Burrowing by Sailfin Catfish (*Pterygoplichthys* sp.): A Potential Cause of Erosion in Disturbed Environments

by Oliver van den Ende

PURPOSE: The purpose of this study is to quantify suckermouth catfish (Loricariidae) burrows in disturbed environments and to evaluate habitat factors associated with burrow densities. Burrows were sampled in central Florida, an area where sailfin catfishes (Loricariidae: *Pterygoplichthys* spp.) have long been established, but have been problematic only in recent years. Burrow densities were quantified for a variety of habitat types and were associated with substrate and shoreline characteristics.

BACKGROUND: Suckermouth armored catfishes (Loricariidae), commonly called "plecos," have been exported from tropical America as aquarium fishes for over a century (Sterba 1966). Numbers exported to North America have been substantial. During the period 1972-1974, Colombia alone exported more than 3.7 million "plecos" to the United States (Conroy 1975). No restrictions were placed on imports by US authorities and 15 genera appeared on a "clean list" of "low risk" wildlife. One genus of pleco, that of the sailfin catfishes, *Pterygoplichthys* spp., is now widespread throughout peninsular Florida (Nico and Fuller 2005, Nico et al. 2009).

Sailfin catfishes attain large (and problematic) sizes in home aquaria (Sandford and Crow 1991) and can be cultured in outdoor ponds (Grier 1980). Consequent releases by hobbyists and escapes from tropical fish farms resulted in introduced populations of this fish in south Florida. Introductions occurred during the 1970s and 1980s and may have taken place much earlier (Cimbaro 2000, Hill 2001). Large populations were reported in the 1990s (e.g., Ludlow and Walsh 1991), but the group was still comparatively rare as recently as 1996-1998 (e.g., McPherson et al. 2000). Within a few years, however, populations and geographic range had grown substantially. By 2003, large numbers were observed in residential lakes and in drainage canals; commercial catches from Lake Okeechobee went from a few individuals per day to thousands of pounds per day (King 2004). Sailfin catfishes have now colonized most freshwater habitats in peninsular Florida.

Sailfin catfishes graze on algae and detritus, and nest in burrows that they dig into banks and shorelines (Carter and Beadle 1931, Ferraris 1991, Burgess 1989). They burrow and spawn throughout most of the year (Cimbaro 2000, Liang et al. 2005, Gestring et al. 2010). Concern exists that these burrows result in increased siltation, damage to banks, impaired shoreline stability, and exacerbated erosion (Hill 2001, Hoover et al. 2004, Nico et al. 2009). Assessing the environmental and economic risks associated with catfish burrows requires data on burrow densities, relationships to littoral and shoreline features, and attendant erosion.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **MAR 2014**	2. REPORT TYPE	3. DATES COVERED **00-00-2014 to 00-00-2014**

4. TITLE AND SUBTITLE **Burrowing by Sailfin Catfish (Pterygoplichthys sp.):A Potential Cause of Erosion in Disturbed Environments**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **US Army Engineer Research and Development Center CEERD-IS-L,3909 Halls Ferry Rd,Vicksburg,MS,39180**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**10**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

METHODS

Study area. Fieldwork was conducted during the period June-September 2005 in Brevard County, Florida. Sailfin catfish, believed to be vermiculated sailfin catfish (*Pterygoplichthys disjunctivus*) based on pigmentation (Page 1994)), were present in most freshwater systems connected to the St. Johns River (Figure 1). Sites selected represented small urban water bodies, a flood control canal, and a borrow area (Figure 2).

Easterseal Ditch (N28.03.1253 / W80.37.1662) is a waterway bisecting a road that connects the cities of Melbourne and Palm Bay. It is 4 m wide and approximately 0.5 m deep. Mechanical harvesting of aquatic vegetation is frequent. Imperial Hotel retention pond (N28.13.5469 / W80.43.0406) connects via culvert to a series of urban lakes in the city of Viera. It is approximately 1 ha in size. Sampling took place alongside a parking lot due to impenetrable Brazilian pepper tree thickets located on the other edges of the pond.

