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Article

Assessing the species in the CARES Preservation Program and the role of aquarium hobbyists in freshwater fish conservation

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Abstract: Freshwater fish represent half of all fish species and are the most threatened vertebrate group. Given their considerable passion and knowledge, aquarium hobbyists can play a vital role in their conservation. CARES is made up of many hobbyist organizations, whose purpose is to encourage aquarium hobbyists to the most endangered or extinct-in-the-wild freshwater fish to help ensure their survival. We found the CARES priority list contains nearly six hundred species from twenty families and two dozen species extinct-in-the-wild. The major families were typically the ones with largest hobbyist affiliations such as killifish, livebearers, and cichlids; which alone were half of CARES species. CARES contained every IUCN threatened species of Pseudomugilidae and Valenciidae, but only one percent of threatened Characidae, Cobitidae, and Gobiidae species. No Loricariidae in CARES were in the IUCN red list as they were not scientifically described. Tanzania and Mexico contained the largest amount of species, with the latter containing the most endemics. A large percent of species were classified differently than the IUCN, including a third of extinct-in-the-wild species classified as least concern by the IUCN. The vast disconnect exemplifies the importance of collaboration and information exchange required between hobbyists, the scientific community, and conservation organizations.

Keywords: Aquarists; aquarium trade; captive-breeding; IUCN red list; ornamental fish; threatened fish; undescribed species

1. Introduction

Although freshwater habitats constitute only 0.01% of all water on Earth and 2.3% of the Earth's surface, they support approximately 9.5% of all described animal species, including one third of all vertebrates [1,2]. Given the disproportionately high biodiversity value of freshwater systems, it is of serious concern that they are one of the most threatened habitats on Earth. The World Wide Fund for Nature's Living Planet Index 2018 indicates that populations of freshwater species have declined by an average of 83% since 1970, much larger than declines seen in terrestrial (38%) and marine (36%) species [3]. This is especially true for freshwater fishes which are the most threatened vertebrate group [4], with an extinction rate estimated to up to 877 times greater than the background extinction rate [5].

Freshwater fish make up approximately half of all known fish species and nearly a quarter of global vertebrate diversity, with many new species being discovered every year [4]. Despite marine ecosystems being comprised of a relatively larger area, fish species are far richer per volume in freshwater habitats. This is due to the geographical isolation of these systems, which has led to the evolution of many species with very small ranges that may encompass merely a single isolated lake or river basin [1,4]. Such high levels of fragmentation and resultant high species endemism has made freshwater habitats biodiversity hotspots. However, it has also made them especially sensitive to

anthropogenic impacts where large numbers of species can rapidly become extirpated [1]. Even for those species that have yet to entirely disappear, human activities have reduced or eliminated such a high proportion of populations that they have incurred an extinction debt due to their low-viability [1]. Currently, the greatest threats that freshwater habitats are facing include habitat degradation from pollution (contaminants, micro-plastics, and algal blooms) and flow modification (dams and hydropower), overexploitation (commercial fishing, pet trade), climate change, invasive species, and infectious diseases [3,6]. These combined, and often interacting, changes cause bottom-up and top-down ecosystem level changes, the net effect of which is a reduction in the future viability of freshwater species [3]. Expanding population pressures and accelerating urbanization, along with the ever-growing need for fresh water and food production, irrigation and water infrastructure developments, will only exacerbate the steep decline and loss of freshwater biodiversity [3,6]. It is the magnitude of these anthropogenic threats to freshwater fish that now warrants a more proactive and interventionist conservation strategy that combines different levels of management with a multi-stakeholder approach [4].

Organizations such as the American Zoo and Aquarium Association (AZA), the European Association of Zoos and Aquaria (EAZA), and World of Zoos and Aquariums (WAZA) have helped integrate a holistic approach to conservation, reinforcing the important roles that zoos and aquariums must play if biodiversity and ecosystems in general are to be conserved [7,8]. Although the number of aquariums have increased at a much faster rate than zoos, with up to 450 million people visiting each year [7], they are vastly under-represented in conservation projects given their prevalence in nature and popularity [9]. Aquariums and zoos only hold about 7% of all threatened fishes with only two out of 31 actively involved in a fish conservation reintroduction project [9,10]. This may be attributed to the undefined conservation needs of many fish species, with approximately only half of all known species having been assessed by the IUCN [9]. To close these conservation and knowledge gaps, aquarium hobbyist organizations, which make up 99 percent of the global ornamental fish market, may play a vital role given the considerable expertise of aquarists in the husbandry, reproduction, and ecology of fresh water species [11].

