into this system. The largest drainage area is the St. Johns marsh.

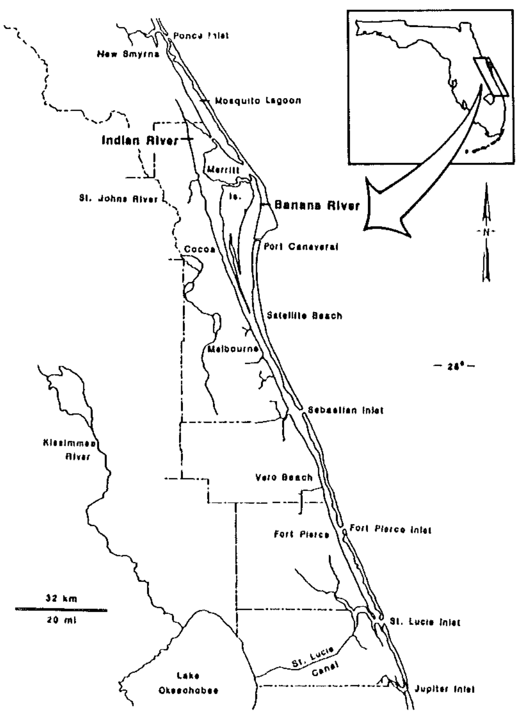

Figure 1. The Indian River lagoon system, Florida.

Field Methods

Sampling was conducted from August 1987 to August 1990, to determine the distribution of blackchin tilapia in the Indian River system. Collections were made in coastal habitats from Merritt Island, Brevard County, south to Fort Pierce, St. Lucie County. A total of 30 sites, representing a variety of habitats (including canals and drainage ditches, lagoonal areas at the mouths of creeks and canals, open water areas, and freshwater tributaries), were repeatedly sampled for quantitative data. Fish were collected by seining each area for 30-minute intervals. The seines were 5 m long with 6.4 mm mesh, or 10 m long with 12.7 mm mesh. They were equipped with heavy lead lines to prevent tilapia from evading capture. We recorded numbers of tilapia collected, associated species, and location and habitat characteristics of sampling sites. Precise sampling localities are available from the authors. Voucher material preserved in the field was deposited in the Florida Museum of Natural History, Gainesville, Florida. Water temperature and dissolved oxygen were measured with a YSI dissolved oxygen meter, and salinity was measured using a temperature-compensated refractometer.

In addition to quantitative sampling, we qualitatively sampled 35 additional sites using cast nets, gill nets, and visual

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observations. Fish houses and local seafood markets were also visited to determine the frequency of catch of blackchin tilapia in areas where they were commonly fished.

Data on species associations from seine collections were analyzed with Chi Square tests to determine whether there was a greater probability of finding blackchin tilapia given the presence of another species. The level of acceptance was $P \leqslant 0.05$.

Laboratory Methods

Blackchin tilapia were collected from a freshwater drainage canal in Brevard County, Florida, and transported to the laboratory. All were adults, averaging 123.4 mm SL and 84.5 g weight for males and 131.2 mm SL and 95.8 g weight for females.

Two salinity experiments were conducted. First, salinity tolerance was investigated by exposing a group of nine blackchin tilapia to increasing salt concentrations. The fish were placed into a 500-L tank with a large viewing window and allowed to acclimate in fresh water at 18-19° C for 7 days. Salinity was measured with a temperature-compensated refractometer. The concentration of synthetic aquarium salts (Aquarium Systems, Mentor, Ohio) was initially increased at a rate of 5 ppt per day up to 35 ppt. Fish were held at 15 ppt and 35 ppt for 7 days each to allow for osmoregulatory adjustments. Concentration of sea salts added to the tank was then reduced to 2.5 ppt per day from 35 to 60 ppt, 2.5 per day every 2 days from 60 to 75 ppt, and finally to 2.5 ppt per every 7 days between 75 and 100 ppt. Concentration was maintained at 100 ppt for one day. Observations of behavior were recorded on a daily basis.

