Southeastern Fishes Council Proceedings

Number 49 (July 2007)

7-1-2007

Assessment and Control of an Invasive Aquaculture Species: An Update on Nile Tilapia (*Oreochromis niloticus*) in Coastal Mississippi after Hurricane Katrina

Pamela J. Schofield

W. Todd Slack

Mark S. Peterson

Denise R. Gregoire

Assessment and Control of an Invasive Aquaculture Species: An Update on Nile Tilapia (*Oreochromis niloticus*) in Coastal Mississippi after Hurricane Katrina

Assessment and Control of an Invasive Aquaculture Species: An Update on Nile Tilapia (*Oreochromis niloticus*) in Coastal Mississippi after Hurricane Katrina

PAMELA J. SCHOFIELD*, W. TODD SLACK, MARK S. PETERSON AND DENISE R. GREGOIRE

(PJS and DRG) U.S. Geological Survey, Florida Integrated Science Center,
7920 NW 71st Street, Gainesville, FL 32653

(WTS) Mississippi Department of Wildlife, Fisheries and Parks,
Mississippi Museum of Natural Science, 2148 Riverside Drive, Jackson, MS 39202

(MSP) The University of Southern Mississippi, Department of Coastal Sciences,
703 East Beach Drive, Ocean Springs, MS 39564

*corresponding author: pschofield@usgs.gov

ABSTRACT

We provide information about the effects of Hurricane Katrina on populations of an invasive fish, the Nile tilapia (*Oreochromis niloticus*) in southern Mississippi. By resampling areas surveyed before the storm, we attempted to determine whether the species expanded its range by moving with storm-related floods. Additionally, we used rotenone to eradicate individuals of this species at a hurricane-damaged aquaculture facility on the Mississippi coast. Although our survey was limited geographically, we did not find the species to occur beyond the aquaculture facility, other than in an adjacent bayou. Our rotenone treatment of the facility appeared effective with only a single *O. niloticus* being collected six weeks after the treatment. To reduce the spread of *O. niloticus* in the southeastern U.S., it is important to continue to control feral populations, work to eliminate vectors for dispersal, and continue monitoring their distribution.

INTRODUCTION

Maintaining the integrity of aquatic ecosystems and their fish resources in the face of ever-increasing rates of introduction and establishment of non-native species can be problematic and hierarchical. It is believed that the first level should be prevention, followed by eradication prior to dispersal, and then finally the use of detailed knowledge of population biology to develop effective and adaptive management protocols (Simberloff, 2003). The eradication of aquatic invasive species works well if populations have yet to disperse far from their point of introduction or are limited to small, confined water bodies or both (e.g., Hill and Cichra, 2005; Lazur et al., 2006).

Tilapias (Family Cichlidae) are warm-water fishes native to Africa and the Middle East of the genera *Oreochromis*, *Sarotherodon*, and *Tilapia* (Trewavas, 1983). These fishes are used widely in aquaculture because of their quick growth, tolerance of a wide range of environmental conditions, and ability to feed at different trophic levels (Costa-Pierce, 2003; Canonico et al., 2005). While these attributes make tilapias valuable for use in aquaculture, they also contribute to their ability to colonize non-native environments (Peterson et al., 2005). Nile tilapia (*Oreochromis niloticus*) has been introduced to at least 88 countries and has become established in at least 49 of them (Casal, 2006). After common carp (*Cyprinus carpio carpio*) and Mozambique tilapia (*O. mossambicus*), *O. niloticus* ranks third world-wide in negative ecological consequences and frequency of establishment (Casal, 2006).

In the United States, *O. niloticus* is one of the most commonly used tilapias in aquaculture (Costa-Pierce, 2003) and has been raised in fish farms in southern Mississippi since the late 1980s (Peterson et al., 2002). As has happened in other regions where it has been cultured, *O. niloticus* has escaped from culture and has been reported in rivers and marshes of coastal Mississippi since the mid-1990s (Peterson et al., 2002; 2005). Studies on food habits, habitat use, and reproductive strategies of *O. niloticus* in Mississippi indicate that the species has successfully colonized freshwater and low-salinity regions of the area (Peterson et al., 2004, 2005, 2006; McDonald, 2006).

