

Original Article

Evolution of Natural History Collection autonomy in the Global South: the case of Neotropical freshwater fishes

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ABSTRACT

Neotropical freshwater fish type specimens have historically been concentrated in Global North institutions, which led scientific activity in the 19th and 20th centuries. Despite recent advances in taxonomic activity in Neotropical countries, the dispersion of type specimens still hinders biodiversity research in the Neotropics. This study examines the spatiotemporal (1758–2025) distribution of 8252 Neotropical freshwater fish type specimens, analysing retention trends, geopolitical influences, and legislative impacts. Our results revealed that 61% of types are housed in Global North collections. Historical dominance by European and US institutions shifted after 1950 and especially in the last few decades, with Brazil and Colombia retaining almost all of their type specimens collected in the post-2000 period, while Venezuela lost retention capability in the same period. Legislative efforts boosted retention in Brazil and Colombia but had little effect elsewhere. Natural History Collections remain threatened by underfunding and institutional instability, which can lead to the disappearance of unique type specimens. We advocate for the ethical deposition of type specimens in origin countries, fostering access to Neotropical type specimens for researchers from the original countries, and infrastructure investments in Global South collections to decentralize biodiversity knowledge, build capacity, and strengthen taxonomic research in the Neotropics.

Keywords: holotypes; legislative impact on biodiversity collections; neotropical ichthyological heritage; taxonomic equity; type locality; taxonomy, type specimen retention

INTRODUCTION

Fishes constitute Earth's most diverse group of vertebrates, with over 18000 species inhabiting the freshwater rivers and lakes on all continents (51% of all fishes of the world), except Antarctica (Fricke *et al.* 2025). In the past 20 years, an average of more than 200 new freshwater fish species have been described yearly, with nearly half of them originating from the Neotropical region (Miqueleiz *et al.* 2020, Edmonstone *et al.* 2025, Fricke *et al.* 2025). The Neotropics have a rich history of taxonomic exploration that dates back to von Linnaeus (1758), including some of the earliest described species using binomial nomenclature (Albert *et al.*

2011) and notable expeditions such as the Thayer Expedition led by Louis Agassiz from the Harvard University Museum of Comparative Zoology (<https://library.mcz.harvard.edu/thayer>). Over the last 250 years, ichthyologists have described more than 6200 freshwater fish species in Neotropical rivers and lakes, from Mexico to Argentina (Albert *et al.* 2020). Despite this progress, it is estimated that only 13–18% of the world's species have been described to date (Mora *et al.* 2011, Costello *et al.* 2013), with tropical regions representing a major frontier for new species discoveries and taxonomic resolution (Reis *et al.* 2016, Moura and Jetz 2021). However, the description of Neotropical fish species

and the distribution of their type specimens reflect historical inequalities, with many specimens deposited in institutions in the Global North. This imbalance poses significant challenges for researchers in the Neotropics, impacting regional and global biodiversity research.

The history of freshwater fish taxonomy in the Neotropics reflects a legacy of scientific activity dominated by Global North institutions (Trisos *et al.* 2021). Historically, expeditions and new species descriptions were conducted primarily by European and North American researchers, with collected specimens stored in their Natural History Collections (Aldrich 2009). This power imbalance has created biased views of biodiversity patterns, often devaluing local expertise and disregarding countries' collection laws (Stefanoudis *et al.* 2021, Raja *et al.* 2022). These practices have hampered domestic scientific progress and perpetuated inequality, promoting mistrust between local and foreign researchers, and impacting collaborations (Raja *et al.* 2022). Many countries in the Neotropics still face significant challenges for biodiversity exploration, including shortages of taxonomists and limited infrastructure for collections (Paknia *et al.* 2015). Recognizing and investing in locally led taxonomical efforts can strengthen Natural History Collections and expand their value in other disciplines beyond taxonomy, such as education and documenting environmental changes through space and time.

Type specimens, defined by the International Commission of Zoological Nomenclature as the specimen or set of specimens formally associated with a scientific name (International Commission on Zoological Nomenclature 2000), are vital to biodiversity research. They constitute the taxonomic reference for species descriptions, including the original specimen used to describe a species (holotype), and other variants (e.g. syntypes, paratypes, lectotypes, neotypes) (Snow and Keating 1999), and the physical evidence of a species' existence before scientific description. Access to type specimens is essential for taxonomic studies, reviewing descriptions, describing new species, and determining their relationships (Nakahama 2021). Despite advances in legislation to retain these biodiversity assets in their countries of origin, many freshwater fish holotypes collected in Neotropical countries are hosted in foreign institutions (Paknia *et al.* 2015), and the effectiveness of such legislation in holotype retention remains unclear.

In this study, we examined the global distribution of Neotropical freshwater fish types and its link to historical socioeconomic dynamics, highlighting how geopolitical power shaped the accumulation of biological knowledge and our understanding of biological patterns. Specifically, our study seeks to (i) quantify temporal trends in the collection and retention of type specimens across Neotropical countries; (ii) identify clusters of countries with similar retention patterns; (iii) examine the movement of type specimens across institutions; and (iv) evaluate the potential impact of national legislation on the retention of type specimens. Freshwater fishes are ideal for this analysis because they are the most species-rich vertebrate group in the Neotropics (Albert *et al.* 2020), their description rates are consistently high (Miqueleiz *et al.* 2020), and they are among the most threatened groups of species globally (Sayer *et al.* 2025). These factors combined highlight the urgency of studying their biology to ensure their conservation (Reis *et al.* 2016). First, we analysed the spatiotemporal trends in type specimen discovery and housing, examining

changes in patterns of type specimen retention over time. Moreover, we examined the effect of national legislation and increased sovereignty of countries in the Neotropics over their biological assets in type specimen concentration. We argue that hosting type specimens in Natural History Collections in their respective Neotropical countries of origin would help promote equitable access to biological knowledge through cataloguing, organization, and description of biodiversity.

MATERIAL AND METHODS

We compiled information on primary types (holotypes, lectotypes, syntypes, and neotypes, henceforth 'type specimens') of Neotropical freshwater fish species associated with valid names and synonyms from Eschmeyer's Catalog of Fishes (ECF) (Fricke *et al.* 2025). We included both valid names and synonyms to maximize the number of type specimens and historical trends in host institutions, as synonymized names also reflect past patterns of species descriptions. For each type specimen, we extracted the author and description year, type locality and country, and the Natural History Collection and the country where the specimen is held. The acronyms of the fish collections present at the ECF were consulted from Sabaj (2020) and Fricke *et al.* (2025). For type specimens hosted in more than one collection over time, we included information about temporary hosting institutions and their countries. We standardized all country names to ISO3 codes.

We compiled a dataset of 8252 type specimen records from freshwater taxa collected across the Neotropical region (Supporting Information Table S1). We selected type specimens collected in the following Neotropical countries: Mexico, Cuba, Guatemala, Honduras, El Salvador, Nicaragua, Belize, Costa Rica, Panama, Colombia, Venezuela, Suriname, Guyana, Brazil, Uruguay, Paraguay, Argentina, Chile, Bolivia, Ecuador, and Peru. While some specimens may originate from peripheral areas (e.g. Patagonia or northern Mexico), and excluding some nations in the Caribbean region, we consider this selection representative of the Neotropics. For this survey, we only considered sovereign countries in the Neotropics. Territories were treated as part of their respective administrative countries (e.g. French Guiana as overseas department of France). Additionally, these regions share a history of scientific activities historically led by Global North institutions, which shaped the distribution and accessibility of type specimens. We removed records with missing information for either the type locality, country, or hosting institution.

Analysis

We analysed the flux of type specimens from the type locality countries to hosting institutions between 1758 (first record) and 2025. We divided the timeline into four periods to assess trends in the flux of type specimens: before 1900, 1900–1949, 1950–1999, and after 1999.

