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Short Communication

Successful eradication of the non-native loricariid catfish *Pterygoplichthys disjunctivus* from the Rainbow River, Florida

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Abstract

Non-native *Pterygoplichthys* (Loricariidae) are increasingly introduced and established in tropical and subtropical regions worldwide. Florida (USA) has a long history of introduction of loricariid catfishes. These catfishes are of management concern, particularly when they occupy sensitive habitats such as springs and spring runs. Limiting introduction and spread is important because springs are among the most imperiled aquatic habitats in Florida and serve as thermal refuges in winter for *Pterygoplichthys*. Herein we report the only known eradication of an introduced loricariid catfish by direct human intervention and the only eradication of a non-native fish in Florida by means other than the fish toxicant rotenone. Vermiculated sailfin catfish (*Pterygoplichthys disjunctivus*) was first observed in the Rainbow River, Marion County, Florida in December 2002 but disappeared by March 2003. Occurrence was documented again in April 2006. Monthly surveys and removals were done and 28 individuals were removed from 2006 through 2008 by hand and fish spear. No additional individuals have been found since June 2008 and quarterly monitoring continues. Factors that facilitated the removal efforts included the springs' protected status as a Florida Aquatic Preserve, on-going monitoring and control programs for invasive aquatic macrophytes, high water clarity, small numbers and spatial extent of observed *Pterygoplichthys*, relative isolation from other source populations, and little evidence of reproduction and recruitment. Decisions to undertake eradication or control programs for non-native fishes require consideration of the vulnerability of the site, spatial scale, habitat, interconnectivity with source populations, impacts of the non-native in the absence of management intervention, and available resources.

Key words: control, invasive, removal, spring, suckermouth catfish

Introduction

Establishment of loricariid catfishes of the genera *Pterygoplichthys* Gill, 1858 and *Hypostomus* Lacepède, 1803 outside of their native ranges is widespread and increasing in tropical and subtropical regions of the world (Nico et al. 2012). Florida has a long history of introduction of these fishes with records dating back to the 1950s (USGS 2014). Reproducing populations of introduced loricariid catfishes occur in many river systems and lakes of the Florida peninsula (USGS 2014), including recent discovery within the Suwannee River basin (Nico et al. 2012). The most dominant and widespread genus in Florida is *Pterygoplichthys*, the armored sailfin catfishes. Species identification is difficult but at least four species of armored sailfin catfishes occur within Florida (USGS 2014).

Non-native *Pterygoplichthys* are of management concern, particularly when they occupy sensitive habitats such as springs and spring runs. Introduced populations in Florida are generally successful, reaching high densities and dispersing to new areas (Gestring et al. 2010; Nico et al. 2012). Males dig spawning burrows into stream banks, increasing local erosion (Figure 1, 2; Nico et al. 2009a). *Pterygoplichthys* graze algae from submersed rocks, woody debris, and other substrates and consume considerable amounts of detritus,

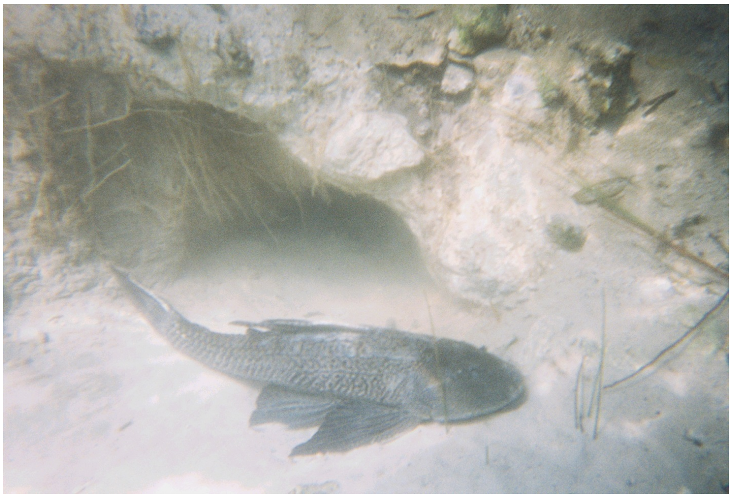

Figure 1. *Pterygoplichthys disjunctivus* at the mouth of a spawning burrow, Rainbow River, Florida. Photograph by Jeff Sowards, FDEP.