On 29 August 2005, Hurricane Katrina impacted a large portion of coastal Louisiana, Mississippi, and western Alabama. In western and eastern portions of coastal Mississippi, storm surge heights reached 7.5 m and 6 m, respectively. Damage and flooding from the storm provided *O. niloticus* with potential corridors of expansion across a large geographic area (Fig. 1). Within the zone of impact, one aquaculture facility was severely damaged by the storm and was closed for business immediately afterwards. Prior to the 2005 storm season the facility had cultured both *O. niloticus* and giant Asian prawn, *Macrobrachium rosenbergii*. In examining this facility after the storms, we were concerned that these aquaculture species might have gained access to adjacent freshwater and low-salinity waterways as a result of the storm surge. Our initial inspection revealed that *O. niloticus* persisted in small in-ground ponds at the facility from which the species might disperse into adjacent coastal marshes. Thus, the focus of our study was to: 1. document post-hurricane changes to the distribution of *O. niloticus* based on selected pre-hurricane data (Peterson et al., 2005), and 2. actively control the number of *O. niloticus* at the damaged aquaculture facility in an attempt to stem the expansion of this species into nearby natural areas. We also made an effort to document any occurrences of *M. rosenbergii* during our survey because specimens of this non-native species had been collected in 2001 from Simmons Bayou which is adjacent to the damaged facility (Woodley et al., 2002).

MATERIALS AND METHODS

Post-hurricane survey. In October and November 2006 we surveyed Simmons Bayou, Graveline Bayou (east of the facility), and Biloxi Back Bay (west of the facility) to test for the presence of *O. niloticus* and *M. rosenbergii* (Fig. 1). To assess physico-chemical conditions, we measured water temperature, salinity, and dissolved oxygen in each of the water bodies (Table 1). Using the same gear types and techniques of Peterson et al. (2005), we sampled those same areas that had been surveyed prior to the hurricane. In Simmons and Graveline bayous, sampling consisted of fishing trammel nets overnight. Trammel nets were 30 to 60 m long and 2.4 m deep with 0.36 m square mesh outer panels and 0.06 m square mesh inner panels. A total of 335.3 m of trammel nets was fished. Seines (3 m length with 0.5 cm DELTA mesh) and dipnets (0.41 m by 0.41 m frame with 0.5 cm ACE mesh) were used for sampling in Simmons Bayou and Biloxi Back Bay.

Control of tilapia at aquaculture facility. In October 2006 we visited the aquaculture facility with the goal of taking action to control the expansion of the *O. niloticus* population. The facility consisted of 14 ponds (designated A – M) and three ditches (designated back ditch, G ditch, and H ditch). Pond L did not have enough water to sample and was excluded from our analyses. Water-quality data were collected from the other 13 ponds and three ditches with a calibrated YSI model 556 MPS meter (Table 2). Preliminary sampling of ponds and ditches with minnow traps (baited with bread, 2 h soak time), seines (6.1 m with 0.5 cm DELTA mesh), and cast nets revealed that there were no fish in six ponds: ponds A, B, C, J, K, and L. The eight remaining ponds (ponds D, E, F, G, H, I, M, and N) and three ditches contained fishes and on 24 October we treated these with a Prentox© rotenone solution at 5 ppm (concentrations for total product, not active ingredient, per conventional use; Bettoli and Maceina, 1996; Lockett, 1998; McClay, 2000; Lazur et al., 2006). Fishes and decapod crustaceans were collected from the ponds and ditches from 23–26 October. All *O. niloticus* collected during 24 and 25 October were measured (TL to the nearest mm) whereas individuals collected on 26 October were simply counted. All fishes collected (other than voucher specimens) were buried on site. The facility was revisited on 27 November 2006 (six weeks after the rotenone treatment) and ponds that had yielded *O. niloticus* were re-sampled with seines (3 m and 6.1 m with 0.5 cm DELTA mesh). Voucher specimens of all fishes were deposited into the Ichthyology Collection at the Mississippi Museum of Natural Science.

