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Ecological Impacts of Suckermouth Catfishes (Loricariidae) in North America: A Conceptual Model

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Purpose

Suckermouth catfishes, native to Central and South America, have been established in US and Mexican waters since the 1950s (Fuller et al. 1999, Hill 2002) and have become problematic since the late 1990s (Hoover et al. 2004, Mendoza-Alfaro et al. 2009). Nuisance populations of these fishes in three states (Hawaii, Texas, and Florida) have been implicated in a broad range of ecological problems, including erosion of streambanks and imperilment of threatened species, but documented accounts of their impacts are often equivocal and sometimes contradictory. This bulletin presents a conceptual model based on reports by the press and findings by researchers working throughout the non-native range of these animals. The model is intended as a tool for identifying potential impacts of introduced suckermouth catfishes on local fauna.

Nomenclature of Suckermouth Catfishes

Two families of tropical New World catfishes have bodies covered by distinctive boney plates (Burgess 1989). The family Callichthydae is comprised of terete, thin-lipped species, many of which are exploited by the aquarium industry as "scavengers" that will consume uneaten fish food (e.g., *Hoplosternum* spp., *Corydoras* spp.). Callichthyds have only two rows of boney plates and have eyes with round pupils. The family Loricariidae is comprised of ventrally flattened, thick-lipped species, which are also exploited by the aquarium hobby, but as grazers that will keep tanks free of algae (i.e., various genera collectively referred to as "plecos"). Loricariids have three or more rows of boney plates and have eyes with lunate pupils. Both families are considered "armored catfishes." The loricariids, however, are sometimes referred to as "suckermouth armored catfishes" or simply "suckermouth catfishes" (Page and Burr 1991). The Portuguese word "cascudo" is also used for these fishes in some aquarium literature and is the common name used in their native range.

In North America, two groups (i.e., genera) of suckermouth catfishes have become established: the armadillo del rio (*Hypostomus* spp.) and the sailfin catfishes (*Pterygoplichthys spp.*). Older literature uses different generic names for the same fishes (i.e., *Plecostomus* for *Hypostomus*; *Liposarcus* and *Glyptoperichthys* for *Pterygoplichthys*). Although these groups have been studied for over a century, taxonomy is still developing. Revised information on this family has been published recently (Armbruster 2004), but assignment of scientific names often lags behind the discovery, depiction, and marketing of new forms. As a result, a system was established by the German aquarium magazine *Die Aquarien und Terrarien-zeitschrift* (aka, DATZ) in which numbers preceded by the letter "L" were assigned to morphologically distinctive forms so that they might be referenced conveniently in aquarium publications pending formal taxonomic descriptions (Finley 2009). Eight "interesting and distinctive" species of armadillo del rio have been reported for the aquarium trade (Walker 1968) but genetic diversity within this genus is extremely high (Alves et al. 2005). Modern references typically identify the common aquarium pleco specifically, *Hypostomus plecostomus*, and other forms collectively, *Hypostomus* spp. (Mendoza-Alfaro et al. 2009). Twelve species of sailfin catfishes and nine species belonging to other genera in the family are recognized in the aquarium trade (Mendoza-Alfaro et al. 2009).

Both groups of suckermouth

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catfishes established in North America are similar in appearance and belong to the same subfamily: Hypostominae. They are readily differentiated, however, by their dorsal fins – short (seven rays) in armadillo del rio (Figure 1) and longer (10-14 rays) in the sailfin catfishes (Figure 2). At least three unknown but "morphologically distinct" species of armadillo del rio and four species of sailfin catfishes are established in the United States and Mexico (Page and Burr 1991; Guzmán and Barragán 1997; Nico 1999a, 1999b, 2000a, 2000b; Nico and Fuller 1999; Nico and Martin 2001; Ramirez-Soberon et al. 2004; Wakida-Kusonaki et al. 2007; Sandoval-Huerta et al. 2012). Sailfin catfishes appear very similar to each other morphologically but are highly variable in pigmentation (Figure 3). They can sometimes be distinguished from each other based on a combination of dorsal, ventral, and lateral markings (Table 1). Hybrids may occur, however, with many fish in south Florida believed to be hybrids between the Amazon sailfin catfish (*P. pardalis*) and the vermiculated sailfin catfish (*P. disjunctivus*) . Taxonomy and relationships among these and other suckermouth catfishes have been described recently (Weber 1991, Page 1994, Armbruster 2004).

Figure 1. Armadillo del rio (*Hypostomus* sp.) from the San Antonio River, Texas. Note dorsal fin with single spine and seven soft rays. Appearance is consistent with that of Hypostomus niceforoi. Photo: San Antonio River Authority.

Figure 2. Sailfin catfish (*Pterygoplichthys* sp.) from southern Florida. Note dorsal fin with single spine and 12 soft rays.

Figure 3. Ventral pigmentation of sailfin catfishes from south Florida. Appearance of fish at left is consistent with that of *P. disjunctivus*, appearance of fish at center and right with that of *P. pardalis* or hybrids.

Morphological and Physiological Adaptations of Suckermouth Catfishes

In addition to their remarkable boney armor, other adaptations of suckermouth catfishes enable them to survive environmental extremes, food limitations, and predation. A large, vascularized stomach functions as a lung and as a swim bladder allowing fish to breathe

Table 1. Number of dorsal fin rays and pigmentation patterns of suckermouth catfishes (*Pterygoplichthys* spp. and *Hypostomus* spp.) established in the United States.

Species (Native River Basin)	**Dorsal Rays**	**Dorsal**	**Lateral**	**Ventral**	**Dorsal fin**
Amazon sailfin catfish *P. pardalis* (Amazon)	9+	White vermiculations	Spots combining to form dark chevrons at posterior edges of plates	Black spots on a white background, spots either separate or with about 3-5 combining to form short vermiculations. Dark and light areas of approximately equal width.	Dark spots
Snow king *P. anisitsi* (Paraná)	9+	White spots	White spots located centrally on plates	White spots on black background, white spots larger than dark interspaces.	White spots
Vermiculated sailfin catfish *P. disjunctivus* (Madeira)	9+	White vermiculations and spots	Large dark spots, usually no chevrons	All dark spots combining to form complex net of vermiculations. Dark and light areas of approximately equal width.	Dark spots
Orinoco sailfin catfish *P. multiradiatus* (Orinoco)	9+	Small dark spots	Small dark spots	Small dark spots never combining. Dark and light areas of approximately equal width.	Dark spots
Armadillo del rio *Hypostomus* spp. (Various drainages)	7	Usually small dark spots	Usually small dark spots	Small dark spots or tan.	Dark spots

air during hypoxia and to increase buoyancy for moving about and feeding in the water column (Carter and Beadle 1931, Graham and Baird 1982). High levels of glucose and lactate in the bloodstream (highest recorded for any species of teleost), provide fuel to sustain (or elevate) heart rate during periods of hypoxia (MacCormack et al. 2003a). Under anoxic conditions, potassium channels in the heart reduce the force of blood leaving the heart, thereby conserving energy and preventing cardiac injury when normal oxygen levels are restored (MacCormack et al. 2003b).

Eyes of suckermouth catfishes, unlike those of predatory catfishes that feed in the dark, are equipped with unusual light-adjusting pupils (i.e., an expandable iris operculum) and a retina void of double cone cells, composed entirely of single cones and large rods, and with nasally and a temporally located ganglia (Douglas et al. 2002). These adaptations provide acuity for herbivores feeding on non-moving prey in turbid water and increased spatial resolution along the longitudinal axis of the fish (i.e., directly ahead and behind). The unusual lunate (i.e., omega) pupils may also confer some level of camouflage from predators observing the fish from above while preserving vision of the catfish anteriorly, ventrally, and posteriorly. A more obvious adaptation to reduce predation, however, is the defensive posture exhibited by suckermouth catfish (and many other species of catfishes) when they are handled or threatened: erection of fin spines and expansion of fins (Grier 1980). This makes the fish appreciably larger, and more difficult (and dangerous) to swallow.

Means of Introduction

Three pathways are known for the introduction of suckermouth catfishes: biocontrol, aquaculture (including suppliers for the commercial aquarium trade), and the aquarium hobby (including individual pet owners). Biocontrol is probably a negligible pathway globally but may be important locally or regionally. Suckermouth catfishes were released into the upper San Antonio River during the 1960s in an effort to control algae in pools at the city zoo; they escaped into the river, and persist there today in large numbers (Barron 1964). They have also been introduced into some Mexican waters, including the Balsas Basin, to control macrophytes and algae and are now established in multiple water bodies (Mendoza-Alfaro et al. 2009).

Aquaculture for the aquarium trade is unlikely to be important globally, but is significant regionally. Most species of loricariid catfishes are not readily bred in captivity or easily cultivated in ponds, with some notable exceptions. Armadillo del rio were effectively produced in large numbers by tropical fish farmers prior to 1980 with at least one commercial operation described as a “plecostomus factory” (Grier 1980). Techniques used to harvest the catfish, autumn drawdowns and harvest, make it possible that young fish were dispersed with pumped water at the time adults were harvested. In addition, species of sailfin catfishes have been cultivated in ponds in south Florida and the Balsas River Basin, Mexico (Mendoza-Alfaro et al. 2009). They may have been introduced into adjacent waterways through a combination of failed containment structures, floods, and migration through existing channels (especially in the extensive network of artificial waterways in south Florida).

Release by aquarists is a significant source of introductions globally due to the ubiquity of the hobby and the size of the industry in the United States and Mexico(Mendoza-Alfaro et al. 2010). Suckermouth catfishes are typically kept as solitary specimens by most hobbyists, but due to their famed "janitorial" skills, they are owned by a substantial number of aquarists. A biologist and breeder of suckermouth catfish estimated the captive US population 30 years ago to be 7 million fish (Grier 1980). Because of their distinctive appearance and unusual behavior, the fish endear themselves to their owners (Rogers and Fletcher 2004). They also grow rapidly, attain large sizes, and can be highly disruptive in small tanks (Sandford and Crow 1991). As a result, they soon exceed the abilities of many hobbyists to contain them and are subject to release by well-intentioned, but environmentally misguided, owners. Aquarium releases are believed to account for the establishment of many nonindigenous populations in Hawaii, Mexico, Texas, and Florida.