The global trade in ornamental fish has grown 14% annually since the 1970s and now involves approximately 125 countries. Over 1 billion fish are internationally traded annually, including over 5300 freshwater and 1800 marine species, with an estimated worth of between US $15–30 billion each year [7,12,13]. This international trade is dominated by freshwater fishes, accounting for over 90% of the total trade volume, with 90% of species being captive bred and typically sourced from breeding facilities in Asia, South America, Israel, USA and Europe [12-14]. Recently, fisheries and ornamental fish organizations have recognized their role in freshwater fish conservation by creating initiatives that promote sustainable practices that serve to provide a livelihood for local communities, promote environmental stewardship and protect vulnerable freshwater ecosystems and species. Notable examples include Project Piaba, a community-based interdisciplinary project strongly supported by zoos and aquariums which promotes sustainable fisheries and provide a livelihood for local communities [15]; the Indonesia Nature Foundation in Bali, Indonesia, which are among the main suppliers of the Indonesian fish trade and supports communities to build artificial reefs, train in sustainable collection methods and a captive rearing program for the Banggai cardinalfish (Pterapogon kauderni Koumans); and the AZA Freshwater Fish Taxon Advisory Group which help conserve Lake Victoria-Kyoga's indigenous fishes including Lake Victoria cichlids, many which were donated or acquired though hobbyist and the aquarium trade [4].

Aquarium hobbyist organizations have also been instrumental in leading their own projects and generating scientific knowledge in collaboration with professional scientists. This includes the discovery of new species such as Pseudolaguvia lapillicola, Danionella dracula, the rainbow killifish (Nothobranchius rachovii), the goodeid (Zoogoneticus purepechus), and the Sahara aphanius (Aphanius saourensis), as well as the rediscovery of the Azraq killifish (Aphanius sirhani) [16]. Many hobbyist associations also maintain extensive database depositories of thousands of species (e.g. catfish (http://www.planetcatfish.com/), Fresh Water Fishes of Mexico (http://www.mexfish.info/default.php?lang=es), killifishes (http://www.killidata.org/), and cichlids

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(http://www.cichlidae.com/), with information on their biology, ecology, range and behaviors; with many species unknown by researchers or neglected by governments and conservation organizations. These organizations take an active role in conservation projects funded by their members or crowdfunding, especially important for non-commercially important species, and have led to the successful reintroduction of the endangered Spanish toothcarp (Aphanius iberus) in restored lagoons by the Llobregat delta Sociedad de Estudios Ictiológicos (SEI), and three endangered Aphanius species (A. apodus, A. danfordii and A. sirhani), as well as the wild-extinct Potosi pupfish (C. alvarezi) by the Spanish Killifish Association (SEK) [16]. Since many species (mainly livebearer, cichlids and killifish species) are available only from aquarium hobbyists (approximately a quarter of aquarium species are exclusively owned by hobbyists), hobbyist conservation projects have been created to help maintain a viable bank of germplasm of the most endangered species [12]. This includes conservation projects such as the Fish Ark Project (FAP), Hobbyist Aqualab Conservation Project (HACP), and the Goodeid Working Group (GWG) which successfully keep populations of the 12 most endangered or extinct-in-the-wild and 24 threatened goodeid species in Mexico, and have provided specimens of rare fishes to 34 universities, public aquaria, zoos and other hobbyists in 15 countries to ensure species survival [16].

The largest conservation program is the CARES (Conservation, Awareness, Recognition, Encouragement, and Support) preservation program. Founded in 2004, CARES is currently made up of 30 aquarium societies and international organizations whose purpose is to encourage aquarium hobbyists around the world to devote tank space and distribute to other members one or more of 500 listed vulnerable, endangered, or extinct in the wild species to help preserve species for future generations. The other main goal is to share ecological, husbandry and habitat knowledge about these species with other aquarists, scientists, and conservationists. The CARES program also has their own risk classification for listed species not classified by the IUCN red list or those they believe require a different classification. However, to better serve its goals of preserving at risk species and sharing information it is critical to assess the species within the program to evaluate what groups and regions are well represented and which may require more attention, as well as comparing their conservation classification to those of the IUCN. The aim of this paper is to assess the species and regions in the CARES preservation program and compare their IUCN conservation status.

