

A decade of Philippine freshwater goby research (2010–2022): a systematic review and meta-analysis of ichthyofaunal surveys

Baron C.T.¹, Garces J.J.C.^{1,2*}

¹ Graduate School, Department of Biology, College of Computing, Artificial Intelligence, and Sciences (CCAIS), Cebu Normal University, Osmeña Boulevard, Cebu city, 6000, Philippines

² Department of Biology, College of Computing, Artificial Intelligence, and Sciences (CCAIS), Cebu Normal University, Osmeña Boulevard, Cebu city, 6000, Philippines

ABSTRACT. Freshwater goby (Family *Gobiidae*) is one of the diverse and widespread fish species in rivers and lakes, with economic values ranging from ornamental and subsistence provisions. Several ichthyofaunal surveys have been conducted in the Philippines; however, no systematic review and meta-analysis was performed to analyze freshwater goby species richness over fish species richness. Following the PRISMA Protocol, twenty-three (23) studies were assessed and statistically analyzed using JASP Version 0.18.3. Each paper was reviewed to identify study sites, goby genera, diversity indices (Shannon, Pielou's evenness, and Simpson), and physicochemical parameters, with correlations analyzed across fish species, goby species richness, and diversity indices. Results revealed that most freshwater goby studies take place in Luzon, and the genus *Glossogobius* is the prevalent goby species at most study sites. The diversity index for introduced fish species ranged from low to medium, as indicated by the enriched biodiversity index score from Guerrero (2014). In terms of physicochemical parameters, all values generally met the standards set by DAO 2016-08. However, the forest plot revealed that the effect size was entirely on the positive side of zero, with a combined effect size of 0.46, suggesting a moderate impact. The funnel plot indicated an asymmetrical pattern among studies, suggesting potential publication bias. Analysis suggests that goby diversity in the Philippines is high in terms of species richness, with a moderate effect size when compared to overall fish species richness based on the collated studies. Taking into account the high publication bias observed, we recommend including more studies from Southeast Asian countries. Researchers are encouraged to prioritize biodiversity studies in the Visayas and Mindanao regions to mitigate study bias. A comparative analysis of native and introduced fish species richness would also be beneficial in determining their potential impact on the overall effect size of species richness.

Keywords: freshwater gobies, *Gobiidae*, Philippines, PRISMA, systematic review, meta-analysis

For citation: Baron C.T., Garces J.J.C. A decade of Philippine freshwater goby research (2010–2022): a systematic review and meta-analysis of ichthyofaunal surveys // Limnology and Freshwater Biology. 2026. - № 3. - P. 135-147. DOI: 10.31951/2658-3518-2026-A-3-135

1. Introduction

Freshwater gobies (Family *Gobiidae*) play a crucial ecological role in tropical freshwater ecosystems, particularly in insular streams where they dominate due to the absence of primary freshwater fishes. However, approximately 20% of their populations are increasingly threatened by habitat degradation, pollution, climate change, and human activities such as deforestation, agricultural runoff, and dam construction, which disrupt their migratory routes and breed-

ing grounds (Millenium Ecosystem Assessment [MEA], 2005). Recent estimates indicate that 25% of evaluated freshwater fish species worldwide face extinction (Vié et al., 2009). Despite their widespread distribution and ecological importance, many freshwater gobies remain understudied, and their conservation status is largely unknown, particularly in the Philippines and other Southeast Asian regions. The conservation status of freshwater gobies (Family *Gobiidae*) varies globally, with many species facing population declines due to habitat degradation, invasive species, pollution, and

*Corresponding author. E-mail address: garcesji@cnu.edu.ph (J.J.C. Garces)

Received: March 11, 2026;

Accepted after revised: April 28, 2026;

Available online: June 18, 2026

© Author(s) 2026. This work is distributed under the Creative Commons Attribution-NonCommercial 4.0 International License.



climate change, particularly in Southeast Asia and the Pacific. While conservation efforts in regions like Japan and Hawaii have led to improved habitat protection, many goby species remain understudied, highlighting the need for further research and sustainable management strategies (Guo et al., 2013).