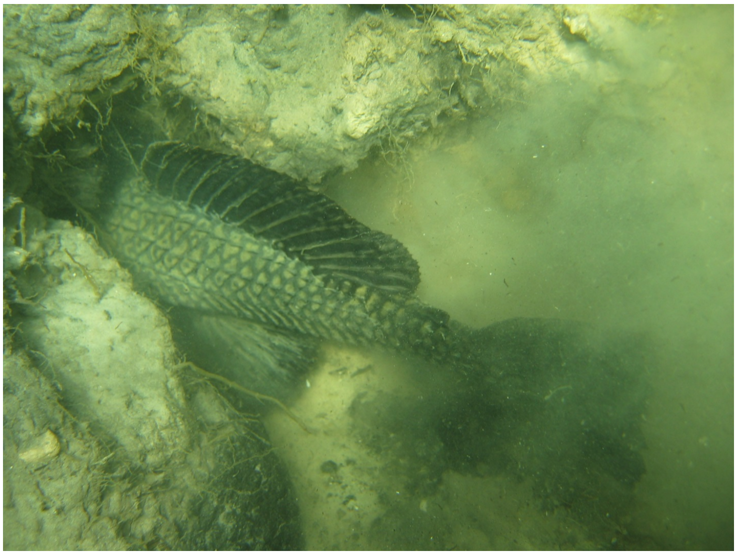

Figure 2. *Pterygoplichthys disjunctivus* digging a spawning burrow, Rainbow River, Florida. Photograph by Jeff Sowards, FDEP.

potentially altering grazing dynamics and trophic structure of aquatic communities (Hoover et al. 2004; CEC 2009). Aquatic macrophytes may be dislodged by feeding activities, digging, or other movement (Hoover et al. 2004; CEC 2009). Grazing by these catfishes on the epibiota of the Florida manatee, *Trichechus manatus latirostris* (Harlan, 1824), occurs in Volusia Blue Spring and other springs within the St. Johns River basin (Nico et al. 2009b; Nico 2010). Effects on Florida Manatees refuging in the winter in the warm springs includes increased activity levels and movement outside of warm spring waters to dislodge attached catfishes and disruption of calf nursing behavior (Nico et al. 2009b; Gibbs et al. 2010). Other effects of *Pterygoplichthys* are poorly known though numerous hypothetical impacts are discussed in the literature (e.g., Hoover et al. 2004; CEC 2009; Nico et al. 2012; but see Gestring et al. 2010).

Despite widespread occurrence of *Pterygoplichthys* within peninsular Florida, many springs, streams, and lakes are still un-invaded. Limiting introduction and spread into springs and spring runs is particularly important because these habitats serve as thermal refuges in winter for this tropical group. Springs serve to buffer *Pterygoplichthys* populations from periodic cold episodes and facilitate re-colonization of areas suffering winter kills. Springs and associated runs also are among the most imperiled aquatic habitats in Florida, undergoing