Once introduced into suitable habitat, these cryptic herbivores may go undetected for long periods. They are hardy and long-lived, so repeated introductions of a few animals can provide sufficient founders to establish a population. These animals also make lateral movements during rising water (Garutti and Figueiredo-Garutti 2000), and may be capable of overland travel. Dispersal and station-holding in flowing water is facilitated by diverse behaviors distinctive to the unusual morphology of the group: substrate suction using the oral disc formed by thick rubbery lips, fin beats using the pelvic fins, and hooking-and-bracing using the pectoral fins, which are equipped with long, tooth- (odontode-) studded spines (Gerstner 2007). These behaviors enable even comparatively small individuals (approximately 80 mm total length) to negotiate flows up to 145 cm/s. Consequently, a single population can quickly colonize adjacent water bodies.

Established populations of suckermouth catfish documented before 1995 include Wahiawa Reservoir, HI (Devick 1988, 1989, 1991), Hillsborough River, FL (Ludlow and Walsh 1991), Bayamon River, Rio Piedras, Rio Loco, and other water bodies in Puerto Rico (Bunkley-Williams et al. 1994), and the San Marcos River, TX (Afflerbach 2005). Established populations documented after 1995 include: Lake Okeechobee, FL (King 2004; Nico 2005); tributaries of Galveston Bay, TX (Robinson and Culbertson 2005), San Felipe Creek, TX (Lopez-Fernandez and Winemiller 2005), and six Pacific and Gulf coastal drainages in Mexico. The San Antonio River appears to have been colonized twice: armadillo del rio prior to 1995, sailfin catfishes after 1995 (Harrison 1969, Hubbs et al. 1978, Edwards 2001).

Interestingly, three of the largest populations occur in areas with a high diversity and abundance of non-native fishes, especially large cichlids: south Florida (Shafland et al. 2008); San Antonio River, TX (Hubbs et al. 1978, Edwards 2001); Infierinillo Reservoir, Mexico (Mendoza-Alfaro et al. 2009). This would suggest that, for North American waters, disturbance by some exotic species facilitates establishment of suckermouth catfishes. One such explanation is that the topographic variation provided by nests of tilapia provide habitat that can be exploited by burrowing suckermouth catfish.

Populations of suckermouth catfishes have also become established in Taiwan (Liang et al. 2005), the Phillipines (Banos 2006; Chavez et al. 2006), peninsular Malaysia including Singapore, Indonesia including Java and Sumatra (Page and Robins 2006), and Turkey (Özdilek 2007). The presumed pathway of introduction in Asian waters is aquarium release or escape from aquaculture facilities. Impacts in these isolated (in some cases, insular) waters may be more rapid and severe than those in continental waters and could provide insights on future conditions in North America.

Loricariid Workshop: Reports and Discussion of Ecological Impacts

A workshop was held 30-31 May 2006 in Gainesville, Florida to present information and concerns regarding suckermouth catfish populations in US and Mexican waters. Twenty-three participants included representatives from universities, consulting firms,

Table 2. Participants in the Loricariid Workshop, 30-31 May 2006, Gainesville, Florida and respondents to survey of field biologists.

Name (Abbreviation Used in Text)	**Affiliation**	**Workshop Attendee**	**Workshop Presenter**	**Survey Respondent**
Jon Armbruster (JA)	Auburn University	+	+	+
Amy Benson (AB)	US Geological Survey	+		
Tim Bonner (TB)	Texas State University			+
Jeremy Brown (JB)	Commission on Environmental Cooperation	+		
Walt Courtenay (WC)	US Geological Survey	+		
Jan Culbertson (JC)	Texas Parks and Wildlife Department	+	+	
Bob Edwards (RE)	University of Texas – Pan American			+
Terry Farrell (TF)	Stetson University	+		
Jeff Fisher (JF)	Entrix	+		
Pam Fuller (PF)	US Geological Survey	+	+	
Gary Garrett (GG)	Texas Parks and Wildlife Department			+
Kelly Gestring (KG)	Florida Fish and Wildlife Conservation Commission	+	+	+
Missy Gibbs (MG)	Stetson University	+		+
Mike Gonzales (SARA)	San Antonio River Authority	+		+
Jeff Hill (JH)	University of Florida	+	+	+
Jan Hoover (ERDC)	US Army Engineer Research and Development Center	+	+	
Howard Jelks (HJ)	US Geological Survey	+		
Roberto Mendoza (RM)	Universidad Autónoma de Nuevo Leon	+	+	+
Catherine Murphy (ERDC)	US Army Engineer Research and Development Center	+		
Leo Nico (LN)	US Geological Survey	+		+
Carlos Ramirez (CR)	Universidad Autónoma de Nuevo Leon	+		
Ramon Ruiz-Carus (RR-C)	Florida Fish and Wildlife Conservation Commission	+	+	+
Bill Smith-Vaniz (BS-V)	US Geological Survey	+		
Oliver Van den Ende (OV)	Dynamac, Florida Technological University	+		+
Steve Walsh (SW)	US Geological Survey	+		
Jim Williams (JW)	US Geological Survey	+		
Kirk Winemiller (KW)	Texas A&M University			+
TOTAL		**23**	**8**	**13**

federal and state resource agencies, and from the Commission on Environmental Cooperation (CEC) (Table 2). The CEC is a tri-national organization established under the aegis of the North American Free Trade Agreement (NAFTA) to address regional environmental concerns, to help prevent potential trade and environmental conflicts, and to promote the effective enforcement of environmental law. The workshop allowed researchers, resource managers, and policy makers to share information on all aspects of loricariid biology including environmental, economic, and social impacts. Day 1 of the workshop consisted of presentations on natural history, field research, and commercial utilization of suckermouth catfishes. Day 2 of the workshop was a group discussion, led by two of the co-authors (Jan Jeffrey Hoover and Catherine Murphy), on development of a conceptual model for environmental risk assessment.

Following the workshop, a survey of 13 field researchers was conducted via email to solicit opinions on the impacts and management of suckermouth catfishes. Three of these respondents were referred by colleagues and were not present at the workshop. Collectively, the respondents worked throughout the introduced and native ranges of those species of loricariidae now occurring in North America, with most doing research in Florida or Texas (Table 3). All worked with either sailfin catfishes or armadillo del rio, and most worked with both. The majority of respondents believed environmental impacts were substantial. Nine ranked impacts high or medium to high; four researchers, all from Florida, ranked environmental impacts low or low to medium.

Table 3. Compilation of responses to a survey of biologists working with suckermouth catfishes in 2006. If respondents provided a range of assessments of environmental impact, then multiple scores are reported (e.g., “low to medium” as “low” and “medium”). If respondents did not specify impacts as low, medium, or high, but listed three or more impacts, a score of “high” was assigned and indicated with an asterisk.

	Geographic Area of Research				**Genera Studied**			**Assessment of Environmental Impacts**		
Respondent	**Florida**	**Texas**	**Mexico**	**Native Range**	***Pterygoplichthys***	***Hypostomus***	**Other**	**Low**	**Medium**	**High**
Jon Armbruster				+	+	+	+			+
Tim Bonner		+			+	+			+	+
Robert Edwards		+			+	+				*
Gary Garrett		+				+				+
Kelly Gestring	+				+	+		+		
Melissa Gibbs	+				+					*
Mike Gonzales		+			+	+				+
Jeff Hill	+				+	+		+		
Roberto Mendoza			+		+	+				+
Leo Nico	+	+		+	+					
Ramon Ruiz-Carus	+				+				+	
Oliver Van Den Ende	+				+			+	+	
Kirk Winemiller		+		+	+	+				*
Total	6	6	1	3	12	9	1	3	3	8

Data, observations, and hypotheses from the workshop and survey are summarized and attributed to workshop participants (identified by their initials or institutional abbreviation throughout the remainder of this article; see Table 2 for identifications). Studies published prior to and subsequent to the workshop are also cited.

Actions of Catfish, Effects on Fauna

Occurrence - Suckermouth catfishes inhabit littoral areas of diverse habitats, are readily observed in clear shallow water, and are frequently abundant. Established populations are known from lakes, rivers, reservoirs, and waterways (Mendoza et al. 2007, Nico et al. 2009) and from urban streams (Tompkins 2004, Cook-Hildreth 2008). They also inhabit warm thermal refugia such as large springs (Barnes 2005, Smith 2005), sub-surface springs and seeps (RR-C), and sewage effluent (JC). Suckermouth catfishes have been collected in oligohaline and mesohaline waters of estuarine systems, and can survive > 7 days in salinities up to 10 ppt, 1-3 days at 11-12 ppt, and up to 5 hr at 16-22 ppt (Capps et al. 2011).

Because they can attain sizes up to 70 cm (Fuller et al. 1999), plough over substrates like bulldozers, and make occasional rapid movements, displacement of other smaller animals (e.g., aquatic insects, crayfishes, fishes, tadpoles) is likely. Displacement may be short-term (i.e., minutes) from startle responses by smaller animals or longer-term (i.e., hours, days) based on prolonged occupation of a specific site by a catfish. Displacement of aquatic animals through “intimidation” by suckermouth catfishes can reduce habitation by amounts comparable to those of extreme physical disturbance or predation (Flecker 1992).

Feeding - Suckermouth catfishes feed by grazing on algal films attached to submerged surfaces including rocks, wood, aquatic vegetation, sediments, and occasionally animals (e.g., Power et al. 1989; Flecker 1992). They also feed on detritus, sediment, and wood (Power 1984a; Ferraris 1991). Wood-eating (xylophagy) is characteristic of some genera (e.g., *Panaque* spp.) and some species of armadillo del rio (e.g., those in the *H. cochliodon* group, which previously had belonged to the separate genus *Cochliodon*) (Armbruster 2003); these wood-eating fishes are famous among hobbyists, who must accommodate their diet and are notorious among local people in their native ranges who must endure them as “canoe eaters” and “canoe destroyers” (Finley 2007).

