Canals as Vectors for Fish Movement: Potential Southward Range Expansion of *Lepisosteus osseus* L. (Longnose Gar) in South Florida

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Abstract - *Lepisosteus osseus* (Longnose Gar) is a large-bodied predator, whose Florida distribution remains unclear at the southern edge of its range. We reviewed available literature and museum voucher specimens to provide a more accurate range description, and we discuss recent collections in south Florida. Longnose Gar has not been previously reported in natural habitats south of Lake Okeechobee. Instead, records south of the lake are from canals, and most are recent (since 2000), including our own southernmost 2011 record. No records from Everglades natural habitats have been collected. Previous studies have shown native range expansions in anthropogenically disturbed landscapes. We suggest that the Longnose Gar is expanding its range southward in Florida using canals as dispersal vectors and/or suitable habitat.

Introduction

Lepisosteus osseus L. (Longnose Gar) is one of seven extant species in the fish family Lepisosteidae. Longnose Gar has anatomically distinct characteristics—primarily its thin, elongate snout, which more than doubles head length and is significantly longer than that of close relatives (Suttkus 1963)—that easily distinguish it from other Lepisosteids. Aside from snout length, a single row of sharp villiform teeth in the upper jaw allows this species to be easily distinguishable from *Atractosteus spatula* Lacepede (Alligator Gar; Page and Burr 1991). The coloration of Longnose Gar is olivaceous brown dorsally and into the sides, fading to a pale yellow or white ventrally (Becker 1983, Suttkus 1963). Young have a pronounced broad, dark mid-lateral stripe that runs from the snout to the base of the caudal fin with a distinct white stripe directly below it (Becker 1983, Smith 2002). Coloration varies in relation to water clarity; dark spots on unpaired fins extending into the body and the dorsal region of the head in clear water, and a deeper green coloration with stronger brown hues in murky waters (Suttkus 1963). Longnose Gar is more common in freshwater, although individuals have been caught at salinities as high as 33 psu (Goodyear 1967, Hildebrand and Schroeder 1928, Jean 1946, Schwartz 2003, Swift et al. 1977).

Once geographically widespread, fossils of all seven extant species of gar have been found throughout North America, Europe, Africa, and Asia, and date to the lower Cretaceous period (Helfman et al. 2009, Stiassny et al. 2004, Wiley 1976).

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However, its present-day range is considerably narrower, extending from Quebec to Florida, into the Mississippi and Rio Grande drainages (Hubbs et al. 2008, Page and Burr 1991). In Florida, the delineation of its distribution is somewhat unclear. Some authors have described Longnose Gar's distribution to be statewide (Briggs 1958, Carr and Goin 1955, Stevenson 1976), while others suggest a southern boundary. Kilby and Caldwell (1955) conducted the first survey of fishes in south Florida, and considered Lake Okeechobee to be the southern end of its range. Ager (1971) also reported Longnose Gar in Lake Okeechobee, while Lee et al. (1980) mapped a central Florida boundary and vaguely stated its distribution as "Florida", and Page and Burr (1991) delineated its range as "central Florida".

To clarify the natural range of Longnose Gar in Florida, particularly along the southern boundary of its distribution, we compiled available records of its occurrence in natural habitats from the published and available grey literature and from museum voucher specimens. By natural habitats, we refer to lakes, ponds, rivers, wetlands, and estuaries, but exclude artificial habitats such as canals. We also noted icthyofaunal studies that report no observations or collections of this species. Lastly, we highlight recent records of this species south of Lake Okeechobee, all from canals, including the southernmost record to date, which is from our own sampling. Our objectives were to (1) clarify the native range distribution of Longnose Gar in natural waters of Florida, and (2) discuss the possibility that the Longnose Gar is undergoing a recent southern range expansion in the Everglades region, facilitated by canals.

Methods

Our literature review yielded 15 studies (1935–1990) showing 32 records of Longnose Gar from nine of the 14 major Florida drainages excluding south Florida (Table 1). We complemented the literature findings with over 160 museum voucher specimens (1948–2009) obtained from the Florida Museum of Natural History and the Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute. We plotted these records, which span the past 74 years, using ArcGIS 9 (Fig. 1). For the museum specimens, we plotted only those that constituted new locations from those already reported in the field studies, totaling 37 additional records (Fig. 1). To explore the possibility of a southward range expansion of Longnose Gar, we then noted at least 17 observations reported from the Everglades region, beginning with the first reports by Dineen (1974) (Table 2). These new records include the southernmost record to date, in western Miami-Dade County, from our own monitoring efforts of fishes in canals bordering Everglades National Park (ENP). Similarly, we used ArcGIS 9 to map these new south Florida records (Fig. 2).