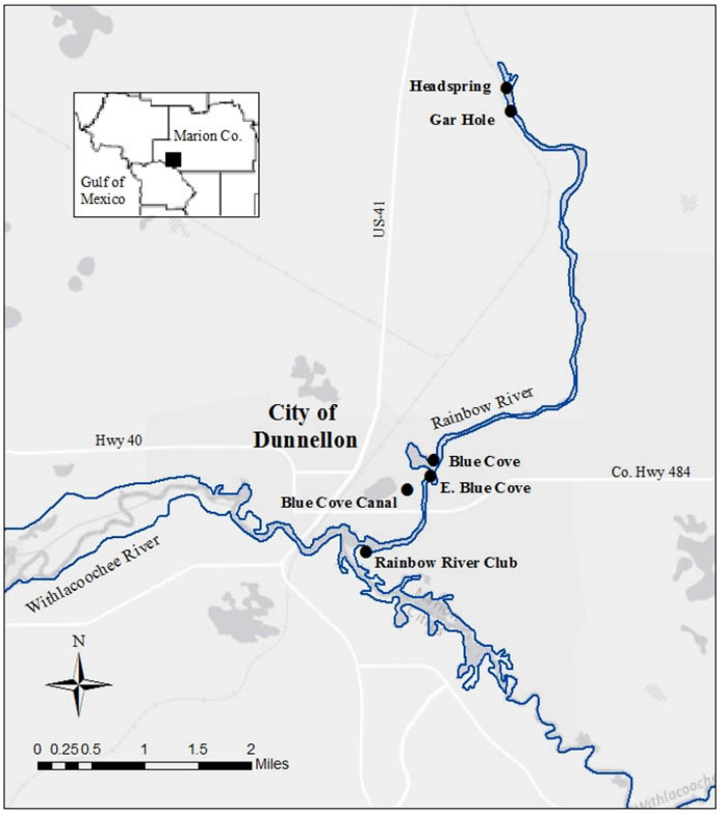

Figure 3. Rainbow River Aquatic Preserve and surrounding area. The six labeled points represent collection sites for *P. disjunctivus*. Inset shows the location of the Rainbow River in Florida.

pressures from human development and water withdrawal, eutrophication, and invasive species (FWC 2005).

Pterygoplichthys disjunctivus (Weber, 1991), the vermiculated sailfin catfish, was first observed in the Rainbow River, Marion County, Florida in December 2002 but had disappeared by March 2003. The catfish were found near a connection with Blue Cove, a phosphate borrow lake about 1.75 km upstream from the Rainbow River confluence with the Withlacoochee River (Figure 3). *Pterygoplichthys* was again documented by Rainbow Springs Aquatic Preserve staff in April 2006 in the same area of the river. The presence of two or more individuals and three spawning burrows suggested the beginnings of a reproducing population. The status of the Rainbow River as a Florida Aquatic Preserve and the concerns of the preserve manager (JS) about potential impacts prompted an intensive removal and monitoring program to eliminate *Pterygoplichthys* from the river. Herein we report on the only known successful eradication of an introduced loricariid catfish by direct human intervention and the only successful eradication of a non-native fish in Florida by means other than the fish toxicant rotenone. Information on eradication, control, and monitoring programs for non-native fishes is scarce in the literature and is sorely needed by natural resource managers.

Methods

Study area

The Rainbow River of north-central Florida arises in Rainbow Springs, the fourth largest spring by discharge in Florida (average 22 m^3/s), flows for 9.2 km, and enters the Withlacoochee River just upstream of Lake Rousseau (SWFWMD 2004). Average width is 46 m and depth is 2.5 m. Submersed aquatic vegetation occurs in 89–95% of the submersed area (SWFWMD 2008). The dominant native species is *Sagittaria kurziana* Glück (53%) followed by *Vallisneria americana* Michx. (12%); the non-native plant *Hydrilla verticillata* (L. f.) Royle is common at 37% (FDEP

Table 1. Dates, removal numbers, and removal locations for systematic, daytime control and monitoring of *Pterygoplichthys disjunctivus* in the Rainbow River, Florida. The entire 9.2-km course of the river from the headspring to the confluence with the Withlacoochee River was surveyed on each reported date. Systematic surveys continued quarterly from late 2008 to present with no additional *Pterygoplichthys* observed or removed. Ad hoc surveys of a more limited spatial extent (primarily daytime but also nighttime) were done in addition to those reported in the table.

Date	Quantity removed	Location
5/25/2006	3	Blue Cove
6/16/2006	4	Blue Cove
7/19/2006	2	Rainbow River Club
8/16/2006	0	
9/5/2006	2	East Blue Cove
10/18/2006	0	
11/8/2006	0	
12/19/2006	1	Rainbow River Club
1/15/2007	0	
2/22/2007	0	
3/13/2007	1	East Blue Cove
4/12/2007	2	Blue Cove
5/15/2007	0	
6/14/2007	3	Blue Cove
7/25/2007	3	Blue Cove
8/28/2007	1	East Blue Cove
9/6/2007	0	
10/16/2007	1	East Blue Cove
11/6/2007	0	
12/13/2007	0	
3/13/2008	2	Head Spring, Rainbow River Club
6/19/2008	3	Gar Hole
9/8/2008	0	

2000). The Rainbow River was designated an aquatic preserve by the Florida Legislature in 1986 for the purpose of maintaining the spring head and associated river run in an essentially natural condition. The preserve is approximately 61 hectares in size and includes only the sovereign submerged lands located below the ordinary high water line (Figure 3).