Despite interspecific variation among taxa, mouth and gut morphology are consistent and characteristic of grazing herbivores (e.g., rasping mouth with numerous teeth, long gut) and gut contents are dominated by plant materials. Armadillo del rio in a Texas river fed primarily on amorphous detritus, and on small quantities of filamentous red algae and picoplankton, but did not feed on macrophytes, macroinvertebrates, or fish eggs (Pound et al. 2011). Sailfin catfish in Florida waterways fed principally on detritus and algae, with crustaceans, insects, mollusks, and arachnids each comprising < 1% of the food volume (Gestring et al. 2010). Concern exists, however, that organisms associated with algae (especially filamentous algae) could be incidentally ingested during grazing.

Less equivocal are the effects of suckermouth grazing on algal standing crops and composition. Reduced algal biomass is obvious as "grazing scars" in otherwise lush growths of algae (Figure 4). Remaining algal communities may change in composition from green-algae-dominated communities to diatoms (Flecker 1992) or diatom-dominated communities to blue-green algae (Power 1984b). Together these result in lost cover and reduced quality of habitat for algae-dwelling invertebrates, lost spawning habitat for phytophilic fishes, and lost food sources for other grazing animals.

Suckermouth catfishes are believed to compete for food with smaller fish, disturb nest sites excavated in algae, and ingest eggs. In Texas, they have been implicated in declines of algae-eating central stonerollers (*Campostoma anomalum*) in the San Antonio River (Hubbs et al. 1978), and are believed to jeopardize populations of the federally threatened Devils River minnow (*Dionda diaboli*) in San Felipe Creek (GG) and the federally endangered fountain darter (*Etheostoma fonticola*) in the San Marcos River (TB). The Devils River minnow is a grazing minnow threatened by competition for food with suckermouth catfishes and possibly egg predation. The fountain darter lays its eggs on algae and is believed to be threatened by loss of spawning habitat and possibly egg predation. The latter case is supported by experiments in which darter egg survival was reduced in the presence of armadillo del rio and by the observation of three darter eggs found in the guts of two armadillo del rio used in the experiments (Cook-Hildreth 2008).

Figure 4. Submersed boulders in the Caloosahatchie River, Florida. White bands are grazing scars denuded of algae by suckermouth catfishes. A sailfin catfish (*Pterygoplichthys* sp.) is present in the center of the picture (within red circle).

Reproduction - Suckermouth catfishes burrow into banks and bottom sediments to create chambers in which females lay eggs and males guard the developing mass of eggs (Burgess 1989; Ferraris 1991). Burrows may be especially evident in highly disturbed urban ponds (ERDC) and streams (Tompkins 2004). When burrows are dense, erosion, sedimentation, and elevated turbidity may result (Devick 1988, 1989, 1991). Bank failure, shoreline collapse, and a characteristic terracing have been observed in Mexico, Texas, and Florida where burrow densities were high (RM; ERDC; OV). Not all infested waters, however, exhibit significant erosion. Detectable habitat changes (e.g., in depth) are only pronounced in the littoral zone closest to the water's edge. A survey of 32 professional water managers from central and south Florida indicated that "loricariids were not a major source of shoreline erosion except in a few local areas" (Gestring et al. 2010). Smaller, shallow water bodies (e.g., urban lakes and ponds) appear more vulnerable to shoreline erosion, possibly due to greater expanses of open banks (i.e., lacking vegetation with supportive root systems) and, in some cases, more adhesive soils with higher silt and organic content (OV). Habitats with extremely sandy substrates have fewer or no burrows (OV, ERDC, LN). In larger, deeper water bodies (e.g., natural lakes), suckermouths may be more likely to burrow in detrital-rich bottom sediments. In navigable rivers, burrows appear to exacerbate erosion but may not be the primary factor due to waves, boat wakes, and other causes (LN).

Published descriptions of burrows of the two genera differ. Burrows of armadillo del rio in Florida ponds have a single opening but subdivide into three or four different tunnels that extend 0.9-1.2 m parallel to the surface of the water (Grier 1980). Burrows of sailfin catfishes in Florida waterways also have a single opening, but a simple straight configuration. They average 14 cm in height, 21 cm in width, and 77 cm in depth (Nico et al. 2009). Burrows are typically located in steeply sloping banks with soils containing almost no gravel > 2 mm, typically < 10 % coarse sand (0.42-2.0 mm), and high percentages of fine sand (0.15-0.25 mm), very fine sand (0.074-0.149 mm), and silts and clays (< 0.074 mm). The cross-sectional area of burrows varies among waterways and is correlated with vertical distance from the water's surface. Density of burrows ranges from 0.48 to 3.93/m^2, which could "significantly contribute to erosion of banks and modification of benthic habitats." Whether differences in structure are due to differences among taxa (*Hypsotomus* versus *Pterygoplichthys*) or in habitat (ponds versus rivers and canals) is unknown, but variation in form and position of burrows could influence sediment export and erosion.

Contours to facilitate burrowing are also provided by variation in bottom topography and, possibly, by depressions constructed by fish that build pit nests (e.g., native centrarchids, exotic cichlids). Suckermouth catfishes have been observed burrowing in the nests of blue tilapia (*Oreochromis aureus*). This could cause fish to abandon nests, reducing reproductive success. After establishment of suckermouth catfishes in the Balsas Basin in Mexico, abundant populations of commercially valuable tilapia (*Oreochromis niloticus*) declined precipitously (RM). Suckermouth catfishes co-occur with tilapia in several areas including San Felipe Creek (Lopez-Fernandez and Winemiller 2005), San Antonio River, Texas (Edwards 2001), and the Hillsborough River system, Florida.

Population growth – Although data on absolute density (numbers/area) and population size (total number of breeding adults) have not been published, data on relative abundance (catch per unit effort) and qualitative observations (intervals between first observation and large number of observations) indicate a high rate of population growth. Typically, populations expand rapidly, with fish becoming abundant within 5-10 years of initial detection and presumed introduction. This has been observed for suckermouth catfishes in Hawaiian waters (Devick 1988, 1989, 1991), San Antonio River (Harrison 1969, Edwards 2001; ERDC), San Felipe Creek (GG), Lake Okeechobee (King 2004, Mendoza-Alfaro et al. 2009), the Wekiva and Little Wekiva Rivers, Florida (Barnes 2005), the Infiernillo Reservoir, Mexico (Mendoza-Alfaro et al. 2009). This is likely a product of continuous emigration from nearby sources (e.g., tropical fish farms, individual hobbyists) and a naturally high intrinsic rate of increase due to rapid growth, high fecundity, and extreme parental investment of individual fish.

Growth and maturity of individuals is extremely rapid. Armadillo del rio in Florida may be mature at lengths of only 150 mm (Grier 1980) – less than half their typical adult size of 400-500 mm (Burgess 1989). This observation is comparable for sizes at maturity of < 140 to 160mm standard length documented for *Hypostomus* spp. in their native range (Nomura and Mueller 1980, Mazzoni and Caramaschi 1995). Female Orinoco sailfin catfish in Florida mature at 160 mm TL (Gestring et al. 2010). In their native range, post-hatching larvae of the snow king (P. anisitsi) attain lengths of 40 mm TL in 7-10 days, even without food (Carter and Beadle 1931). Overall size of other sailfin catfishes is approximately 100-200 mm TL by Age I, and > 300 mm TL by Age II and older (RR-C, JC). Age of maturity is assumed to be 12 months (based on studies within their native range (Winemiller 1989).

Fecundity of suckermouth catfishes is high. Egg masses of armadillo del rio typically contain 500-700 eggs (JH), but fish as small as 242 mm (presumably total length) contain approximately 3000 eggs total fecundity (Azevedo 1938). Batch fecundity (i.e., number of mature oocytes in dissected fish) of armadillo del rio in the San

Marcos River, TX ranged from 871-3367 eggs/ovary (Cook-Hildreth 2008). In Florida, an egg mass was reported to contain 527 eggs (Grier 1980). Data are similar to those from various Hypostomus species in their native range, which have total fecundities of several thousand eggs, and batch fecundities of approximately 1000 eggs (Mazzoni and Caramaschi 1997). Egg masses of sailfin catfishes typically consist of approximately 1000-2000 eggs (RM, KG, JH). Mean batch fecundity of the vermiculated sailfin catfish in Volusia Blue Spring, Florida ranged from 3655 to 6902 (Gibbs et al. 2008). Total fecundity for Orinoco sailfin catfish in southeast Florida ranged from 992-3381 eggs and averaged 1983 eggs (Gestring et al. 2010). Batch fecundity for the same species in its native range is 763 (Winemiller 1989).

Fish are believed to spawn multiple times throughout a protracted spawning season. Several sizes of oocytes, indicative of multiple spawners, are documented for both armadillo del rio and for sailfin catfish (Cook-Hildreth 2008; Gibbs et al. 2008). Based on gonado-somatic indices, the spawning season for armadillo del rio in Texas is March through September and for vermiculated sailfin catfish in Florida, it is May through September. In their native range, Hypostomus spp. also exhibit protracted spawning periods (e.g., > 5 months), usually coinciding with the warm rainy season, and asynchronous oocyte development, indicating serial spawning (Mazzoni and Caramaschi 1997). Orinoco sailfin catfish in south Florida may spawn almost year-round. Gonado-somatic indices are high from April through September, but ripe females were collected every month of the year except December and February (Gestring et al. 2010). In their native range, seasons appear to be shorter (3 months) but multiple reproductive bouts occur (Winemiller 1989). Because suckermouth catfishes are long-lived, with documented lifespans (in their native range) of 7-8 years (Antoniutti et al. 1985; Goulart and Verani 1992) and observed longevity (in aquaria) approaching 20 years (Hinton 1962), the potential lifetime production of gametes by a single adult and resulting population growth are substantial.

