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Rapid Communication

Discovery of a reproducing wild population of the swamp eel *Amphipnous cuchia* (Hamilton, 1822) in North America

Frank Jordan[1,2,*], Leo G. Nico[3], Kristal Huggins[4], Peter J. Martinat[4], Dahlia A. Martinez[1] and Victoria L. Rodrigues[2]

[1]*Department of Biological Sciences, Loyola University New Orleans, New Orleans, LA 70118, USA*
[2]*Environment Program, Loyola University New Orleans, New Orleans, LA 70118, USA*
[3]*Wetland and Aquatic Research Center, U.S. Geological Survey, Gainesville, FL 32653, USA*
[4]*Department of Biology, Xavier University, New Orleans, LA 70125, USA*

Author e-mails: *jordan@loyno.edu (FJ), lnico@usgs.gov (LGN), kahuggin@xula.edu (KH), didymops@hotmail.com (PJM), damartin@my.loyno.edu (DAM), vlrodrig@my.loyno.edu (VLR)*

**Corresponding author*

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Abstract

We report discovery of an established population of the Asian swamp eel *Amphipnous cuchia* (Hamilton, 1822) in Bayou St. John, an urban waterway in New Orleans, Louisiana, USA. This fish, commonly referred to as cuchia (kuchia), is a member of the family Synbranchidae and is native to southern and southeastern Asia. Recently-used synonyms include *Monopterus cuchia* and *Ophichthys cuchia*. We collected both adult and young-of-year cuchia from dense mats of littoral vegetation at several locations in Bayou St. John. Presence of multiple age and size classes is the first documented evidence of reproduction of this species outside of its native range. Establishment of this air-breathing, burrowing, salt-tolerant, opportunistic predator is of concern given that Bayou St. John is a tributary of Lake Pontchartrain, which provides a direct pathway for dispersal into the Mississippi River basin and coastal wetlands of the Gulf of Mexico.

Key words: invasive fish, Mississippi River drainage, riparian habitat, Synbranchidae, teleost, urban waterway

Introduction

Amphipnous cuchia (Hamilton, 1822), also recently referred to as *Monopterus cuchia* (Hamilton, 1822) and *Ophichthys cuchia* (Hamilton, 1822), is a species of swamp eel (Actinopterygii: Synbranchiformes: Synbranchidae). Commonly referred to as cuchia (kuchia) or mud eel, *A. cuchia* is native to parts of Bangladesh, India, Myanmar, Nepal, and Pakistan (Nico et al. 2019). The species may reach maturity at 25-cm total length (TL) and is known to attain a maximum size of about 90-cm TL (Narejo et al. 2002). Cuchia is an opportunistic predator that feeds on small fishes, snails, shrimp, aquatic insects, and worms (Nasar 1991; Miah et al. 2015). In Asia, swamp eels are commonly harvested for human consumption and several Asian taxa, including cuchia, are exported alive and sold as food in ethnic food markets in the United States, Canada, and elsewhere (Nico et al.

2019). Cuchia have been introduced into several water bodies in the United States, but there has been no evidence of their establishment or reproduction in the wild (Nico et al. 2019). We herein describe the discovery of an established population of cuchia in an urban waterway in southeastern Louisiana, USA.

Taxonomy

The history of swamp eel taxonomy and identification is long and complicated (Nico et al. 2019 and references therein). Fortunately, many of the taxonomic problems plaguing the Synbranchidae, especially with respect to generic divisions, are expected to be resolved by the ichthyologist Tyson Roberts upon conclusion of his ongoing systematic revision of the family. Until that work is published, most modern researchers have depended on Rosen and Greenwood (1976) who recognized only four genera in the family: *Ophisternon* McClelland, 1844, *Synbranchus* Bloch, 1795, *Monopterus* Lacepède, 1800, and *Macrotrema* Regan, 1906. Tyson Roberts (Smithsonian Tropical Research Institute, *pers. comm.*, March 2020) recognizes an additional genus, *Amphipnous* Müller, 1841, to be valid (distinct from *Monopterus*) and assigns *cuchia* to this group. Recently, Britz et al. (2020) proposed revival of the genus *Ophichthys* Swainson, 1839, calling for use of the combination *Ophichthys cuchia*. Roberts (*pers. comm.*, March 2020) considers *Ophichthys* to be a *nomen oblitum*, a forgotten or unused name. Based on this recommendation, and consistent with Nico et al. (2019), we use the binomial combination *Amphipnous cuchia* in lieu of either *Monopterus cuchia* or *Ophichthys cuchia*.