As key players in maintaining the ecological stability of island environments, these small but significant fish species help regulate ecological processes and provide multiple ecosystem services in freshwater ecosystems (Benstead et al., 2003; N'Guyen et al., 2018). Many species exhibit amphidromous life cycles, requiring both freshwater and marine habitats to complete their development. In oceanic islands, such as some islands in the Philippines, there are no primary freshwater fishes, but instead peripheral freshwater fishes are typically found with the dominant *Gobiidae* group (Herre, 1953; Leveque et al., 2008). Smith et al. (2003) added that many freshwater fish species are phylogenetically derived from marine ancestors such as gobies, sleepers, and eels because their planktonic larvae drift long distances among islands in oceanic currents. These species, found in insular streams, also support fewer freshwater species than continental streams since multiple factors (i.e., island age, length, and geographical location) shape their biodiversity. Insular streams, found mostly in Southeast Asian countries, possess a complex combination of species dispersal from multiple continental sources and other islands, inter-island migration, and the evolution of new endemic species (Covich, 2006; Reichenbacher et al., 2020).

In the Philippines, despite their ecological and economic significance, freshwater gobies face numerous threats that jeopardize their populations and the livelihoods of communities dependent on them (Herre, 1953). Overfishing affects subsistence fisheries such as 'ipon' fisheries, which has led to declining stocks due to unsustainable harvesting practices and the lack of strict regulations (Herre, 1927; Blanco, 1956). Human-mediated activities have resulted in sedimentation, water pollution, and the destruction of critical breeding and nursery grounds. Additionally, the rapid expansion of urbanization, dam construction, and river channelization disrupts the natural migratory patterns of amphidromous goby species, leading to population fragmentation and genetic bottlenecks. The ornamental fish trade threatens goby populations due to high demand and unregulated collection, while the lack of comprehensive research and conservation efforts further leaves many species understudied and vulnerable (Kornis et al., 2013). Without immediate intervention through habitat conservation, sustainable fisheries management, and stricter policy enforcement, the future of goby populations in the Philippines remains at risk, along with the ecological balance of the freshwater ecosystems they support.

Several ichthyofaunal surveys have been conducted in the Philippines, but yet no comprehensive systematic review and meta-analysis have been performed to quantify the effect size of goby species richness relative to overall fish species richness. Understanding the abundance and diversity of goby species is crucial for

assessing their ecological significance and conservation status. This study aims to bridge this research gap by conducting a systematic review and meta-analysis of ichthyofaunal surveys in the Philippines from 2010 to 2022. Specifically, the study seeks to: (1) assess the existing goby species documented in the Philippines up to the genus level, (2) analyze diversity trends over time and across different freshwater ecosystems, and (3) generate forest and funnel plots to statistically determine the effect size of goby species richness in relation to total fish species richness in these studies. Synthesizing data from various surveys provides a more comprehensive understanding of goby biodiversity patterns, which can serve as a foundation for future conservation and management efforts.

2. Materials and Methods

PRISMA Protocol: We developed a search strategy that minimized bias when identifying the cohort of studies for our review. The study utilized the Preferred Reporting Items for Systematic Reviews (PRISMA) (Page et al., 2021) to review the occurrence of Freshwater goby species (Family *Gobiidae*) in the recently conducted Ichthyofaunal surveys from January 2024-June 2024. Using the literature search software *Publish or Perish* (Version 7.26; <https://harzing.com/pophelp/index.htm>). We conducted searches across multiple academic databases, including Google Scholar, Scopus, and Web of Science (ISI) for articles related to Gobi richness and fish species richness in freshwater ecosystems in the Philippines, with no restrictions on language and publication year. Using the search term "Freshwater Fish Diversity Philippines", we initially identified 980 articles from Google Scholar and Web of Science (ISI) while 34 articles from Scopus. After applying screening criteria to assess quality and relevance, we narrowed the selection to 45 articles, ensuring that only high-quality and pertinent studies were included in our review. This systematic approach allowed us to compile a robust dataset for analyzing goby species diversity and their ecological significance in Philippine freshwater ecosystems. (Fig. 1)