C-54 is a flood control canal built by the US Army Corps of Engineers (USACE) and managed by St. Johns River Water Management District (SJRWMD). It is approximately 75 m wide and 4 m deep and drains the upper St. John's River. The primary function of C-54 is to divert water to the Indian River Lagoon in the event that a controlled release of the upper St. John's River and associated natural/retention lakes is not adequate. Due to the natural topography of this area, water can only flow east during a catastrophic flood, which would inundate the Melbourne-Palm Bay metropolitan area (home to over 150,000 people) without the presence of C-54 and major canals. C-54 is bounded on both sides by levees and intersected by two sluice gates, which are closed under normal circumstances. The bank and levees are grass. Aquatic plants consist principally of cattails and water lilies; submerged aquatic plants are scarce. Two study sites, C-54 East (N27.49.4165/W80.33.1097) and C-54 West (N27.49.3849/W80.33.2659), were located along the north side of the canal, 75 and 500 m, respectively, from the I-95 Bridge.

Eau Gallie Ditch in Melbourne was excavated at the easternmost edge of Lake Washington for fill. Two sites were sampled that were separated by a 50-m stand of rushes and cattails: Eau Gallie East (N28.07.1164/W80.43.2720) and Eau Gallie West (N28.07.1000/W80.43.3595). This area is managed by SJRWMD. Sotille Canal is a waterway draining agricultural and wildlife management areas in the upper St. Johns' Water Management Area. It is approximately 15 m wide and 3 m deep. Sotille Canal (N27.53.1995/W80.44.3422) originates at a large levee, which was built to create a water retention (to control excess water) and water bird management area. The levee and canal are under the jurisdiction of the SJRWMD. Bank vegetation is grass and at the sampling sites (200 m east of the levee), only floating aquatic plants are present.

Field and laboratory techniques. At each site, a transect was established parallel to the shoreline. Transect lengths ranged from 15 to 80 m, depending on the accessibility of the shoreline and burrows. For each burrow, distance from the transect origin was measured to the nearest 5 cm; length of each burrow (from opening to terminus) was measured to the nearest 5 cm. The littoral zone was also noted at each site, along with shoreline characteristics : vegetation, bank slope, bank stability (low, moderate, high), and erosion (low, moderate, high).

Figure 1. Vermiculated sailfin catfish: Ventral pigmentation (top) and burrowing behavior (bottom).

Figure 2. Representative localities: Imperial Hotel retention pond (top); Eau Gallie Ditch (middle); Sotille Canal showing burrow-ridden bank (bottom).

A sediment sample (500 ml) was collected at each site at a point where burrows were most abundant. To evaluate effects of sediment on burrow parameters at four sites, a second sample was taken where burrows were absent. In the laboratory each sample was dried in stainless steel trays in a 60 °C convection oven. Two methods of quantitative analysis were performed to determine the sediment composition in terms of grain size. The first was via the (dry) shaker/sieve method, where sieves with successively smaller mesh sizes segregated the sediment into sand, silt, and clay. In some samples, the drying process caused small-grained (silt/clay) cohesive sediments to coagulate effectively, invalidating the sieve segregation results as large chunks of silt/clay (which became trapped in the sand sieves). Consequently, a gravimetric process was substituted. Sediments were suspended in water and the differential precipitation over time (based on particle size) caused each sediment component to form distinct layers. The relative thickness of each layer (percent volume) was then converted into percent weight using coefficients specific to grain size. The organic content of five samples was determined using the loss-on-ignition method. Samples were dried and weighed (nearest 0.0001 g) after which they were placed in a 500 °C muffle furnace for over 8 hr. Following the "burn," the samples were weighed again, with the difference being the total organic content. This was then converted to percent carbon using an appropriate coefficient. This method only works for samples in which the total organic content is more than 0.5 % and less than 90%.

Analytical techniques. Overall density was expressed as the total number of burrows per transect length (number/meter). To evaluate spatial patterns in burrow distribution, transects were subdivided into 5-m segments and densities were expressed as minimum, mean, and maximum density per segment (number/meter). Dispersion was described using the variance-to-mean ratio (VMR). VMR > 1 suggests a clumped pattern of distribution; VMR ≈ 1 suggests a random pattern; VMR < 1 suggests a uniform pattern. Correlations among burrow characteristics, and between burrow characteristics and environmental variables (e.g., substrate composition, bank height, bank slope), were identified using Pearson product moment correlations. Because of low sample size (n=7), values for Pearson product moment correlations were considered significant at the $p < 0.10$ level.