We grouped countries in clusters based on their temporal trend of type specimen retention. We calculated type specimen retention rate for each year and country as the fraction of the total number of type specimens hosted within the same country of collection. We then performed a K-means clustering to determine which countries exhibit similar trends. K-means clustering is an unsupervised machine learning algorithm used to partition data

into k distinct, nonoverlapping clusters based on feature similarity (Aghabozorgi *et al.* 2015). Our goal was to minimize within-cluster variance, measured by the sum of squared distances between data points and their respective cluster centroids, the within-cluster sum of squares (WCSS). To determine the optimal number of clusters, we plotted the WCSS against the number of clusters and identified the ‘elbow point’, where the rate of decrease in WCSS slows down significantly (Supporting Information Fig. S1). Once the number of clusters was determined, we created a dendrogram to represent the distance among countries and group them into clusters. The hierarchical clustering used Ward’s method to minimize variance when merging clusters, so the height in the dendrogram represents the increase in variance when clusters are merged.

We investigated the movement of type specimens between Natural History Collections by analysing data from ECF that included information on both current and former host institutions. We extracted these records to analyse the flow of type specimens from the original collection countries, through intermediate institutions, to their final destination.

We also reviewed information on national legislation explicitly regulating or prohibiting the collection and export of type specimens in Neotropical countries. We accessed online repositories of legislation and identified the year in which the legislation was

enacted (Table 1). We then compared retention rates in the 10 years before and after the year the legislation was passed using a t-test. We hypothesized that legislation passed in a given year would increase a country’s type species retention rate in subsequent years.

RESULTS

Since 1758, the description of Neotropical freshwater fish species (von Linnaeus 1758) has oscillated over the years (Fig. 1), with notable contributions by Heckel and Valenciennes (1840) (Nelson *et al.* 2015), (Günther 1864), and (Eigenmann 1912) in the mid-to-late 1800s and early 1900s. The First and Second World Wars between 1914–1918 and 1939–1945, respectively, are correlated with a decline in species collections and descriptions in the region in the 20th century, with type specimen description activity recovering in recent decades.

The total number of type specimens collected in Neotropical countries as of our survey is 8252 (Supporting Information Table S1). Most of them correspond to holotypes (6588; 80% of the total), followed by syntypes (978; 12%), lectotypes (619; 7%), and neotypes (67; < 1%). Brazil has the highest number of collected type specimens in the Neotropics (3692; 45%), followed by Colombia (647; 8%), Peru (612; 7%), Mexico (578; 7%),

Table 1. National legislation regulating specimen collection and export across Neotropical countries, including the year of enactment, the source link to the official document, and whether it explicitly contains information for type specimens.

Country (ISO3 code)	Legislation year	Source	Type specimens explicitly mentioned
Argentina (ARG)	2019	https://www.boletinoficial.gob.ar/detalleAviso/primera/219599/20191024	Yes
Bolivia (BOL)	1997	https://www.lexivox.org/norms/BO-RE-DS24676A.html	No
Brazil (BRA)	1990	https://antigo.mctic.gov.br/mctic/opencms/legislacao/portarias/migracao/Portaria_MCT_n_55_de_14031990.html	Yes
Chile (CHL)	1970	https://www.patrimoniocultural.gob.cl/sites/www.patrimoniocultural.gob.cl/files/2024-06/LEY-17288_04-FEB-1970%20%282%29.pdf	Yes
Colombia (COL)	2013	https://www.icbf.gov.co/cargues/avance/compilacion/docs/decreto_1375_2013.html	Yes
Costa Rica (CRI)	1998	http://www.pgrweb.go.cr/scij/Busqueda/Normativa/Normas/nrm_texto_completo.aspx?nValor1=1&nValor2=39796	Yes
Cuba (CUB)	2023	https://www.parlamentocubano.gob.cu/sites/default/files/documento/2023-10/goc-2023-o84.pdf	Yes
Ecuador (ECU)	2003	https://www.ambiente.gob.ec/wp-content/uploads/downloads/2018/05/TULSMA.pdf	Yes
Guatemala (GTM)	2011	https://conap.gob.gt/wp-content/uploads/2020/06/NORMATIVO-INVESTIGACIONES-BIOLOGICAS.pdf	No
Guyana (GUY)	2017	https://www.fao.org/faolex/results/details/en/c/LEX-FAOC204590/	Yes
Honduras (HND)	2011	https://icf.gob.hn/wp-content/uploads/2021/12/ACUERDO-No.-045-2011-Aprobar-el-Manual-de-Normas-Tecnico-Administrativas-para-el-Manejo-y-Aprovechamiento-Sostenible-de-la-Vida-Silvestre-de-Honduras.pdf	No
Mexico (MEX)	2001	https://dof.gob.mx/nota_detalle.php?codigo=768503&fecha=20/03/2001#gsc.tab=0	Yes
Nicaragua (NIC)	2014	https://faolex.fao.org/docs/pdf/nic138661.pdf	No
Panama (PAN)	1995	https://www.fao.org/faolex/results/details/es/c/LEX-FAOC026789/	Yes
Peru (PER)	2009	https://www.minam.gob.pe/wp-content/uploads/2013/09/ds_003-2009-minam-y-anexo.pdf	Yes
Paraguay (PRY)	1992	https://www.bacn.gov.py/leyes-paraguayas/2391/ley-n-96-esta-ley-tiene-por-objetivo-la-proteccion-manejo-y-conservacion-de-la-vida-silvestre-del-pais-asi-como-su-incorporacion-a-la-economia-nacional	Yes
El Salvador (SLV)	NA	NA	NA
Suriname (SUR)	NA	NA	NA
Uruguay (URY)	2011	https://www.impo.com.uy/bases/decretos/392-2011	No
Venezuela (VEN)	2008	https://www.fao.org/faolex/results/details/en/c/LEX-FAOC089953	No

NA entries indicate the absence of national legislation related to the topic.

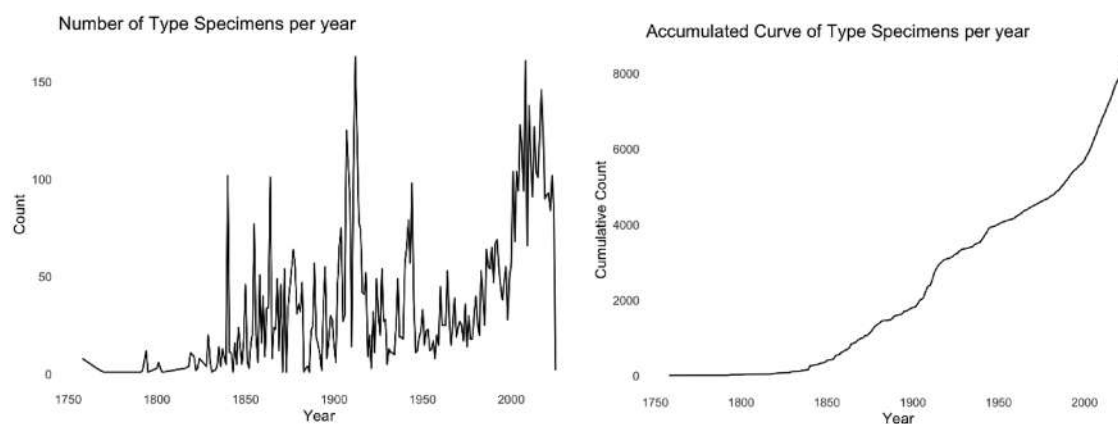


Figure 1. Temporal distribution (left) and cumulative count (right) of type specimen descriptions from 1758 to 2025 in the Neotropics.

Venezuela (568; 7%), Guyana (473; 6%), Argentina (261; 3%), Ecuador (220; 3%), Suriname (217; 3%), and Bolivia (205; 2%) (Fig. 2; Table 2). All other Neotropical countries had fewer than 200 type specimens collected ($\leq 2\%$).

Neotropical freshwater fish type specimens are hosted primarily in Global North Natural History Collections (5054; 61%). Among these, the USA holds the largest share (2549 specimens; 50%), followed by the UK (637; 13%), Austria (495; 10%), France (446; 9%), Germany (423; 8%), and the Netherlands (174; 3%) (Figs 2, 3). All other Global North countries each hold fewer than 100 type specimens ($\leq 2\%$).