Adult population densities are high (GG, TB, ERDC), with large numbers characteristic of disturbed habitats such as reservoirs (RM), urban streams (JC), urban ponds (ERDC), and canals (KG). Because of their rapid maturation, high densities, and long lives, suckermouth catfishes can rapidly monopolize nutrient resources for indefinite periods and can physically inhibit other organisms. Thick boney plates of these massive and abundant animals may constitute a significant sink of phosphorus from some oligotrophic systems, like the San Marcos River (TB). This could reduce primary productivity, which could reduce algal standing crops, secondary productivity, and invertebrate standing crops. All aquatic organisms, especially those that are short-lived and feed on other aquatic prey (plant and animal), could be impacted.

In addition, sheer numbers of these large, grazing animals can create problems for other animals (e.g., competition for food or space with like-sized aquatic organisms, or interference with other animals. Competition has apparently taken place in Hawaiian streams where native species no longer exist in the presence of high densities of suckermouth catfishes (Englund et al. 2000) or are threatened by low water quality after fishkills (Honolulu Advertiser 2006). In Lake Okeechobee, Florida, population increases of Orinoco sailfin catfish between 2005 and 2006 were associated with substantial reductions (i.e., 31-66%) in the abundance of native fishes, notably white catfish (*Ameiurus catus*), Florida gar (*Lepisosteus platyrhincus*), threadfin shad (*Dorosoma petenense*), gizzard shad (*Dorosoma cepedianum*), and largemouth bass (*Micropterus salmoides*) (Mendoza-Alfaro et al. 2009). In Infiernillo Reservoir, declines have been observed in two native fishes, the Balsas catfish (*Ictalurus balsanus*) and the Balsas mojarra (*Cichlasoma istlanum*), coincident with proliferation of suckermouth catfishes (Mendoza-Alfaro et al. 2009). Predation by shorebirds has resulted in death of endangered brown pelicans (Bunkley-Williams et al. 1994). Although this has not been observed in Florida (KG, JH), predation by wading birds is documented in the tropics and is believed to influence depth-distribution of suckermouth catfishes (Power 1984c, Power et al. 1989).

Interactions between suckermouth catfishes and manatees have also been reported. Populations in springs have resulted in increasing numbers of catfish harassing manatees and possibly driving the endangered mammals from their preferred habitat (Barnes 2005, Smith 2005, MG). Recent studies documented dozens of sailfin catfish congregating on manatees, apparently to graze epibiota from their skin, causing some manatees to react with apparent agitation, attempts to dislodge the fish, and in one instance, to cease nursing a calf (Nico et al. 2009). Catfish attachment to manatees takes place during the day, at twilight, and at night; it is most frequent during the day but is restricted to adult fish; and is less frequent at night, when aggregations include adult and juvenile fish (Nico 2010).

Conceptual Model of Ecological Impacts

Suckermouth catfishes function as an environmental stressor; they interact directly with native animals and physically alter the aquatic habitats in which they occur. In their native range, they have been proven to significantly and substantially reduce algal standing crops, overlying organic sediments, and densities of aquatic invertebrates, especially mayflies and midges (Power 1984a, Flecker 1992). Synoptic studies of environmental impacts in North America are lacking. Professional opinions are mixed, with some biologists suggesting negligible or low levels of impact (KG, JH, OV), others moderate levels of impact (RR-C, TB), and other significant or high levels of impact (JA, MG, SARA, GG; KW; RE, RM) (Table 3).

Figure 5 is a conceptual model of the environmental impacts of suckermouth catfishes (observed, likely, and hypothetical). The model identifies the type and potential severity of impacts to different groups of animals (i.e., receptors) and may be used as a tool in assessing environmental risk, managing resources, and planning future research. The severity of impact to individual receptors was determined by the authors of this publication based on literature review, press reports, information presented at the workshop, and personal observations. The model is based on the following assumptions:

Impacts are equally probable from any taxon of suckermouth catfish. The model does not distinguish among taxa, since all introduced species of armadillo del rio and

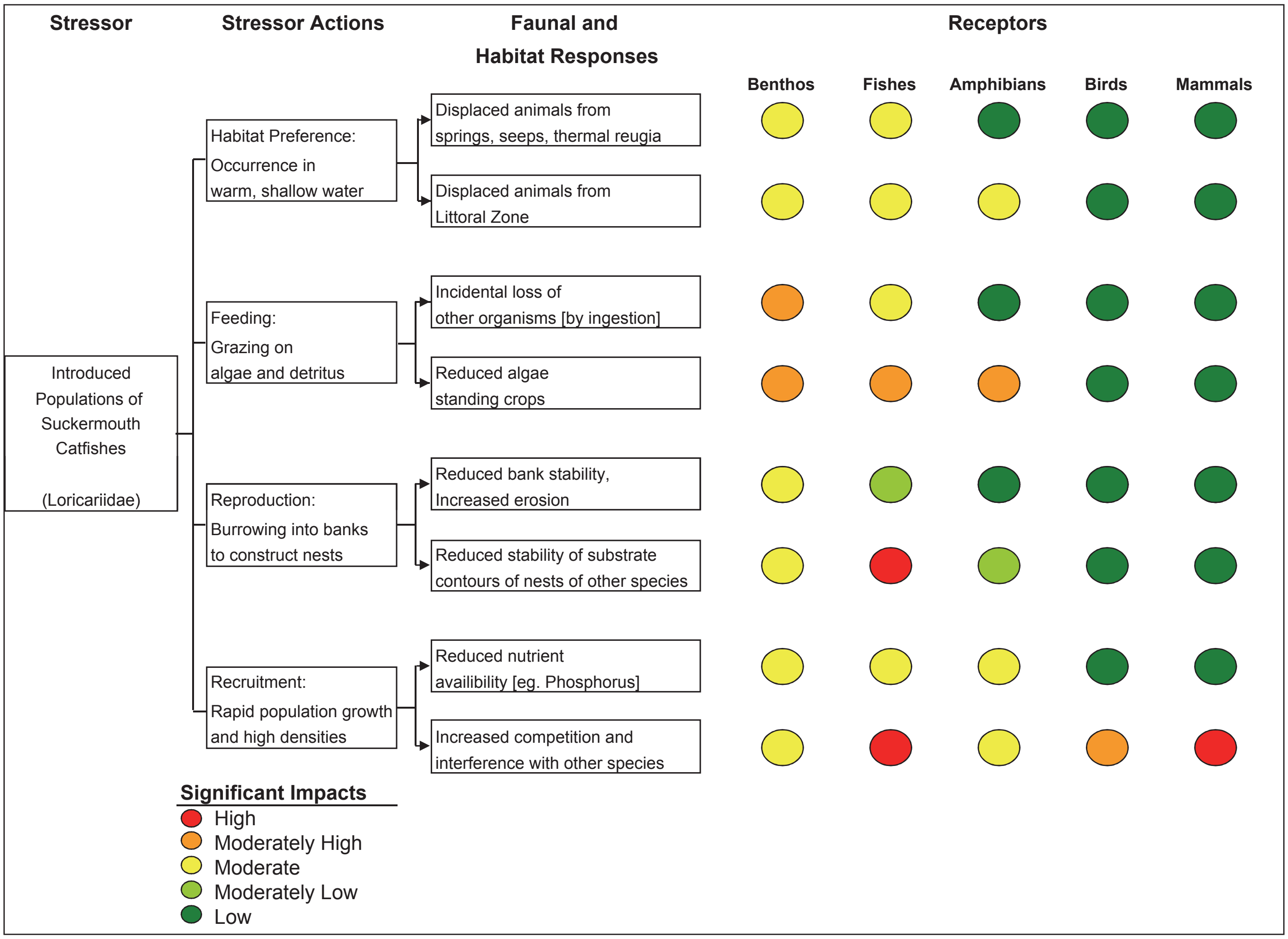

Figure 5. Conceptual model for ecological impacts of suckermouth catfishes.

sailfin catfishes share the same basic life history characteristics (i.e., grazing, burrowing, rapid population growth) and since species-level identifications are tenuous. Established armadillo del rio cannot be reliably identified to species (Page and Burr 1991). Sailfin catfishes occur in polyspecific assemblages in south Florida (ERDC), central Florida (RR-C), Texas (ERDC, SARA), and Mexico (RM). Multiple phenotypes are conspicuous including intermediate forms, which may be hybrids (RM, RR-C). In one case, multiple genotypes have been identified within a single species (JC) and nine forms from a single river system (RR-C).

Impacts are possible in any region or habitat suitable for catfish establishment. GARP (Genetic Algorithm for Rule-Set Prediction) analyses indicate that suckermouth catfishes could potentially occupy extensive portions of Mexico, the southeastern United States, and most Caribbean islands (Mendoza-Alfaro et al. 2009). Consequently, the conceptual model does not distinguish among different geographic regions or habitats. Variation in severity of impacts is known, however. For example, long-term studies in south Florida canals indicate no change in native fish biomass despite invasion and significant population growth by suckermouth catfishes (Gestring et al. 2010). During the same period in Mexican reservoirs, commercial tilapia fisheries collapsed (Mendoza-Alfaro et al. 2009). Level of impact, therefore, is indicated for the worst case scenario based on known case studies.

Local temperature regime does not provide effective control. Most tropical fish commercially available to hobbyists have recommended temperature requirements > 20 °C (e.g., Innes 1948) but suckermouth catfishes are more tolerant of cooler temperatures. Breeders note that armadillo del rio survive at temperatures to 16 °C, but at 13 °C exhibit a distinctive reddening of fins from cold stress (Grier 1980). Winterkills of suckermouth catfishes are not documented for Galveston Bay where water temperatures remain above 15 °C (Robinson and Culbertson 2005) but have been observed in the Hillsborough River at 10-12 °C (RR-C). This suggests lower lethal temperatures of 12-14 °C, but laboratory studies by the Florida Fish and Wildlife Conservation Commission suggest even lower lethal temperatures of < 10 °C (KG). As a result, temperature-based control cannot be assumed for latitudes in which established populations have been documented.