RESULTS

Post-Hurricane Katrina surveys using the same sampling gear and effort as Peterson et al. (2005) produced only two *O. niloticus* in Simmons Bayou (Table 1; MMNS 48981 and 48985). These individuals (332 and 308 mm TL, respectively) were taken in trammel nets just downstream from the aquaculture facility. Physico-chemical conditions measured during these collections (water temperature, salinity, and dissolved oxygen) were typical for the time of year (Table 2). No *O. niloticus* were collected in Graveline Bayou or Biloxi Back Bay.

Twenty-five taxonomically recognizable units (23 fishes and 2 decapod crustaceans) were collected from the ponds and ditches within the damaged aquaculture facility after treatment with rotenone (Table 3). The most interesting discovery was that of 21 juvenile tarpon (*Megalops atlanticus*; 69 – 199 mm TL) that were collected from pond F. Pond F also contained numerous potential prey species (e.g., *Gambusia* spp., *Poecilia latipinna*, *Menidia* spp., and *Mugil cephalus*) as well as other predator species (*Lepisosteus oculatus* and *L. osseus*; Table 3). A total of 9,173 *O. niloticus* were collected from four main ponds: ponds F, G, H, and I (Table 2). One individual *O. niloticus* was taken from pond E. These *O. niloticus* ranged in size from 20 to 360 mm TL, though the size structure varied among ponds. For example, pond F and G tended to have larger individuals (mean TL: pond F = 104 mm; pond G = 144 mm) while pond H contained smaller individuals (mean TL: pond H = 49 mm). Pond I had the highest abundance of *O. niloticus* with 94% of individuals occurring between 6 - 120 mm TL (mean TL: pond I = 74 mm). Some *O. niloticus* collected from the ponds contained eggs in their mouths indicating that the species (a maternal mouthbrooder) was actively reproducing in the ponds at the facility. When we returned to the facility six weeks after the rotenone treatment, only a single *O. niloticus* (165 mm TL, pond I) was collected. While specimens of *M. rosenbergii* had been collected from Simmons Bayou in 2001 (Woodley et al., 2002), none were collected during our 2006 sampling.

DISCUSSION

While Hurricane Katrina devastated coastal Mississippi in 2005, our sampling at and around a coastal aquaculture facility suggests that two invasive species, *O. niloticus* and *M. rosenbergii*, did not expand their ranges into nearby natural areas as a result of the facility being damaged. Admittedly our sampling was not comprehensive and did not encompass all of coastal Mississippi. Therefore we cannot definitively claim that ranges for *O. niloticus* or *M. rosenbergii* either stayed the same or shrank as a result of the hurricane. Our rotenone treatment of the ponds and ditches of the facility appeared effective with only a single *O. niloticus* being collected six weeks after the treatment. The treated ponds and ditches were typical of aquaculture facilities, being relatively small and unconnected to flowing waterways (Hill and Cichra, 2005; Lazur et al., 2006). Though our treatment efforts greatly reduced the *O. niloticus* population at the facility, it is possible that some individuals may have persisted.

Hurricanes may affect large geographic areas with high winds and flood waters, causing great damage and either facilitating invasion by non-native species or distributing them directly. For example, the first records of lionfish (*Pterois volitans*) in marine waters off Florida occurred in 1992 shortly after Hurricane Andrew damaged a large outside aquarium housing the fish and liberated them into the Atlantic Ocean (Courtenay, 1995). After passage of Hurricane Andrew, wind damage to trees created large-scale light gaps in hammocks that were quickly colonized by invasive non-native plants that were superior competitors of native species (Horovitz et al., 1998; Kwit et al., 2000). Additionally, flooding from Hurricane Katrina in 2005 allowed rapid dispersal by non-native African jewelfish (*Hemichromis letourneuxi*) in Everglades National Park (Loftus et al., 2006). In contrast, hurricanes may restrict the range of non-natives by creating environmental conditions not conducive to survival or by directly killing them. For example, distribution of giant Salvinia (*Salvinia molesta*) along the Pascagoula River in southern Mississippi was greatly reduced after the 2005 hurricane season (Fuller and Diaz, in prep). Much of the population of giant Salvinia was moved onto dry land where it died, while the salinity of storm surge waters killed most of the remaining plants. This range reduction was so significant that it allowed natural resource managers to control remaining populations with herbicide, a task not possible before the storms (Fuller and Diaz, in prep).