Neotropical countries host 3197 type specimens, 39% of all freshwater fish type specimens collected in the region (Figs 2, 3; Table 2). Among them, Brazil hosts most type specimens (2278; 71% of all types hosted in the Neotropics), including specimens collected both in Brazil and in other Neotropical countries. It is followed by Venezuela (266; 8%), Colombia (256; 8%), Argentina (115; 4%), and Mexico (59; 2%) (Fig. 3). All other Neotropical countries host fewer than 40 type specimens ($\leq 1\%$).

The flow of Neotropical freshwater fish type specimens has changed greatly over time (Fig. 3). Our historical analysis reveals a shift in dominance from European Natural History Collections hosting type specimens during the 19th century—a consequence of the colonial history in Central and South America—to the USA emerging as a primary host for type specimens in the 20th century. In the past 25 years, the dominance of Global North countries has decreased, with other countries, like Colombia and especially Brazil, playing an increasingly important role as type specimen hosts. Natural History Collections in the UK, Germany, Austria, and France, once major recipients of Neotropical type specimens in the 1800s and 1900s, have largely lost relevance in the current century.

The dominance of European countries and the USA in hosting Neotropical freshwater fish type specimens peaked before 1949. In this period, 1763 type specimens (98%) collected before 1900 and 2017 type specimens (92%) collected between 1900 and 1949 were hosted in Global North institutions. This trend has since declined, with 768 type specimens (45%) collected between 1950 and 1999, and 2275 (87%) after 1999 hosted in Neotropical countries. This shift in relative retention is particularly evident in Brazil, which currently hosts 2245 of the 3692 type specimens

collected in the country (62%, Table 2). For much of the 19th and 20th centuries, type specimens collected in Brazil were predominantly sent to North American and European institutions (e.g. Austria, France, Germany, and the UK, Fig. 3). However, since the second half of the 20th century, Brazilian Natural History Collections took the lead in retaining local type specimens. Nearly all type specimens collected in Brazil after 1999 have been retained domestically (Table 2).

Other type specimen flows reflect the history of Neotropical countries. For instance, type specimens from Suriname were predominantly exported to the Netherlands during the period 1950–1999, a pattern not observed for other Neotropical countries. In the last 25 years, Neotropical countries with high numbers of freshwater fish species described have increased type specimen retention, including Colombia, Peru, and Venezuela. However, some still display lower levels of type specimen retention, such as Mexico and Guyana. Venezuela presents an inverse pattern, as it achieved 75% type specimen retention during the period 1950–2000, but this decreased to 66% after 2000 (Fig. 4). Finally, a few Neotropical countries (Guatemala, Honduras, Nicaragua, and El Salvador) do not host any freshwater fish type specimens in their Natural History Collections (Fig. 4).

We grouped Neotropical countries based on their temporal trends of type specimen retention rates using K-means clustering. Based on the WCSS parameter of K-means grouping, we classified Neotropical countries into five clusters according to their type specimen retention rate over time (Fig. 5; Supporting Information Fig. S1). Two large groups are formed: first, countries that have zero to low (<0.5) retention rates (Chile, Costa Rica, Cuba, Guatemala, Honduras, Nicaragua, Panamá, Paraguay, El Salvador, Surinam); and second, countries in different stages of increased type specimen retention. Among the latter, Brazil has maintained a long-lasting tradition of type specimen retention over the last 50 years, a pattern shared with Venezuela despite its recent losses in retention capacity. Uruguay and Mexico share a recent increase in their type specimen retention, whilst the number of species described in Uruguay is significantly lower than in more biodiverse countries (19 species in the past 25 years, and 17 retained, compared to 48 and 27, respectively, for Mexico). Argentina has alternated in periods of high and low type specimen retention (Fig. 4). Bolivia, Colombia, Ecuador, and Peru have also increased

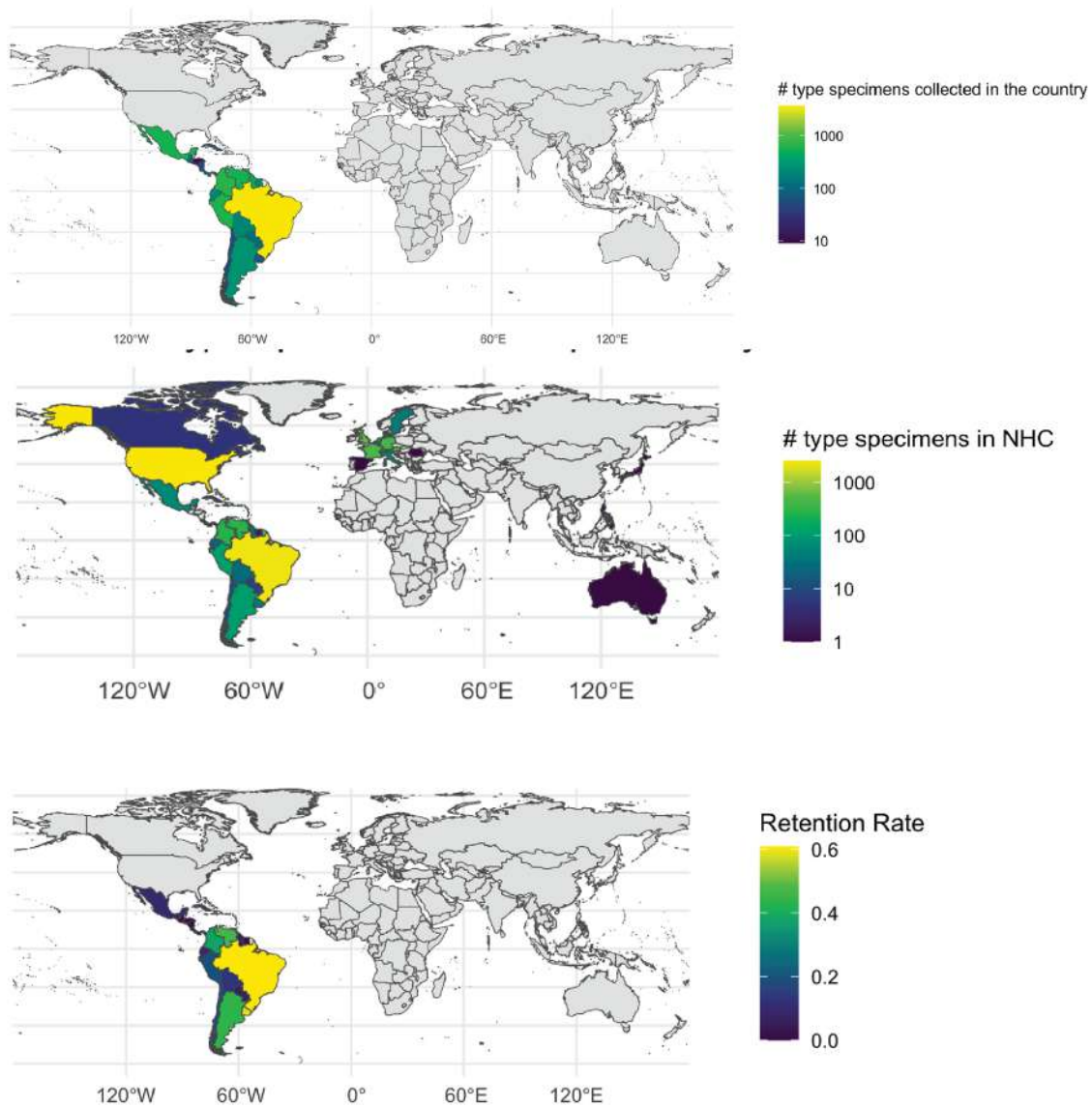


Figure 2. Geographical representation of the distribution of type specimens across Neotropical countries. Top: number of type specimens collected per country. Middle: number of type specimens hosted in the countries' Natural History Collections. Bottom: retention rate of type specimens by country. Legend scale is $\log_{10}$ transformed for representation in the top and middle figures.

their retention rate in the last few years, yet their success is still below that of Brazil, the most accomplished country in the Neotropics in terms of freshwater type specimen retention.