Data collection and extraction

We compiled a comprehensive list of 23 articles that were included in our systematic review and meta-analysis, synthesizing research on goby species richness and overall fish species richness in Philippine freshwater ecosystems. For each study, key details were documented, including the province where the survey was conducted, the specific location, and the corresponding scientific references from ichthyofaunal surveys in the Philippines. To ensure efficient organization and management of sourced literature, Zotero was utilized, a widely used reference management tool that facilitates the storage, citation, and retrieval of academic materials. This systematic approach allowed us to maintain accuracy, streamline data handling, and ensure transparency in our analysis of goby diversity trends across the country.

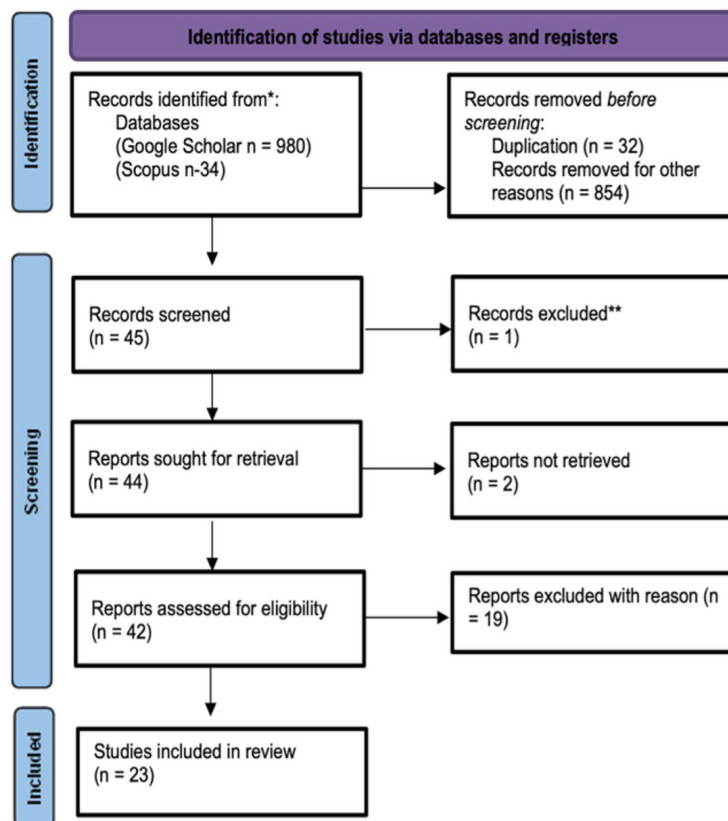


Fig.1. The study utilized the PRISMA flow diagram to showcase the plotted systematic review that comes from published articles.

Inclusion and exclusion criteria: To ensure the rigor and reliability of our meta-analysis on goby species richness relative to overall fish species richness, we established a set of a priori inclusion criteria for selecting published articles (van Rhee et al., 2015). These criteria were designed to filter studies that provided comprehensive and comparable ecological data from ichthyofaunal surveys in the Philippines. Specifically, a study was included only if it reported goby species richness and total fish species richness, ensuring that the data were relevant to our analysis. Additionally, the study must have been conducted within Philippine freshwater ecosystems and provided key biodiversity metrics, such as species richness, relative abundance, and diversity indices, including Shannon, Evenness, and Simpson indices. To account for changes in biodiversity over time, if multiple studies were conducted at the same location, only the most recent reassessment study was considered. This approach prevented data redundancy while capturing the most up-to-date trends in goby diversity.

Only studies with active and passive random sampling, which are standard for ichthyofaunal assessments, were included to ensure consistent methodology. Additionally, studies had to report critical physicochemical parameters such as water temperature, pH, and dissolved oxygen, as these factors significantly influence freshwater fish distribution and diversity. By enforcing these strict inclusion criteria, we ensured that our meta-analysis incorporated only high-quality, standardized data, allowing for robust statistical comparisons and reliable insights into the patterns of goby species richness in Philippine freshwater ecosys-

tems. This meticulous selection process was crucial in reducing bias and enhancing the validity of our findings, ultimately contributing to a more comprehensive understanding of goby diversity and its ecological implications.