Moderate impacts (or greater) are likely on benthos, fishes, larval amphibians. Suckermouth catfishes will impact littoral aquatic animals in two ways: 1) displacement through physical contact or proximity; 2) reduction in available food through grazing on detritus and algae. Effects on aquatic invertebrates and fishes have been suggested by various researchers (GG, TB, ERDC), but amphibians, to date, have not. Because frog and toad tadpoles have diets similar to those of grazing minnows, but shorter lives and lower mobility (as larvae), food-web-related impacts are presumed comparable or greater than those experienced by fishes.

Impacts to receptor taxa are direct results of catfish life history activities. Indirect, subtle, or unconfirmed environmental changes (e.g., shifts in sediment particle size from fecal production, release of sediment bound nutrients from burrowing) are not addressed. These effects are likely to have significant and long-term impacts on aquatic ecosystems. Suckermouth catfishes produce copious and conspicuous feces (Sandford and Crow 1991, Ferraris 1991, MG, ERDC) which, in aquatic systems, transforms and translocates nutrients, alters sediment characteristics, and impacts microbial and benthic communities (Wotton and Malmqvist 2001), notably so in subtropical environments (e.g., Iovino and Bradley 1969, Frouz et al. 2004). Burrowing activities can displace substantial quantities of bank or bottom material, altering sediment dynamics and water quality (Devick 1988, 1989, 1991). Evaluating severity of impacts to specific faunal receptors, however, would be tenuous based on limited data for recently introduced populations of the catfish.

Parsimonious and prudent assessment of environmental risk should adopt the approach used in a recent risk assessment for snakeheads (Channidae): impacts were assumed to result from direct effects (i.e., predation) rather than indirect effects (e.g., changes in nutrient cycling) (Courtenay and Williams 2004). Snakeheads also provide an interesting test-case for assessing risks associated with suckermouth catfishes. Both groups share important characteristics associated with successful establishment and environmental impacts: high taxonomic diversity, convergent appearance among different species, high degree of parental care and dispersal capability, air-breathing abilities and survival of environmental extremes, and high commercial value in local markets.

Economic and Social Impacts

Impacts from any introduced species reduce the value of ecosystem productivity, ecosystem diversity, recreation, integrity of material goods and aesthetics, and may compromise human health (JB). Invasive populations of suckermouth catfish have been implicated in all of these. Although not explicitly addressed in the conceptual model, they are presented here as possible effects of ecological impacts.

Economic impacts of suckermouth catfishes have been quantified for commercial tilapia fishing in Florida and for Mexico (Mendoza-Alfaro et al. 2009). In Florida, during the period 1993-2006, tilapia catch in six lakes decreased from 45-80% to 17-30% after suckermouth catfishes became established, after which they represented 11-65% of the commercial catch. Assuming no change in absolute numbers of tilapia harvested, three profitability scenarios of increased by-catch of suckermouth catfishes (3,000-9,000 lb/day) could result in doubling of work days (from 7 to 15 hr), a 60% loss in hourly wages, and an $890.00 loss/day/boat (in 2006 dollars). In Mexico, tilapia catch in a reservoir decreased 83% after proliferation of suckermouth catfishes. As a result, individual fishermen spend an additional $1400-$2600/year to replace damaged nets, work an additional 2 hr/day, and lose > $29,000 (US) per year. Total economic losses are approximately $16.4 million: $11.63 million from commercial fishing (e.g., losses in gear, hours worked, revenue from catch, health status), $ 4.74 million from natural capital (e.g., losses in carbon sequestration, water quality, shoreline formation, native fauna), and an unknown quantity from effects on aquarium trade (e.g., sale of illegally traded wild-caught suckermouth catfishes).

Social impacts resulting from economic impacts have been most pronounced in Mexico, where thousands of livelihoods in the Balsas Basin have been affected by the collapse of commercial fisheries. The collapse has impacted health status (e.g., wounds, infections, vaccinations), unemployment, emigration, and has created changes in household structure (Mendoza-Alfaro et al. 2009). Changes in the United States are less severe, but are diverse and potentially significant in Florida. Commercial fishermen in Lake Okeechobee may catch, transport, and dispose of thousands of pounds of suckermouth catfish a day, necessitating longer work-days and requiring payment of substantial disposal fees (King 2004). Fishermen working Gulf estuaries are finding suckermouth catfish in their crab traps (Spinner 2005). Anglers occasionally encounter and sometimes seek out suckermouth catfishes, but widespread effects on recreational fishing are not documented (The City Fisher 2000). Property owners worry about eroding shorelines and the need to stabilize shorelines with unnatural materials like lumber, riprap (ERDC), concrete, and geotextiles (KG), making residential areas less aesthetically pleasing, and reducing property values. Fish kills, such as those recently observed in Hawaii, necessitate biological investigations (Hawaii Channel 2006, Hawaii News 2006) and the possible need for shoreline clean-ups. Based on results from ongoing studies, future social impacts could include conservation and protection measures for threatened and endangered species, particularly in Texas and Mexico.

Two industries have developed around suckermouth populations in Florida that could be considered economic benefits: harvesting and extermination. Year-round demand by the aquarium industry for small “plecos” and the extended spawning season of invasive populations in Florida have created an exploitable resource (i.e., young-of-year and egg masses), harvested by private individuals and purchased for rearing and re-sale by tropical fish farms (Mendoza-Alfaro et al. 2009). In 2006, harvesters could get $0.25 per young-of-year but $5.00 per egg mass (JC, JH). Because each mass can provide 600 young-of-year, to provide 10 million fish annually, fish farmers would need to purchase approximately 17,000 egg masses for $85,000. The share of this total designated for individual collectors is unknown, but is potentially high. A single collector can obtain 100-150 masses per day for a daily income of $500-$700/day (2006 dollars) during the April-October spawning period. Individual incomes are unknown since the work is temporary and part-time, and it is unknown how many collectors exist. Similarly, concentrated populations of suckermouth catfishes in urban environments have fostered a cottage industry of catfish control specialists; business is based on the assumption that reduced numbers of adult fish will reduce erosion and safeguard property value (Distler 2003; Scroggins 2004). “Exterminators” may be paid as much as $10 per catfish removed (Distler 2003). In Hawaii, where nuisance populations have been established the longest, education programs and round-ups are both incorporated as part of Earth Day activities (Hawaii News 2006).

If recreational and commercial markets for suckermouth catfishes and their products could be developed in North America, socio-economic benefits would result and some level of population suppression would be exercised. Suckermouth catfishes are baked “in the shell” and eaten by some people in parts of their native range (Burgess 1989). In Mexico, suckermouth catfishes have been used to produce collagen (a protein used in food and medicines), surimi (fish paste for human consumption) and fishmeal (to feed aquacultured fish)(Mendoza-Alfaro et al. 2009). Around the Infierinillo Reservoir, local communities consume the fish as ceviche (raw fish marinated in citrus juice), soups, and baked (in solar ovens). Concern exists, however, that suckermouth catfishes are prone to high contaminant loads due to their position near the base of the aquatic food web. High levels of mercury were detected in the stomach contents and muscle tissue of suckermouth catfish inhabiting a gold-mining area in South America (Nico and Taphorn 1994), likely a result of these fish ingesting large quantities of contaminated river sediment. Similarly, in Mexico, suckermouth catfishes from Laguna de Bay were found with accumulations of heavy metals (Chávez et al. 2005, cited in Mendoza-Alfaro et al. 2009). Comparable information is not available for Texas and Florida populations, but market value and consumer safety will vary substantially among localities.

Management of Suckermouth Catfishes

Eradication of suckermouth catfishes on any large geographic scale is unlikely but some biologists believe that local suppression and management of populations is possible. Judicious use of ichthyocides in burrows could reduce reproductive success (JA), as could removal of egg masses and young (LN, OV). Removal of larger fish by intensive fishing may be effective in some habitats like springs (RR-C) and could be used to support a commercial market (JH). Effectiveness of different fishing methods (i.e., traps, nets, baits) is under study (GG). Assuming that suckermouth catfishes are food-limited (Power 1984 b, 1984c), creation or restoration of riparian forests to increase shading and reduce primary productivity may also reduce fish abundance, as well as stabilize banks to prevent burrowing. Inability to reduce numbers or contain dispersal will limit management options to damage control via shoreline stabilization (KG, SARA).

Paramount to any management effort is education and public awareness (LN, OV, TB, KW, RE). Educational efforts encouraging aquarists not to release fish are underway at national levels. One such program is Habitattitude TM (http://www.habitattitude.net/) sponsored by the Aquatic Nuisance Species Task Force, US Fish and Wildlife Service, National Oceanic and Atmospheric Administration, and Pet Industry Joint Advisory Council. Local efforts also exist such as press releases in vulnerable regions at times of special risk (e.g., Hodge 2006). Unless aquarists, collectors, and fishermen are informed not to release these fish into the environment, populations of these and related species will grow.

Future Threats from Suckermouth Catfishes

Geographic expansion of range in North America and invasions of North American waters by suckermouth catfishes are likely to continue. Suckermouth catfishes occur throughout the Florida peninsula from 25 to 30 °N (Nico 1999a, 1999b, 2000a, 2000b, 2005). Within this latitudinal range is south Louisiana, where aquaculture is a significant industry. An unlicensed tropical fish operation was documented in south Louisiana in 2004, and a specimen of suckermouth catfish was collected from receding floodwaters following Hurricane Rita in 2005. Above 30 °N are parts of the Florida panhandle, the bootheels of Alabama and Mississippi, and central Louisiana, where urbanized water bodies are numerous and tropical storm-related floods are not uncommon. Location of warm, disturbed, flood-prone waters between areas with

Table 4. Genera of suckermouth catfishes addressed in popular aquarium literature. A "+" indicates text and/or illustrations of that genus appeared in the book; an asterisk (*) indicates mention of the genus. Taxonomy is updated consistent with FishBase. For example, genera reported in historic literature as *Plecostomus* and *Cochliodon* are listed as *Hypostomus*, *Loricaria* (in part) as *Rineloricaria* and *Dasyloricaria*, *Xenocara* as *Ancistris*.