In total, 679 of the 889 (76%) type specimens that have been hosted in more than one Natural History Collection had an intermediate institution in the USA before moving to the final hosting collection (Fig. 6). While most of these type specimens remain in the USA (653; 96%), a small proportion of them have returned to Neotropical countries (26; 4%), primarily Brazil and Venezuela. In contrast, other countries like Guyana and Colombia have received back a significantly smaller proportion of type specimens.

We found legislation aimed at protecting type specimens in 11 out of the 20 Neotropical countries (Table 1). Brazil and Colombia significantly increased their type specimen retention rate after passing laws regulating type specimen collections ($P < .01$, Supporting Information Table S2). Ecuador, Guyana, Mexico, and

Peru, however, did not show a significant increase after laws were passed. Chile, Costa Rica, Cuba, Panama, and Paraguay did not have sufficient data 10 years before and after the laws were passed to perform a reliable comparison.

DISCUSSION

Our study provides the first comprehensive analysis of the global distribution of Neotropical freshwater fish type specimens in Natural History Collections. Historically, Neotropical type specimens have been concentrated in Global North institutions, with retention in many Neotropical countries increasing substantially only after 1999. This uneven distribution has profound implications for scientific practice, the understanding of biodiversity patterns, and access to research materials. To better understand biodiversity patterns, we must address these biases in the global distribution of biodiversity knowledge. Recent estimates of species discoveries

Table 2. Number of freshwater fish type specimens collected across Neotropical countries, number of types retained within the country, and retention rate, defined as the proportion (percentage) of type specimens preserved in collections located in the same country where the specimen was originally collected.

Country (ISO3 code)	Before 1900			1900–1949			1950–1999			After 1999			All		
	Col- lect	Retain %	Retain %	Col- lect	Retain %	Retain %	Col- lect	Retain %	Retain %	Col- lect	Retain %	Retain %	Col- lect	Retain %	Retain %
ARG	74	12	16.22	58	5	8.62	35	23	65.71	94	74	78.72	261	114	43.68
BOL	18	0	0	85	0	0	39	2	5.13	63	25	39.68	205	27	13.17
BRA	683	15	2.2	727	145	19.94	657	486	73.97	1625	1599	98.4	3692	2245	60.81
CHL	24	0	0	14	0	0	13	7	53.85	5	3	60	56	10	17.86
COL	45	0	0	274	5	1.82	85	30	35.29	243	211	86.83	647	246	38.02
CRI	3	0	0	48	0	0	35	0	0	6	3	50	92	3	3.26
CUB	48	0	0	26	0	0	11	4	36.36	2	1	50	87	5	5.75
ECU	72	0	0	64	0	0	52	2	3.85	32	19	59.38	220	21	9.55
GTM	47	0	0	34	0	0	20	0	0	9	0	0	110	0	0
GUY	140	0	0	188	1	0.53	75	0	0	70	30	42.86	473	31	6.55
HND	0	0	0	2	0	0	4	0	0	3	0	0	9	0	0
MEX	196	0	0	176	4	2.27	158	28	17.72	48	27	56.25	578	59	10.21
NIC	24	0	0	13	0	0	3	0	0	12	0	0	52	0	0
PAN	49	0	0	82	0	0	18	0	0	10	1	10	159	1	0.63
PER	200	1	0.5	159	8	5.03	117	9	7.69	136	99	72.79	612	117	19.12
PRY	16	0	0	61	0	0	29	0	0	18	8	44.44	124	8	6.45
SLV	2	0	0	8	0	0	1	0	0	2	0	0	13	0	0
SUR	91	0	0	9	0	0	96	0	0	21	2	9.52	217	2	0.92
URY	17	0	0	18	9	50	23	19	82.61	19	17	89.47	77	45	58.44
VEN	42	0	0	154	3	1.95	188	142	75.53	184	118	64.13	568	263	46.3

Values are presented for all periods combined, as well as separately for specimens collected before 1900, during 1900–1949, 1950–1999, and after 1999.

and taxonomic revisions suggest that tropical regions are likely to yield many new species discoveries in the coming years (Moura and Jetz 2021). Moreover, taxonomic revisions are more frequent for species described earlier (Guedes et al. 2023). In this case, our selection of Neotropical countries as case studies provides insights that can inform both current Natural History Collection management and the inclusion of newly discovered species.

The Natural History Collections of countries that dominated the global economy in the 19th and 20th centuries have been the principal repositories of type specimens from Neotropical countries. Contrary to other studies that show a pattern of type specimen movement from former colonies to their respective former ruling countries (Raja et al. 2022), the influence of European countries in type specimen hosting does not present a similar pattern here. For instance, neither Spain nor Portugal host significant proportions of Neotropical specimens from their former territories, and the only relationship regarding type specimens related to a common historical background is that of specimens going from Suriname to the Netherlands and hosted in the Naturalis Biodiversity Center Collection (Dondorp and Creuwels 2025). In this context, the relatively early independence movements in Ibero-America, combined with the loss of power and political instability in Spain (Elena and Ordóñez 2000) and Portugal (Carneiro and Simões 2000) across the 19th and 20th centuries, hampered these countries' efforts to return to their former territories to collect potential type specimens. Moreover, the development of scientific disciplines such as zoology in the 19th century in France, the UK, Prussia (Germany), Austria, Belgium, and

Sweden positioned these countries as the primary collectors of Neotropical type specimens. For instance, many of Brazil's pre-1900s type specimens deposited in Austria resulted from the influence of Archduchess Maria Leopoldina, the first wife of Brazilian Emperor Dom Pedro I (Sepúlveda dos Santos 2014). Although not included in this study, type specimens collected in French Guyana are mostly hosted in the *Muséum National d'Histoire Naturelle* in Paris (MNHN and Chagnoux 2025). These countries, along with the USA, which engaged in a scientific race with Europe in the 19th century, host most of the Neotropical type specimens despite their limited colonial influence in the region.

A reflection of these countries' dominance in the zoology discipline is evident when authors are ranked by the number of fish species described: the top 10 most prolific are from Europe and the USA, and seven of these 10 were most productive in the 19th century (Fricke et al. 2025). The list includes authors who worked extensively on describing freshwater fishes, like Peter Bleeker (Dutch), Achille Valenciennes (French), Albert Günther (German), Henry Fowler (American), George Boulenger (Belgian), Georges Cuvier (French), Franz Steindachner (Austrian), and Charles Tate Regan (British). Fishes described by these authors are mostly tropical, many of them from the Neotropics (Supporting Information Table S1), and, with few exceptions, the material was deposited in museums in the Global North, reflecting in the current distribution of Neotropical freshwater fish types.

Since the late 20th century, Neotropical countries have been increasingly gaining control over type specimens collected in their

