An island invaded by exotics: a review of freshwater fish in Puerto Rico

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ABSTRACT
The introduction of exotic fishes in streams and water reservoirs has modified autochthonous freshwater fish communities in Puerto Rico. There are approximately 46 fish species in inland waters, and most of them were introduced during the last century. We here summarize relevant information on 46 freshwater fish species reported for the island. Approximately 80% of the species are non-native. An evaluation of the local trade revealed another 128 freshwater fish species are sold locally as pets. This raises serious concerns, as we detected a potential pool of non-native species that are either considered invasive elsewhere, or that, based on their ecology, could become invasive on the island in the near future. We also found that cichlids as a group pose the highest risk to freshwater ecosystems, with 13 species established in the wild, and another 38 potential invaders in the local pet trade. This study may be used as a baseline for the conservation and management purposes of both native and non-native fish species, including the development of strategies for preventing the release of live fish pets into the wild. More specific management for non-native fish, especially those identified here that pose significant threats to Puerto Rico’s native fish and their ecosystems, are warranted.

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Introduction
The Neotropical realm has the highest diversity of freshwater fish, with more than 5,160 recorded species worldwide [1]. Native freshwater fish communities on tropical islands usually have low species diversity and are composed entirely of species with catadromous or amphidromous life histories [2,3]. Puerto Rico has nine native freshwater fish species, all of which require contact with marine environments during some phase of their life cycle [4]. These native species include representatives within the families Anguillidae, Eleotridae, Gobiidae, and Mugilidae [5,6]. Today, however, there are about 77 reported freshwater fish species that inhabit the inland waters of Puerto Rico [3].

Unsustainable human development has considerably impacted freshwater ecosystems globally, and native freshwater fish face a variety of threats [7]. Catchment-scale modifications (i.e. altered movement pathways of sediments in water systems due to land-use changes or increased imperviousness) and stream channelization projects in urban areas, often employed as a strategy to control flooding, have a strong impact on the distribution and composition of fish species and their communities [8]. Hence, the migratory patterns and life cycles associated with the development of a species are modified or broken, and thus the native species assemblages become overtaxed, while the establishment of exotic species remains rampant [5,9].

Highly urbanized areas degrade freshwater ecosystems due to the interplay between the loss of appropriate habitat for native fish species and the proliferation of introduced non-native species (which are often more tolerant to disturbed ecosystems), resulting in a decrease of native freshwater fish diversity [10], and in the loss of the ecological services they provide [11]. In Puerto Rico, over the last century, anthropogenic disturbances such as the modification of watersheds through the alteration of river courses, construction of dams, channelization of reaches, deforestation, road crossings, water pollution, and changes in the species composition – which includes the introduction of non-native fish – have greatly modified the inland freshwater ecosystems [12]. For example, dam construction and some channel modifications serve as barriers to Puerto Rico’s native fish species, affecting their migratory patterns and species assemblages of native fish. Most the major rivers of Puerto Rico have some degree of damming (i.e. water retention structures), which has negatively impacted freshwater fish communities through habitat fragmentation [13].

With the establishment of Biological Invasion as a discipline, we now know, without a doubt, that the detrimental effects of biological invasions have intensified greatly during the last decades [14]. The ever-present threat of new introductions on non-native fish to indigenous ecosystems represents a serious threat to freshwater systems, especially on island ecosystems. The
Introduction of non-native fish in the inland freshwater systems of Puerto Rico has severely impacted native fish communities, with local depletion or local extinction of native species [3,8,15]. Currently, freshwater habitats are mostly composed of fish species introduced from America, Africa and Asia [15]. Although the introduction of non-native fish into the water reservoirs of Puerto Rico began in the early 1900s, most of the non-native species present in the wild today are the result of both accidental and intentional releases during the last decades. Non-native fishes were brought for aquaculture and the sport fishing industries, and some escaped from fish hatcheries and fishponds that were mainly established in the 1930s [16]. Hence, species such as goldfish (Carassius auratus), swordtails (Xiphophorus hellerii), sailfin catfish (Pterygoplichthys sp.), algae-eater (Gyrinocheilus aymonieri), and several cichlid species have been released to the wild by their owners and have become common throughout the island [17]. What ecological impacts these non-native fish may have on native species is a shared concern amongst scientists that study freshwater ecosystems in Puerto Rico. For example, predation by introduced non-native freshwater fish upon native snail and bird species has been reported in Puerto Rico [18].

Early studies of freshwater fish communities in Puerto Rico focused on biological aspects of native species [19,20], and they gradually shifted to include species distributions, the biology and management of non-native species, and the impacts of these on native freshwater fish communities [15]. More recently, studies have focused on the effects of ecological factors influencing freshwater fish populations and communities (e.g. parasitization), genetics, and urban fish assemblages [8,17,21,22]. However, and although Puerto Rican freshwater ecosystems are relatively well studied when compared to other islands, biologists keep recording new species established in the wild. For example, just in 2018, Rodríguez-Barreras and Zapata-Arroyo [23] recorded the occurrence of an established population of the highly invasive African catfish Clarias gariepinus in Puerto Rico, a species considered harmful to native species elsewhere, which raised grave concerns amongst state and federal agencies tasked with the management of the native and sport fish resources of the island.

The availability of scientific information on the identity of both native and non-native fish species that currently inhabit the island, and on locally traded non-native freshwater fish is critical to effectively manage the freshwater fish resources. However, there is currently no updated list of freshwater species to accomplish this. To fill this gap, here we present a comprehensive list of native and non-native freshwater fish species established in Puerto Rico, and the species that have not yet been reported in the wild, but that are traded locally. For the freshwater fish fauna that are present in the wild, we synthesize the most relevant information, which includes aspects of their biology, ecology, and their geographic distribution. Additionally, we provide information about freshwater fish species that are sold through the aquarium pet trade in Puerto Rico and their potential invasiveness.

Methods

Site description

The Puerto Rican Archipelago is located in the Caribbean Sea, and composed of three main populated-islands (Puerto Rico, Vieques, and Culebra), and numerous other islands, islets and cays, which, together with the US and UK Virgin Islands (except for St. Croix) form the biogeographic area known as the Puerto Rican Bank. This study focuses on the main island of the Puerto Rican Archipelago, Puerto Rico, which is the smallest of the Greater Antilles, with an area of approximately 8,870 km². Puerto Rico currently has a human population of approximately 3.2 million inhabitants with a human-population density of ca. 351 inhabitants per km², after experiencing a dramatic decrease in population (of ca. −0.5 million, or a 15.3% decrease) in just 8 years [24]. Geologically, Puerto Rico is of volcanic origin, but possesses karst regions [17], and has diverse climatic zones [25]. The climatic zones of the freshwater systems of the island vary from perennial streams in areas of high precipitation, to intermittent streams in areas of low precipitation [26]. The Central Cordillera is the main mountainous chain that runs east-west through the center of Puerto Rico. It reaches 1,340 m at its highest point and is the origin of most of the rivers and streams on the island. The rivers and streams draining towards the north include many underground systems flowing through the Karst Region and include the longest river systems on the island, whereas there are fewer and shorter length rivers and streams draining towards the south [27,28]. When compared to the other Greater Antilles, the rivers and streams of Puerto Rico are generally small and flashy, and composed of mainly rocky substrates of volcanic origin (e.g. pebbles, gravel, boulders) and sand.

Compilation of fish species present in puerto rico

To generate a comprehensive and updated list of freshwater fish species present in Puerto Rico that may be used to inform conservation and management strategies, we focused on identifying: i) species present in the wild, and ii) locally traded species, especially those present only in captivity (i.e. that may be potentially released into the wild).

Fish species present in the wild

To compile a list of fish species present in the wild, we reviewed the literature (which included published and unpublished scientific articles and technical reports of
government agencies), performed a survey of specimens collected and deposited in zoological collections, and carried out sampling in-situ.

To identify the species of fish present in the wild, we considered species with life histories recognized as catadromous, amphidromous and stream resident. We excluded fish species with life histories dominated primarily by phases inhabiting marine, estuarine and brackish water habitats. To compile a list of fish species present in the wild, we reviewed the literature – which included published and unpublished scientific articles and technical reports of government agencies, performed a survey of specimens collected and deposited in zoological collections, and carried out sampling in-situ. Local distribution for all species was not uniform due to differences in information sources.