Data analysis: We extracted data for 17 key categories from each article to ensure a comprehensive and standardized dataset (Table 1 and Table 2). Given that a single publication could report abundance data for multiple goby species, we structured our dataset by article, ensuring that each observation recorded was associated with a specific publication. Each goby species documented within a study was assigned to a separate row in our database, and its abundance statistics were recorded along with the presence or absence of other measurements of fish species richness within the same study (Table 2). This systematic approach allowed us to capture species-specific trends while maintaining consistency in data organization (Hak et al., 2016).

The extracted data included publication characteristics such as (1) publication year, (2) title of the study, (3) author(s), (4) province, (5) municipality, (6) freshwater ecosystem type (lake or river), (7) survey year, (8) protection status (protected or unprotected area), (9) seasonality, and (10) survey method (see Table 2). Additionally, we gathered information on (11) dissolved oxygen, (12) pH, and (13) water temperature at each study site. Key biodiversity metrics were also recorded, including (14) goby species richness, (15) total fish species richness, and three diversity indices: (16) Shannon Diversity Index, (17) Pielou's Evenness Index, and (18) Simpson's Dominance Index (see Table 2). To determine whether a study was con-

Table 1. Final list of publications included in the systematic review and meta-analysis.

Publication No.	Site	Province	References
1	Minalin Channel-Pampanga River Basin	Pampanga	Baysa et al., 2022
2	Ambuklao Dam, Karao River, Eddet River, Adaoay River, Agno River, Galiano River, Sab-dang River, Amburayan River, Payay-Asin River, Poblacion River, Asin-Lewen River Dopi River	Benguet	Bestre et al., 2018
3	Lake Taal River System (Looc, Magapi {Inlets} and Pasipit {Outlet})	Batangas	Corpuz et al., 2015a
4	Lake Bato, Agos River, Bagacay Falls, Lake Baao-Bula, and Pawili River	Camarines Sur	Corpuz et al., 2015b
5	Lake Oro and Lake Dakong Napo, Esperanza	Agusan Del Sur	Cuadrado et al., 2019
6	Santa Cruz River System	Laguna	Cui et al., 2022
7	Tigum River	Iloilo	Denusta et al., 2020
8	Candaba Wetland	Pampanga	Garcia, 2010
9	Tablas Island Wetlands	Romblon	Gonzalez et al., 2023
10	Eight Floodplain Lake in Agusan Marsh (Panlabuhan, Mihaba, Tugno, Kasawangan, Mambagongon, Sabang-Gibong, Kilobidan, and Tikgon)	Agusan Del Sur	Jumawan and Seronay, 2017
11	Tikub Lake	Quezon	Labatos and Briones, 2014
12	Sawaga River	Bukidnon	Lubos et al., 2020
13	Pajo-Sto. Domingo River System	Catanduanes	Masagca et al., 2022
14	Daniog River	Surigao Del Sur	Mercado, 2018
15	Ihawan Spring Community Watershed	Surigao Del Sur	Ojao et al., 2021
16	Ilog-Hilabangan River System	Negros Occidental	Pacalioga and Peralta, 2016
17	Bago River	Negros Occidental	Pacalioga et al., 2010
18	Watersheds of Mt. Makiling Forest Reserve	Laguna	Paller et al., 2011
19	Tayabas River	Quezon	Paller et al., 2013
20	Lake of San Pablo (Yambo, Sampalok, Pandin, Palakpakin, Mohicap, Calibato, & Bunot)	Laguna	Paller et al., 2017
21	Danao Lake	Leyte	Romero et al., 2023
22	Talabaan River Sytem	Misamis Oriental	Vedra et al., 2022
23	Bega Watershed	Agusan Del Sur	Visto et al., 2015

ducted on an island or the mainland, we relied on information provided within each article and used it to contextualize goby species richness and fish species richness in relation to geographical location.