Results and Discussion

Our review indicates that the Longnose Gar occurs naturally throughout Florida, extending as far south as Lake Okeechobee and the Loxahatchee River, but we found no records from natural habitats in the extreme southern part of Florida, including the Everglades (Table 1, Fig. 1). Four studies indicated that Longnose Gar commonly occur throughout the Florida panhandle (Table 1, Fig. 1), whereas 11 studies

describe their occurrence in water bodies spanning from the St. Johns and southward to the Peace and Kissimmee drainage basins. The voucher specimens contributed records for an additional two drainages (Aucilla-Waccasassa and East Coastal) along the coastal panhandle and the Atlantic coastal region of central Florida.

For the Greater Everglades region, we examined 20 fish studies south of Lake Okeechobee conducted between 1955 and 2011, none of which reported Longnose Gar occurrences from natural habitats (Table 1, Fig. 1). Collectively,

Table 1. Summary of 35 studies noting the occurrence or absence of *L. osseus* in Florida. All of these studies are shown in Figure 1. For habitat type: E = estuarine, C = canal, CC = coastal creeks, L = lake, M = marsh, P = pond, R = river, S = spring. For notes on occurrence: O = observed, C = collected, NS = not specified, A = not observed or collected. For sampling gear: A = angling, D = drop trap, E = electrofishing, EG = entanglement gear, O = other, R = rotenone, SP = spear fishing, T = throw trap, V = visual.

Source	Habitat type	Drainage basin	Occurrence	Sampling gear
Goff 1935	L	St. Johns	O	O
Fowler 1940	L	St. Johns	O	V
Hubbs and Allen 1943	S	St. Johns	C	SP
Allen 1946	S	St. Johns	O, C	V
Herald and Strickland 1949	R, S	Tampa	O	O
Moody 1954	L	Tampa, St. Johns	C	EG
Holloway 1954	L, R	St. Johns	C	SP
McLane 1955	R	St. Johns	O, C	EG, O
Hellier 1967	R	Suwannee	O, C	EG, O
Tagatz 1967	R	St. Johns	NS	EG
Ager 1971	L	Kissimmee	C	EG
Beecher et al. 1977	R	Escambia	O, C	E, EG
Swift et al. 1977	R, E	Ochlockonee	C	EG, O
Beecher and Hixson 1982	R	Choctawhatchee, Apalachicola, Escambia	O, C	E
Champeau 1990	R	Peace	O, C	E
Kilby and Caldwell 1955	M, C	South Florida	A	O
Kahl 1964	M	South Florida	A	EG, O
Kushlan 1972	M	South Florida	A	O
Kushlan and Lodge 1974	M, C	South Florida	A	O
Kushlan 1976	M	South Florida	A	O
Carlson and Duever 1977	M	South Florida	A	O
Loftus and Kushlan 1987	M, R, C	South Florida	A	A, E, EG, O, R, T
Lorenz et al. 1997	M, E	South Florida	A	D
Fury et al. 1995	M, C	South Florida	A	EG
Trexler et al. 2001	M, C	South Florida	A	E, T
Chick et al. 2004	M	South Florida	A	E
Ellis et al. 2003	M, R, P, C	South Florida	A	E, EG, O, V
Trexler et al. 2005	M	South Florida	A	T
Ruetz et al. 2005	M	South Florida	A	T
Kline and Bamford 2006	M, C	South Florida	A	O, T
Lorenz and Serafy 2006	M, E	South Florida	A	D
Rehage and Trexler 2006	M	South Florida	A	E, T
Rehage and Loftus 2007	HC	South Florida	A	E
Kline and Fratto 2008	M, C	South Florida	A	O, T
Parkos et al. 2011	M	South Florida	A	E

these studies surveyed wide expanses of the Greater Everglades region, from the water conservation areas (WCAs), south to ENP, and stretching into the marsh-mangrove ecotone (Table 1, Fig. 1). The studies used different sampling techniques and targeted a variety of habitats, including freshwater marshes, coastal mangroves, alligator holes, and ponds. Additionally, eight of those studies also surveyed canals but reported no records (Table 1). Similarly, a number of studies by P. Shafland (Non-Native Fish Laboratory, Florida Fish and Wildlife Conservation Commission, Boca Raton, FL) conducted between 1975–2008 largely in canals, reported no occurrences over this period (e.g., Shafland et al. 2008). Loftus and Kushlan (1987) sampled 181 sites encompassing a range of freshwater and coastal habitats in urban Miami and the southern Everglades and noted Longnose Gar to be a species of "doubtful occurrence" that had not been collected in extreme southern Florida.