RESULTS

Burrow characteristics. Length, densities, and dispersion of burrows varied among sites (Table 1). Overall, burrows ranged from < 20 cm to 100 cm in length. Mean length was 39 cm at C-54 sites, 52.7-58.9 for most sites, and 70 cm at Sotille. Mean length of burrows was not correlated with measures of burrow density or dispersion. All sites contained segments ≥ 5 m with no observed burrows. Variance-to-mean ratio data for density at most sites suggested that burrows were randomly dispersed (VMR=0.50-0.91) at lower densities (< 0.35/m), and clumped (VMR > 1.75) at higher densities (≥ 0.35/m). An exception to this was Eau Gallie East, for which the lowest VMR was observed, indicating the most uniform dispersion for the seven sites.

Sediment composition. Sediment composition was highly variable within and between sites (Table 2). However, sand composed over 50% of the sediment in terms of weight at most sites, with the exception of Sotille Canal, which had a high percentage of peat. The organic content and carbon content was low (< 3 % weight) at all sites with the exception of Sotille Canal. At four of the sites, the percent silt in the samples taken from areas with burrows (indicated by "sample proximity" of 1) was two to four times higher than from areas at the same sites without burrows (indicated by "sample proximity" of 2). Correlation between percent silt and number of burrows among sites was positive and significant ($R^2 = 0.45$, $p < 0.10$), but there was no significant relationship between burrow length and silt ($R^2 = 0.07$, $p > 0.10$).

Table 1. Length, densities, and dispersion of sailfin catfish burrows at seven sites in Broward County, Florida, June-September 2005.

Site	Mean Length (cm)	Mean Density, Range (number/m)	Dispersion (variance to mean ratio)
Easterseal	70.0	0.13, 0-.20	0.50
Imperial	54.6	0.14, 0.60	0.91
C-54 East	39.2	0.30, 0-.40	0.67
C-54 West	39.0	0.35. 0-1.00	1.78
Eau Gallie East	58.9	0.47, 0-0.80	0.46
Eau Gallie West	54.8	0.50, 0-1.20	2.15
Sotille	52.7	0.93, 0-1.80	2.71

Table 2. Burrow density and substrate characteristics at seven localities in Brevard County, Florida, June-September 2005.

Site	Burrow Density (#/m)	Sample Proximity to Burrow[1]	Sediment (% weight)			Organics (% weight)	Carbon (% weight)
			Sand	Silt	Clay		
Easterseal Ditch	0.10	1	91	9	0	2.44	0.98
Imperial Hotel	0.19	1	89	11	0	2.56	1.02
		2	94	6	0	1.01	0.40
C-54 Canal East	0.30	1	50	50	0	-	-
		2	84	16	0	-	-
C-54 Canal West	0.35	1	87	13	0	2.33	0.93
		2	97	3	0	0.47	0.19
Eau Gallie Ditch East	0.47	1	58	42	0	-	-
		2	87	13	0	-	-
Eau Gallie Ditch West	0.50	1	49	51	0	-	-
Sotille Canal	0.93	1	<5	-	-	>90	>40
		2	<5	-	-	>90	>40

[1] Sample Proximity of 1: sediment sample taken near a burrow in a "high burrow density zone."
Sample Proximity of 2: sediment samples taken at the same site as 1, but in an area (layer) where not many burrows were present.

Shoreline characteristics. Stability of the shoreline was moderate at most locations (Table 3). In most areas where there were high burrow densities, terrestrial plant cover (i.e. grasses, forbs) was sparse. In these areas, bare patches of soil were visible with highly friable dirt, which would give way when stepped on. Furthermore, aquatic vegetation (especially emergent plants such as rushes and cattails) was less abundant in areas with high burrow densities. The degree of erosion was moderate at most localities.

Table 3. Burrow density and shoreline characteristics at seven sampling locations in Brevard County, Florida, June-September 2005.