The second experiment evaluated the ability of blackchin tilapia to reproduce over a range of salinity concentrations typical of the Indian River system. A total of 48 fish were selected for study in 8-1700L circular fiberglass tanks. The tanks were maintained on 4 separate filter systems, providing 2 replicates for each of 4 salinity treatments (0, 10, 20, and 35 ppt). Salinity concentration was monitored on a daily basis and adjusted using synthetic aquarium salts (Aquarium Systems, Mentor, Ohio).

Salinity acclimation was accomplished by initially introducing all fish to the freshwater system and, at 2-week intervals, acclimating the remaining proportion in a step-wise fashion to the other respective salinity concentrations. Sexes were separated during the salinity acclimation period. Water temperature was maintained at 23° C during the acclimation period with thermostatically controlled chillers. After 3 weeks of acclimation to the appropriate test salinity, sexes were combined so that 3 males and 3 females occupied each tank. The spawning substrate consisted of pea gravel in 4 equally spaced shallow 10-L pans, that were placedd along the edge of each tank. Each pair of fish was identified by the particular pea gravel pan they selected. Chiller units were disconnected to allow water temperature to gradually return to an ambient temperature of 28° C. After 2 weeks of no obvious activity, the water flow from the recirculating systems was turned off and large sponge filters were placed in each tank to ameliorate the tank environment and attempt to induce courtship and spawning. Fish were monitored on a daily basis for evidence of reproductive activity and mouth-brooding behavior. The experiment was terminated after 3 months. The mean precentage survival of the larvae at each salinity concentration was calculated.

RESULTS

Field Observations

Since 1980, the blackchin tilapia has expanded its range northward in the Banana River approximately 37 km, to just north of Whites Point, Brevard County, and southward in the Indian River about 68 km to Vero Beach, Indian River County (Figure 2). Areas where this species was most abundant included drainage ditches and canals, typically with muddy substrate and submergent vegetation, with salinities ranging from 0-10 ppt. We seined 14 sites in this habitat type, for an average of 20.7 blackchin tilapia per site; numbers ranged from 0 to 282 tilapia per collection. Additional areas where blackchin tilapia occurred included mouths of creeks and canals. These lagoonal areas typically had an accumulation of detrital material with salinities ranging from 8-35 ppt. Three sites were sampled, with an average of 1.1 tilapia collected per site; numbers of tilapia per collection ranged from 0 to 9. Blackchin tilapia were commonly taken by fishermen in their mullet nets in open water on grass beds during the summer months. Eight open-water areas we sampled resulted in an average of 0.6 tilapia per site; numbers per collection ranged from 0 to 5. No tilapia were collected from five sites sampled in natural creeks and tributaries.