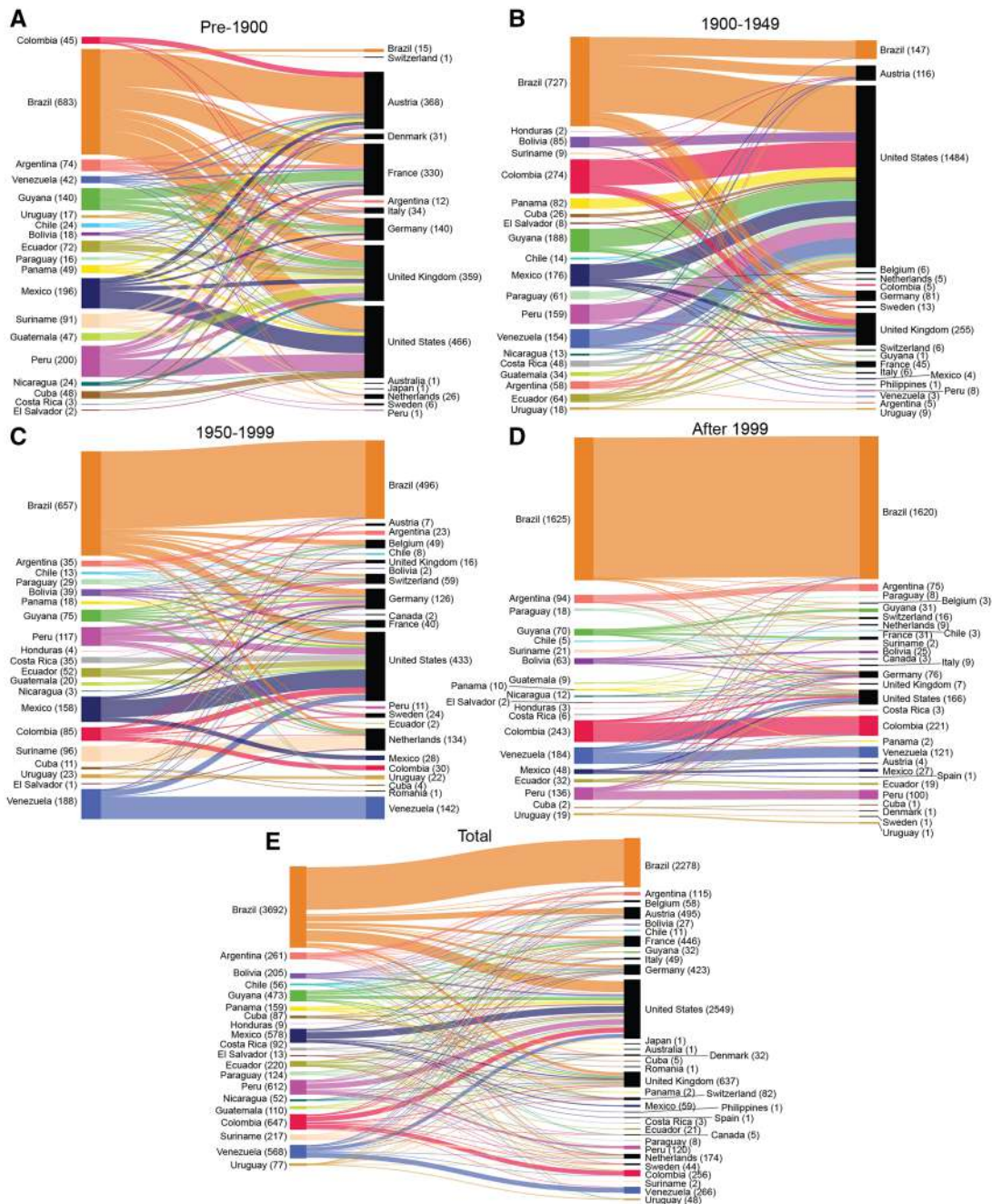


Figure 3. Flows of type specimens from collection countries (left) to hosting institution countries (right). Frame sizes are proportional to the number of type specimens, and colours correspond to different countries. Hosting institution countries outside the Neotropical region are shown in black. Diagrams represent: A, pre-1900 period; B, 1900–1949; C, 1950–1999; D, after 1999; and E, all data together.

territory. Increasing retention rates in several countries, especially Brazil, Colombia, and Peru, could be related to the strengthening of national biodiversity institutions and policies promoting and regulating movement of type specimens (Figs 3, 4). Brazil has experienced a notable rise in retention since the 1980s, probably tied to increased investment in science (de Meis *et al.* 2007), including the establishment and expansion of collections and their personnel, such as the *Museu de Zoologia da Universidade de São Paulo* (Percequillo *et al.* 2022), and the expansion of awarded graduate degrees in biological sciences (CAPES 2025). Likewise, Colombia has achieved a high retention rate in the same period

(Figs 3, 4) and developed relevant biodiversity-focused institutions like the *Instituto de Investigación de Recursos Biológicos Alexander von Humboldt* (Arbeláez-Cortés *et al.* 2015). Other countries, such as Peru and Uruguay, show promising increases in retention rate, but substantial gaps remain in the region. Until the end of the 20th century, Venezuela also had a high retention of type specimens of freshwater species, a result of the development of fish collections in scientific research institutions (e.g. *Museo de Historia Natural La Salle*, MHNLS) and universities (e.g. *Museo de Ciencias Naturales de Guanare*, MCNG; *Museo de Biología de la Universidad Central de Venezuela*, MBUCV) (Sabaj 2020,

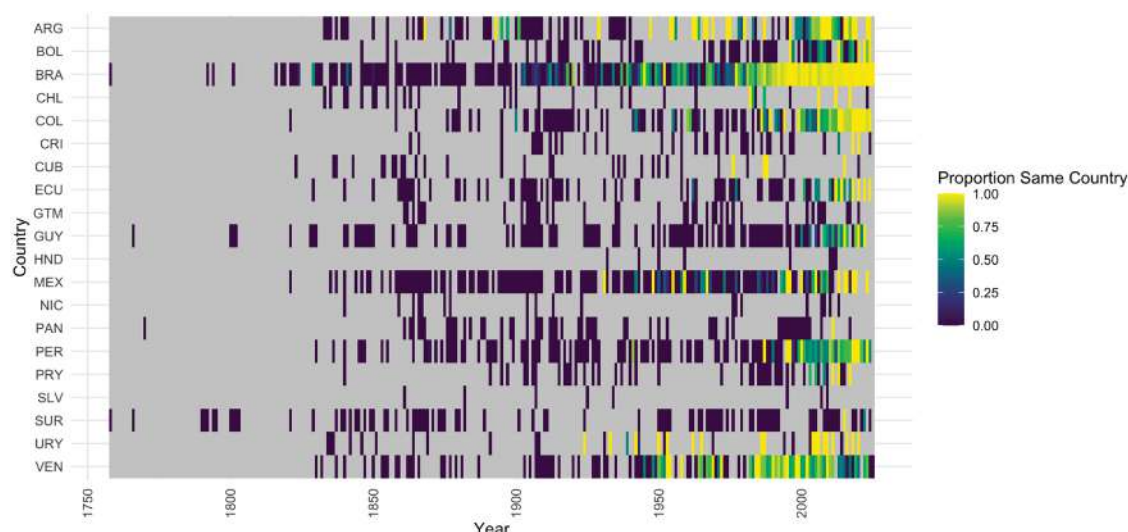


Figure 4. Heatmap of type specimen retention over time for Neotropical countries. Colours represent countries' retention rate, from 0 (no type specimens retained) to 1 (all type specimens retained). Years without data are shown in grey.

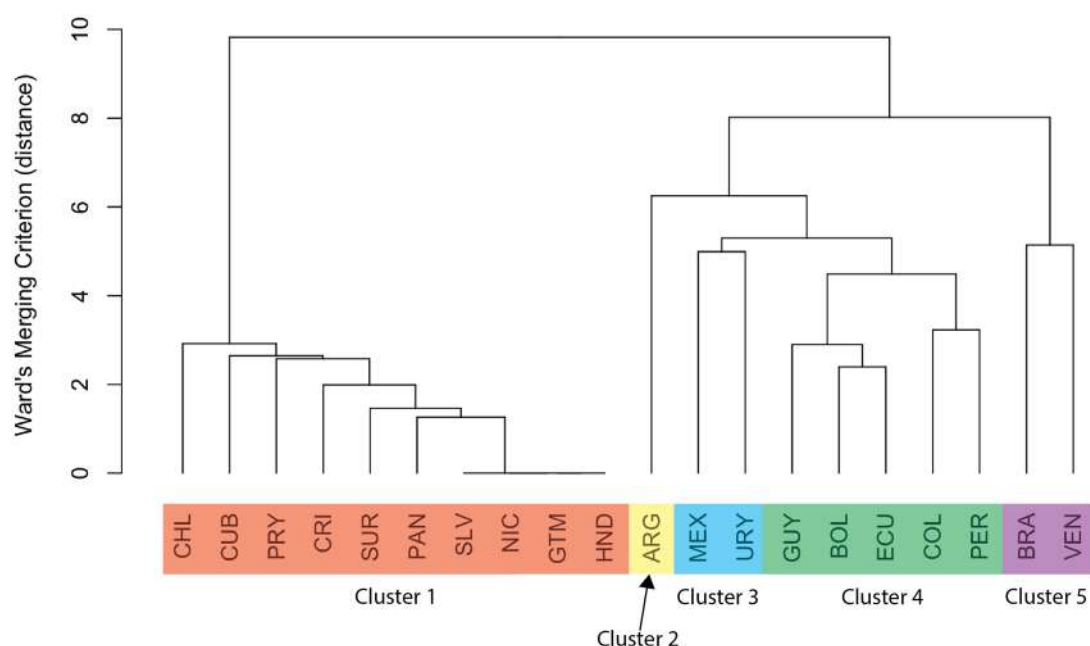


Figure 5. Countries clustered according to their type specimen retention trends, coloured by cluster. Groups derived from hierarchical clustering with Ward's grouping method and set to five clusters from WCSS analysis (cluster 1, orange; cluster 2, yellow; cluster 3, blue; cluster 4, green; cluster 5, purple).