The ability of a non-native species to use altered environments and expand its range is certainly dependent on the environmental tolerances and life-history attributes of the species. The region in which *O. niloticus* evolved is prone to seasonal floods, so the species is tolerant to a wide range of environmental conditions, including low salinity and hypoxia (Lowe-McConnell, 1991; Avella et al., 1993; Chapman et al., 1995). Additionally, *O. niloticus* is a trophic generalist and can feed on a wide array of food items (Peterson et al., 2006; McCrary et al., 2007). Thus, conditions following the 2005 hurricane season would have been advantageous for *O. niloticus* to disperse and expand its range beyond the area determined by Peterson et al. (2005). Nevertheless, we collected only two *O. niloticus* from Simmons Bayou, which is adjacent to the aquaculture facility and where the species had been collected previously. No other specimens were collected in either of the other adjacent bayous we surveyed. It was interesting, however, that the fish and decapod crustacean assemblage collected at the aquaculture facility consisted of a combination of freshwater, estuarine, and marine organisms (Table 3). We think this illustrates the ability of hurricanes to move aquatic assemblages considerable distances in a short time and that many species can persist in isolated ponds and ditches for more than a year after storm-related inundation. The most convincing evidence of this was the occurrence of juvenile *M. atlanticus* at the facility after the hurricane. This species was not being cultured at the facility so the collected individuals must have originated from marine or estuarine habitats.

The relevance of our findings to the conservation of native Southeastern fishes is that tilapia species such as *O. niloticus* have caused great harm to natural systems where they have gained access and become established. Some negative consequences of tilapia introductions, in general, include competition with native fishes for food or space or both, agonistic interactions with native species, direct predation on eggs and fry of native fishes, genetic introgression, spread of disease, shifts in the composition of native fish assemblages, and environmental alterations that degrade habitats such as the reduction or elimination of vegetation, bioturbation, and eutrophication (Courtenay, 1997; Canonico et al., 2005; Casal, 2006;

McCrary et al., 2007). In Nicaragua, *O. niloticus* has eliminated submersed aquatic vegetation that once served as habitat for native species and has supplanted native fish species in local markets (McCrary et al., 2007). Non-native tilapias inhabit watersheds that cover more than half of Nicaragua and are thought to be responsible for spreading a disease that causes blindness in native fishes (McCrary et al., 2007). Ramifications of the introduction, spread, and establishment of *O. niloticus* in Nicaragua are poignant as researchers suggest there is no realistic mechanism to control the species now that it is so widespread (McCrary et al., 2007).

The *O. niloticus* colonization of natural systems in the southeastern U.S. is in its early stages. We feel there may still be time to protect native fishes and other natural resources against the spread of this highly invasive species. Currently, established populations of *O. niloticus* exist in southern Mississippi (Peterson et al., 2005), bayous of Galveston Bay and Texas (Texas Parks and Wildlife Department, unpublished data). Populations also may exist in Lake Seminole on the Florida-Georgia border (Fuller et al., 1999; J.D. Williams, pers. comm.) and peninsular Florida (Jelks and Nico, pers. comm.). To reduce the further spread of *O. niloticus* in the Southeast, it is important to control existing feral populations. Sources and vectors of dispersal for new and existing populations need to be eliminated and continual monitoring of distributions is necessary to detect possible expansions. It is paramount that we implement successful management strategies with the aquaculture industry that minimize or completely prevent introductions during periods of normal operation. However, it is even more important to do so in regions that can be regularly impacted by natural disasters such as hurricanes. Successful conservation of native Southeastern aquatic organisms will require, in part, a vigilance for invasive species and the use of adaptive preventative management.