Materials and methods

Study area

Bayou St. John (29.9923°N; 90.0894°W) is a highly modified, urban waterway in New Orleans, Louisiana, in the southern United States (Smith 2015). The climate of the region is subtropical and is characterized by hot and humid summers and mild, short-lived winters. Bayou St. John drains into the southern part of the Lake Pontchartrain estuary (1,630 km^2). Historically, Bayou St. John was a natural, sluggish, marshy stream. The current waterway is approximately 6.5-km long, with widths ranging from 20 to 180 m, and much of its banks are lined with concrete bulwarks and earthen levees. The littoral zone of the waterway contains dense beds of floating and emergent vegetation (Figure 1), with invasive species such as alligator weed *Alternanthera philoxeroides* (Mart.) Griseb., water hyacinth *Eichhornia crassipes* (Mart.) Solms, torpedograss *Panicum repens* L., and recently introduced giant salvinia *Salvinia molesta* Mitchell, being dominant.

Bayou St. John is part of an extensive network of surface and underground canals used to pump water out of flood-prone New Orleans.

Figure 1. (A) Typical dense mat of floating and emergent littoral vegetation in Bayou St. John, Louisiana (USA) inhabited by adult and juvenile cuchia and (B) students from Loyola University New Orleans demonstrating seining technique used to scoop up clumps of vegetation containing cuchia. Photographs by Frank Jordan.

Hydrology is driven by precipitation and tidal and wind-driven exchange of brackish water from the Lake Pontchartrain estuary characterized by salinities ranging from about 1.5 to 8 psu (practical salinity units) (Smith 2015). Bayou St. John connects to Lake Pontchartrain via a floodgate operated by the Orleans Levee Board. Lake Pontchartrain itself has multiple connections to the main channel of the lower Mississippi River, including a southeast connection via extensive wetlands and the Industrial Canal (Inner Harbor Navigation Canal) and a southwest connection via

the Bonnet Carré Spillway. The lake is also directly or indirectly connected to other drainage systems (e.g., Lake Maurepas, Tchefuncta River).

Sampling sites and methods

Swamp eels were first collected from Bayou St. John on 18 June 2019 during an event organized to remove and control the spread of invasive aquatic plants. What initially appeared to be freshwater eels or amphibians were found enmeshed in dense mats of aquatic vegetation that volunteers had pulled onto shore. The captured organisms were placed on ice and subsequently identified as cuchia by FJ and LGN using the following morphological characteristics detailed in Nico et al. (2019): presence of paired, laterally-positioned, suprapharyngeal air chambers; laterally expanding head during aerial respiration; very small scales limited to tail region; moderately large, uniserial palatine teeth; and upper body coloration brown with numerous circular or oval black spots. We searched for additional cuchia over the next few weeks at over a dozen locations throughout Bayou St. John and in three vegetated locations along nearby southern shoreline areas of Lake Pontchartrain. We spent about one hour at each location using a combination of visual inspection of removed mats of vegetation, dip nets, and seines (Figure 1) to collect cuchia. All collected specimens were preserved in 10% buffered formalin, later transferred to 60% isopropanol, identified, and measured to the nearest mm TL. Salinity, conductivity and temperature of water were measured with a YSI® meter model 85. Upon learning of the discovery of cuchia, the Louisiana Department of Wildlife and Fisheries (LDWF) began using a boat-mounted electrofisher to sample cuchia in Bayou St. John and nearby waterways. The agency provided information from those sampling sorties to us.

Results

The first collection of cuchia in Bayou St. John consisted of 12 adult specimens taken on 18 June 2019. These ranged in size from 292–455 mm TL (359 ± 56 mm TL; mean ± 1 SD). We returned to the original capture site a few days later and collected 11 young-of-year juveniles (Figure 2). These ranged in size from 43–69 mm TL (52 ± 7 mm TL) and were estimated to be three to five weeks old based on growth data available on larval cuchia taken from the wild in Bihar, India (Banerji et al. 1981). Subsequent sampling sorties in 2019 by us resulted in the collection of another 39 adult and juvenile specimens (126 ± 91 mm TL; range 57–371 mm TL), all taken from locations in Bayou St. John within approximately 2 km of the original collection site. No cuchia were detected in more distant reaches of Bayou St. John nor were any observed in nearby connected waterways sampled by us or LDWF. Louisiana sites where cuchia were found are recorded in the online USGS Nonindigenous Aquatic Species (NAS) Database. Also, voucher specimens are being permanently archived in the