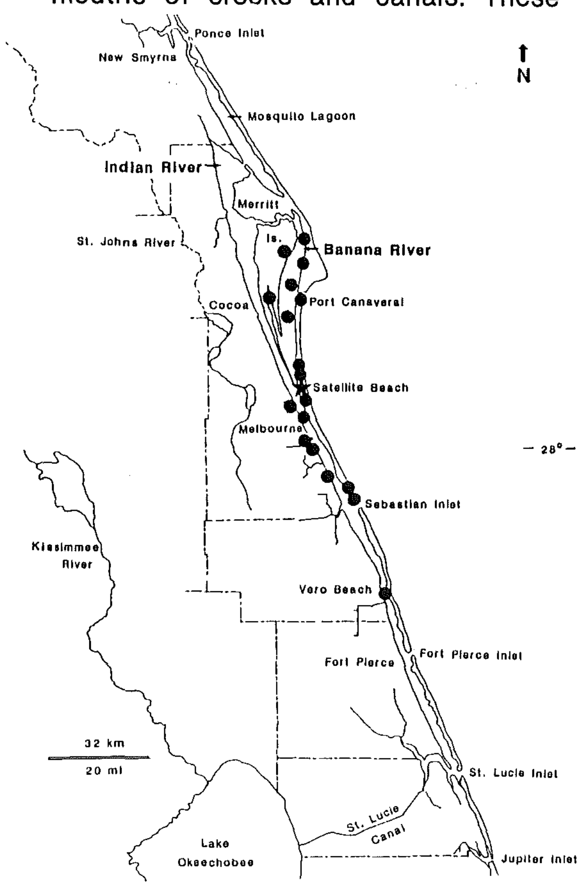

Figure 2. Present distribution of blackchin tilapia, *Sarotherodon melanotheron*, in the Indian River system, Florida. The star indicates the apparent location of the initial introduction.

Table 1 lists species commonly collected with blackchin tilapia by habitat. There were no statistically significant associations of any of these species with the blackchin tilapia.

Laboratory Results

During the salinity tolerance test, all fish behaved normally and continued to feed until salinity concentration reached 70-80 ppt. At this point, the fish appeared stressed and remained tightly clustered together. At a salinity concentration of 80 ppt the fish became quite calm. They continued to feed, however, exhibited a reduced behavioral response to external stimuli. The experiment was terminated at 100 ppt when one fish began to lose equilibrium. Fresh water was slowly added to the tank and the fish became gradually readjusted to fresh water. No mortalities occurred as a result of this study.

There was no observable difference in the reproductive behavior of blackchin tilapia at different salinity concentrations. Immediately after eliminating the water current in each tank, all fish began chasing and displaying as a form of courtship behavior and territoriality. Mate selection was completed within a 7-day period, and each pair of fish was observed defending a particular pea-

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Table 1. Species collected with *Sarotherodon melanotheron* by habitat type.

Canals / Ditches	Canal Mouths / Lagoonal Areas	Open Water
Cyprinodon variegatus	*Achirus lineatus*	*Archosargus probatocephalus*
Diapterus auratus	*Anchoa mitchelli*	*Floridichthys carpio*
Elops saurus	*Bathygobius soporator*	*Lagodon rhomboides*
Eucinostomus harengulus	*Centropomus undecimalis*	*Lucania parva*
Floridichthys carpio	*Cynoscion nebulosus*	*Menidia beryllina*
Gambusia holbrooki	*Cyprinodon variegatus*	*Mugil cephalus*
Gobionellus shufeldti	*Diapterus auratus*	*Mugil curema*
Gobiosoma bosci	*Eucinostomus harengulus*	
Heterandria formosa	*Fundulus grandis*	
Lepomis macrochirus	*Gobiosoma bosci*	
Lepomis microlophus	*Lucania parva*	
Lucania goodei	*Menidia beryllina*	
Lucania parva	*Mugil curema*	
Menidia beryllina	*Poecilia latipinna*	
Micropterus salmoides	*Syngnathus scovelli*	
Mugil curema		
Poecilia latipinna		
Strongylura marina		
Trinectes maculatus		

gravel pan as a potential nest site. Within two weeks after choosing a nest site, at least one male in each tank was observed brooding eggs in its mouth. Each pair remained monogamous during egg incubation; the brooding male stayed quiescent around the nest site and the female continued to aggressively defend their territory. In two instances, a female was observed mouthbrooding eggs, once at 10 ppt and once at 20 ppt.

Larvae were removed from the buccal cavity of the parent approximately 12 days after the initial observation of mouthbrooding behavior. At this time, the yolk sac was absorbed and the larvae were able to convert directly to artificial feed. In some instances, however, the parent released the larvae prior to capture; therefore, we could not determine a correlation between the numbers of larvae produced and the size of the parent. Upon collection, the larvae were transferred to 57-L aquaria at the same salinity concentration. They were fed pulverized TetraMin flakes (TetraWerke, Melle, Germany) and brine shrimp twice daily for a 3 month period. No data on growth rates of the larvae at different salinities were analyzed because all larvae became stunted in the aquaria.