Control and monitoring program

Observed catfish were captured by hand or fish spear and the Blue Cove site was monitored for additional activity. Frequent visual day time surveys (monthly, April 2006–December 2007 and quarterly 2008–present; Table 1) were conducted throughout the length of the river to attempt to locate additional individuals or burrows. Qualitative nighttime observations throughout the control and monitoring period revealed no additional catfish. Sites with evidence of *Pterygoplichthys* occurrence (individuals or burrows) were more intensively and frequently surveyed but all portions of the head spring and river were covered each survey period. Surveys were done primarily by boat, but surveys in some reaches were accomplished by use of snorkel equipment. Adult *Pterygoplichthys* are large (commonly 40–60 cm total length in Florida; Nico et al. 2012; Gibbs et al. 2013) and easily observed while they graze or rest on the substrate if water clarity is high (Nico et al. 2012). Spawning burrows often are prominent and are used as a means to detect *Pterygoplichthys* presence and spawning activity across a wide range of water clarity (e.g., Nico et al. 2009a). Observations were facilitated by the high water clarity of the spring-fed system (horizontal Secchi disk measurements of up to 70 m in the headspring with a normal range of about 45 m of clarity 2 km downstream down to 8–10 m at 9 km downstream of the headspring (SWFWMD 2004)). Monitoring continues because of the potential for reintroduction from release along the river course or from the Withlacoochee River downstream.

Results and discussion

A total of 28 catfish were removed from the Rainbow River between April 2006 and June 2008 (Table 1).The majority of individuals and spawning burrows were observed in the general area of Blue Cove and East Blue Cove in near proximity to the original observation site in the lower Rainbow River; however in March 2008 active burrows and individuals were observed in the head spring within the Rainbow Springs State Park's boundary area (Figure 3). Only adult specimens have been documented to date with an average total length of 52.1 cm (size range 47–56 cm). Although small numbers of the catfish were observed and removed in this program, clearly initiating eradication or control efforts when only a few individuals are found is preferable to waiting until a large, reproducing population establishes (Simberloff 2009). *Pterygoplichthys disjunctivus* has not been observed in the Rainbow River since June 2008 despite its establishment downstream in the Withlacoochee River since the late 1990s (see Nico et al. 2009a).

The range of eradication or control options was limited for *Pterygoplichthys* within the Rainbow River Aquatic Preserve. Application of the fish toxicant rotenone is the most common method for eradicating non-native fishes in Florida but this method is not legal for use in flowing waters within the state (Hill and Cichra 2005; Shafland et al. 2008). Passive capture gears such as traps or gill nets were unlikely to prove effective in eliminating all *Pterygoplichthys* individuals. Surveys revealed only low numbers of *Pterygoplichthys* in a small spatial range suggesting that active methods targeting those individuals and locations would be most effective. Hand capture and fish spear were determined to be the most likely effective active capture methods, especially for individuals located near spawning borrows (see also Nico et al. 2012). Burrows also were checked for egg masses to remove large numbers of potential recruits at one time.

No egg masses were observed in the burrows and no juveniles were seen, suggesting a lack of reproduction and recruitment within the Rainbow River. Year-round cool water temperatures of 22°C though suitable for survival may not be conducive to sustained reproductive effort (Nico et al. 2012; C. Martinez, University of Florida Tropical Aquaculture Laboratory, personal communication), though some locations away from the main channel such as Blue Cove may have higher temperatures in warmer months. Preliminary observations and discussions with collectors in Florida who sell *Ptergoplichthys* egg masses to aquaculturists to support the aquarium trade suggest that these species spawn primarily at temperatures at or above 23°C (C. Martinez, University of Florida Tropical Aquaculture Laboratory, personal communication; Hill, unpublished data). Gibbs et al. (2008, 2013) reported little spawning activity of *P. disjunctivus* in a spring in the St. Johns River basin despite often high abundance of large females of reproductive condition. They concluded that the individuals observed in the spring were the product of reproduction in the warmer St. Johns River. Nevertheless, we cannot be certain that there was not at least some level of reproduction in the Rainbow River. Our monthly sampling schedule was not sufficient to determine that no eggs were laid considering that *Pterygoplichthys* eggs hatch in 3–4 days and juveniles leave the burrow in another 3–4 days depending on temperature (C. Martinez, University of Florida Tropical Aquaculture Laboratory, personal communication). Moreover, small *Pterygoplichthys* are rare in fish samples and would be relatively difficult to observe during our visual surveys. Clearly there was no widespread, prolonged recruitment despite the potential for reproduction by *Pterygoplichthys* in the Rainbow River.