Lasso-Alcala *et al.* 2022). Advancing retention will promote the relevance of Natural History Collections in the Neotropics, which can foster scientific activity in these countries in different ways (Suarez and Tsutsui 2004), such as including voucher specimens for ecological studies (Tarli *et al.* 2018, Salvador and Cunha 2020), broadening the participation of researchers not traditionally involved in museum activities (McLean *et al.* 2016), and helping fill biodiversity data gaps (Miller *et al.* 2020).

While national legislation regulating type specimen retention was effective in Colombia and Brazil, results were inconsistent in other countries, and differences in retention were nonsignificant or could not be calculated. Lack of clarity in policy could also

prevent effective changes in type retention. For instance, not all countries have type specimens explicitly mentioned in their environmental legislation. Venezuela has passed three laws on environmental and biological diversity management between 2006 and 2009 (<https://www.fao.org/faolex/results/details/en/c/LEX-FAOC089953>; <https://www.fao.org/faolex/results/details/en/c/LEX-FAOC092999>; <https://www.fao.org/faolex/results/details/es/c/LEX-FAOC069651>), but none explicitly mentions type specimens as a protection objective. In this sense, an international agreement on type specimen collection practices could help ensure that countries explicitly include them in national legislation. For instance, the Nagoya Protocol is an international

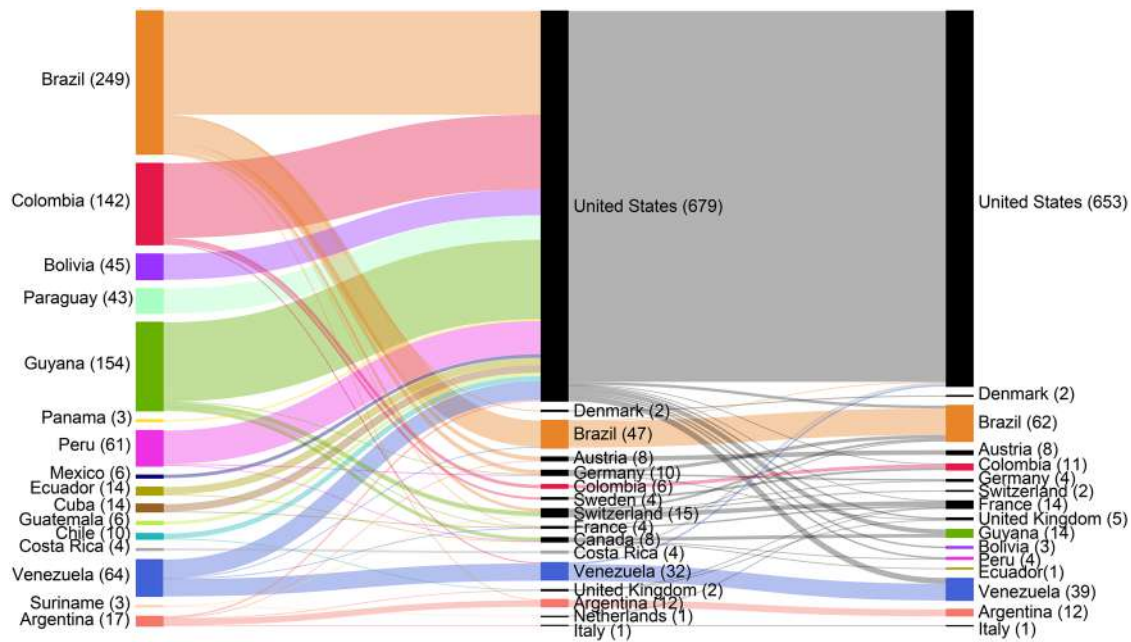


Figure 6. Flow of type specimens from type locality country (left), through intermediate institution country (middle), to their final hosting institution country (right). Data are shown only for type specimens with information on intermediate hosting institution.

agreement under the Convention on Biological Diversity that established in 2010 a legal framework for the fair and equitable sharing of benefits derived from the utilization of genetic resources. Although the Nagoya Protocol was challenging to achieve and has not been universally adopted, its application has promoted countries' ability to control their genetic information. A similar framework for type specimens would greatly contribute to the development of Natural History Collections in the Global South.

Overcoming threats and access to Neotropical freshwater fish type specimens

Natural History Collections in the Neotropics face significant challenges that hamper their development. Neotropical countries have faced institutional and political obstacles to advancing their scientific activity in the last decade (Fernandes *et al.* 2017), including lack of institutional, political, and social responsibility and stability (Ciocca and Delgado 2017), and economic shortfalls. However, these problems are not endemic to the Global South, since they affect Natural History Collections beyond the Neotropics (Andreone *et al.* 2014).

In recent years, Natural History Collections worldwide have faced numerous challenges, including budget cuts, diminished institutional support, staff reductions or closure, competition for research and teaching space, and a decline in curatorial expertise (Bradley *et al.* 2014, Rohwer *et al.* 2022), including some of the most renowned institutions (Naggs 2022). Baker *et al.* (2014) calculated an average cost of \$17.51 per specimen to curate, install, and computerize its associated data, and an additional \$0.25 per specimen per year for long-term care of the collection. The chronic underfunding of Natural History Collections exacerbates their vulnerability to physical threats like theft, fire, and water damage. The partial destruction of collections at the Butantã Museum in

São Paulo (2010) and the Brazil National Museum in Rio de Janeiro (2018) are examples of the risks posed by inadequate infrastructure (Bakker *et al.* 2020).

Taxonomy, a fundamental component of life sciences, often fails to engage learners and educators with the same enthusiasm as other topics, even though the species it studies are often what initially draws an individual to science. This lack of interest could stem from the fact that the study of taxonomy is only appreciated when learners develop deep knowledge informed about new approaches, and keep a positive mentality toward both the subject and the species while fighting constant challenges. Finally, taxonomic research rarely features in high-impact journals, undervaluing the effort and science done by taxonomists (Krell 2000). All these obstacles result in the number of scientists working on taxonomy reducing worldwide (Engel *et al.* 2021). This global shortage of taxonomists creates a significant bottleneck in biodiversity research and conservation efforts, particularly in biodiversity hotspots, which harbour unique and endangered species (Al-Asif and Nerurkar 2024). These challenges are compounded by the accelerating effects of climate change, threatening organisms at ever faster rates. Strategies like participatory science, integrating molecular tools, and capacity building and training are essential to reverse the loss of taxonomic expertise in the Global South and across the world (Agnarsson and Kuntner 2007).