ACKNOWLEDGMENTS

We thank Dennis Riecke and Stan Crider of the Mississippi Department of Wildlife, Fisheries, and Parks. We also thank Mark Dugo, Robert L. Jones, Scott Peyton, and LaToya Turner of the Mississippi Museum of Natural Science. Thanks also go to Dale Diaz, Mike Pursley and Ruth Posadas of the Mississippi Department of Marine Resources and to John D. Lopez of the University of Southern Mississippi. Pam Fuller of the U.S. Geological Survey provided helpful logistical and field assistance. We appreciate the generosity of the landowners of the aquaculture facility in allowing access to their property. Jackie Langston created the map. The comments of four anonymous reviewers improved the manuscript. Funding was provided by the U.S. Geological Survey Invasive Species Program and the U.S. Fish and Wildlife Service (Region 4).

LITERATURE CITED

Avella, M., J. Berhaut and M. Bornancin. 1993. Salinity tolerance of two tropical fishes, *Oreochromis aureus* and *O. niloticus*. I. Biochemical and morphological changes in the gill epithelium. J. Fish Biol. 42: 243-254.

Bettoli, P.W. and M.J. Maceina. 1996. Sampling with toxicants. Pages 303–333 in Murphy, B.R. and D.W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Casal, C.M.V. 2006. Global documentation of fish introductions: the growing crisis and recommendations for action. Biol. Invas. 8: 3-11.

Canonico, G., A. Arthington, J.K. McCrary and M.L. Thieme. 2005. The effects of introduced tilapias on native biodiversity. Aquat. Conserv.: Mar. Freshwat. Ecosyst. 15: 463-483.

Chapman, L.J., L.S. Kaufman, C.A. Chapman and F.E. McKenzie. 1995. Hypoxia tolerance in twelve species of East African cichlids: potential for low oxygen refugia in Lake Victoria. Conserv. Biol. 9: 1274-1288.

Costa-Pierce, B.A. 2003. Rapid evolution of an established feral tilapia (*Oreochromis* spp.): the need to incorporate invasion science into regulatory structures. Biol. Invas. 5:71-84.

Courtenay, W.R., Jr. 1995. Marine fish introductions in southeastern Florida. Newsletter of the Introduced Fish Section, American Fisheries Society 14: 2-3.

Courtenay, W.R., Jr. 1997. Tilapias as non-indigenous species in the Americas: environmental, regulatory and legal issues. Pages 18-33 in: Costa-Pierce, B.A. and J.E. Rakocy (Eds.). Tilapia Aquaculture in the Americas, Volume 1. World Aquaculture Society, Baton Rouge, LA, USA.

Fuller, P.L., L.G. Nico and J.D. Williams. 1999. Nonindigenous Fishes Introduced into Inland Waters of the United States. American Fisheries Society Special Publication 27, Bethesda, MD, USA.

Fuller, P.L. and D. Diaz. In Prep. Effects of Hurricane Katrina on an incipient population of Giant Salvinia in the lower Pascagoula River, Mississippi.

Hill, J.E. and C.E. Cichra. 2005. Eradication of a reproducing population of convict cichlids (*Cichlasoma nigrofasciatum*) in North-Central Florida. Fla. Sci. 68:65–74.

Horovitz, C.C., J.B. Pascarella, S. McMann, A. Freedman and R.H. Hofstetter. 1998. Functional roles on invasive non-indigenous plants in hurricane-affected subtropical hardwood forests. Ecol. Appl. 8: 947-974.

Kwit, C., W.J. Platt and H.H. Slater. 2000. Post-hurricane regeneration of pioneer plant species in south Florida subtropical hardwood hammocks. Biotropica 32: 244-251.