The origin of *P. disjunctivus* in the Rainbow River is unknown but individuals may have moved upstream from the Withlacoochee River or may have been released somewhere along the length of the river by residents or visitors. *Ptergoplichthys disjunctivus* is common in the aquarium trade and along with several congeners is increasingly introduced around the world (Nico et al. 2012). Residential use is a major land use category along the river (SWFWMD 2004) and the river receives high recreational use (Cichra and Holland 2012), potential sources of introduction of non-native fishes. Blue Cove is one of the most highly modified sections of the Rainbow River. The location has steep vertical banks of relatively bare sediments (Figure 1), an unusual feature in the river, possibly facilitating burrowing activities (see Nico et al. 2009a). Moreover, this disturbed site has low flushing rates leading to increased algal densities and elevated amounts of detritus, abundant food resources for this species. *Pterygoplichthys* often are associated with human-modified habitats and increased trophic state in other invaded systems in Florida (Gestring et al. 2010; Hill, unpublished data). The concentration of *P. disjunctivus* at the phosphate pit location suggests either this was the site of multiple releases or the conditions of this somewhat unique site along the river attracted the catfish. Continuing monitoring programs will allocate disproportionate effort to this and other sections of the river where *P. disjunctivus* has been observed (Figure 3) while simultaneously allocating remaining effort throughout the river.

Directed removals of non-native fishes in Florida have been largely unsuccessful and have not resulted in eradication. The most prominent example was the U.S. Fish and Wildlife Service attempt to control the abundance of *Monopterus albus* (Zuiew, 1793), the Asian swamp eel, in a series of canals to prevent the spread of this species into Everglades National Park (ENP, Schofield and Nico 2007; Kolar et al. 2010). Thousands of *M. albus* were removed by boat electrofishing over several years of effort, but the species remains abundant in the canals (Shafland et al. 2010). The control project was abandoned following confirmation of *M. albus* presence within the ENP (Shafland et al. 2010). Control of *Pterygoplichthys* has been attempted in Rock Springs, Volusia Blue Spring, and Wekiwa Springs in the St. Johns River basin in Florida. From 2005–2011 seining and hand removal collected over 8,500 individuals (Nico et al. 2012; Gibbs et al. 2013). In Wekiwa Springs removals were targeted during cool periods when *Pterygoplichthys* refuge within the springs, though effort was irregular (Nico et al. 2012). Effort in the Volusia Blue Spring was more regular though the use of the spring as a winter refuge for Florida manatees precluded removals during cold periods when these imperiled mammals were present (Gibbs et al. 2013). Temporary declines were observed but the presence of *Pterygoplichthys* in other springs and throughout much of the St. Johns River basin resulted in subsequent re-colonization (Nico et al. 2012).

Analysis of the Rainbow River control and monitoring program reveals several factors that facilitated success of this removal effort (see also Kolar et al. 2010; Nico et al. 2012). The river is a designated Florida Aquatic Preserve with historic and ongoing efforts to eradicate or control non-native aquatic macrophytes and is largely un-invaded by non-native fishes, so there was interest and willingness to attempt eradication of *P. disjunctivus*. The preserve manager viewed this effort as a priority and allocated staff time and resources from his limited budget to accomplish the task. The removal effort was sustained and accompanied by follow-up monitoring. Water clarity is extremely high in the river, increasing the effectiveness of visual sampling. Therefore, the *P. disjunctivus* and burrows were located while their numbers and spatial range were small. Despite a water connection with the Withlacoochee River and its potential source population, the invaded sites were relatively isolated and likely received few migrating adults as propagules. *In situ* reproduction and recruitment were non-existent or too low to detect, potentially related to year-round water temperatures that are suboptimal for *Pterygoplichthys* reproduction. Although some or all of these factors may be present in systems where eradication efforts have been unsuccessful, these factors nevertheless led to rapid detection and removal of new individuals and reduced the probability of establishment.