2. Results

The CARES priority list contained 572 freshwater species in 20 different family groups with 30 species classified as extinct in the wild. The priority list was overrepresented by Cichlidae with 47% of all CARES species (268) which also made up over half of the extinct in the wild species (17) (Table 1). The families representing the highest proportion of the total IUCN threatened and data deficient species were Pseudomugilidae and Valenciidae where all species were represented, and Goodeidae and Aplocheilidae with over 80% of the total threatened and data deficient species in the IUCN (Table 1). Approximately two-thirds (383) of the species were found in the IUCN redlist, 82% (471) were in fishbase.org database, while 14% (85) were not found in either database (Table 1). The group with the highest proportion of unclassified species not identified in any database was Loricariidae with 58.6% (17), Cichlidae with 22.8% (61) and Aplocheilidae with 15.4% (2) (Table 1).

Table 1. Families in the CARES priority list and their IUCN classification.

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Family	CARES total	Classified in IUCN	IUCN total threatened	Proportion of IUCN threatened/data deficient	Undescribed	Critically Endangered	Extinct in the wild
Adrianichthyidae	6	6	15	0.40	0	0	0
Anabantidae	42	14	9	1.56	0	5	0
Aplocheilidae	13	8	10	0.80	2	2	1
Bedotiidae	23	21	28	0.75	2	5	0
Characidae	3	1	91	0.01	0	0	0
Cichlidae	268	197	500	0.39	61	60	17
Cobitidae	1	1	79	0.01	0	0	0
Cyprinidae	20	18	1081	0.02	1	2	1
Cyprinodontidae	16	16	44	0.36	0	5	4
Fundulidae	1	1	9	0.11	0	1	0
Gobiidae	3	3	254	0.01	0	0	0
Goodeidae	37	13	15	0.87	0	10	3
Loricariidae	29	0	62	0.00	17	0	0
Melanotaeniidae	22	18	26	0.69	0	0	2
Mochokidae	6	6	84	0.07	0	0	0
Nothobranchiidae	25	24	120	0.20	1	0	0
Poeciilidae	28	19	60	0.32	0	3	2
Pseudomugilidae	13	6	6	1.00	1	3	0
Rivulidae	14	9	36	0.25	0	0	0
Valenciidae	2	2	2	1.00	0	2	0
Total	572	383	2531		85	98	30

Of those species in the IUCN, 64 (16.7%) species were classified differently than the IUCN, with 7 species labeled least concern and that CARES classified as extinct in the wild (Figure 1). Due to some species classified differently by CARES, Anabantidae had more threatened species than were classified as threatened in the IUCN (Table 1). None of the 29 Loricariidae species were found in the IUCN red list, while only 1% of threatened Characidae, Cobitidae, Gobiidae species were in CARES (Table 1). The greatest number of species came from East Africa, Mexico, Brazil, Southeast Asia (Figure 2a); specifically Tanzania (118), Mexico (78), Madagascar (66), Kenya (61) and Uganda (60) (Figure 2a). The greatest number of endemics were from Mexico (76, 17.5%) and Madagascar (65, 15%), followed by Tanzania (47, 11%), Brazil (43, 9.9%), and Indonesia (42, 9.7%) (Figure 2b).