In contrast, recent records indicate that Longnose Gar is in fact present in south Florida, but appear confined to canal habitats (Table 2, Fig. 2). We report 12 observations (totaling at least 17 fish) beginning with several specimens reported in 1974, and a number of recent observations since 2000, which include one museum specimen (Table 2, Fig. 2). Dineen (1974) collected the species in the northern Everglades as part of a 12-year monitoring project (1962–1974) conducted by the Florida Game and Freshwater Fish Commission. He reported several Longnose Gar collected from the south side of the L-39 canal in northern WCA 2A in 1965 (collected via rotenone and netting), and noted one other specimen caught by an

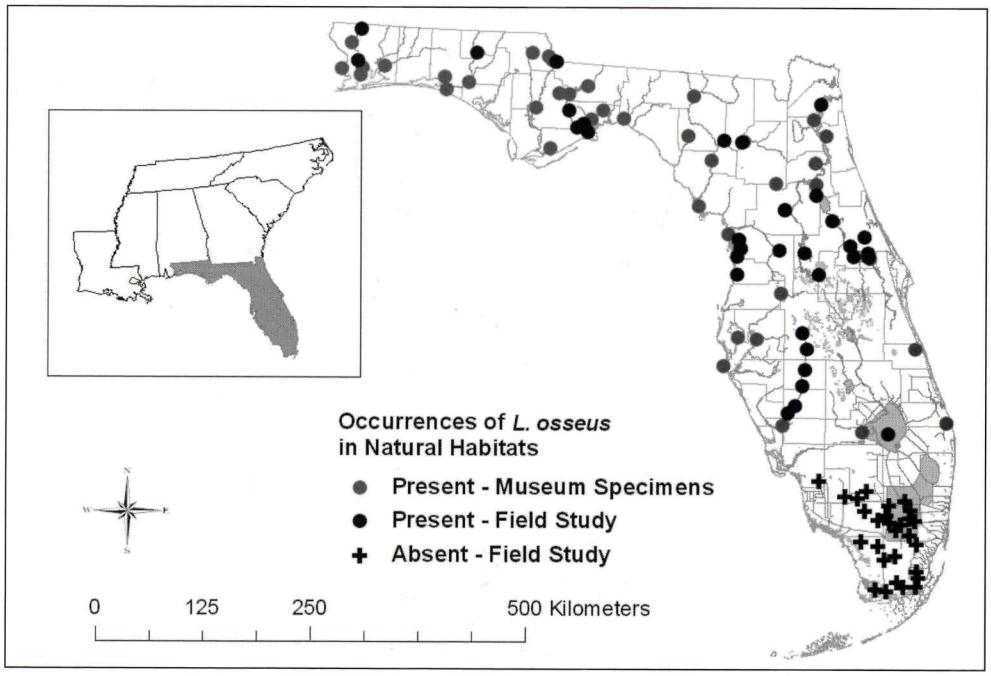

Figure 1. Map of the State of Florida showing presence or absence of *L. osseus* in natural habitats (e.g., marshes, rivers, lakes). Presence studies are from 1935 to 1990, while absence studies date from between 1950 to 2011 (see Table 1). Museum voucher specimens are shown in grey symbols (37 records), while field studies are shown in black symbols (32 records).

angler in 1972 from the L-39B canal (Fig. 2). The remaining 15 specimens collected or observed between 2000 and 2011 are also exclusively from Everglades or urban canals. This includes the southernmost record to date (one specimen, 118 cm TL), collected in November 2011 from the L-31W canal via boat-mounted electrofishing (Table 2, Fig. 2). Interestingly, most records are of adults (80–118 cm TL), whereas the five juvenile records (41–47.5 cm TL) are from the L-40 and L-7 canals (closer to Lake Okeechobee than all adult records).