To perform the literature review, we used the institutional database of the library in the University of Puerto Rico, and search engines using the keywords: “freshwater”, “fish”, “exotic species”, and “Puerto Rico”. To complement the information extracted from the literature, we surveyed the specimens deposited in the Zoological Museum of the University of Puerto Rico – Río Piedras Campus. For each collection, we recorded the following information: sample identification number (ID), species identity, number of individuals, and collection date.

We conducted fish surveys in four locations in the metropolitan area of San Juan, which includes Guanabo River (18°21’59.78”N, 66°06’41.32”W; [June/2018]), a tributary of the Guanabo River in the Camarones suburb (18°12’20.52”N, 66°03’48.99”W; [June/2018]), a tributary of the Bayamón River (18°22’11.03”N, 66°8’49.69”W; July/2018)), and Mameyes River, located in Rio Grande (18°19’26.57”N, 65°44’55.89”W; [July/2018]). Sites were selected because these are areas of high suspected invasion potential due to proximity to aquaria owners and have not been frequently sampled. Fish species were identified visually by snorkeling or by capturing them using a hand net. All captured individuals were released immediately after identification.

**Locally traded fish species**

To identify locally traded fish species, primarily through the aquarium (ornamental) and pet trade markets, and to identify those species that have invasive potential, we followed Falcón and Tremblay [29]. Briefly, during April of 2019, we conducted surveys *in situ*, focusing on pet- and aquarium shops in the Metropolitan Area of San Juan. Moreover, we surveyed online community groups covering topics related to biodiversity, pet trade, aquarium fish, and collected available posted data (e.g. location, species, photographs). Surveyed Facebook ([http://www.facebook.com](http://www.facebook.com)) groups included *The fish outlet, Nativos Ciclids fish shop, Adictos a los peces, Báez Aquarium and more, Aquarium Xtra, and Pet Ways* (see Supplemental Information). We also surveyed the pet section of local online classified (user-generated ads) webpage *Clasificados Online*.

**Scientific name nomenclature**

After taxonomic identification (at the lowest possible level), we followed the nomenclature established by the Integrated Taxonomic Information System to assign the corresponding scientific name for each identified taxon, and updated the scientific name of fish reported in the literature or preserved in zoological collections, as needed [30]. We provide common names for fish currently present in the wild in Puerto Rico in both English and Spanish in Table 1.

**Results**

We report 46 freshwater fish for Puerto Rico freshwater systems, belonging to 7 orders, 14 families, and 32 genera (Table 1, Figure 1). The Order Perciformes was the best represented with 26 species, whereas the Orders such as Anguilliformes and Characiformes were represented only by one species (Table 1). The family Cichlidae was the best represented with 13 species followed by Poeciliidae with 7 species, both families include only non-native species (Figure 2). Most fish species found in Puerto Rico’s streams and water reservoirs are non-native; only 9 species of this list are native, which represents 19.6% of the total number of freshwater fish species reported for Puerto Rico. We also found another 128 freshwater fish species commercialized in stores and local websites. The most represented families were Cichlidae with 39 species, Cyprinidae with 16 species and Characidae with 11 species (Figure 2). See Appendix 1 for more details.

The following list includes all freshwater fish species with established populations on the island:

**Order Anguilliformes**

*Family Anguillidae Rafinesque, 1810*

*Anguilla rostrata* (Lesueur, 1817)

**Distribution**

Northwest to western Central Atlantic: Greenland south along the Atlantic coast of Canada and the USA to Panama and throughout much of the south Caribbean to Trinidad.
| Species | Common name | Occurrence | Migratory status | Max length (cm) | Pet trade |
|---------|-------------|------------|------------------|-----------------|----------|
| Anguilla rostrata | American Eel, Angieula | Introduced Resident | Catadromous | 152.0 | - |
| Mylolepis rubripinnis | Redhook Silver Dollar, Pacú | Introduced Present | Present | 41.5 | Y |
| Dorosoma petenense | Threadfin shad, Sardina de agua dulce | Introduced Resident | Resident | 33.0 | U |
| Carassius auratus | Goldfish, Pez de Colores | Introduced Resident | Resident | 48.0 | Y |
| Pethia conchonius | Rosy Barb, Mino Rosado | Introduced Resident | Resident | 14.0 | Y |
| Gymnocheilus aymonieri | Siamese Algae-eater | Introduced Resident | Resident | 28.0 | Y |
| Gambusia affinis | Western Mosquitofish | Introduced Resident | Resident | 5.1 | Y |
| Poecilia latipinna | Salinfl Molly | Introduced Resident | Resident | 15.0 | Y |
| Poecilia reticulata | Guppy | Introduced Resident | Resident | 5.0 | Y |
| Poecilia wingei | Unidentified | Introduced Resident | Resident | 5.2 | U |
| Poecilia splendens | Molly | Introduced Resident | Resident | 7.5 | Y |
| Xiphophorus helleri | Green Swordtail | Introduced Resident | Resident | 14.0 | Y |
| Xiphophorus maculatus | Southern Platfish, Platy | Introduced Resident | Resident | 4.0 | Y |
| Agonostomus monticola | Mountain Mullet, Dajao | Native | Amphidromous | 36.0 | - |
| Lepomis auritus | Redbreast Sun Shad, Sardina | Introduced Resident | Resident | 30.5 | U |
| Lepomis macrochirus | Bluegill, Chopa Ciénega | Introduced Resident | Resident | 41.0 | U |
| Lepomis microlophus | Redear Sunfish, Chopa caricola | Introduced Resident | Resident | 43.2 | U |
| Micropterus salmoides | Chattahoochee Bass | Introduced Resident | Resident | 40.6 | U |
| Micropterus salmoides | Largemouth Bass, Bobina, Perca Americana | Introduced Resident | Resident | 97.0 | U |
| Amphipholis centrinus | Midsal Chich, Diablotto Rojo | Introduced Resident | Resident | 24.4 | Y |
| Amphipholis labiatus | Red Devil, Diablotto Rojo | Introduced Resident | Resident | 24.0 | Y |
| Archocentrus nigrofuscatus | Convict Cichlid | Introduced Resident | Resident | 10.0 | Y |
| Astronotus ocellatus | Oscar | Introduced Resident | Resident | 45.7 | Y |
| Cichla ocellaris | Butterfly Peacock Bass, Tucunaré | Introduced Resident | Resident | 74.0 | U |
| Hemiculter cyprinoguttatus | Rio Grande Chichlid | Introduced Resident | Resident | 30.0 | U |
| Oreochromis aureus | Blue Tilapia, Tilapia Azul | Introduced Resident | Resident | 45.7 | Y |
| Oreochromis mossambicus | Mozambique Tilapia, Tilapia de Mozambique | Introduced Resident | Resident | 39.0 | Y |
| Oreochromis niloticus | Nile Tilapia | Introduced Resident | Resident | 60.0 | Y |
| Parachromis managuensis | Jaguar Guapote | Introduced Resident | Resident | 53.0 | Y |
| Thorichthys meeki | Firemouth Chichlid, Boca de Fuego | Introduced Resident | Resident | 17.0 | Y |
| Tilapia rendalli | Redbreast tilapia, Tilapia | Introduced Resident | Resident | 45.0 | Y |
| Vieja melanura | Redhead Cichlid, Cabeza de Fuego | Introduced Resident | Resident | 35.0 | Y |
| Dorosoma maculatum | Fat Sleeper, Mapiro | Native | Amphidromous | 70.0 | - |
| Electrophorus Silver | Spinycheek Sleeper, Morón | Native | Amphidromous | 25.0 | - |
| Gobiomorus dormitor | Bigmouth Sleeper, Guavina | Native | Amphidromous | 90.0 | - |
| Awaous brevirostris | Goby, Saga | Native | Amphidromous | 30.0 | - |
| Sicydium buski | Olivo | Native | Amphidromous | 6.0 | - |
| Sicydium plumieri | Sirajo Goby, Olivo | Native | Amphidromous | 11.0 | - |
| Sicydium punctatum | Olivo | Native | Amphidromous | 8.0 | - |
| Claris gariepinus | African Catfish | Introduced Present | Present | 170.0 | U |
| Ameiurus catus | White Catfish, Barbudo Blanco | Introduced Resident | Resident | 132.0 | U |
| Ameiurus nebulosus | Brown Bullhead, Torito Barbudo | Introduced Resident | Resident | 53.0 | U |
| Ictalurus punctatus | Channel Catfish, Barbudo de Canal | Introduced Resident | Resident | 132.0 | U |
| Pterygophis multiradiatus | Safflin Catfish, Pleco | Introduced Resident | Resident | 14.0 | Y |
| Pterygophis paralius | Amazon Safflin Catfish, Pleco | Introduced Resident | Resident | 42.3 | Y |
| Pangasius hypophthalmus | Basa Catfish | Introduced Resident | Resident | 130.0 | U |