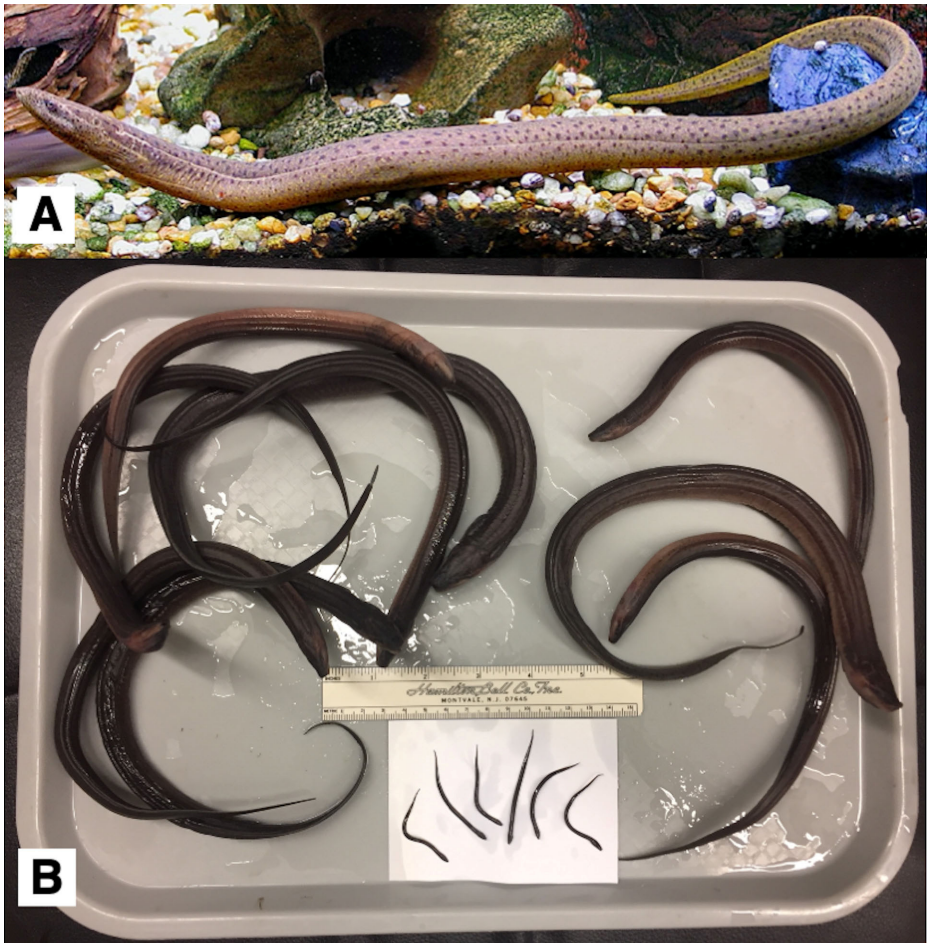

Figure 2. (A) A living adult cuchia that was obtained from a food market in Florida (USA) and (B) preserved adult and juvenile cuchia collected from Bayou St. John, Louisiana (USA) in June 2019. Photographs by Leo G. Nico (top) and Frank Jordan (below).

ichthyology collection of the Tulane University Museum of Natural History in Belle Chase, Louisiana. Salinity (0.39 ± 0.07 psu), conductivity (734 ± 152 µS/cm), and temperature (30.2 ± 0.4 °C) were measured at collection locations within Bayou St. John.

Discussion

Nico et al. (2019) recently reviewed the status of non-native Asian swamp eels in North America and provided information on their biology, taxonomy, identification, introduction pathways, and potential impacts. Non-native populations of Asian swamp eels of the *Monopterus albus/javanensis* species complex are established in the wild in multiple states in the USA (Hawaii, Georgia, Florida, and New Jersey) as well as in other regions of the world (Japan, Philippines, possibly elsewhere) (Nico et al. 2019). In contrast, although adult cuchia have been reported in open waters in several states in the USA (Nico et al. 2019), the presence of both adult and young-of-year juveniles in Bayou St. John is the first documented evidence of reproduction and apparent establishment of this Asian species in the wild outside its native range. Based on the approximate natural

geographic distribution of cuchia and a coarse-scale climate-matching analysis, Nico et al. (2019) surmised that the species had the potential to establish in the southern USA (a more restricted range than that predicted for members of the *M. albus/javanensis* complex). We recently learned that cuchia have been collected from a 38-ha retention basin in urban Houston, Texas (Alice Best, Texas Parks and Wildlife Department, *pers. comm.*, November 2019). The specimens collected in Texas consisted of adult cuchia that varied considerably in size, suggesting apparent establishment of a second population in the southern USA.