Genus	**1933**	**1934**	**1935**	**1948**	**1955**	**1961**	**1962**	**1963**	**1966**	**1987**	**1988**	**1991a**	**1991b**	**2003**	**2009**
Acestridium														+	
Acanthicus													+		+
Ancistrus					+	+	+	+	+	+	+	+	+	+	
Baryancistrus														+	+
Chaetostoma											+		+	+	
Dasyloricaria									+						
Dekeyseria														+	
Dolichancistrus													+		
Farlowella				+	+	*	*	+	+	+	+	+	+		+
Hemiancistrus												+			
Hemiodontichthys										+			+	+	
Hisonotus									+	+				+	
Hypancistrus														+	*
Hypoptopoma										+	+	+	+	+	
Hypostomus	+	+	+	+	+	+	+	+	+	+	+	+	+		+
Isorineloricaria												+			
Lamontichthys													+	+	
Leporacanthicus												+			+
Lithoxus													+		
Loricarichthys											+	+	+		
Otocinclus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
Panaque										+	+	+	+		+
Panaqolus															+
Parancistrus												+	+	+	
Parotocinclus									+	+	+	+	+	+	
Peckoltia										+	+	+	+	+	
Pseudanthicus							+		+	+		+	+		
Pseudohemiodon											+		+		
Pseudolithoxus														+	
Pseudoloricaria													+		
Pterygoplichthys										+	+	+	+		
Pyxiloricaria													+		
Ricola													+		
Rineloricaria	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
Spatuloricaria													+		
Sturisoma										+	+	+	+	+	+
Genera/reference	3	3	3	4	5	5	6	5	8	14	14	17	25	17	9
Genera/time period	3			9						35					

References used: Coates 1933, Peters 1934, Stoye 1935, Innes 1948, Axelrod and Schultz 1955, Frey 1961, Axelrod et al. 1962, Hervey and Hems 1963, Sterba 1966, Sands 1988, Axelrod et al. 1987, Ferraris 1991, Kobayagawa 1991, Elson and Lucanus 2003, Finley 2009.

established, extensive populations place those water bodies at risk of invasion from colonists moving east from Texas, west from peninsular Florida, or derived locally from aquarium releases. Nearly all of Mexico lies below 30 ^{o}N. Sub-tropical and tropical climates, combined with a large (and in some cases unregulated) tropical fish industry (RM), place much of Mexico within the potential range of suckermouth catfishes.

Taxonomic diversification of imports. Threats exist not only from expanding geographic ranges of suckermouth catfish species already established in North America, but from the expanding pool of species that could become established. Specific and generic designations of suckermouth catfishes are sometimes "ill-defined," but their popularity among, and increasing availability to, aquarists is well-documented (e.g., Robins et al. 1991).

A survey of popular aquarium literature reflects exponential growth of suckermouth genera (most consisting of several species) available to hobbyists over the past century. Numbers of genera discussed in individual reference books has more than doubled and cumulative number of genera has tripled every 35 years (Table 4). Trade in suckermouth catfishes began in 1893 with commercial imports of armadillo del rio (Sterba 1966). By the mid-1930s, three groups represented the aquarium hobby in North America: armadillo del rio (*Hypostomus* spp.), otocinclus (*Otocinclus* spp.), and some whip-tail catfishes (*Rineloricaria* spp.). During the mid-1960s, nine genera were known to hobbyists, including bristle-nosed catfishes (*Ancistrus* spp.), stick or twig catfishes (*Farlowella* spp.), and flame plecos (*Pseudanthicus* spp.). In the early 1970s, these and other suckermouth catfishes were imported into North America at very low prices and in very large numbers. Wholesale prices ranged from $0.10 to $0.50 each; imports from Colombia alone exceeded 1.5 million fish, over 99% of which entered the United States (Conroy 1975). After the 1980s, > 30 genera were known to aquarists, including the sailfin catfishes (*Pterygoplichthys* spp.). These genera often consist of undescribed species, which are made available to hobbyists (e.g., Rogers and Fletcher 2004). Ironically, the natural history, ecology, and physiology of many of these taxa are poorly known.

During the 1970s, more than a dozen suckermouth catfish genera were "clean listed" by US authorities as low-risk wildlife and no state prohibited their sale (Conroy 1975). This included armadillo del rio and sailfin catfishes, which at that time appeared to present no significant environmental impacts. Had greater information been available on their biology (e.g., cold tolerance, proclivity for burrowing, rate of population growth), steps could have been taken to prevent their establishment. At this same time, snakeheads (Channidae), known to be voracious predators, were NOT "clean listed" and many states specifically restricted (Texas) or prohibited imports (Arizona, Florida, Kenntucky, Nevada, Oklahoma, Utah), possibly sparing the United States from earlier and more extensive introductions of that invasive group.

Recommendations

Restricting the import and interstate commerce of suckermouth catfishes is probably not a viable option for management or control. Suggested actions to limit further spread of existing populations in North America and to prevent establishment of new species include:

1) Development of risk assessment tools with greater specificity – for evaluation of newly detected fish (e.g., first records for a locality), newly imported or poorly documented taxa (e.g., genera other than *Hypostomus* and *Pterygoplichthys*), individual water bodies (e.g., an urban pond), and best management practices (e.g., water control devices, shoreline stabilization, removal programs, etc.)

2) Description of natural history and limiting factors on populations – for assessment of threats posed by individual species.

3) Standardization of data collection among field studies – for consistent identification of species, quantification of abundance, and description of environmental impacts so that region-specific risk assessment and management guidelines can be developed.

4) Controlled experimentation investigating candidate impacts – to establish cause-and-effect relationships between occurrence/ abundance of suckermouth catfishes and receptor taxa.

5) Evaluation of efficacy of management techniques – to establish cost benefits and long-term success of eradication

programs (e.g., bounty hunting, round-ups), water level manipulations (i.e., to strand egg masses, reduce movements of adults), and construction and operation of barriers to non-infested water bodies (e.g., electrical arrays, acoustic features).

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References

Afflerbach, F. 2005. Suckers on the loose. *San Marcos Daily Record* [21 Dec 2005].

Alves, A.L., C. Oliveira, and F. Foresti. 2005. Comparative cytogenetic analysis of eleven species of subfamilies Neoplecostominae and Hypsotominae (Siluriformes: Loricariidae). *Genetica* 124: 127-136.

Antoniutti, D.M., M.J.T. Ranzani-Paiva, H.M. Godinho, and P. Paiva. 1985. Relaçã peso/comprimento total, crescimento e idade do cascudo *Plecostomus albopunctatus* Regan, 1908 (Osteichthys, Loricariidae) do rio Jaguari, São Paulo, Brasil. *Boletim do Instituto de Pesca 12*: 105-120.

Armbruster, J. W. 2004. Phylogenetic relationships of the suckermouth armored catfishes (Loricariidae) with emphasis on the Hypostominae and the Ancistrinae. *Zoological Journal of the Linnean Society* 141:1-80.

Armbruster, J. 2003. The species of the *Hypostomus cochliodon* group (Siluriformes: Loricariidae). *Zootaxa* 249: 1-60.

Armbruster, J.W., and L.M. Page. 2006. Redescription of *Pterygoplichthys punctatus* and description of one new species of *Pterygoplichthys* (Siluriformes: Loricariidae). *Neotropical Ichthyology* 4(4): 401-409.

Axelrod, H.R., and L.P. Schultz. 1955. *Handbook of tropical aquarium fishes*. New York: McGraw-Hill.

Axelrod, H.R., C.W. Emmens, D. Sculthorpe, W. Vorderwinkler, and N. Pronek. 1962. *Exotic tropical fishes.* Jersey City, NJ: TFH Publications.

Axelrod, H.R., W.E. Burgess, C.W. Emmens, N. Pronek, J.G. Walls, and R. Hunziker. 1987. *Dr. Axelrod's mini-atlas of freshwater aquarium fishes - mini-edition*. Neptune City, NJ: TFH Publications.

Azevedo, P. de. 1938. O cascudo dos acudes nordestinos: *Plecostomus plecostomus*. *Arquivis do Instituto de Biologia Sao Paulo* 9(20): 211-224.

Banos, M. 2006. Janitor fish threatens Asia's largest marshland. *American Chronicle* [05 Jun 2006].

Barnes, S. 2005. These suckers are dangerous. *Orlando Sentinel* [27 Mar 2005].

Barron, J.C. 1964. Reproduction and apparent overwinter survival of the suckermouth armor catfish, *Plecostomus* sp., in the headwaters of the San Antonio River. T*exas J. Sci.* 16(4): 449-450.

Bunkley-Williams, L., E.H. Williams, Jr., C.G. Lilistrom, I. Corujo-Flores, A.J. Zerbi, C. Aliaume, and T.N. Churchill. 1994. The South American sailfin catfish *Liposarcus multiradiatus* (Hancock), a new exotic established in Puerto Rican fresh waters. *Carrib. J. Sci.* 1-2: 90-94.

Burgess, W.E. 1989. *An atlas of freshwater and marine catfishes – a preliminary survey of the Siluriformes.* Neptune City, NJ: TFH Publications.

Capps, K.A., L.G. Nico, M. Mendoza-Carranza, W. Arevalo-Frias, A.J. Ropicki, S.A. Heilpern, and R.Rodiles-Hernandez. 2011. Salinity tolerance of non-native suckermouth armoured catfish (Loricariidae: *Pterygoplichthys*) in south-eastern Mexico: Implications for invasion and dispersal. *Aquat. Conserv.: Mar. Freshwat. Ecosyst*. 21: 528-540.

Carter, G.S., and L.C. Beadle. 1931. The fauna of the swamps of the Paraguayan Chaco in relation to its environment.-II.