Many favorable factors were in place that facilitated the success of removal efforts within the Rainbow River. Managers in other locations, including other Florida springs, may face much more difficult circumstances (see Nico et al. 2012). Management options include eradication, control, research, monitoring, or “do nothing.” Eradication is most desirable but may not be possible. If eradication is not feasible, control efforts might be effective. If local control measures remove a sufficient proportion of recruits, whether locally spawned or immigrants, suppression of invasive fish abundance can be achieved even for aquatic systems with high connectivity to uncontrolled populations. For example, local suppression of abundance and size structure of the marine Indo-Pacific lionfish (*Pterois* spp. Oken, 1817) has been successful using agency and non-governmental agency staff and the public in directed removal projects (Frazer et al. 2012). Lionfish represents a near worst-case control scenario because of the large scale and interconnectivity of marine systems and the near-continuous re-invasion of removal sites by adult, juvenile, and larval individuals.

Springs represent a more manageable scenario for *Pterygoplichthys* control because entry is limited to upstream movement into the spring run, the control area is more compact and delineated by land features, reproduction within the spring system may be limited, targeted egg removal is possible, and springs may concentrate and increase the vulnerability of individuals during cold periods (Nico et al. 2012). In cold winters in central or north Florida, springs may be essential thermal refuges and control efforts during those periods might produce highly successful and lasting results. Nevertheless, sustained and consistent efforts will be required to effect local suppression in most cases, requiring dedicated resources in labor and funding. Volunteer labor may be used to help reduce control costs. Nevertheless, success in spring systems may prove as elusive as eradication and control efforts in even simple systems like ponds (see Kolar et al. 2010). Decisions to undertake eradication or control programs for *Pterygoplichthys* or other non-native fishes require consideration of the vulnerability or protected status of the site, spatial scale, habitat, interconnectivity with source populations, impacts of the non-native in the absence of management intervention, and available resources (see also Nico et al. 2012 for additional management recommendations). Certainly any water body that contains non-native fish would be vulnerable to re-invasion by some mechanism following a successful eradication. So far the investment in resources seems warranted after 6.5 years (and counting) of effectiveness against a species with known impacts.

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References

CEC (2009) Trinational risk assessment guidelines for aquatic invasive species: test case for the snakeheads (Channidae) and armored catfishes (Loricariidae) in North American inland waters. Commission for Environmental Cooperation, Montreal, Canada. http://www.cec.org/Storage/37/2919_2544_Full-report_en.pdf (Accessed 10 February 2015)

Cichra CE, Holland SM (2012) Rainbow River environmental study Dunnellon, Florida, final report (revised). Florida Department of Environmental Protection, Tallahassee, FL, USA

FDEP (2000) Rainbow Springs Aquatic Preserve 2000 vegetation mapping project: an assessment of the plant assemblages. Florida Department of Environmental Protection, Dunnellon, FL, USA

Frazer TK, Jacoby CA, Edwards MA, Barry SC, Manfrino CM (2012) Coping with the lionfish invasion: can targeted removals yield beneficial effects? *Reviews in Fisheries Science* 20: 185–191, http://dx.doi.org/10.1080/10641262.2012.700655

FWC (2005) Florida's wildlife legacy initiative: Florida's comprehensive wildlife conservation strategy. Florida Fish and Wildlife Conservation Commission, Tallahassee, FL, USA. http://www.myfwc.com/media/134715/legacy_strategy.pdf (Accessed 10 February 2015)

Gestring KB, Shafland PL, Stanford MS (2010) Status of the exotic Orinoco sailfin catfish (*Pterygoplichthys multiradiatus*) in Florida. *Florida Scientist* 73: 122–137