Swamp eels are characterized by a suite of adaptations that increase their likelihood of establishment and spread. These adaptations include an ability to survive long periods outside water due to advanced air-breathing capabilities; ability to crawl in snake-like fashion overland from one water body to another; tolerance of a wide range of salinities; parental care of eggs and young; ability to survive droughts and cold while buried in the mud or deep in burrows; and ability to survive months without food (Nico et al. 2019). Swamp eels also tend to be quite secretive, highly fossorial, and primarily nocturnal. When outside their burrows, they commonly reside in dense vegetation or within debris and therefore may go undetected even when common (Nico et al. 2019). Many species of swamp eels are sequential hermaphrodites that undergo sex reversal from adult female to functional male, but this phenomenon has not been documented in cuchia (Liem 1968).

Evaluation criteria and screening protocols potentially helpful in determining which non-native species are most likely to be injurious have been proposed (Lawson et al. 2013; Marcot et al. 2019). Because swamp eels possess many traits that facilitate establishment and dispersal, cuchia could be injurious to native species, habitats, and ecosystems. There are no current federal regulations prohibiting importation of live swamp eels into the United States, although some states such as Louisiana prohibit possession. There are records from 2016 and 2017 of live cuchia for sale in a food market in New Orleans (Nico et al. 2019). However, the actual source of the cuchia population in Bayou St. John cannot be deduced with certainty and previous introductions of Asian swamp eels have been linked to the live food trade, Buddhist prayer release rituals, the pet trade, and even use of swamp eels as live bait by anglers (Nico et al. 2019). Regardless of introduction pathway, the presence of cuchia in Bayou St. John is a concern because of their potential to disperse and invade the Mississippi River basin and other aquatic systems in the region.

Establishment of cuchia in North America open waters poses several potential risks. Swamp eels are highly opportunistic feeders and, based on their behavior (amphibious) and morphology, the taxon represents a new and rather unique type of predator in inland waters of the United States.

Introduced novel predators may result in strong impacts because of "prey inexperience" and, consequently, are more likely to alter the structure and function of food webs (David et al. 2017). For instance, the ability of swamp eels to move overland and invade waters where other predatory fishes normally do not occur may negatively impact native amphibians and aquatic invertebrates (e.g., commercially harvested crawfish) that depend on fishless habitats. Finally, cuchia and other Asian swamp eels imported live and introduced into the wild are a potential health risk because they are host to multiple parasites (Nico et al. 2011), including at least one non-native nematode that causes disease in humans (Cole et al. 2014).

Introduction of cuchia into Bayou St. John appears to be a recent event and the population thus far appears restricted to a single reach. Fisheries managers therefore should consider aggressive eradication efforts given the potential injuriousness of swamp eels and because there is a greater likelihood of successful removal before they become more abundant and widespread (Kolar et al. 2010). Toxicants such as rotenone have proven effective at reducing abundance, limiting spread, and even eradicating introduced fishes from sites larger than the reach of Bayou St. John that is currently occupied by cuchia (Kolar et al. 2010; Rytwinski et al. 2018). Unfortunately, laboratory tests suggest that air-breathing swamp eels are less susceptible to rotenone than many other fishes (Schofield and Nico 2007). Behaviors such as burrowing deep into soil and inhabiting dense beds of vegetation may further reduce the vulnerability of swamp eels to ichthyotoxins. The use of ichthyotoxins is often controversial (Gozlan et al. 2013) and such may be the case for Bayou St. John given that it is a popular, residential waterbody that supports public activities such as bird watching, kayaking, canoeing, and recreational fishing. If eradication is not considered viable, then management efforts should focus on attempts to control swamp eel numbers and dispersal. Such efforts would likely require the continued removal of invasive aquatic vegetation and routine electrofishing, coupled with long-term monitoring of fishes in Bayou St. John. Without eradication, cuchia will likely expand their distribution in the region.

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