Lazur, A., S. Early and J.M. Jacobs. 2006. Acute toxicity of 5% rotenone to northern snakeheads. N. Am. J. Fish. Manage. 26:628–630.

Lockett, M.M. 1998. The effect of rotenone on fishes and its use as a sampling technique: a survey. Z. Fischkd. (Solingen) 5:13–45.

Loftus, W.F., J.C. Trexler, K. Dunker, S.E. Liston and J.S. Rehage. 2006. Introduced Fishes in Short-Hydroperiod Wetlands: Evaluation of Sampling, Status, and Potential Effects. Final Report from USGS to Everglades NP for Agreement # CESI IA F5284-04-0039.

Lowe-McConnell, R.H. 1991. Ecology of cichlids in South American and African waters, excluding the African Great Lakes. Pages 60-85 in: Keenleyside, M. H. A., (ed.). Cichlid fishes. Behaviour, Ecology and Evolution. Chapman and Hall, London.

McClay, W. 2000. Rotenone use in North America (1988-1997). Fisheries 25:15–21.

McCrary, J.K., B.R. Murphy, J.R. Stauffer, Jr. and S.S. Hendrix. 2007. Tilapia (Teleostei: Cichlidae) status in Nicaraguan natural waters. Env. Biol. Fish. 78: 107-114.

McDonald, J.L. 2006. Habitat characteristics and reproductive behavior of introduced Nile tilapia (*Oreochromis niloticus* (Linnaeus) in coastal Mississippi: interactions with native centrarchid species? Unpublished MS thesis, The University of Southern Mississippi, Hattiesburg, MS.

Peterson, M.S., W.T. Slack and C.M. Woodley. 2002. The influence of invasive, non-native tilapiine fishes on freshwater recreational fishes in south Mississippi: spatial/temporal distribution, species associations, and trophic interactions. Report No. 206. Annual Report (Grant No. F-129), Mississippi Department of Wildlife, Fisheries and Parks. 35 pp.

Peterson, M.S., W.T. Slack, N.J. Brown-Peterson and J.L. McDonald. 2004. Reproduction in non-native environments: establishment of Nile tilapia, *Oreochromis niloticus*, in coastal Mississippi watersheds. Copeia 2004: 842-849.

Peterson, M S., W.T. Slack and C.M. Woodley. 2005. The occurrence of non-indigenous Nile tilapia, *Oreochromis niloticus* (Linnaeus) in coastal Mississippi, USA: ties to aquaculture and thermal effluent. Wetlands 25:112-121.

Peterson, M.S., W.T. Slack, G.L. Waggy, J. Finley, C.M. Woodley and M.L. Partyka. 2006. Foraging in non-native environments: comparison of Nile tilapia and three co-occurring native centrarchids in invaded coastal Mississippi watersheds. Env. Biol. Fish. 76:283-301.

Simberloff, D. 2003. How much information on population biology is needed to manage introduced species? Conserv. Biol. 17:83–92.

Trewavas, E. 1983. Tilapiine Fishes of the Genera *Sarotherodon*, *Oreochromis* and *Danakilia*. British Museum of Natural History, London.

Woodley, C.M., W.T. Slack, M.S. Peterson and W.C. Vervaeke. 2002. Occurrence of the non-indigenous giant Malaysian prawn, *Macrobrachium rosenbergii* (De Man, 1879) in Simmons Bayou, Mississippi, U.S.A. Crustaceana 75: 1025-1031.

TABLE 1. Summary of physico-chemical conditions and number of *Oreochromis niloticus* collected in bayous adjacent or near an aquaculture facility that was damaged as a result of Hurricane Katrina. Simmons Bayou was sampled with trammel nets and seines, Biloxi Back Bay with seines and dipnets, and Graveline Bayou with trammel nets. Each area sampled with trammel nets was set with seven total nets overnight (length = 335.3 m).