Puerto Rico localities: Found in nearly all rivers of Puerto Rico in the lowlands. Occasionally found in farms and reservoirs. Canovanas River (18°23'48',18°N), 65°54'44.89"W), Herrera River (18°33'01',20", 65°), 51°50',27"W), Tabonuco Ravine (18°21'15',53", 65°), 28°09',18"W), Marmeyes River (18°19'26',57", 65°), 44°55',89"W), Sabana River (18°15'44',05", 65°), 47°39',13"W), Pitahaya River (18°21'53',73", 65°), 43°06',53"W), Juan Martin River (18°21'07',85", 65°), 41°00',90"W), Juan Diego Ravine (18°18'27',67", 65°), 46°08',63"W), Rincón Ravine (18°17'28',25", 65°), 41°37',67"W), Guayanés River (18°04',12',51", 65°), 50°32',70"W), Caño Santiago (18°03',29',08", 65°), 49°32',71"W), Maunabo River (18°00',12',59", 65°), 54°13',65"W), Tallaboa River (18°02',17',33", 66°), 43°17',40"W), Guayanilla River (18°18',13',36", 66°) to 47°55',91"W), Yauco River (17°59',23',53", 66°), 50°24',92"W), Loco River (18°00',53',10", 66°), 52°33',10"W), Los Llanos Ravine (18°01',44',65", 67°), 3°49',65", 67°) lagoons. References [3,16,31,34].
Remarks: I-00003, three organisms collected on 28 March 1969; I-00004, one org. collected on 03 June 1969; I-00005, four orgs. collected on 03 June 1969; I-00006, one org. collected on 08 March 1976; I-00007, one org. collected on 14 June 2000; and I-00008, two orgs. collected on 22 May 1999.

Order Characiformes
Family Serrasalmidae Bleeker, 1859
*Myleus rubripinnis* (Müller and Troschel, 1844)

**Distribution**
Naturally occurs in South America: Amazon and Orinoco River basins; and Guiana Shield rivers.

Puerto Rico localities: Cerrillos reservoir (18°05'49.92"N, 66°34'43.83"W).

References [35,36].

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Order Clupeiformes
Family Clupeidae Cuvier, 1816
*Dorosoma petenense* (Günther, 1867)

**Distribution**
North and Central America: Gulf of Mexico drainage, Mississippi system, from the Ohio River of Kentucky and southern Indiana southwest to Oklahoma, and south to Texas and Florida, also rivers around the Gulf to northern...
Guatemala; also found in Belize Rivers. Introduced in Hawaiian waters, and in Chesapeake Bay tributaries. Puerto Rico localities: in May 1963, 40 adults from Georgia were introduced to Guajataca reservoir (18°23'26,86"N, 66°55'25,94"W). Currently found in Great River of Arecibo (18°24'06,07"N, 66°41'27,10"W), and in most of the island reservoirs. References [15, 16, 36].

Remarks: I-00012, four organisms collected on 14 June 2000; and I-00017, three orgs. collected on 15 June 2000.

Order Cypriniformes

Family Arcticidae Newton, 1891

Carassius auratus (Linnaeus, 1758)

Distribution
Worldwide distributed, but originally from Asia: central Asia and China and Japan.

Pethia conchonius (Hamilton, 1822)

Distribution
Afghanistan, Bangladesh, Pakistan, India, Nepal, and Myanmar. Puerto Rico localities: Caguítas River (18°13'52,39"N, 66°03'05,79"W), Cañas River (18°17'22,84"N, 66°03'58,96"W), Canovanillas River (18°19'17,07"N, 65°54'13,36"W), Majada River (18°02'30,63"N, 66°12'36,38"W), Yunes River (18°19'21,34"N, 66°35'15,67"W), Barranquita River (18°10'24,90"N, 66°17'53,82"W), La Zapatera Ravine (18°07'23,70"N, 66°05'07,65"W), Patillas Canal (17°58'40,63"N, 66°08'56,52"W), Loiza (18°18'54,98"N, 66°01'14,52"W) and Dos Bocas (18°19'57,68"N, 66°40'05,12"W) reservoirs.

Puerto Rico localities: Guajataca (18°23'26,86"N, 66°55'25,94"W), and Guayabal (18°05'44,53"N, 66°30'14,13"W) reservoirs, but also in small ponds around the island.

References [16, 36, 37].
References [3,36,38].

Family Gyrinocheilidae Gill, 1905

Gyrinocheilus aymonieri (Tirant, 1883)

Distribution
Asia (Mekong, Chao Phraya and Meklong basins, and the northern Malay Peninsula).
Puerto Rico localities: Cañas River (18°17’22.84″N, 66°03’58.96″W).
References [3,36,39].

Family Poeciliidae Bonaparte, 1831

Gambusia affinis (Baird and Girard, 1853)

Distribution
North and Central America: Mississippi River basin from central Indiana and Illinois in the USA south to The Gulf of Mexico and Gulf Slope drainages west to Mexico.
Puerto Rico localities: Considered the most abundant fish in the freshwater reservoirs of the island. Found in the following reservoirs: Carite (18°04’44.13″N, 66°06’00.05″W), Caonillas (18°16’28.90″N, 66°39’10.30″W), Dos Bocas (18°19’57.68″N, 66°40’05.12″W), Guayabal (18°05’44.53″N, 66°30’14.13″W), Loiza (18°18’54.98″N, 66°01’14.52″W), Patillas (18°01’27.38″N, 66°01’23.76″W), and Toa Vaca (18°06’09.99″N, 66°28’57.91″W) reservoirs. Also, near the coast, all the way upstream to the headwaters at Mount Guajarte.
References [16,34,36].

Poecilia latipinna (Lesueur, 1821)

Distribution
North America: From Cape Fear drainage in North Carolina in the USA to Veracruz in Mexico.
Puerto Rico localities: Great River of Loiza (18°23’48.19″N, 65°54’44.89″W), and Canóvanas River (18°23’48.18″N, 65°54’44.89″W).
References [3,34].
Remarks: I-00029, + 200 organisms collected on 21 March 1998; and I-00030, 50 orgs. collected on 03/21/1998.

Poecilia reticulata Peters, 1859

Distribution
South America: Venezuela, Barbados, Trinidad, northern Brazil and the Guyanas. Widely introduced and established elsewhere, mainly for mosquito control, but had rare to non-existing effects on mosquitos, and negative to perhaps neutral effects on native fish. Africa: Feral populations reported from the coastal reaches of Natal river from Durban southwards, as well as in the Kuruman Eye and Lake Ojikoto in Namibia.
Puerto Rico localities: Guaynabo River (18°21’59.78″N, 66°06’41.32″W), tributary to Bayamón river (18°22’11.61″N, 66°08’33.44″W), Caguas River (18°13’52.39″N, 66°03’05.79″W), Cañas River (18°17’22.84″N, 66°03’58.96″W), Canovillas River (18°19’17.07″N, 65°54’13.36″W), Canóvanas River (18°23’48.18″N, 65°54’44.89″W), Herrera River (18°33’01.20″N, 65°51’50.27″W), Humacao River (18°09’03.55″N, 65°51’55.77″W), Guayanés River (18°04’12.51″N, 65°50’32.70″W), Majada River (18°02’30.63″N, 66°12’36.38″W), Descalabrado River (18°03’57.07″N, 66°25’48.19″W), Macaná River (18°00’51.57″N, 66°45’55.35″W), Yauco River (17°59’23.53″N, 66°50’24.92″W), Los Llanos Ravine (18°01’44.65″N, 67°06’49.65″W), Blanco River (18°13’46.94″N, 65°47’09.12″W), Prieto River (18°15’19.81″N, 65°46’52.57″W), Juncal River (18°17’10.99″N, 66°53’39.73″W), Guatemala River (18°20’35.75″N, 66°59’59.16″W), Salada Ravine (18°21’04.74″N, 67°01’32.95″W), tributaries to Culebrinas River, Camuy River (18°27’00.37″N, 66°49’36.47″W), Naranjito River (18°16’55.50″N, 66°35’00.61″W), Limón River (18°19’33.34″N, 66°36’56.01″W), La Ventana River (18°10’29.79″N, 66°21’05.86″W), Yunes River (18°19’21.34″N, 66°35’15.67″W), Tamáná River (18°24’39.05″N, 66°42’54.54″W), Jobos Ravine (18°19’18.03″N, 66°40’46.04″W), Great River of Manatí (18°24’31.31″N, 66°29’46.04″W), Cañabón River (18°13’24.69″N, 66°20’17.26″W), Bauta River (18°17’52.09″N, 66°27’35.69″W), Sana Muerto River (18°17’12.32″N, 66°25’19.97″W), Caltos River (18°17’09.70″N, 66°30’53.76″W), Maravilla River (18°21’05.76″N, 66°17’50.17″W), Morovis River (18°20’57.45″N, 66°23’10.50″W), Unibón River (18°20’36.43″N, 66°22’00.04″W), Barranquita River (18°10’24.90″N, 66°17’53.82″W), La Zapatera Ravine (18°07’23.70″N, 66°05’07.65″W), and Rio Piedras River (18°24’00.98″N, 66°03’42.58″W).
References [3,36,40].
Remarks: I-00031, 25 organisms collected on unknown date; I-00032, 1 org. collected on 20 May 2002; I-00033, 2 orgs. collected on 01 March 1998; I-00034, 3 orgs. collected on 01 March 1999; I-00035, 1 org. collected on unknown date; I-00036, 4 orgs. collected on 25 March 1997, I-00042, 15 orgs. collected on 20 March 1969; and I-00043, 1 org. collected on 14 March 1969.