Some type specimens stored in Global North collections have returned to their type locality countries in the Neotropics (Fig. 6). For instance, *Leporinus enyae*, an anostomid from the Venezuelan Amazonia, was transferred from its original deposit in a Natural History Collection in the USA to a Venezuelan institution (Burns *et al.* 2017). The historical lack of museum infrastructure in countries of the Global South, combined with most formally trained naturalists being based outside the Neotropics and sending materials to their home countries, contributed strongly to the

early development of type specimen biases favouring the Global North. The repatriation of type specimens (e.g. holotypes or paratypes) to Neotropical countries would be an equitable way of sharing and redistributing biological knowledge and further fostering taxonomic activity in the Global South. However, this is a subject of debate without a clear consensus among taxonomists and institutions. An alternative to specimen translocation is for Neotropical researchers to travel northward to conduct taxonomic research. This practice is often limited by significant barriers such as travel costs, currency exchange rates, and visa requirements, especially for graduate students with less access to resources. This movement of researchers constitutes an opportunity to foster international collaboration and benefits research activities, but it may require greater investment in science for Neotropical countries, which has struggled even in those countries with higher type specimen retention ability, e.g. Brazil (Fernandes *et al.* 2017) and Colombia (Huddart *et al.* 2022). Museums that retain meaningful collections from the Global South could mitigate barriers in origin by opening specific lines of funding to enable students and scientists from the Global South to access materials from their home countries, as done by the Smithsonian Institution (<https://fellowships.si.edu/opportunity/smithsonian-institution-fellowship-program-sifp>). Such initiatives can complement the programmes of Global South institutions, such as Brazil's *Bolsa Estágio de Pesquisa no Exterior* (BEPE) from the *Fundação de Amparo à Pesquisa do Estado de São Paulo* (FAPESP).

The International Code of Zoological Nomenclature (International Commission on Zoological Nomenclature 2000) states that authors describing a new species must deposit the type specimens in an institution with a research collection, equipped with appropriate infrastructure to preserve them and ensure their accessibility for study (Recommendation 16C). The code also addresses institutional responsibility, including the recognition, safe conservation, accessibility, and regular publication of type material in collections (Recommendation 72F). We argue that, to promote fair and equitable science, an ethical practice (equivalent to the Nagoya Protocol for genetic resources) would be required to regulate the deposit of specimens from the type series—such as holotypes and paratypes—in a reference collection of the species' country of origin, but also considering the possibility of deposition in other institutions (to ensure the long-term viability of the collection). Currently, this depends on the personal initiative of the researchers describing the new species and the curators or collection managers handling the studied material (see Salazar and Lasso 2011, Henschel *et al.* 2020, Rodrigues and Netto-Ferreira 2020, Perez Lozano *et al.* 2022, Reis and Pablo 2022, Provenzano-Rizzi 2023). While the ICZN does not mandate deposition in the country of origin, this would enhance the scientific value of Neotropical Natural History Collections and promote security and conservation of type material by distributing the type series across multiple biological collections in different countries. In cases where the political, social, or economic situation in the country of origin poses a risk to the conservation of type material, it may be temporarily deposited in foreign collections, desirably in countries with greater institutional stability, particularly where the describing researchers are affiliated (Henschel *et al.* 2020).

CONCLUSION

Our comprehensive analysis of Neotropical freshwater fish type specimens reveals a clear historical shift in both their description and curation. Species descriptions peaked in the mid-19th and early 20th centuries under European authors, declined during the World Wars, and have only recently returned to pre-war levels. Geographically, Brazil, Colombia, and Mexico remain the principal source countries, yet for much of the 19th and 20th centuries the vast majority of their type specimens were housed in Global North collections—primarily in the USA, UK, Germany, Austria, and France. Only since the late 20th century have Neotropical institutions, led by Brazil and Colombia, markedly increased their retention of local type material.

Our temporal retention analysis demonstrates that several countries (notably Brazil, Colombia, Uruguay, and Argentina) now retain over 60% of their new type specimens, with Brazil approaching 100% retention after 1999. By contrast, long-standing patterns of low retention persist in others (e.g. Mexico, Guyana, Panama), and a handful of nations (Guatemala, Honduras, Nicaragua, El Salvador) host virtually no Neotropical freshwater fish types. Legislative measures in Brazil and Colombia were associated with the most pronounced increases in retention, whereas the impact of similar laws in Ecuador, Guyana, Mexico, and Peru was negligible or could not be assessed. This suggests that explicit legal mandates alone are insufficient without concurrent investment in national collections, infrastructure, and international collaboration.

Moving forward, we advocate for: (i) the adoption of international guidelines—modelled on the ICZN and Nagoya Protocol—that regulate the deposition of type specimens in the country of origin and the distribution of specimens among different Natural History Collections; (ii) sustained funding and training to strengthen Neotropical Natural History Collections; and (iii) expanded digital access and research programmes to democratize specimen-based research, especially for Global South researchers visiting Global North institutions. By fostering taxonomic expertise and Natural History Collections capabilities in the Global South, the scientific community can both correct historical biases and foster taxonomic research where biodiversity remains richest.

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AUTHOR CONTRIBUTIONS

I.M., V.d.B., C.B.D., and P.B.M. conceptualized the paper. I.M., V.d.B., and C.B.D. developed the methodology and carried out the investigation. I.M. and V.d.B. performed the formal analyses and visualization. I.M. wrote the first draft, with significant input from V.d.B., O.M.L.S., M.N.L.P., and C.B.D. All authors contributed to the discussion of the methodology and results, the review of the first manuscript and the final version of the manuscript.

SUPPLEMENTARY DATA

Supplementary data are available at *Biological Journal of the Linnean Society* online.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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NON-ENGLISH VERSION

A non-English version of the article in Spanish can be found in the [supplementary material](#) (Supporting Information S2).

DATA AVAILABILITY STATEMENT

All data are incorporated into the article and its online supporting information.