Waterbody	dates sampled	temp. (°C)	salinity (ppt)	dissolved oxygen (mg/L)	number of *O. niloticus*
Simmons Bayou	7-8 Nov. 2006	19.3-20.6	12.4-18.4	3.5-3.8	2
Graveline Bayou	28-29 Nov. 2006	21.6-22.5	16.6-17.4	6.5-9.2	0
Biloxi Back Bay	29 Nov. 2006	17.7-21.0	2.1-12.6	5.4-6.2	0

TABLE 2. Physico-chemical conditions, estimated water volumes, and total number of *Oreochromis niloticus* removed from ponds at an aquaculture facility that was damaged as a result of Hurricane Katrina. Sampling was conducted 23-26 October 2006. Pond L was not sampled due to lack of water. Water volumes are given only for ponds treated with rotenone.

pond/ditch designation	temp (°C)	sal (ppt)	dissolved oxygen (mg/L)	cond. (mS/cm)	volume (acre-ft)	number of *O. niloticus*
A	24.59	5.7	10.17	10.12	–	0
B	22.8	5.92	14.85	10.02	–	0
C	23.15	3.94	14.33	6.91	–	0
D	23.35	9.75	13.65	16.07	0.094	0
E	21.78	9.18	16.8	14.73	0.138	1
F	23.55	16.74	16.6	26.51	0.546	93
G	23.08	13.69	13.78	21.86	0.548	994
H	21.9	11.78	9.3	18.58	0.284	595
I	22.17	4.08	9.1	6.98	0.628	7,490
J	23.67	0.25	8.69	0.51	–	0
K	24.18	0.12	4.6	0.24	–	0
M	22.25	12.88	14.6	20.29	0.017	0
N	22.42	13.87	14.41	21.81	0.003	0
Back ditch	21.07	18.66	15.9	27.81	0.025	0
G ditch	19.88	15.88	12.3	23.52	0.009	0
H ditch	13.21	17.09	6.15	no data	0.013	0
					Total *O. niloticus* =	**9,173**

TABLE 3. Fishes and decapod crustaceans collected from an aquaculture facility in coastal Mississippi that was damaged as a result of Hurricane Katrina. Organisms were collected after treatment with rotenone and identified either to species or taxonomically recognizable units (TRU).

Family	Species or TRU	Common Name
Decapod crustaceans		
Palaemonidae	*Palaemonetes* spp.	grass shrimp
Portunidae	*Callinectes sapidus*	blue crab
Fishes		
Lepisosteidae	*Lepisosteus oculatus*	spotted gar
	Lepisosteus osseus	longnose gar
Elopidae	*Megalops atlanticus*	tarpon
Anguillidae	*Anguilla rostrata*	American eel
Ophichthidae	*Myrophis punctatus*	speckled worm eel
Clupeidae	*Dorosoma cepedianum*	gizzard shad
Mugilidae	*Mugil cephalus*	striped mullet
Atherinopsidae	*Menidia* spp.	silverside species
Fundulidae	*Adinia xenica*	diamond killifish
	Fundulus chrysotus	golden topminnow
	Fundulus grandis	Gulf killifish
	Fundulus pulvereus	bayou killifish
Poeciliidae	*Gambusia* spp.	mosquitofish species
	Poecilia latipinna	sailfin molly
Cyprinodontidae	*Cyprinodon variegatus*	sheepshead minnow
Centrarchidae	*Lepomis macrochirus*	bluegill
	Lepomis microlophus	redear sunfish
Cichlidae	*Oreochromis niloticus*	Nile tilapia
Eleotridae	*Dormitator maculatus*	fat sleeper
	Eleotris amblyopsis	largescaled spinycheek sleeper
Gobiidae	*Evorthodus lyricus*	lyre goby
	Gobionellus oceanicus	highfin goby
	Gobiosoma bosc	naked goby