Poecilia vivipara Bloch and Schneider, 1801

Distribution
South America, between Suriname and Brazil (not the Atlantic area South of the Laguna dos Patos basin in Brazil). Also introduced in the Caribbean.
Puerto Rico localities: Reported at Ponce, Fajardo, Arroyo, Guánica, and Comerio municipalities, Cartagena reservoir (18°00'51.06"N, 67°06'16.17"W), Aibonito River (18°09'39.98"N, 66°18'41.21"W), Ingenio River (18°04'33.66"N, 65°50'34.40"W), Guayanés River (18°04'12.51"N, 65°50'32.70"W), and the mouth of the Loiza River (18°25'57.43"N, 65°53'02.61"W),

References [31,33,41,43].

Remarks: I-00037, two organisms collected on 15 March 1998; I-00038, five organs. collected on 22 March 1969; and I-00040, five organs. collected on unknown date.

Poecilia sphenops Valenciennes in Cuvier and Valenciennes, 1846

Distribution

Central and South America: Mexico to Colombia.

Puerto Rico localities: Guaynabo River (18°21’59.78”N, 66°06’41.32”W), Caguitas River (18°13’52.39”N, 66°03’05.79”W), Cañas River (18°17’22.84”N, 66°03’58.96”W), Canovillas River (18°19’17.07”N, 65°54’13.36”W), Canóvanas River (18°23’48.18”N, 65°54’44.89”W), Majada River (18°02’30.63”N, 66°12’36.38”W), Dascalbrado River (18°03’57.07”N, 66°25’48.19”W), Yauco River (17°59’23.53”N, 66°50’24.92”W), Guatemala River (18°20’35.75”N, 66°59’59.16”W), tributaries to Culebrinas River, Camuy River (18°27’00.37”N, 66°49’36.47”W), Naranjito River (18°16’55.50”N, 66°35’00.61”W), Limón River (18°19’33.34”N, 66°36’56.01”W), La Ventana River (18°10’29.79”N, 66°21’05.86”W), Yunes River (18°19’21.34”N, 66°35’15.67”W), Great River of Manati (18°24’31.31”N, 66°29’46.04”W), Cañabón River (18°13’24.69”N, 66°20’17.26”W), Sana Muerto River (18°17’12.32”N, 66°25’19.97”W), Toro Negro River (18°13’49.25”N, 66°30’44.99”W), Cialitos River (18°17’09.70”N, 66°30’53.76”W), Maravilla River (18°21’05.76”N, 66°17’50.17”W), Unión River (18°20’36.43”N, 66°22’50.04”W), Barranquita River (18°10’24.90”N, 66°17’53.82”W), and La Zapatera Ravine (18°07’23.70”N, 66°05’07.65”W).

References [3,44].

Xiphophorus maculatus ( Günther, 1866)

Distribution

North and Central America: Ciudad Veracruz, Mexico to northern Belize.

Puerto Rico localities: found in several drainages around the island.

References [15,36,40].

Order Mugiliformes

Family Mugilidae Jarocki, 1822

Agonostomus (Bankroft in Griffith and Smith, 1834)

Distribution

North to South America: North Carolina, Florida, Louisiana and Texas in the USA to Colombia and Venezuela, including the West Indies.

Puerto Rico localities: Canovanas River (18°23’48.18”N, 65°54’44.89”W), Herrera River (18°33’01.20”N, 65°51’50.27”W), Tabonuco Ravine (18°21’15.53”N, 65°28’09.18”W), Waimeyes River (18°19’26.57”N, 65°44’55.89”W), Sabana River (18°15’44.05”N, 65°47’39.13”W), Pitahaya River (18°21’53.73”N, 65°43’06.53”W), Juan Martin River (18°21’07.85”N, 65°41’00.90”W), Juan Diego Ravine (18°18’27.67”N, 65°46’08.63”W), Rincon Ravine (18°17’18.25”N, 65°41’37.67”W), Humaaco River (18°09’03.55”N, 65°09’03.55”W), Yauco River (17°59’23.53”N, 66°50’24.92”W), Los Llanos Ravine (18°04’44.65”N, 67°07’49.69”W), Blanco River (18°13’46.94”N, 65°47’09.12”W), Prieto River (18°15’19.81”N, 65°46’52.57”W), Juncal River (18°17’10.99”N, 66°53’39.73”W), Guatemala River (18°20’35.75”N, 66°59’59.16”W), Camuy River (18°27’00.37”N, 66°49’36.47”W), Naranjito River (18°16’55.50”N, 66°35’00.61”W), Limón River (18°19’33.34”N, 66°36’56.01”W), La Ventana River (18°10’29.79”N, 66°21’05.86”W), Yunes River (18°19’21.34”N, 66°35’15.67”W), Tamamá River (18°24’39.05”N, 66°42’54.54”W), Jobos Ravine (18°19’03”N, 66°40’46.04”W), Great River of Manati (18°24’31.31”N, 66°29’46.04”W), Cañabón River (18°13’24.69”N, 66°20’17.26”W), Bauta River (18°17’52.09”N, 66°27’35.69”W), Cialitos River (18°17’09.70”N, 66°30’53.76”W), Maravilla River (18°21’05.76”N, 66°17’50.17”W), Unión River (18°20’36.43”N, 66°22’50.04”W), Barranquita River (18°10’24.90”N, 66°17’53.82”W), La Zapatera Ravine (18°07’23.70”N, 66°05’07.65”W), and Rio Piedras River (18°24’00.98”N, 66°03’42.58”W).

References [3,44].
Lepomis auritus (Linnaeus, 1758)

Distribution
North America: Eastern Rivers of USA and Canada.
Puerto Rico localities: Cañas River (18°17′22″N, 66°03′58″W), Great River of Manati (18°24′31″N, 66°29′46″W), Barranquita River (18°10′24″N, 66°17′53″W), La Zapatera Ravine (18°07′27″N, 66°05′07″W), Carite (18°04′44″N, 66°06′00″W), Cidra (18°11′38″N, 66°08′18″W), Dos Bocas (18°19′57″N, 66°40′05″W), Guayabal (18°05′44″N, 66°30′14″W), Cerillos (18°05′49″N, 66°34′43″W), Luchetti (18°05′37″N, 66°52′09″W), La Plata (18°20′04″N, 66°14′08″W), Guajataca (18°23′26″W, 66°55′25″W), Guay (18°11′56″W, 66°50′01″W), Patillas (18°01′27″W, 66°01′23″W), and Tortuguero Lagoon (18°27′50″N, 66°26′36″W).

References [3,34].