Respiratory adaptations in the fishes. *J. Linn. Soc. Lond.* 37: 327-368.

Chávez, H.A., E. Casao, M. Villanueva, M. Guinto Paras and M. Mosqueda, 2005. *Heavy metals and microbial analyses of janitor fish Pterygoplichthys spp. In Laguna de Bay—An Initial Study*. Unpublished Report, De La Salle University, Manila, Philippines

Chávez, J.M., R.M. de la Paz, S.K. Manohar, R.C. Pagulayan, and J.R. Carandang VI. 2006. New Phillipine record of South American sailfin catfishes (Pisces: Loricariidae). *Zootaxa* 1109: 57-68.

Coates, C. 1933. *Tropical fishes for a private aquarium (=Tropical fishes as pets)*. New York: Liveright Publishing Corporation.

Conroy, D.A. 1975. *An evaluation of the present state of world trade in ornamental fish*. Rome: Food and Agriculture Organization of the United Nations.

Cook-Hildreth, S.L. 2008. Exotic armored catfishes in Texas: Reproductive biology and effects of foraging on egg survival of native fishes (*Ethoestoma fonticola*, endangered, and *Dionda diabola*, threatened). MS thesis, Texas State University, San Marcos, TX.

Courtenay, W.R., Jr., and J.D. Williams. 2004. *Snakeheads (Pisces, Channidae) – a biological synopsis and risk assessment.* Circular 1251. Dever, CO: US Geological Survey

Devick, W. S. 1988. *Disturbances and fluctuations in the Wahiawa Reservoir ecosystem*. Project F-14-R-12, Job 4, Study I. City? Division of Aquatic Resources, Hawaii Department of Land and Natural Resources.

Devick, W. S. 1989. *Disturbances and fluctuations in the Wahiawa Reservoir ecosystem*. Project F-14-R-13, Job 4, Study I. City? Division of Aquatic Resources, Hawaii Department of Land and Natural Resources.

Devick, W. S. 1991. Patterns of introductions of aquatic organisms to Hawaiian freshwater habitats. In *New directions in research, management and conservation of Hawaiian freshwater stream ecosystems. Proceedings of the 1990 symposium on freshwater stream biology and fisheries management,* 189-213. Division of Aquatic Resources, Hawaii Department of Land and Natural Resources.

Distler, L. 2003. Catfish burrows damage lake shoreline. *Florida Community Association Journal* (formerly titled Managers Report) 17[8]: 26-27.

Douglas, R.H., S.P. Collin, and J. Corrigan. 2002. The eyes of suckermouth armoured catfish (Loricariidae, subfamily *Hypostomus* [sic]): Pupil response, lenticular longitudinal spherical aberration and retinal topography. *J. Exp. Biol.* 205: 3425-3433.

Edwards, R.J. 2001. New additions and persistence of the introduced fishes of the upper San Antonio River, Bexar County, Texas. *Texas J. Sci.* 53(1): 3-12.

Elson, G., and O. Lucanus. 2003. *Catfish – everything about natural history, purchase, health care, breeding, and species identification.* Hauppage, NY: Barron's Educational Series, Inc.

Englund, R.A., K. Arakaki, D.J. Preston, S.L. Coles, and L.G. Eldredge. 2000. *Nonidigenous freshwater and estuarine species introductions and their potential to affect sportfishing in the lower stream and estuarine regions of the south and west shores of Oahu, Hawaii*. Bishop Museum Technical Report No. 17. Honolulu, HI.

Ferraris, C., Jr. 1991. *Catfish in the aquarium.* Morris Plains, NJ: Tetra Press.

Finley, L. 2009. *Catfishes – the complete guide to the successful care and breeding of more than 100 catfish species*. Neptune City, NJ: TFH Publications.

Finley, L. 2007. Xylophages and banjofiles. *Tropical Fish Hobbyist* 55(5): 58-60.

Flecker, A.S. 1992. Fish trophic guilds and the structure of a tropical stream: Weak vs. strong indirect effects. *Ecology* 73: 927-940.

Frey, H. 1961. *Illustrated dictionary of tropical fishes*. Jersey City, NJ: TFH Publications.

Frouz, J., R.J. Lobinske, and A. Ali. 2004. Influence of Chironomidae (Diptera) faecal pellet accumulation in lake sediment quality and larval abundance of pestiferous midge *Glyptotendipes paripes*. *Hydrobiologia* 518: 169-177.

Fuller, P., L.G. Nico, and J.D. Williams. 1999. *Nonindigenous fishes introduced to inland waters of the United States*. American Fisheries Society Special Publication 27. Bethesda, MD.

Garutti, V., and M. L. Figueiredo-Garutti. 2000. Lateral migration of *Liposarcus anisitsi* (Siluriformes, Loricariidae) in the Preto river, Alto Parana Basin, Brazil. *Dieringia Serie Zoologia* 88: 25-32.

Gerstner, C.L. 2007. Effect of oral suction and other friction-enhancing behaviors on the station-holding performance of suckermouth catfish (*Hypostomus* spp.). *Canadian Journal of Zoology* 85(1): 133-140.

Gestring, K.B., P.L. Shafland, and M.S. Stanford. 2010. Status of the exotic Orinoco sailfin catfish (*Pterygoplichthys multiradiatus*) in Florida. *Fla. Sci.* 73(2): 122-

137.

Gibbs, M.A., J.H. Shields, D.W. Lock, K.M. Talmadge, and T.M. Farrell. 2008. Reproduction in an invasive exotic catfish *Pterygoplichthys disjunctivus* in Volusia Blue Spring, Florida, USA. *J. Fish Biol.* 73: 1562-1572.

Goulart, E., and J.R. Verani. 1992. Idade e crescimeto do cascudo Hypostomus commersonii Valeneciennes, 1840 (Osteichthys – Loricariidae) da represa Capivari-Cachoeira, Paraná, Brasil. *Revista UNIMAR Orgão Oficial da Universidade Estadual de Maringá* 14(Suppl.): 1-17.

Graham, J.B., and T.A.Baird. 1982. The transition to air-breathing in fishes – I. Environmental effects on the facultative air breathing of *Ancistrus chagresi* and *Hypostomus plecostomus* (Loricariidae). *J. Exp. Biol.* 96: 53-67.

Grier, H. 1980. Plecostomus. *Freshwater and Marine Aquarium* 3(8): 23-26, 85.

Guzmán, A. F. and J. Barragán. 1997. Presencia de bagre sudamericano (Osteichthyes: Loricariidae) en el río Mezcala, Guerrero, México. *Vertebrata Mexicana* 3 : 1-4.

Harrison, R.C. 1969. Plecostomus. *The Aquarium* 2(6): 22-23, 65, 67.

Hawaii Channel. 2006. Hundreds of catfish die in Manoa Stream. *HawaiiChannel* [06 Jan 2006].

Hawaii News. 2006. State to investigate dead fish in Manoa Stream. *Hawaii News* [07 Jan 2006].

Hervey, G.F., and J. Hems. 1963. *Freshwater tropical aquarium fishes*. London: Spring Books.

Hill, J.E. 2002. *Exotic fishes in Florida*. 2002[Spring]: 39-43.

Hinton, S. 1962. Longevity of fishes in captivity, as of September, 1956. *Zoologica* 47(9): 105-116.

Hodge, L. D. 2006. Don't don't dump that aquarium – cute aquarium fish become ugly monsters in springs and streams. *Texas Parks and Wildlife Magazine* 2006 [Aug].

Honolulu Advertiser. 2006. EarthDay events – Armored catfish roundup. *Honolulu Advertiser* [21 Apr 2006]

Hoover, J.J., K.J. Killgore, and A.F.Cofrancesco. 2004. Suckermouth catfishes: Threats to aquatic ecosystems of the United States? *Aquatic Nuisance Species Research Program Bulletin* 4: 1-9.

Hubbs, C., T. Lucier, G.P. Garrett, R.J. Edwards, S.M. Dean, and E. Marsh. 1978. Survival and abundance of introduced fishes near San Antonio, Texas. T*exas J. Sci.* 30(4): 369-376.

Innes, W. T. 1948. *Exotic aquarium fishes*. Philadelphia, PA: Innes Publishing Co.

Iovino, A.J., and W.H. Bradley. 1969. The role of larval Chironomidae in the production of lacustrine copropel in Mud Lake, Marion County, Florida. *Limnol. Oceanogr.* 14: 898-905.

King, R.P. 2004. Burrowing catfish a threat to Lake O. *Palm Beach Post* [21 Jun 2004].

Kobayagawa, M. 1991. *The world of catfishes*. W.E. Burgess, ed. Neptune City, NJ: TFH Publications [originally published as: Catfishes of the World, Marine Planning Co., Tokyo].

Liang, S-H, H-P Wu, and B-S Shieh. 2005. Size structure, reproductive phenology, and sex ratio of an exotic armored catfish (*Liposarcus multiradiatus*) in the Kaoping River of southern Taiwan. *Zool. Studies* 44: 252-259.

Lopez-Fernandez, H., and K.O. Winemiller. 2005. Status of Dionda diaboli and report of established populations of exotic fish species in lower San Felipe Creek. *Southwestern Nat*. 50: 246-251.

Ludlow, M.E., and S.J. Walsh. 1991. Occurrence of a South American armored catfish in the Hillsborough River, Florida. *Fla. Sci.* 54: 48-50.

MacCormack, T.J., R.S. McKinley, R.Roubach, V.M.F. Almeida-Val, A.L. Val, and W.R. Driedzic. 2003a. Changes in ventilation, metabolism, and behaviour, but not bradycardia, contribute to hypoxia survival in two species of Amazonian armoured catfish. *Can. J. Zool.* 81: 272-280.

MacCormack, T.J., J.R. Treberg, V.M.F. Almeida-Val, A.L. Val, and W.R. Driedzic. 2003b. Mitochondrial KATP channels and sarcoplasmic reticulum influence cardiac force development under anoxia in the Amazonian armored catfish *Liposarcus pardalis*. *Comp. Biochem. Physiol.* A 134: 441-448.