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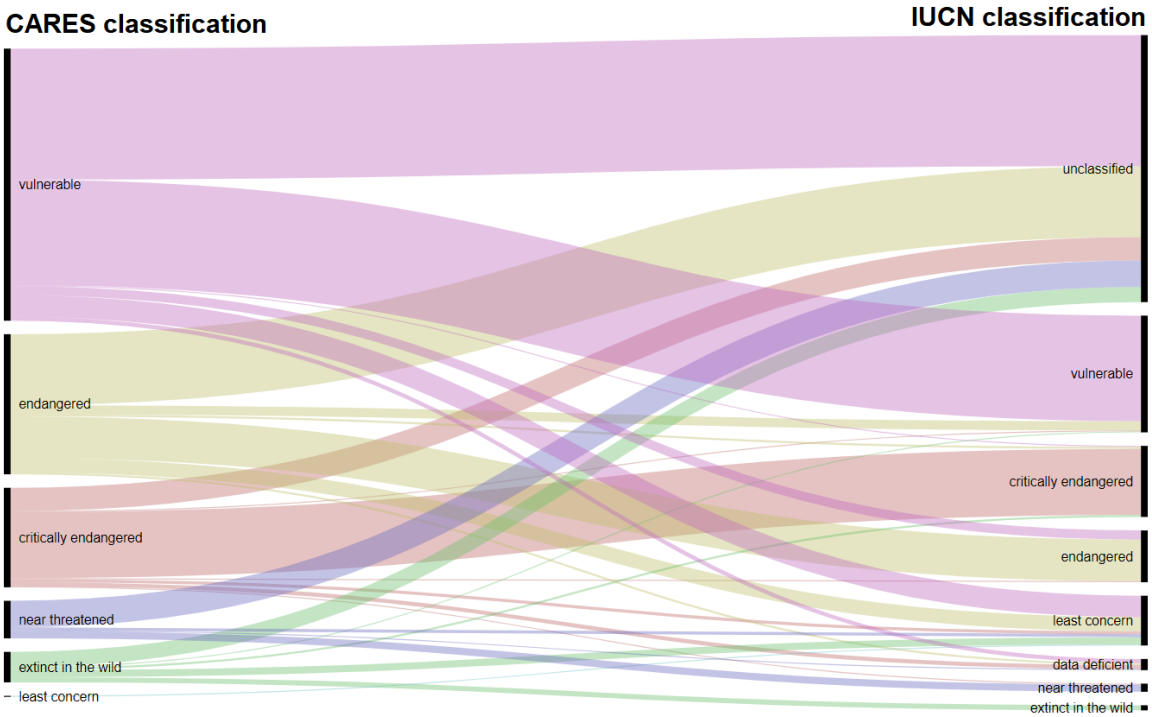

Figure 1. Classification of CARES species found in the IUCN. http://app.rawgraphs.io/

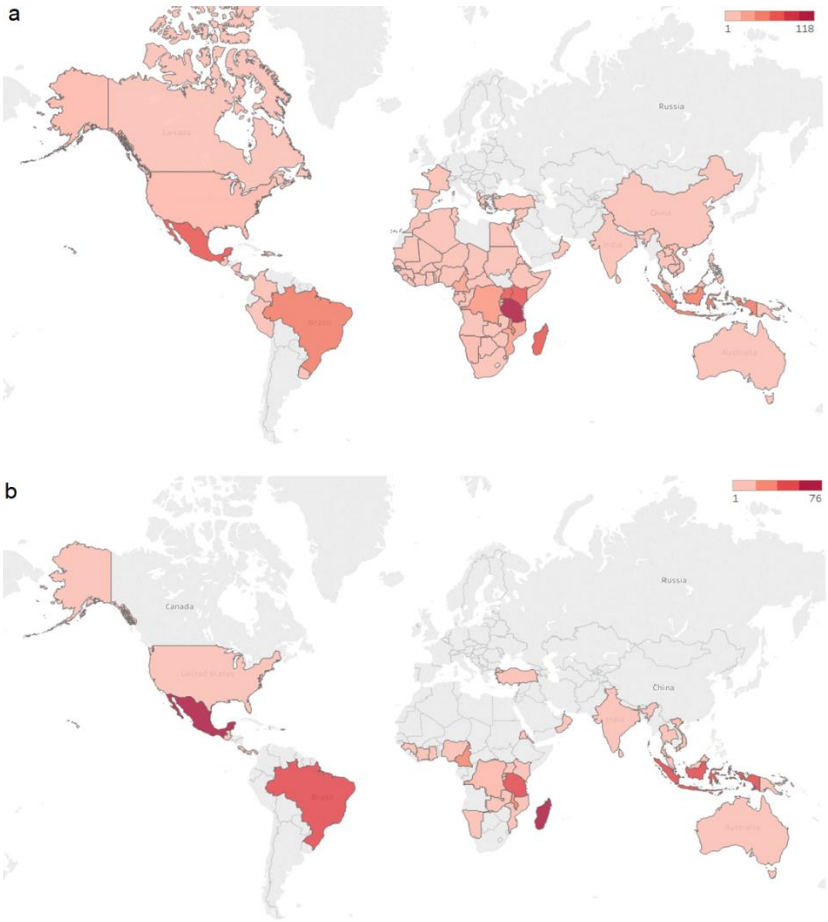

Figure 2. Total (a) number of species and (b) endemics in the CARES priority list. Tableau public 2019.1.