Gibbs M, Futral T, Mallinger M, Martin D, Ross M (2010) Disturbance of the Florida manatee by an invasive catfish. *Southeastern Naturalist* 9: 635–649, http://dx.doi.org/10.1656/058.009.0401

Gibbs MA, Kurth BN, Bridges CD (2013) Age and growth of the loricariid catfish *Pterygoplichhtys disjunctivus* in Volusia Blue Spring, Florida. *Aquatic Invasions* 8: 207–218, http://dx.doi.org/10.3391/ai.2013.8.2.08

Gibbs MA, Shields JH, Lock DW, Talmadge KM, Farrell TM (2008) Reproduction in an invasive exotic catfish *Pterygoplichthys disjunctivus* in Volusia Blue Spring, Florida, U.S.A. *Journal of Fish Biology* 73: 1562–1572, http://dx.doi.org/10.1111/j.1095-8649.2008.02031.x

Hill JE, Cichra CE (2005) Eradication of a reproducing population of convict cichlids, *Cichlasoma nigrofasciatum* (Cichlidae), in north-central Florida. *Florida Scientist* 68: 65–74

Hoover JJ, Kilgore KJ, Cofrancesco AF (2004) Suckermouth catfishes: threats to aquatic ecosystems of the United States? *Aquatic Nuisance Species Research Program Bulletin* 4(1): 1–13

Kolar CS, Courtenay, WR Jr, Nico LG (2010) Managing undesired and invading fishes. In: Hubert WA, Quist MS (eds), Inland Fisheries Management in North America, 3rd ed. American Fisheries Society, Bethesda, MD, USA, pp 213–259

Nico LG (2010) Nocturnal and diurnal activity of armored suckermouth catfish (Loricariidae: *Pterygoplichthys*) associated with wintering Florida manatees (*Trichechus manatus latirostris*). *Neotropical Ichthyology* 8: 893–898, http://dx.doi.org/10.1590/S1679-62252010005000014

Nico LG, Butt PL, Johnston GR, Jelks HL, Kail M, Walsh SJ (2012) Discovery of South American suckermouth armored catfishes (Loricariidae, *Pterygoplichthys* spp.) in the Santa Fe River drainage, Suwannee River basin, USA. *BioInvasions Records* 1: 179–200, http://dx.doi.org/10.3391/bir.2012.1.3.04

Nico LG, Jelks HL, Tuten T (2009a) Non-native suckermouth armored catfishes in Florida: description of nest burrows and burrow colonies with assessment of shoreline conditions. *Aquatic Nuisance Species Research Program Bulletin* 9(1):1–30

Nico LG, Loftus WF, Reid JP (2009b) Interactions between non-native armored suckermouth catfish (Loricariidae: *Pterygoplichthys*) and native Florida manatee (*Trichechus manatus latirostris*) in artesian springs. *Aquatic Invasions* 4: 511–519, http://dx.doi.org/10.3391/ai.2009.4.3.13

Schofield PJ, Nico LG (2007) Toxicity of 5% rotenone to nonindigenous Asian swamp eels. *North American Journal of Fisheries Management* 27: 453–459, http://dx.doi.org/10.1577/M05-206.1

Shafland PL, Gestring KB, Stanford MS (2008) Florida's exotic freshwater fishes—2007. *Florida Scientist* 71: 220–245

Shafland PL, Gestring KB, Stanford MS (2010) An assessment of the Asian swamp eel (*Monopterus albus*) in Florida. *Reviews in Fisheries Science* 18: 25–39, http://dx.doi.org/10.1080/10641260903225542

Simberloff D (2009) We can eliminate invasions or live with them: successful management projects. *Biological Invasions* 11: 149–157, http://dx.doi.org/10.1007/s10530-008-9317-z

SWFWMD (2004) Rainbow River Surface Water Improvement and Management (SWIM) plan. Southwest Florida Water Management District, Tampa, FL, USA

SWFWMD (2008) Rainbow River technical summary. Southwest Florida Water Management District, Brooksville, FL, USA

USGS (2014) Nonindigenous aquatic species database. U.S. Geological Survey, Gainesville, FL, USA. http://nas.er.usgs.gov/default.aspx (Accessed 10 February 2015)