REFERENCES

- Aghabozorgi S, Seyed Shirkhorshidi A, Ying Wah T. Time-series clustering—a decade review. *Information Systems* 2015;**53**:16–38.
- Agnarsson I, Kuntner M. Taxonomy in a changing world: seeking solutions for a science in crisis. *Systematic Biology* 2007;**56**:531–9.
- Al-Asif A, Nerurkar S. Taxonomy in crisis: addressing the shortage of taxonomists in a biodiversity hotspot era. *Journal of Aquatic Research and Sustainability* 2024;**01**:01–4.
- Albert JS, Petry P, Reis RE. Major biogeographic and phylogenetic patterns. In: Albert JS, Reis RE (eds.), *Historical Biogeography of Neotropical Freshwater Fishes*. Berkeley, CA: University of California Press, 2011, 21–58.
- Albert JS, Tagliacollo VA, Dagosta F. Diversification of neotropical freshwater fishes. *Annual Review of Ecology, Evolution, and Systematics* 2020;**51**:27–53.
- Aldrich R. Colonial museums in a postcolonial Europe. *African and Black Diaspora: An International Journal* 2009;**2**:137–56.
- Andreone F, Bartolozzi L, Boano G *et al.* Italian natural history museums on the verge of collapse? *ZooKeys* 2014;**139**–46.
- Arbeláez-Cortés E, Torres MF, López-Álvarez D *et al.* Colombian frozen biodiversity: 16 years of the tissue collection of the Humboldt Institute. *Acta Biológica Colombiana* 2015;**20**:163–73.
- Baker R, Bradley L, Garner H, Bradley R. 'Door to Drawer' Costs of Curation, Installation, Documentation, Databasing, and Long-term Care of Mammal Voucher Specimens in Natural History Collections. *Occasional Papers Museum of Texas Tech University*, 2014;**323**:1–15.
- Bakker FT, Antonelli A, Clarke JA *et al.* The Global Museum: natural history collections and the future of evolutionary science and public education. *Peer J* 2020;**8**:e8225.
- Bradley RD, Bradley LC, Garner HJ *et al.* Assessing the value of natural history collections and addressing issues regarding long-term growth and care. *BioScience* 2014;**64**:1150–8.
- Burns MD, Chatfield M, Birindelli JLO *et al.* Systematic assessment of the *Leporinus desmotes* species complex, with a description of two new species. *Neotropical Ichthyology* 2017;**15**:e160166.
- CAPES. Plataforma Sucupira, 2025. <https://sucupira.capes.gov.br/>
- Carneiro A, Simões A. Enlightenment science in Portugal: the estrangeirados and their communication networks. *Social Studies of Science* 2000;**30**:591–619.
- Ciocca DR, Delgado G. The reality of scientific research in Latin America; an insider's perspective. *Cell Stress & Chaperones* 2017;**22**:847–52.
- Costello MJ, May RM, Stork NE. Can we name Earth's species before they go extinct? *Science (New York, N.Y.)* 2013;**339**:413–6.
- Dondorp E, Creuwels J. Naturalis Biodiversity Center (NL) - Pisces. Naturalis Biodiversity Center. Occurrence dataset, 2025.
- Edmonstone MRJ, Bull G, Nathaniel SRN, Ou C. *New Species 2024: The Freshwater Fish Species Described in 2024 (Report 4)*. London: SHOAL, 2025.
- Eigenmann CH. Some results from an ichthyological reconnaissance of Colombia, South America. Part I. (Contrib. Zool. Lab. Ind. Univ.). *Indiana University Studies* 1912;**16**:1–27.
- Elena A, Ordóñez J. Science, technology, and the Spanish colonial experience in the nineteenth century. *Osiris* 2000;**15**:70–82.
- Engel MS, Ceriaco LMP, Daniel GM *et al.* The taxonomic impediment: a shortage of taxonomists, not the lack of technical approaches. *Zoological Journal of the Linnean Society* 2021;**193**:381–7.
- Fernandes GW, Vale MM, Overbeck GE *et al.* Dismantling Brazil's science threatens global biodiversity heritage. *Perspectives in Ecology and Conservation* 2017;**15**:239–43.
- Fricke R, Eschmeyer WN & Van der Laan R (Eds.). *Eschmeyer's catalog of fishes: genera, species, references*. California Academy of Sciences, 2025.
- Guedes JJM, Moura MR, Alexandre F *et al.* Species out of sight: elucidating the determinants of research effort in global reptiles. *Ecography* 2023;**2023**:e06491.
- Günther A. XLII.—Descriptions of three new species of fishes in the collection of the British Museum. *Annals and Magazine of Natural History* 1864;**14**:374–6.
- Henschel E, Lujan NK, Baskin JN. *Ammoglanis natgeorum*, a new miniature pencil catfish (Siluriformes: Trichomycteridae) from the lower Atabapo River, Amazonas, Venezuela. *Journal of Fish Biology* 2020;**97**:1481–90.
- Huddart JEA, Crawford AJ, Luna-Tapia AL *et al.* EBP-Colombia and the bioeconomy: Genomics in the service of biodiversity conservation and sustainable development. *Proceedings of the National Academy of Sciences of the United States of America* 2022;**119**:e2115641119.
- International Commission on Zoological Nomenclature. *International Code of Zoological Nomenclature*, 2000.
- Krell FT. Impact factors aren't relevant to taxonomy. *Nature* 2000;**405**:507–8.
- Lasso-Alcala OM, Quintero TE, Mikolji I, Exposito O. Las Colecciones de Peces de la Fundación La Salle de Ciencias Naturales. COFA November, 2022.
- von Linnaeus C. *Systema Naturae*, Ed. X. (*Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Tomus I. Editio decima, reformata.*), 1758.
- McLean BS, Bell KC, Dunnum JL *et al.* Natural history collections-based research: progress, promise, and best practices. *Journal of Mammalogy* 2016;**97**:287–97.
- de Meis L, Arruda AP, Guimaraes J. The impact of science in Brazil. *IUBMB Life* 2007;**59**:227–34.
- Miller SE, Barrow LN, Ehlman SM *et al.* Building natural history collections for the twenty-first century and beyond. *BioScience* 2020;**70**:674–87.
- Miqueleiz I, Bohm M, Ariño AH *et al.* Assessment gaps and biases in knowledge of conservation status of fishes. *Aquatic Conservation: Marine and Freshwater Ecosystems* 2020;**30**:225–36.
- MNHN and Chagnoux. *The fishes collection (IC) of the Muséum national d'Histoire naturelle (MNHN—Paris). Version 57.410*. MNHN—Museum national d'Histoire naturelle, 2025.
- Mora C, Tittensor DP, Adl S *et al.* How many species are there on earth and in the ocean? *PLoS Biology* 2011;**9**:e1001127.
- Moura MR, Jetz W. Shortfalls and opportunities in terrestrial vertebrate species discovery. *Nature Ecology & Evolution* 2021;**5**:631–9.

- Naggs F. The tragedy of the Natural History Museum, London. *Megataxa* 2022;**7**:86–112.
- Nakahama N. Museum specimens: an overlooked and valuable material for conservation genetics. *Ecological Research* 2021;**36**:13–23.
- Nelson JS, Grande TC, Wilson MVH, *Fishes of the World*, John Wiley and Sons, Inc, Hoboken, New Jersey, 2015, 752, 5th edn.
- Paknia O, Rajaei Sh H, Koch A. Lack of well-maintained natural history collections and taxonomists in megadiverse developing countries hampers global biodiversity exploration. *Organisms Diversity & Evolution* 2015;**15**:619–29.
- Percequillo AR, Barbosa MFC, Bockmann FA *et al.* Natural history museums and zoological collections of São Paulo State. *Biota Neotropica* 2022;**22**:e20221426.
- Perez Lozano A, Lasso-Alcala OM, Bittencourt PS *et al.* A new species of *Astronotus* (Teleostei, Cichlidae) from the Orinoco River and Gulf of Paria basins, northern South America. *ZooKeys* 2022;**1113**:111–52.
- Provenzano-Rizzi F. A new genus and species of whiptail armored catfish (Siluriformes: Loricariinae) from southern Venezuela. *Zootaxa* 2023;**5315**:315–28.
- Raja NB, Dunne EM, Matiwane A *et al.* Colonial history and global economics distort our understanding of deep-time biodiversity. *Nature Ecology & Evolution* 2022;**6**:145–54.
- Reis RE, Albert JS, Di Dario F *et al.* Fish biodiversity and conservation in South America. *Journal of Fish Biology* 2016;**89**:12–47.
- Reis RE, Pablo L. A new genus of armored catfish (Siluriformes: Loricariidae) from the Greater Amazon, with a review of the species and description of five new species. *Neotropical Ichthyology* 2022;**20**:
- Rodrigues EKdeQ, Netto-Ferreira AL. A new miniature species of *Odon-tocharacidium* (Characiformes: Crenuchidae) from the Rio Orinoco basin, Venezuela. *Neotropical Ichthyology* 2020;**18**:e190008.
- Rohwer VG, Rohwer Y, Dillman CB. Declining growth of natural history collections fails future generations. *PLoS Biology* 2022;**20**:e3001613.
- Sabaj MH. Codes for natural history collections in ichthyology and herpetology. *Copeia* 2020;**108**:593–669.
- Salazar LMM, Lasso CA. *Apistogramma megaptera* (Perciformes: Cichlidae), una nueva especie para la cuenca del Orinoco. *Biota Colombiana* 2011;**12**:
- Salvador RB, Cunha CM. Natural history collections and the future legacy of ecological research. *Oecologia* 2020;**192**:641–6.
- Sayer CA, Fernando E, Jimenez RR *et al.* One-quarter of freshwater fauna threatened with extinction. *Nature* 2025;**638**:138–45.
- Sepúlveda dos Santos M. Naturalists in nineteenth-century Brazil. *Archiv für Völkerkunde* 2014;**63–64**:38–59.
- Snow N, Keating PL. Relevance of specimen citations to conservation. *Conservation Biology* 1999;**13**:943–4.
- Stefanoudis PV, Licuanan WY, Morrison TH *et al.* Turning the tide of parachute science. *Current Biology: CB* 2021;**31**:R184–R185.
- Suarez AV, Tsutsui ND. The value of museum collections for research and society. *BioScience* 2004;**54**:66–74.
- Tarli VD, Grandcolas P, Pellens R. The informative value of museum collections for ecology and conservation: a comparison with target sampling in the Brazilian Atlantic forest. *PLoS One* 2018;**13**:e0205710.
- Trisos CH, Auerbach J, Katti M. Decoloniality and anti-oppressive practices for a more ethical ecology. *Nature Ecology & Evolution* 2021;**5**:1205–12.