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3. Discussion

The CARES priority list currently contains nearly six hundred species of freshwater fish from twenty families, including over two dozen species extinct in the wild. Unsurprisingly, the major families in CARES were the most popular ornamental fishes and the ones with largest affiliations in aquarium hobby organizations such as killifish (Cyprininodontidae), livebearers (Goodeidae, Poeciliidae), as well as cichlids (Cichlidae) [16] which alone represented nearly half of all species on the CARES list. The over representation of cichlids can be explained by their popularity as freshwater aquarium fish (e.g. angelfish, Oscars, and discus), as well as the fact that they are one of the largest vertebrate groups containing the most endangered vertebrate species. Their high species number is due to their rapid speciation in isolated lakes especially in East African Rift such as Malawi, Tanganyika, and Victoria which are some the richest and biodiverse lakes in the world [20]. Pseudomugilidae and Valenciidae contained every species listed as threatened by IUCN including an extinct in the wild species for the former and both critically endangered species in the latter. Meanwhile, only around one percent of all the threatened IUCN Characidae, Cobitidae, Gobiidae species were represented in CARES. Moreover, although Loricariidae represents the largest group of catfishes none were found in the IUCN red list and over half were not found in fishbase.org. This is because the popularity of armored catfishes in the aquarium hobby has not caught on with the scientific literature due to the fish occurring in areas difficult for studies to be undertaken, with many species designated with an "L-number" instead of a scientific name as most have not been taxonomically described. Nevertheless, all Loricariidae species in CARES are described in the Planet Catfish database, with most found in Brazil, specifically the Xingu River, which has the most sought-after species by hobbyists.

Lake Victoria and Lake Malawi in East Africa are also the major locales where many of the CARES species are located, with some of the most biodiverse regions in the world and species very popular in the aquarium trade. Due to the large number of freshwater fish, especially in these two lakes, the Afrotropical region has by far the most threatened freshwater fish species listed in both CARES and the IUCN [17]. Tanzania contained the largest number of CARES species as they are a major exporter for Lake Malawi and Lake Tanganyika cichlids. Three other East African countries, Madagascar, Kenya, and Uganda, having the third to fifth most, respectively. Madagascar has nearly half of all their species threatened [21] second most endemics in the CARES priority list. Mexico had the second most CARES species, which is no surprise given that it is one of the top five countries with the most threatened species more endemics than any other country [17]. However, it may also be due to the work of major hobbyist organizations in this country, such as the Goodeid Working Group which supports major Goodeid fishes conservation projects in Mexico include captive rearing, research funding, habitat restoration, and public outreach [16]. However, CARES did not proportionally represent the countries with the most threatened freshwater fish species: the U.S. and India; first and second, respectively [17]. The lack of U.S. species presence on this list is not surprising when one considers possession of some of these species would be illegal especially since CARES is predominately a U.S. based organization and since the threatened status of these species are most likely to be known. However, organizations such as North American Native Fish Association (NANFA) promotes breeding and keeping of certain rare North American freshwater fish, and could be useful organization to collaborate with CARES. India harbors the greatest number of endemic species in continental Asia, and the Indomalaysian region has the second most threatened freshwater species [17]. Although India is one of the largest fish exporters along with the Philippines [22], recent crackdown on ornamental fish exports has likely increased the difficulty of obtaining many of these species [11]. We recommend CARES should focus more on getting species from India and other Asian regions, along with Central and South America, which are at exceptional risk due to amount of undescribed species and high extinction risk [23,24]. Nevertheless, some regions and countries will always be better represented than others due to trade restrictions, for example species from South American countries like Peru and Colombia are easier to obtain than those from Guyana and Surinam.