Mazzoni, R., and E.P. Caramaschi. 1997. Spawning season, ovarian development and fecundity of *Hypostomus affinis* (Osteichthys, Loricariidae). *Rev. Brasil. Biol.* 57(3): 455-462.

Mazzoni, R., and E.P. Caramaschi. 1995. Size structure, sex ratio, and onset of sexual maturity of two species of *Hypostomus*. *Journal of Fish Biology* 47: 841-849.

Mendoza-Alfaro, R.E., B. Cudmore, R. Orr, J.P. Fisher, S.C. Balderas, W.R. Courtenay, P.K. Osorio, et al. 2009. *Trinational risk assessment guidelines for aquatic alien invasive species – test cases for the snakeheads (Channidae) and armored catfishes (Loricariidae) in North American inland waters*. CEC Project Report. Montreal (Quebec), Canada: Commission on Environmental Cooperation.

Mendoza-Alfaro, R., C. Ramírez-Martínez, S. Contreras-Balderas, P. Koleff-Osorio, and P. Álvarez-Torres. 2010. *Aquarium trade as a pathway for the introduction of invasive species into México. In Aquaculture: Types, economic impacts, and environmental impacts*, ed. F. De Carlo and A. Bassano, 209-224. New York: Nova Science.

Mendoza, R., S. Contreras, C. Ramirez, P. Koleff, P. Alvarez, and V. Aguilar. 2007. Los peces diabolo: Species invasoras de alto impacto. *Biodiversitas [Boletín Bimestral de la Comisíon Nacional para el Conocimiento y Uso de la Biodiversidad, Mexico* 7: 2-5.

Nico, L. 1999a. *Pterygoplichthys anisitsi*. Nonindigenous aquatic species fact sheet 766. United States Geological Survey. http://nas.er.usgs.gov.queries/SpfactSheet.asp?speciesID=766

Nico, L. 1999b. *Pterygoplichthys disjunctivus. Weber 1991.* Nonindigenous aquatic species fact sheet 767. United States Geological Survey. http://nas.er.usgs.gov.queries/SpfactSheet.asp?speciesID=767

Nico, L. 2000a. *Pterygoplichthys multiradiatus (Hancock 1828).* Nonindigenous aquatic species fact sheet 768. United States Geological Survey. http://nas.er.usgs.gov.queries/SpfactSheet.asp?speciesID=768

Nico, L. 2000b. *Pterygoplichthys pardalis (Castelnau 1855)*. Nonindigenous aquatic species fact sheet 769. United States Geological Survey. http://nas.er.usgs.gov.queries/SpfactSheet.asp?speciesID=769.

Nico, L. 2005. Changes in the fish fauna of the Kissimmee River Basin, peninsular Florida: Non-native additions. In *Historical changes in large river fish assemblages of the Americas*, ed. J. Rinne, R. M. Hughes, and B. Calamusso, 523-556. Bethesda, MD: American Fisheries Society Symposium 45.

Nico, L.G. 2010. Nocturnal and diurnal activity of armored suckermouth catfish (Loricariidae: *Pterygoplichthys*) associated with wintering Florida manatees (*Trichechus manatus latirostris*). *Neotropical Ichthyology* 8(4): 893-898.

Nico, L. G., and D. C. Taphorn. 1994. Mercury in fish from gold mining regions in the upper Cuyuni River system, Venezuela. *Fresenius Environmental Bulletin* 3:287-292.

Nico, L., and P. Fuller. 1999. *Hypostomus sp*. Nonindigenous aquatic species fact sheet 762. United States Geological Survey. http://nas.er.usgs.gov.queries/SpfactSheet.asp?speciesID=762

Nico, L.G., and R.T. Martin. 2001. The South American suckermouth armored catfish, *Pterygoplichthys anisitsi* (Pisces: Loricariidae), in Texas, with comments on foreign fish introductions in the American southwest. *Southwestern Naturalist* 46: 98-104.

Nico, L.G., W.F. Loftus, and J.P. Reid. 2009. Interactions between non-native armored suckermouth catfish (Loricariidae: *Pterygoplichthys*) and native Florida manatee (*Trichechus manatus latirostris*) in artesian springs. *Aquatic Invasions* 4(3): 511-519.

Nomura, H., and I.M. de M. Mueller. 1980. Biologia do cascudo, Plecostomus hermanni Ihering, 1905 do Rio Mogi Guaçu, São Paulo (Osteichthyes, Loricariidae). *Rev. Brasil. Biol.* 40(2): 267-275.

Özdilek, S.Y. 2007. Possible Threat for Middle East Inland Water: An Exotic and Invasive Species, *Pterygoplichthys disjunctivus* (Weber, 1991) in Asi River, Turkey (Pisces: Loricariidae). E.U. *J. Fish. Aquat. Sci.* 24(3-4): 303-306.

Page, L.M., and B.M. Burr. 1991. *A field guide to freshwater fishes – North America North of Mexico*. Boston, MA: Houghton Miflin Company.

Page, L. 1994. Identification of sailfin catfishes introduced to Florida. *Fla. Sci.* 57(4): 171-172.

Page, L.M., and R.H. Robins. 2006. Identification of sailfin catfishes (Telesotei: Loricariidae) in southeastern Asia. *Raffles Bull. Zool.* 54[2]: 455-457.

Peters, C.H. 1934. *Life and love in the aquarium.* New York: Empire Tropical Fish Import Company.

Pound, K.L., W.H. Nowlin, D.G. Huffman, and T.H. Bonner. 2011. Trophic ecology of a nonnative population of suckermouth catfish (*Hypostomus plecostomus*) in a central Texas spring-fed stream. *Environ. Biol. Fish*. 90: 277-285.

Power, M. E. 1984a. The importance of sediment in the grazing ecology and size class interactions of an armored catfish, Ancistrus spinosus. *Env. Biol. Fishes* 10: 173-181.

Power, M.E. 1984b. Habitat quality and the distribution of algae-grazing catfish in a Panamanian stream. *J. Anim. Ecol.* 53: 357-374.

Power, M.E. 1984c. Depth distributions of armored catfish: predator-induced resource avoidance. *Ecology* 65: 523-528.

Power, ME., T.L. Dudley, and S. D. Cooper. 1989. Grazing catfish, fishing birds, and attached algae in a Panamanian stream. *Env. Biol. Fishes* 26: 285-294.

Ramírez–Soberón, G., X. Valencia Díaz, and M. T. Gaspar–Dillanes. 2004. *Nuevo récord de bagres sudamericanos*

Liposarcus multiradiatus y L.spp. en las lagunas de Catazajá y Medellín, Chiapas. Resúmenes del IX Congreso Nacional de Ictiología, Villahermosa.

Robins, C.R., R. M. Bailey, C. E. Bond, J. R. Brooker, E. A. Lachner, R. N. Lea, and W. B. Scott. 1991. *World fishes important to North Americans exclusive of species from the continental waters of the United States and Canada*. Bethesda, MD: American Fisheries Society.

Robinson, L. and J. Culbertson. 2005. *A synoptic survey for non-indigenous ichthyofauna in selected tidal bayous of Galveston Bay*. Unpublished report prepared for the Texas Commission on Environmental Quality, Houston, TX.

Rogers, G., and N. Fletcher. 2004. *Focus on freshwater aquarium fish*. Richmond Hill, ON: Firefly Books.

Sandford, G., and R. Crow. 1991. *The manual of tank busters*. Morris Plains, NJ: Tetra Press.

Sandoval-Huerta, E.R., X. Madrigal-Guridi, A. García-Meraz, N.I. Dimas-Mora, and O. Domínguez-Domínguez. 2012. New record of *Pterygoplichthys disjunctivus* (Actinopterygii: Loricariidae) in the mouth of the Coahuayana River, Coahuayana, Michoacán, Mexico. *Revista Mexicana de Biodiversidad* 83: 294-297.

Sands, D. 1988. *A fishkeeper's guide to South American catfishes*. London, UK: Salamander Books Limited.

Scroggins, B. 2004. *One man's battle against destructive fish*. ABC7-News Fort Myers [19 Nov 2004].

Shafland, P.L., K.B. Gestring, and M.S. Stanford. 2008. Florida's exotic freshwater fishes-2007. *Fla. Sci.* 71(3): 220-245.

Smith, V. 2005. Armored catfish invade winter refuge for manatees. *Daytona Beach News-Journal* [25 Dec 2005].

Spinner, K. 2005. Demand high for blue crabs, but populations dwindling. *Naples Daily News* [12 Nov 2005]

Sterba, G. 1966. *Freshwater fishes of the world*. New York: Pet Library Ltd.

Stoye, F.H. 1935. *Tropical fishes for the home – their care and propagation*. New York: Carl Mertens.

The City Fisher. 2000. New neighbors – exotic fishes – sailfin catfish. *The City Fisher* 4[Jul-Sep]: 1.

Tompkins, S. 2004. We're being invaded by lots of aliens. *Houston Chronicle* 25 Nov 2004.

Walker, B. 1968. The fish with the folded mouth. *The Aquarium Series* II1(10): 4-5, 36-43.

Wakida-Kusonoki, A.T., R. Ruiz-Carus, and E. Amador del Angel. 2007. Amazon sailfin catfish, *Pterygoplichthys pardalis* (Castelnau, 1855) (Loricariidae), another exotic species established in southeastern Mexico. *Southwestern Nat*. 52(1): 141-144.

Winemiller, K.O. 1989. Patterns of variation in life history among South American fishes in seasonal environments. *Oecologia* 81: 225-241.

Weber, C. 1991. Revision du genre *Pterygoplichthys* sensu lato (Pisces, Siluriformes, Loricariidae). *Revue fr. Aquariol.* 19: 1-36.

Wotton, R.S., and B. Malmqvist. 2001. Feces in aquatic ecosystems. *BioScience* 51: 537-544.

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