These new records south of Lake Okeechobee suggest a southern range expansion for Longnose Gar into south Florida. Its presence in south Florida exclusively in a large, interconnected network of canals indicates that canals may be serving as conduits for its dispersal, and/or suitable habitat for this species since no specimens have been collected in natural Everglades marshes or other deep-water habitats. Elsewhere, Longnose Gar is commonly observed over a range of low to moderate flow conditions and salinities, and is more commonly

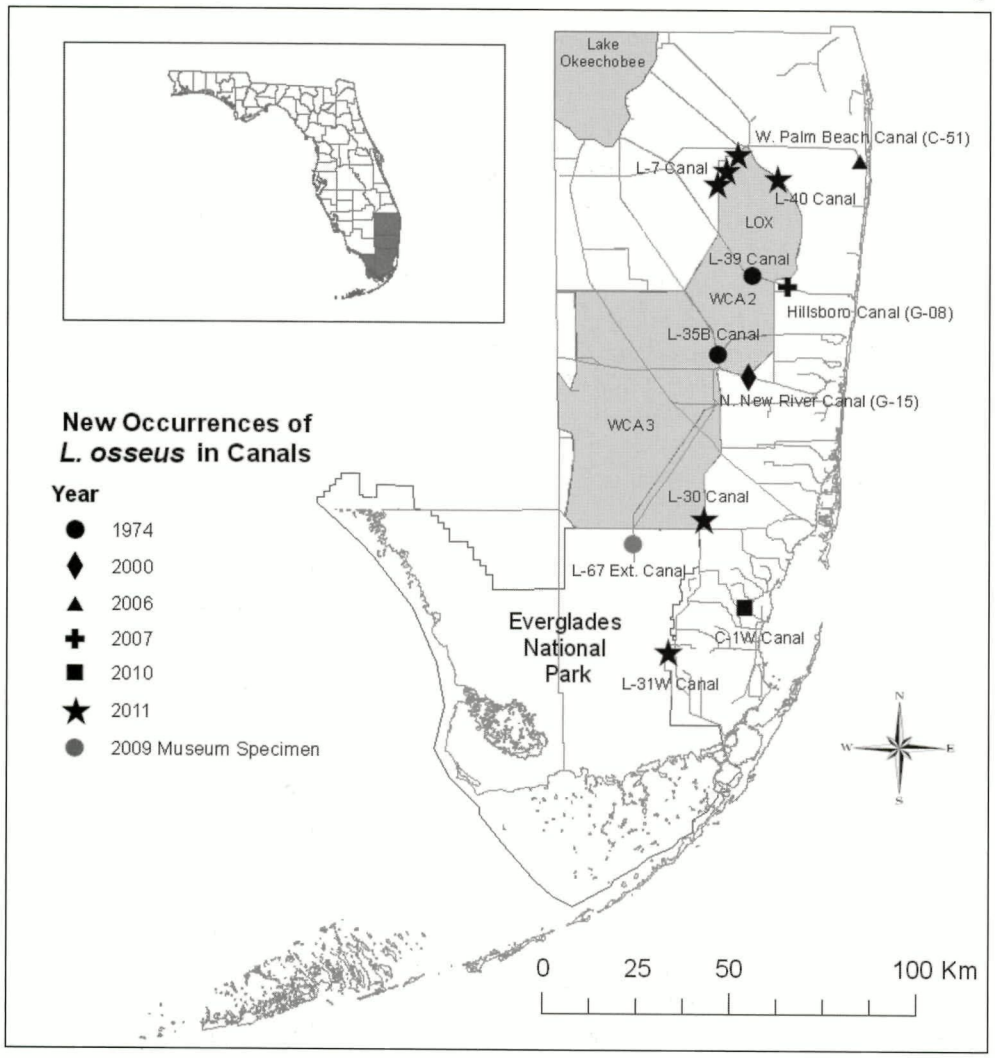

Figure 2. Map of south Florida showing new occurrences of *L. osseus* from 1974 to 2011 in canals both in the Everglades region and urbanized south Florida (see Table 2).

found in deep and structurally complex portions of lakes and river channels (McGrath 2010, Suttkus 1963). Robertson et al. (2008) examined the association between hydrologic connectivity and habitat partitioning among three gar species in a Texas river, and found that 84% of Longnose Gar were captured in the river channel rather than in shallower, associated oxbows.

Relatively little is known about the movement or home range of this species, except for migratory movements during the reproductive season. Johnson and Noltie (1996) found that resident lake Longnose Gar move into stream tributaries to spawn, and reported post-spawning recaptures as far as 48 km away from spawning grounds. Spawning migrations of Longnose Gar were positively correlated to stream flow, and individuals exhibited high annual site fidelity to spawning grounds. In our canals, the majority of records are adults; thus, it remains unclear whether the use of canals is related to spawning. The exact source population for this range expansion is not known, but we hypothesized that movement out of Lake Okeechobee, or via the lake from other water bodies, is most likely because of its connectivity to south Florida's canal network.