Locality	Burrow Density (#/m)	Shoreline		
		Stability	Vegetation	Erosion
Easterseal Ditch	0.10	Low	No emergents	Moderate
Imperial Hotel	0.19	High	Emergents and Submergents	Low
C-54 Canal East	0.30	Low	Emergents	Moderate
C-54 Canal West	0.35	Moderate	Emergents	Moderate
Eau Gallie East	0.47	Moderate	Emergents	Moderate
Eau Gallie West	0.50	Moderate	No emergents	Moderate
Sotille Canal	0.93	Moderate	Floating only	Moderate-High

DISCUSSION: This study showed that there is great variation in burrow densities, both within habitats and among different habitats. Burrow density is highly correlated to the amount of silt in the sediment, a property which increases the cohesiveness of the soil. This cohesiveness should hypothetically be more conducive to proper burrow construction. Florida sediments are typically high in sand content, but sailfin catfish are able to use alternative burrow construction methods to compensate in areas of friable sediment by building directly under sod (i.e. Imperial Hotel retention pond) or between cypress roots.[1] In most areas where burrows were found, they were concentrated in a silt layer (usually less than 25 cm thick) located between sand layers. Most burrows were horizontally distributed along these silt layers, with few found above or below. At one location (Easterseal Ditch), sailfin catfish initiated burrow construction but then abandoned the area (for nest purposes) possibly due to the low silt content of the sediment. Sailfin catfish are still present in Easterseal Ditch, but their burrow locations are not known at this time. In peat sediment (Sotille Canal), the burrows exhibited a more vertical dispersion. Erosion caused by burrows was difficult to prove directly due to the lack of pre-burrow data. However, in most areas there did appear to be more erosion in high-burrow areas. A more quantitative analysis would be justified to describe the level of erosion, such as measuring the percentage of shoreline not populated with plants (due to slumping or washout). Sotille Canal was one of the best indicators of erosion where large sections of shoreline had collapsed along a canal in an area with no other sources of erosion (cattle, people, boat wake, etc).

A positive association between burrow density and erosion, suggested by Hawaiian populations (Devick 1988, 1989; Yamamoto and Tagawa 2000), was not consistently apparent. This may be due to several factors. In this study, man-made habitats were more spatially and temporally uniform than those of larger and more natural systems, which would restrict habitat selection by the fish. Also, sampling in this study was targeted to water bodies known to harbor catfish populations, which may have constrained variation in fish abundance. Lastly, sailfin catfish may be predisposed to burrow in areas already prone to moderate erosion, such as outer bendways and steep banks, especially those having soils sufficiently unconsolidated to allow burrowing but adhesive enough to prevent collapse (Nico et al. 2009). All three factors would reduce likelihood of detecting a relationship between catfish and shoreline erosion in a short-term field investigation (i.e., < 1 year).

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[1] Personal Communication. July 2005. Bob Eisenhauer, Florida Fish and Wildlife Conservation Commission.

Burrow characteristics, however, were comparable to those of populations in larger Florida rivers and canals (Nico et al. 2009). Mean burrow lengths of 53-59 cm in these locations were only a little smaller than those of 77. 5 cm. Mean densities of 0.1-0.9 burrows/m appear higher than those documented in Florida rivers and canals (21-118/km; equivalent to only 0.02-0.1/m) but scale of sampling was substantially different (i.e., transects < 100 m at a colony in this study versus surveys of 2- to 27.5-km river reaches representing two to five colonies). In both studies, burrows were non-uniformly distributed and densities were positively correlated with percent silt (or silt and clay) in substrate.

The data presented herein underscore the pervasive occurrence of sailfin catfishes in Florida waters and support their potential for exacerbating shoreline erosion via natural and anthropogenic wave action (sensu Nico et al. 2009). Effects of catfish burrowing on shoreline erosion have not been rigorously quantified, however, and the topic is a contentious issue for biologists and resource managers (Gestring et al. 2010). Long-term studies (i.e., > 2 years) of bank stability and responses to varying densities of burrows are needed.

ACKNOWLEDGMENTS: Funding for this project was provided by the Aquatic Nuisance Species Research Program, Linda Nelson, Program Manager. Permission to publish was granted by the Chief of Engineers.

POINTS OF CONTACT: For additional information, contact Jan Jeffrey Hoover (601) 634-3996, Jan.J.Hoover@usace.army.mil or the manager of the Aquatic Nuisance Species Research Program (ANSRP), Linda Nelson, (601) 634-2656, Linda.S.Nelson@usace.army.mil. This technical note should be cited as follows:

> Van den Ende, O. 2014. *Burrowing by sailfin catfish (Pterygoplichthys sp.): A potential cause of erosion in disturbed environments.* ANSRP Technical Notes Collection. ERDC/TN ANSRP-14-1. Vicksburg, MS: U.S. Army Engineer Research and Development Center. http://el.erdc.usace.army.mil/ansrp/ansrp.html.

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