Lepomis macrolepis (Rafinesque, 1819)

Distribution
North America: The Great Lakes and Mississippi river basin; from Quebec to northern Mexico.
Puerto Rico localities: Garzas (18°08′12″N, 66°44′38″W), Guay (18°11′56″W, 66°50′01″W), Patillas (18°01′27″W, 66°01′23″W), Cerillos (18°05′49″W, 66°34′43″W), Luchetti (18°05′37″N, 66°52′09″W), and La Plata (18°20′04″N, 66°14′08″W) reservoirs.

References [15,34].

Lepomis microlophus (Günther, 1859)

Distribution
North America: Savannah River in South Carolina to Nueces River in Texas, Mississippi River basin to southern Indiana and Illinois in the USA.
Puerto Rico localities: Tortuguero Lagoon (18°27′50″N, 66°26′36″W), Garzas (18°08′12″N, 66°44′38″W), Cidra (18°11′38″N, 66°08′18″W), Carite (18°04′44″N, 66°06′00″W), Toa Vaca (18°06′09″N, 66°28′57″W), Guayabal (18°05′44″N, 66°30′14″W), Patillas (18°01′27″W, 66°01′23″W), Guay (18°11′56″W, 66°50′01″W), Guajataca (18°23′26″W, 66°55′25″W), Cerillos (18°05′49″W, 66°34′43″W), and La Plata (18°20′04″N, 66°14′08″W) reservoirs.

References [16,34,47].
Family Cichlidae Bonaparte, 1835

*Archocentrus nigrofasciatus* (Günther, 1867)

**Distribution**
Its range extends through Nicaragua and at least into Costa Rica; also found in continental U.S.A and Hawaii.

Puerto Rico localities: Patillas Canal (17°58′40″N, 66°08′56″W), Cañas (18°17′22″N, 66°03′58″W), Guaynabo (18°21′59″N, 66°06′41″W, and Yunes (18°19′21″N, 66°35′15″W) rivers. Also found in Loiza (18°18′54″N, 66°01′14″W), Las Curias (18°20′29″N, 66°02′53″W), Guaynabo (18°23′26″N, 66°55′25″W), Loiza (18°18′54″N, 66°01′14″W), Cañas (18°13′24″N, 66°00′05″W, and Toa Vaca (18°06′09″N, 66°28′57″W) reservoirs.

References [3, 36, 48, 49].

*Amphilophus citrinellus* (Günther, 1864)

**Distribution**
Central America: Atlantic slope of Nicaragua and Costa Rica (San Juan River drainage, including Lakes Nicaragua, Managua, Masaya and Apoyo).

Puerto Rico localities: Cañaboncito (18°12′58″N, 66°04′14″W), Cañas (18°17′22″N, 66°03′58″W), Cañabón (18°13′24″N, 66°20′17″W), and Rio Piedras (18°24′00″N, 66°03′42″W) rivers. Also found in Guajataca (18°23′26″N, 66°55′25″W), Loiza (18°18′54″N, 66°01′14″W), Dos Bocas (18°19′57″N, 66°40′05″W), and Toa Vaca (18°06′09″N, 66°28′57″W) reservoirs.

References [36].

*Amphilophus labiatus* (Günther, 1864)

**Distribution**
Central America: Atlantic slope of Nicaragua, in Lakes Nicaragua and Managua.

Puerto Rico localities: Guaynabo River (18°21′59″N, 66°06′41″W), Great River of Loiza (18°23′48″N, 65°54′44″W), Caonillas (18°16′28″N, 66°39′10″W), and Dos Bocas (18°19′57″N, 66°40′05″W) reservoirs.

References [36, 50].

*Astronotus ocellatus* (Agassiz in Spix and Agassiz, 1831)

**Distribution**
South America: Amazon River basin in Peru, Colombia and Brazil; French Guiana, and Argentina.

Puerto Rico localities: Aibonito farm pond, Bayamón River (18°22′11″N, 66°8′49″W), tributary of Guaynabo River (18°12′20″N, 66°03′48″W), Tortuguero Lagoon (18°27′50″N, 66°26′36″W), Loiza (18°18′54″N, 66°01′14″W), Las Curias (18°20′29″N, 66°02′53″W), Guajataca (18°23′26″N, 66°55′25″W), La Plata (18°20′04″N, 66°14′08″W), Comerio (18°15′35″N, 66°12′19″W), and Guajataca (18°23′26″N, 66°55′25″W) reservoirs.

References [15, 34, 36, 51, 52].

*Cichla ocellaris* (Bloch and Schneider, 1801)

**Distribution**
South America: Marowijne drainage in Suriname and French Guiana to the Essequibo drainage in Guyana.

Puerto Rico localities: Loiza (18°18′54″N, 66°01′14″W), Dos Bocas (18°19′57″N, 66°40′05″W), Caonillas (18°16′28″N, 66°39′10″W), Carite (18°18′44″N, 66°06′00″W), Patillas (18°12′27″N, 66°01′23″W), Cidra (18°11′38″N, 66°08′18″W), Guayabal (18°05′44″N, 66°30′14″W), La Plata (18°20′04″N, 66°14′08″W), Luchetti (18°05′73″W, 66°52′09″W), and Guajataca (18°23′26″N, 66°55′25″W) reservoirs.

References [36, 53].

*Herichthys cyanoguttatum* (Baird and Girard, 1854)

**Distribution**
North America: originally restricted to the lower Rio Grande drainage in Texas, USA and south to northeastern Mexico. Introduced on Edwards Plateau of central Texas and central peninsular Florida, USA, and Verde River basin (La Media Luna region), Mexico.

Puerto Rico localities: Loiza (18°18′54″N, 66°01′14″W) reservoir.

References [34, 36, 54].

*Oreochromis aureus* (Steindachner, 1864)

**Distribution**
Africa and Eurasia: Jordan Valley, Lower Nile, Chad Basin, Benue, middle and upper Niger, Senegal River. Introduced in the oasis of Azraq (Jordan), warm water ponds of USA, South and Central America and South East Asia.

Puerto Rico localities: Widespread throughout the island (rivers and reservoirs).

References [36, 55].
**Oreochromis mossambicus** (Peters, 1852)

**Distribution**
Africa: Lower Zambezi, Lower Shiré and coastal plains from Zambezi delta to Algoa Bay. Occurs southwards to the Brak River in the Eastern Cape and in the Transvaal in the Limpopo system.

Puerto Rico localities: drainage canals, farm ponds, reservoirs and lagoons, though not everywhere. Cañas River (18°17'22.84"N, 66°03'58.96"W), Canovanillas River (18°19'17.07"N, 65°54'13.36"W), Juan Martín River (18°21'07.85"N, 65°41'00.90"W), Guayanés River (18°04'12.51"N, 65°50'32.70"W), Caño Santiago (18°03'29.08"N, 65°49'32.71"W), Majada River (18°02'30.63"N, 66°12'36.38"W), Guayanilla River (18°18'12.33"N, 66°47'55.91"W), Yauco River (17°59'23.53"N, 66°50'24.92"W), Loco River (18°00'53.10"N, 66°52'33.10"W), Prieto River (18°15'19.81"N, 65°46'52.57"W), Guatemala River (18°20'35.75"N, 66°59'59.16"W), Ciales River (18°17'09.70"N, 66°30'53.76"W), marble River (18°21'05.76"N, 66°17'50.17"W), Morovis River (18°20'57.45"N, 66°23'10.50"W), Unión River (18°20'36.43"N, 66°22'50.04"W), Barranquita River (18°10'24.90"N, 66°17'53.82"W), La Zapatera Ravine (18°07'23.70"N, 66°05'07.65"W), Guaynabo River (18°21'59.78"N, 66°06'41.32"W), Rio Piedras River (18°24'00.98"N, 66°03'42.58"W), and Loiza Reservoir (18°18'54.98"N, 66°01'14.52"W).

References [3,16,55].

Remarks: I-00119, one organism collected on 20 January 1975; I-00120, one org. collected on 03/14/1975; and I-00121, one org. collected on 14 March 1975.

**Oreochromis niloticus** (Linnaeus, 1758)

**Distribution**
Widely introduced for aquaculture. Naturally occurring in coastal rivers of Israel, Nile basin, Ethiopian lakes, and West Africa.

Puerto Rico localities: Great River of Loiza (18°23'48.19"N, 65°54'44.89"W), Cañas River (18°17'22.84"N, 66°03'58.96"W), Canovanillas River (18°19'17.07"N, 65°54'13.36"W), and Blanco River (18°13'46.94"N, 65°47'09.12"W).