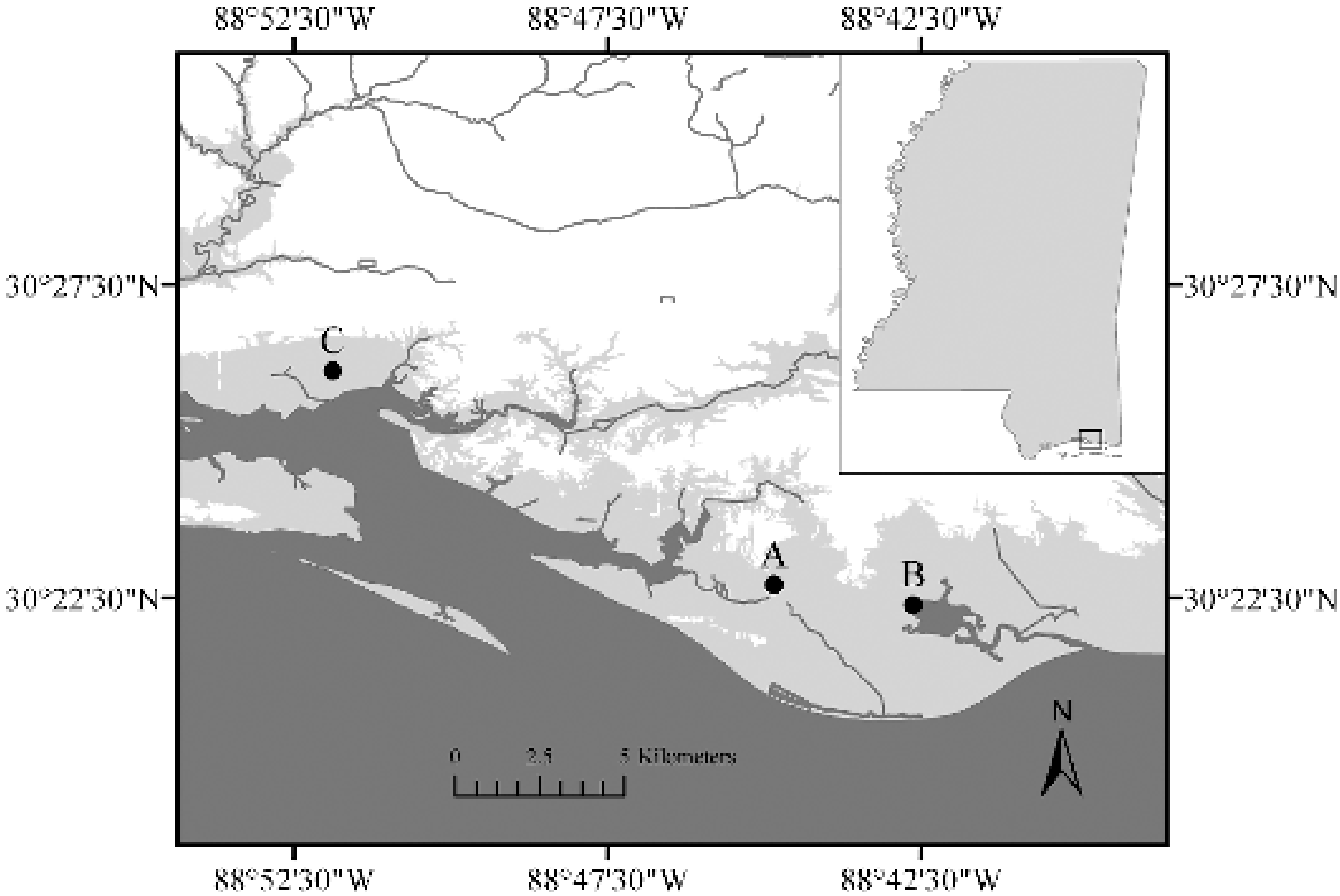

FIGURE 1. Sampling localities for *Oreochromis niloticus* in coastal Mississippi: A = aquaculture facility adjacent to Simmons Bayou; B = Graveline Bayou; and C = Biloxi Back Bay. Gray coloration indicates coverage of flooding from Hurricane Katrina as interpreted from the Federal Emergency Management Agency website (see http://www.fema.gov/hazard/flood/recoverydata/katrina/katrina_ms_mmds.shtm).