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This study also illustrates the discrepancies between aquarium hobbyist organizations and the scientific community. We found CARES listed over eighty species that are currently undescribed by the scientific community, given that they have not been identified in IUCN or fishbase.org, including half of all Loricariidae and a quarter of all Cichlidae. We also found CARES classified a large percent of red list species differently than the IUCN. Although many classifications were different by just one level some disparities were much larger. In the Anabantidae group more species were listed as threatened in CARES than in IUCN, with a third of all extinct in the wild species classified as least concern by the IUCN. The vast disconnect in information of so many species exemplifies the lack of collaboration between hobbyists, the scientific community, zoo/public aquariums and conservation organizations, and the need for stronger partnerships between these groups to ensure no species is left without proper management . This is highlighted by the fact that many species remain undescribed by the IUCN, with their conservation status subsequently unknown, yet many have been named and are well known by aquarium hobbyists. Around nearly a quarter of all fish species are only found to members of hobbyist organizations, which maintain extensive lists of names, origins, and technical reports of many unclassified and undescribed species [16]. Aquarium hobbyists often possess discrete knowledge based on field observations, while many hobby associations dedicated to specific fish groups or regions. As CARES classification is conducted by a handful of qualified authorities, it can collate these many streams of knowledge from these associations with conservation organizations like the IUCN to provide more detailed and accurate species listings.

CARES main goal is to serve as a modern Noah's Ark by maintaining ex situ populations of endangered or extinct-in-the-wild species through captive rearing to help preserve the species for future generations, while perhaps using their knowledge and captive species for conservation and possible reintroductions. The importance of programs such as CARES is that they also focus on many species with little to no commercial value in the ornamental fish trade. Although it seems strange for non-scientists to maintain endangered species due to the threat of overharvesting and further decimation of these populations, over 90% of freshwater fish in the trade market are captive-bred, which means there is little risk of this occurring [25]. For some species, this market has even produced a source of surplus of individuals required for reintroduction programs [15]. While zoos and aquariums invest more than US$350 million annually to captive breeding and reintroduction programs, and are most frequently cited as the action that have led to improvements in species' IUCN Red List status [26], fish hobbyists keep many more species than aquariums and possess invaluable information on species' habitat and breeding requirements. For example, a quick search on the AZA website shows there are currently only 7 freshwater Actinopterygii fish in conservation action plans, and all are Lake Victorian cichlids. As CARES main goal is preservation rather than conservation, cooperating and exchanging information with zoos and aquariums, especially organizations such as AZA and EAZA, is vital since as they have a species survival plans which can help maintain genetic diversity in captive populations. Working collaboratively with well-funded and knowledgeable organizations, CARES can become a major catalyst for improved success of many of these conservation programs.

Aquarium keeping is rated as the second most popular hobby with millions of enthusiasts worldwide [27]. Due to their interest and love for the species they own, aquarium hobbyists can often be more knowledgeable than the scientific community while often caring and breeding species that are critically endangered or already extinct in the wild. Aquarium keeping also helps form a place attachment and bring awareness to specific areas and ecosystems as individuals try to recreate a particular biotope for their fish tank. It helps people care about threatened and endangered places that they have never been to and countries they have never visited, with some hobbyist inspired by their tanks to partake in ecotourism to go visit these places. Aquarium hobbyist organizations help bring hobbyists together to exchange information to maintain and preserve specific groups of fishes and their habitats. CARES is a recent association which combines many of these organizations to specifically breed and keep species that may soon be, and in some cases, already are gone in the wild. However, to fulfil their goals, they must work with larger well-funded organizations such as the AZA and EAZA, while also exchanging their knowledge with conservation organizations such as the

IUCN. By bridging these gaps, fish hobbyists through CARES can help play a major role to help preserve fishes for future generations.

4. Materials and Methods

The CARES priority list was downloaded from https://caresforfish.org on 21 May, 2019, which included nomenclature and risk classification from either IUCN or CARES authorities. Fish species data was downloaded from the IUCN red list to compare classification risk and determine what groups are well represented [17]. We used the "rfishbase" package [18] in R version 3.6.0 [19] to find species that could not be found in the IUCN red list by searching for synonyms and other possible names, as well as find the countries and regions the species are found. This package accesses the fishbase database (http://www.fishbase.org) which describes ecology and biology of the over 30,000 known fish species. We also accessed online databases such as Cat-eLog (https://www.planetcatfish.com/catelog/), seriouslyfish (https://www.seriouslyfish.com/), and the Goodeid Working Group database (http://www.goodeidworkinggroup.com/) to find information of CARES species still not found from the previous databases.

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