References [3,55].

**Parachromis managuensis** (Günther, 1867)

**Distribution**
Central America: Atlantic slope from the Ulua River (Honduras) to the Matina River in Costa Rica.

Puerto Rico localities: Bayamón River (18°22'11.03"N, 66°8'49.69"W), Guaynabo River (18°21'59.78"N, 66°06'41.32"W), and Loiza (18°18'54.98"N, 66°01'14.52"W), Citra (18°11'38.75"N, 66°08'18.24"W), Guajataca (18°23'26.86"N, 66°55'25.94"W), Dos Bocas (18°19'57.68"N, 66°40'05.12"W), and La Plata (18°20'04.89"N, 66°14'08.25"W) reservoirs.

References [36,54].

**Thorichthys meeki** Brind, 1918

**Distribution**
Central America: Atlantic slope in the Usumacinta River drainage, the Belize River drainage, and near Progreso in Mexico, Guatemala, and Belize.

Puerto Rico localities: Dos Bocas (18°19'57.68"N, 66°40'05.12"W), La Plata (18°20'04.89"N, 66°14'08.25"W), Caonillas (18°16'28.90"N, 66°39'10.30"W), Guayabal (18°05'44.53"N, 66°30'14.13"W), and Loiza (18°18'54.98"N, 66°01'14.52"W) reservoirs (Grana 2007).

References [36,56].

**Tilapia rendalli** (Boulenger, 1897)

**Distribution**
Africa: from the middle Congo River basin up to the upper Lualaba and the Bangweulu area. Also, in Lake Malawi, Zambesi, coastal areas from Zambesi Delta to Natal, Okavango, Cunene, Limpopo, Malagarasi and Lake Tanganyika. Introduced elsewhere, usually for weed control and aquaculture.

Puerto Rico localities: Bayamón River (18°22'11.03"N, 66°8'49.69"W), Guaynabo River (18°21'59.78"N, 66°06'41.32"W), Cañas River (18°17'22.84"N, 66°03'58.96"W). Very abundant in most of the island reservoirs.

References [3,57].

**Vieja melanura** (Günther, 1862)

**Family Eleotridae** Bonaparte, 1835

**Distribution**
Central America: Atlantic slope, in the Usumacinta River drainage in Mexico, Guatemala and Belize.

Puerto Rico localities: Guajataca (18°23'26.86"N, 66°55'25.94"W), Guayo (18°11'56.02"N, 66°50'01.79"W) and La Plata (18°20'04.89"N, 66°14'08.25"W) reservoirs. References [36,56].

**Dormitator maculatus** (Bloch, 1792)

**Distribution**
Western Atlantic from North Carolina south along the USA, Bahamas, throughout the Gulf of Mexico and the Caribbean Sea to southeastern Brazil.
Puerto Rico localities: Widespread throughout the island, but only in rivers, not present in freshwater reservoirs.

References [17,36,47,58].

Eleotris perringer (Cope, 1871)

Distribution
Northwest to western Central Atlantic: Bermuda, Bahamas, South Carolina and northern Gulf of Mexico in the USA to southeastern Brazil.

Puerto Rico localities: Tabonuco Ravine (18°21'15.53"N, 65°28'09.18"W), Mameyes River (18°19'26.57"N, 65°44'55.89"W), Sabana River (18°15'44.05"N, 65°47'39.13"W), Pitahaya River (18°21'53.73"N, 65°43'06.53"W), Juan Martin River (18°21'07.85"N, 65°41'10.90"W), Juan Diego Ravine (18°18'27.67"N, 65°46'08.63"W), Rincón Ravine (18°17'18.25"N, 65°41'37.67"W), Guayanés River (18°04'12.51"N, 65°50'32.70"W), Caño Santiago (18°03'29.08"N, 65°49'32.71"W), Maunabo River (18°00'12.59"N, 65°54'13.65"W), Guayanilla River (18°18'12.33"N, 66°47'55.91"W), Yauco River (17°59'23.53"N, 66°50'24.92"W), Los Llanos Ravine (18°01'44.65"N, 67°06'49.65"W), Yagüez River (18°12'26.80"N, 67°07'08.81"W), Salada Ravine (18°21'04.74"N, 67°01'32.95"W), Dulce Ravine (18°23'05.35"N, 67°05'42.48"W), Cialitos River (18°17'09.70"N, 66°30'53.76"W), and Río Piedras River (18°24'00.98"N, 66°03'42.58"W).

References [3,6,16,35,58].

Gobiomorus dormitor (Lacepède, 1800)

Distribution
Western Central Atlantic, southern Florida and southern Texas in the USA to eastern Brazil.

Puerto Rico localities: Reported in all rivers of Puerto Rico, also found in Tortuguero Lagoon (18°27'50.37"N, 66°26'36.91"W), Loiza (18°18'54.98"N, 66°01'14.52"W), Melania (17°58'42.55"N, 66°08'35.92"W), Patillas (18°01'27.38"N, 66°01'23.76"W), and Carite (18°04'44.13"N, 66°06'00.05"W) reservoirs, Canóvanas River (18°23'48.18"N, 65°54'44.89"W), Herrera River (18°33'01.20"N, 65°51'50.27"W), Tabonuco Ravine (18°21'15.53"N, 65°28'09.18"W), Mameyes River (18°19'26.57"N, 65°44'55.89"W), Sabana River (18°15'44.05"N, 65°47'39.13"W), Pitahaya River (18°21'53.73"N, 65°43'06.53"W), Juan Martin River (18°21'07.85"N, 65°41'00.90"W), Juan Diego Ravine (18°18'27.67"N, 65°46'08.63"W), Rincón Ravine (18°17'18.25"N, 65°41'37.67"W), Guayanés River (18°04'12.51"N, 65°50'32.70"W), Caño Santiago (18°03'29.08"N, 65°49'32.71"W), Maunabo River (18°00'12.59"N, 65°54'13.65"W), Majada River (18°02'30.63"N, 66°12'36.38"W), Pastillo River (18°02'19.84"N, 66°39'54.84"W), Tallaboa River (18°02'17.33"N, 66°43'17.40"W), Guayanilla River (18°18'12.33"N, 66°47'55.91"W), Yagüez River (18°12'26.80"N, 67°07'08.81"W), Blanco River (18°13'46.94"N, 65°47'09.12"W), Prieto River (18°15'19.81"N, 65°46'52.57"W), Salada Ravine (18°21'04.74"N, 67°01'32.95"W), Dulce Ravine (18°23'05.35"N, 67°05'42.48"W), Toro Negro River (18°13'49.25"N, 66°30'44.99"W), Cialitos River (18°17'09.70"N, 66°30'53.76"W), Río Piedras River (18°24'00.98"N, 66°03'42.58"W), Guayanés River (18°04'12.51"N, 65°50'32.70"W), and Guajataca River (18°26'52.79"N, 66°57'45.94"W).

References [3,6,16,35,58].

Awaous banana (Valenciennes in Cuvier and Valenciennes, 1837)

Distribution
North, Central and South America: northern Florida, USA southward through the Greater and the Lesser Antilles to Trinidad and Tobago, and from Tamaulipas, Mexico southward to Caracas, Venezuela; central Baja California Sur and Sonora, Mexico southward to Tumbes, Peru.

Puerto Rico localities: Canovianas River (18°19'17.07"N, 65°54'13.36"W), Canovanas River (18°23'48.18"N, 65°54'44.89"W), Herrera River (18°33'01.20"N, 65°51'50.27"W), Tabonuco Ravine (18°21'15.53"N, 65°28'09.18"W), Mameyes River (18°19'26.57"N, 65°44'55.89"W), Sabana River (18°15'44.05"N, 65°47'39.13"W), Pitahaya River (18°21'53.73"N, 65°43'06.53"W), Juan Martin River (18°21'07.85"N, 65°41'00.90"W), Juan Diego Ravine (18°18'27.67"N, 65°46'08.63"W), Rincón Ravine (18°17'18.25"N, 65°41'37.67"W), Guayanés River (18°04'12.51"N, 65°50'32.70"W), Caño Santiago (18°03'29.08"N, 65°49'32.71"W), Maunabo River (18°00'12.59"N, 65°54'13.65"W), Majada River (18°02'30.63"N, 66°12'36.38"W), Pastillo River (18°02'19.84"N, 66°39'54.84"W), Tallaboa River (18°02'17.33"N, 66°43'17.40"W), Guayanilla River (18°18'12.33"N, 66°47'55.91"W), Yagüez River (18°12'26.80"N, 67°07'08.81"W), Blanco River (18°13'46.94"N, 65°47'09.12"W), Prieto River (18°15'19.81"N, 65°46'52.57"W), Salada Ravine (18°21'04.74"N, 67°01'32.95"W), Dulce Ravine (18°23'05.35"N, 67°05'42.48"W), Toro Negro River (18°13'49.25"N, 66°30'44.99"W), Cialitos River (18°17'09.70"N, 66°30'53.76"W), Río Piedras River (18°24'00.98"N, 66°03'42.58"W), Guayanés River (18°04'12.51"N, 65°50'32.70"W), and Guajataca River (18°26'52.79"N, 66°57'45.94"W).