Although the total number of larvae collected from each parent was unequal (135, 79, 90, and 74 in 0, 10, 20, and 35 ppt respectively), survival was similar at each salinity treatment: 94.1% at 0 ppt; 95.0%; 93.4% at 20 ppt and 87.8% at 35 ppt.

DISCUSSION

Blackchin tilapia were first collected from the Indian River system in 1980 (Dial and Wainright 1983). At that time, their range extended a total of 21 km, from Cocoa Beach to just south of Indian Harbor Beach, Brevard County. The area around Satellite Beach is suspected to be the source of initial introduction because of the dense numbers collected there. We also found the highest numbers of blackchin tilapia around the Satellite Beach area. The most tilapia collected during our sampling (282 and 93 each from two collections) was in this area during January 1988, and reflect primarily young-of-the-year from a late fall spawn.

Since 1980, the population of blackchin tilapia has expanded its range at least 84 km throughout the Indian River system. Our northernmost collection was made in a canal on Kennedy Space Center just north of Whites Point (80°35′E, 28°30.5′N), approximately 37 km from Satellite Beach. One specimen was taken at this site. Our southernmost population was found in a drainage ditch in Vero Beach (80°23′E, 27°40′N), nearly 68 km from its origin. Specimens were collected from this site on several occasions.

Both quantitative and qualitative collections revealed that blackchin tilapia prefer quiet, backwater habitats with aquatic vegetation and a mucky, organic substrate, typical of shallow estuarine waters, coastal lagoons and canal systems. These habitats are also common in areas where the blackchin tilapia is native (Fagade 1971, Thys van den Audenaerde 1971).

Results of the laboratory experiments indicate that blackchin tilapia are extremely euryhaline and able to reproduce at salinity concentrations typical of most estuarine systems. Salinity is obviously not a factor limiting survival and does not pose an absolute barrier to potential range expansion of the blackchin tilapia in Florida.

An earlier study by Jennings (1991) revealed that seasonal movements of blackchin tilapia in the Indian River appear to be influenced primarily by water temperature. During warm months, this fish is found throughout the system, and is commonly taken by commercial fishermen in mullet nets in open water and lagoonal areas. As soon as water temperature in the river begins to decrease, however, the tilapia are no longer caught by the fishermen. During winter they move into the thermal refuge of larger canals that have artesian flow. Tilapia remain in these refuge areas until the river temperature warms.

Laboratory studies on the lower lethal temperature tolerance of blackchin tilapia have indicated that death occurs at 6.9° C (Jennings 1991), 10.3°C (Shafland and Pestrak 1981), and 15°C (Stauffer et al. 1984). The variation in these results is probably due to differences in the acclimation temperature, rate of temperature decline and length of exposure prior to and during testing.

Finucane and Rinckey (1967) reported blackchin tilapia in Tampa Bay tolerating water temperatures as cold as 9.6°C. We collected fish in canals in the Banana River at water temperatures as low as 13°C. The Indian River system has experienced several cold periods since the establishment of blackchin tilapia (Snelson and Bradley 1978, Provancha et al. 1986); however, mortalities were not reported until the freeze of December 1989 (Snodgrass 1991). This cold front may have significantly impacted the population of tilapia in the Indian River. We observed thousands of dead tilapia in canals from Sykes Creek south to Vero Beach. Air temperature in Melbourne on 23-24 December 1990 fell to below 0°C for 16 hours and on 24-25 December was below zero for an additional 12 hours (NOAA 1989). According to Merritt Island National Wildlife Refuge personnel, water temperature was as low as 6°C in the Indian River at Titusville, and 11°C as far south as Stuart, Florida.

The blackchin tilapia will probably continue to expand its range in the Indian River system. Its northern distribution will be limited by cold temperature; however, the potential exists for extensive coastal, and possible inland, invasion south of its present limits.

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