The modern Everglades canals date back to the 1880s, and currently amount to 2500 km of canals and levees that compartmentalize the system, disrupting sheet flow and hydrologic connectivity (Light and Dineen 1994, Sklar et al. 2002). Canals in the system play a number of roles, by acting as sources of nutrients, pollutants, and non-native species (Harvey et al. 2010). From a biotic standpoint, their role as thermal refugia for non-native fishes is of importance, and likely a key factor in the persistence of non-native populations (Schofield et al. 2010, Trexler et al. 2001). Canals may also provide permanent deep-water refuge for biota that were historically rare or absent in the ecosystem (Gunderson and Loftus 1993), and whose habitat quality is unknown. Their role as dispersal vectors,

Table 2. Summary of new records of *L. osseus* in south Florida in artificial canals, 1974–2011, also mapped in Figure 2. For occurrence (occur.): A = caught by recreational angler, C = collected, O = observed, NS = not specified and number in parenthesis refers to the number of specimens reported. For sampling gear type: A = angling, E = electrofishing, EG = entanglement gear, R = rotenone.

Water body	Rec. #	Yr	Northing	Easting	Occur.	Sampling gear	Source
L-35B Canal	1	1974	2895649	555367	A (1)	A	Dineen 1974
L-39 Canal	1	1974	2916862	564586	C (NS)	EG, R	Dineen 1974
N New River Canal (G-15)	2	2000	2889937	563592	C (3)	E	This study
W Palm Beach Canal (C-51)	3	2006	2947448	593424	C (1)	E	This study
Hillsboro Canal (G-08)	4	2007	2913997	574002	C (2)	E	This study
L-67 Ext. Canal	5	2009	2844965	532847	C (1)	E	Museum specimen*
C-1W	6	2010	2828223	562775	O (1)	E	This study
L-30 Canal	7	2011	2851843	551886	A (1)	A	This study
L-31W Canal†	8	2011	2816214	542367	C (1)	E	This study
L-7 Canal	9	2011	2949185	560630	C (2)	E	This study
L-7 Canal	10	2011	2944924	557692	C (1)	E	This study
L-7 Canal	11	2011	2941148	555308	C (1)	E	This study
L-40 Canal	12	2011	2942696	571439	C (1)	E	This study

†Denotes the southernmost and most recent record in southern Miami-Dade County.

*Denotes a voucher specimen provided by University of Florida, Florida Museum of Natural History, Division of Ichthyology, Gainesville, FL; collected by J. Kline; and deposited by L.M. Page.

suitable year-around deep habitats, and as corridors for range expansion of native fishes has been previously noted (Ellis et al. 2003, Harvey et al. 2010, Loftus and Kushlan 1987). Loftus and Kushlan (1987) found that *Esox niger* Lesueur (Chain Pickerel), *Ictalurus punctatus* Rafinesque (Channel Catfish), and *Pomoxis nigromaculatus* Lesueur (Black Crappie) were widely distributed in central Florida, but were common in south Florida only in canals. We can now add Longnose Gar to the list of species that use canals as dispersal corridors or suitable habitat in extreme southern Florida.

South Florida canals may break down dispersal barriers previously provided by shallow-vegetated wetlands that experience seasonal dry-down. The pattern of seasonal dry down of Everglades marshes is known to limit the abundance of large-bodied fishes (Chick et al. 2004, Parkos et al. 2011, Rehage and Loftus 2007, Trexler et al. 2005). Biogeographic barriers (e.g., oceans, mountain ranges, and catchment basins) typically limit faunal exchanges, but anthropogenic alterations such as canals, can remove these natural barriers, resulting in biotic homogenization (Rahel 2002). For instance, Mills et al. (1999) noted the expansion of *Morone americana* Gmelin (White Perch), and *Alosa psuedoharengus* Wilson (Alewife) beyond their historical distributions due to the construction of the Erie Canal. Despite ongoing restoration efforts, only a small portion of south Florida canals will be removed, making canals a permanent feature of the Everglades ecosystem (CERP 1999). Thus, understanding the role of canals in the ecosystem, including their role in native range expansions and as dispersal corridors and habitat for native and non-native fishes, is a critical component of understanding the ecology of south Florida.

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