References [3,27,36,58].

Family Gobiidae Cuvier, 1816

Neotropical Biodiversity
09°03,55′N, 65°51′55.77″W, Guayanés River (18°), 04°12,51′N, 65°50′32.70″W, Caño Santiago (18°), 03°29,08′N, 65°49′32.71″W, Maunabo River (18°), 00°12,59′N, 65°54′13.65″W, Majada River (18°, 02°30,63′N, 66°12′36.38″W, Dacalbreo River (18°), 03°57,07′N, 66°25′48.19″W, Cañas River (18°), 17°22,84′N, 66°03′58.96″W, Pastillo River (18°), 02′19,84″N, 66°39′54.84″W, Tallaboa River (18°), 02′17,33′N, 66°43′17.40″W, Macaná River (18°), 00′51,57′N, 66°45′55.35″W, Guayanilla River (18°), 28 March 1969; I-00196, two orgs. collected on 22 March 1976; I-00195, one org. collected on 22 May 1998; and I-00204, 26 orgs. collected on 25 October 1998.

References [42,48,21,31,36,43,61,55,44,99,60,61].

Remarks: I-000203, 1 organism collected on 22 May 1998; and I-00204, 26 orgs. collected on 27 April 2000.

**Sicydium punctatum** Perugia, 1896

**Distribution**
Caribbean coast of Venezuela, Dominica, Jamaica, Martinique, Puerto Rico, Trinidad and Tobago, and Panama.

Puerto Rico localities: Great River of Añasco (18° 16′ 28.28″N, 67° 06′ 47.09″W) and Blanco River (18° 13′ 46.94″N, 65° 56′ 24.28″W). References [3,21,31,36,54,61].

Order Siluriformes

**Sicydium buscki** Evermann and Clark, 1906

**Distribution**
Cuba, Dominican Republic, and Puerto Rico.

Puerto Rico localities: Maricao, Arecibo, and Aguadilla municipalities.

References [21,53,60,61].

**Sicydium plumieri** (Bloch, 1786)

**Distribution**
The Greater and Lesser Antilles, South of Cuba, and Panama.

Puerto Rico localities: Canovänner River (18° 19′ 17.07″N, 65° 54′ 13.36″W), Canóvanas River (18° 23′ 48.18″N, 65° 54′ 44.89″W), Herrera River (18° 33′ 01.20″N, 65° 51′ 50.27″W), Espíritu Santo River (18° 21′ 54.37″N, 65° 48′ 55.44″W), Tabonuco Ravine (18° 21′ 15.53″N, 65° 28′ 09.18″W), Sabana River (18° 15′ 44.05″N, 65° 47′ 39.13″W), Juan Martin River (18° 21′ 07.85″N, 65° 41′ 00.90″W), Juan Diego Ravine (18° 18′ 27.67″N, 65° 46′ 08.63″W), Majada River (18° 02′ 30.63″N, 66° 12′ 36.38″W), Dacalbreo River (18° 03′ 57.07″N, 66° 25′ 48.19″W), Cañas River (18° 17′ 22.84″N, 66° 03′ 58.96″W), Pastillo River (18° 02′19.84″N, 66° 39′ 54.84″W), Tallaboa River (18° 02′ 17.33′N, 66° 43′ 17.40″W), Macaná River (18° 00′ 51.57′N, 66° 45′ 55.35″W), Guayanilla River (18° 18′ 12.33′N, 66° 47′ 55.91″W), Loco River (18° 00′ 53.10″N, 65° 52′ 33.10″W), Yagüez River (18° 12′ 26.80″N, 67° 07′ 08.11″W), Blanco River (18° 1′ 34′ 46.94″N, 65° 47′ 09.11″W), Prieto River (18° 15′ 19.81″N, 65° 46′ 52.57″W), Great River of Añasco (18° 16′ 28.28″N, 67° 06′ 47.09″W), Fría Ravine (18° 1′ 34′ 46.94″N, 65° 56′ 24.28″W), Bauta River (18° 24′ 39.05″N, 66° 42′ 54.54″W), Great River of Manatí (18° 24′ 31.31″N, 66° 29′ 46.04″W), Guayanabo River (18° 21′ 59.78″N, 66° 06′ 41.32″W), and Río Piedras River (18° 24′ 00.98″N, 66° 03′ 42.58″W).

References [21,31,36,54,61].

Order Siluriformes

**Clarias gariepinus** (Burchell, 1822)

**Distribution**
The species is native to most of the African continent and small areas of Asia in Israel, Syria and the south of Turkey. The African catfish has been introduced in at least 37 countries of Africa, Europe, Asia and America, mainly for aquaculture, with negative impacts in freshwater and brackish ecosystems.

Puerto Rico localities: Patillas Canal (17°58′40.63″N, 66°08′56.52″W). References [23,62].
Remarks: MZUPRRP-I-936 and MZUPRRP-I-937, 2 organisms collected in 2018.

**Family Ictaluridae Gill, 1861**

*Ameiurus catus* (Linnaeus, 1758)

**Distribution**
North America: Rivers of the Atlantic coastal states of the USA from Florida to New York.

Puerto Rico localities: Dos Bocas Reservoir (18° 19'57.68"N, 66°40'05.12"W).

References [16,36,63].

*Ameiurus nebulosus* (Lesueur, 1819)

**Distribution**
North America: Atlantic and Gulf Slope drainages from Nova Scotia and New Brunswick in Canada to Mobile Bay in Alabama in the USA, and St. Lawrence-Great Lakes, Hudson Bay and Mississippi River basins from Quebec west to Saskatchewan in Canada and south to Louisiana, USA. Several countries report adverse ecological impact after the introduction. Asia: Iran and Turkey.

Puerto Rico localities: Melanía (17°58’42.55”N, 66°08’35.92”W), Comerio (18°15’29.50”N, 66°12’17.59”W), Carite (18°04’44.13”N, 66°06’00.05”W), Dos Bocas (18° 19’57.68”N, 66°40’05.12”W), Toa Vaca (18°06’09.99”N, 66°28’57.91”W), Patillas (18°01’27.38”N, 66°01’23.76”W), Caonillas (18°16’28.90”N, 66°39’10.30”W), Guayabal (18°05’44.53”N, 66°30’14.13”W) reservoirs, and La Plata River (18°08’14.07”N, 66°12’27.07”W).

References [16,36].

*Ictalurus punctatus* (Rafinesque, 1818)

**Distribution**
Central drainages of the United States to southern Canada and northern Mexico; also introduced in Europe, the Russian Federation, Cuba, and portions of Latin America.

Puerto Rico localities: Dos Bocas (18°19’57.68”N, 66°40’05.12”W), Loiza (18°18’54.98”N, 66°01’14.52”W), Patillas (18°01’27.38”N, 66°01’23.76”W), Carite (18°04’44.13”N, 66°06’00.05”W), Caonillas (18°16’28.90”N, 66°39’10.30”W), Cidra (18°11’38.75”N, 66°08’18.24”W), Guayabal (18°05’44.53”N, 66°30’14.13”W) reservoirs, Toa Vaca (18°06’09.99”N, 66°28’57.91”W) reservoirs, Cañas River (18°17’22.84”N, 66°03’58.96”W), Yauco River (17°59’23.53”N, 66°50’24.92”W), Loco River (18°00’53.10”N, 66°52’33.10”W), Blanco River (18°13’46.94”N, 65°47’09.12”W), Prieto River (18°15’19.81”N, 65°46’52.57”W), and the estuarine area of the Great River of Arecibo (18°27’39.92”N, 66°42’24.67”W).

References [3,16,34,36].

Remarks: I-00018, 1 organism collected on 11 August 1999.

**Family Loricariidae Rafinesque, 1815**

*Pterygoplichthys multiradiatus* (Hancock, 1828)

**Distribution**
South America: Orinoco River basin, Argentina, Taiwan, mainland USA, and Hawaii.

Puerto Rico localities: Bayamón River (18°22’11.03”N, 66°8’49.69”W), Gurabo River (18°16’01.09”N, 65°58’55.04”W), Great River of Loiza (18°23’48.19”N, 65°54’44.89”W), Rio Piedras River (18°24’00.98”N, 66°03’42.58”W), Guayanabo River (18°21’59.78”N, 66°06’41.32”W), Guanajibo River (18°06’18.85”N, 67°03’55.21”W), Loco River (18°00’53.10”N, 66°52’33.10”W), Patillas Channel (17°58’40.63”N, 66°08’56.52”W), Loiza (18°18’54.98”N, 66°01’14.52”W) and Dos Bocas reservoirs (18°19’57.68”N, 66°40’05.12”W), and Dorado Shrimp Farm.

References [18,36,64].

Remarks: I-00020, 1 organism collected in 1999.

*Pterygoplichthys pardalis* (Castelnau, 1855)

**Distribution**
In South America, from lower, middle and upper Amazon River basin; also introduced to countries outside its native range.

Puerto Rico localities: Great River of Loiza River (18°23’48.19”N, 65°54’44.89”W), Cañas River (18°17’22.84”N, 66°03’58.96”W), Juan Martín River (18°21’07.85”N, 65°41’00.90”W), Yauco River (17°59’23.53”N, 66°50’24.92”W), La Zapatera Ravine (18°07’23.70”N, 66°05’07.65”W), Rio Piedras River (18°24’00.98”N, 66°03’42.58”W), Loiza (18°18’54.98”N, 66°01’14.52”W), Dos Bocas (18°19’57.68”N, 66°40’05.12”W), Caonillas (18°16’28.90”N, 66°39’10.30”W), Patillas (18°01’27.38”N, 66°01’23.76”W), Cidra (18°11’38.75”N, 66°08’18.24”W), Guayabal (18°05’44.53”N, 66°30’14.13”W) reservoirs, and Cerrillos (18°05’49.92”N, 66°34’43.83”W) reservoirs.

References [3,64].

**Family Pangasiidae Bleeker, 1858**

*Pangasius hypophthalmus* (Sauvage, 1878)

**Distribution**
Asia: Mekong, Chao Phraya, and Maeklong basins.
Puerto Rico localities: Loiza Reservoir (18°18′54.98″N, 66°01′14.52″W), and Caribe Fisheries Inc. farm (18°01′42.27″N, 66°58′20.83″W) in Lajas.

References [36,65].

Discussion

We review the freshwater fish fauna of Puerto Rico and present an updated list of the species present in the island. We report all known sites occupied by each fish species that inhabit streams and freshwater reservoirs in the island (georeferenced when possible). Although 77 fish species have been reported for Puerto Rico [3], we include only those species considered freshwater residents or species that spend most of their life cycle in freshwater. Consequently, we have excluded native fish such as Bathygobius soporator, Dormitor maculatus, Gerres cinereus, Kryptolebias marmoratus, Microphis brachyurus, Mugil cephalus, Mugil liza, Megalops atlanticus and Strongylura marina, all of which are occasionally found in freshwater streams, but primarily inhabit marine or estuarine ecosystems [16]. One of the highlights of our study, and a source of concern, is the number of introduced species inhabiting streams and water reservoirs in Puerto Rico, compared to the pool of native species currently present on the islands. Less than 20% of the freshwater fish species are native.

The fast development of freshwater aquaculture in the past century has been a major factor responsible for the introduction of many exotic fish in mainland areas, and some islands [66]. However, the dominance of aquarium species in our list and the lack of an established aquaculture industry in Puerto Rico indicate that the pet trade has been critical in the introduction of exotic freshwater fish. In the past, there were short-lived commercial tilapia farms established in Puerto Rico. For example, the Lajas Aquaculture Station and the Maricao Fish Hatchery operated for years [67], with the Maricao Fish Hatchery still being operated today by the Department of Natural and Environmental Resources (D.N.E.R.). The introduction of most (62.6%) non-indigenous resident species in Puerto Rico is associated with the local aquarium and pet trade business, while the vector for the remainder non-native species is equivocal; however, we suspect the aquarium and pet trade market as the likely culprit.

The international fish trade is currently growing and represents an important source of revenue for many countries [68,69]. However, this brings with it the risk of release of live non-native freshwater fish outside their native range, which may have negative impacts on the populations of native species and the ecosystem services they provide. As with many introduced invasive species, the introduction of non-native freshwater fish may have unintended and unpredictable negative effects on local environments and currently represents one of the main threats against the survivorship and genetic integrity of native species populations [70,71]. Moreover, established exotic fish may introduce parasites and diseases, compete for or alter food resources and habitat dynamics, and prey upon native fish [72]. The current freshwater fish community’s composition in Puerto Rico is not only a direct consequence of irresponsible and uninformed attitudes of pet owners but it is also due to the illegal introduction by local aquaculture farms. For example, the Jaguar Guapote Cichlid was introduced to Puerto Rico without the permission of the D.N.E.R by aquaculture farms to control tilapia overpopulation in the culture ponds. Once discovered, the D.N.E.R ordered the eradication of the fish, which was supposedly completed. However, the Jaguar Guapote appeared later in the Loiza Reservoir, which indicates other (geographic) sources are supplying the species into freshwater ecosystems.

The existence of another 128 freshwater fish sold locally as pets represents a serious threat and serves as a “potential pool” of non-native species that could be added to natural freshwater ecosystems in the future (See Appendix 1). Of all the species, those that belong to the family Cichlidae represent the most aggressive invaders, with 13 species established on the island and another 38 potential invasive species sold as pets (Figure 2). The 2010 D.N.E.R Fisheries Regulations [73] published a table with the aquarium species which are allowed for import into Puerto Rico. When we compare this list with our potential invasive species list, we noticed differences. For example, the Family Anguillidae has only one species in the D.N.E.R. list, but we also found another species of eel, Anguilla marmorata, sold as pets. Most alarming is that the Family Cichlidae has 113 species authorized by D.N.E.R to be sold as pets. Thirteen of those have escaped and established while another 39 potential cichlid invaders are still in the local market.

The negative impacts of exotic fish have not yet been thoroughly documented in Puerto Rico, but there are indications that impacts may be, indeed, serious. For example, Red devil cichlids (Amphilophus spp.) are known to be extremely aggressive predators and competitors. D.N.E.R has documented an inverse relationship between non-native sunfish (Lepomis sp.) and red devil abundances, but attributing sunfish decline to the introduction of invasive red devil cichlids is speculative since the evidence may be circumstantial [74]. However, if there is such a relationship between the two non-indigenous species, then we could expect that if the red devil invades Puerto Rican rivers, they will potentially negatively impact the native freshwater fish community. Another species of concern is the armored catfish (Pterygoplichthys spp.) which could compromise shoreline stability by increasing riverbank erosion and suspended sediment loads in the reservoirs as a result of excavating nest burrows at high densities along shorelines [75]. Armored catfish may also pose a threat to
endangered brown pelicans (Pelecanus occidentalis), some of which have died from having catfish lodged in their throat by their spines [18].

There are many different approaches to managing existing invasive species and avoiding new introductions. For example, managers and politicians should create an administrative bill that would establish public education programs and campaigns about the importance of avoiding the release of freshwater fish from aquaria and aquaculture in streams, channels, and reservoirs. New laws could also penalize releasing potential invasive fish with fines. More specific management of current populations of introduced fish, especially those that pose significant threats to Puerto Rico’s native fish and their ecosystems, should be prioritized. In order for management efforts to succeed, further research must be done to fill in the knowledge gaps in the distribution and ecology of introduced species. Efforts should prioritize native ecosystems with higher native fish diversity such as lowland streams and introduced species that are found at high abundances in these environments.

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Author Contribution

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Camille Zapata-Arroyo: study design, fieldwork, writing.
Wilfredo Falcón: study design, writing and web search.
María de Lourdes Olmeda: fieldwork and writing.

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No potential conflict of interest was reported by the authors.

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