To assess effect size and standard deviation, we utilized the web-based Campbell Collaboration Effect Size Calculator (<https://www.campbellcollaboration.org/research-resources/effect-size-calculator.html>). Meta-analysis was conducted using JASP statistical software, focusing on freshwater species richness and goby species richness. Our analysis revealed that Shannon Diversity, Pielou's Evenness, and Simpson's Dominance indices showed no strong correlation with goby species richness. However, due to missing data in some articles, diversity indices were manually calculated when species richness and relative abundance were available.

Descriptive statistical analysis was applied to the physicochemical parameters, including water temperature, pH, and dissolved oxygen, to identify patterns and variations across study sites. The final dataset was

analyzed to ensure thematic consistency among the selected research articles, reinforcing the validity of this systematic review and meta-analysis in evaluating goby diversity and its relationship with freshwater fish communities in the Philippines.

Risk bias assessment: To ensure the reliability and validity of the included studies, we conducted a rigorous risk of bias and quality assessment using the Risk of Bias In studies of Temporal Trends in Ecology (ROBITT) framework, developed by Boyd et al. (2022). This framework consists of a 17-question assessment designed to evaluate potential biases within ecological studies, particularly those analyzing temporal trends in biodiversity and species richness. The ROBITT tool allows for a systematic and standardized evaluation of study quality, helping to identify methodological limitations such as incomplete data reporting, inconsistencies in sampling techniques, and the potential influence of external environmental factors. By implementing this framework, we aimed to minimize the inclusion of

Table 2. Summary of study details, locations, and biodiversity indices of freshwater goby species in the Philippines (2010–2022).

Author	Year	Province	Municipality	Lake/River	Survey year	Method	Species richness	No. of goby species
Uy et al.	2015	Surigao Del Norte & Agusan Del Norte		Mainit Lake and Kalinawan River	2007	sampling survey	41	4
Gonzalez et al.	2023	Romblon	Alcantara, Calatrava, Ferrol, Looc, Odiongana, San Agustin, San Andres, Sante Fe, & Santa Maria	Tablas Island	2019	sampling survey	44	12
Corpuz et al.	2015	Batangas	Taal Lake	Taal Lake (Inlet Looc and Magapi) (Outlet; Pansipit)	2011	sampling survey	37	7
Dantis and Lacey	2021	Pangasinan		Agno River	2018	sampling survey	23	1
Labatos and Briones	2014	Quezon	Tiaong	Tikub Lake		sampling survey	9	1
Opiso et al.	2014	Bukidnon		Alanib River		sampling survey	2	1
Cui et al.	2022	Laguna	Santa Cruz	Santa Cruz River System	2016–2017	sampling survey	12	3
Corpuz et al.	2015	Camarines Sur			2010	sampling survey	29	8
Quimpong et al.	2016	Davao Oriental	Mt. Hamiguitan	River	2015	sampling survey	33	9
Paller et al.	2017	Laguna	San Pablo	Lake	2013–2014	sampling survey	10	1
Dapar et al.	2021	Davao Oriental	Mt. Hamiguitan	River	2019–2021	sampling survey	25	9
Bayasa et al.	2022	Pampanga	Minalin	River	2018	sampling survey	16	3
Cuadrado et al.	2019	Agusan Del Sur	Ezperanza	Lake	2017	sampling survey	12	2
Mercado	2018	Surigao Del Sur	Lanuza	River	2016–2017	sampling survey	13	2
Masagca et al.	2022	Catanduanes		Pajo-Sto. Domingo River	2017–2018	sampling survey	20	3
Lubos et al.	2020	Bukidnon	Malaybalay	Sawaga River	2018–2019	sampling survey	8	0
Yagos et al.	2022	Zamboanga Del Sur	Bayog	Sibugay River	2018	sampling survey	19	2
Romero et al.	2023	Leyte	Ormoc City	Danao Lake	2021–2022	sampling survey	8	1
Paller et al.	2013	Quezon		Tayabas River	2010	sampling survey	15	6
Visto et al.	2015	Agusan Del Sur	Prosperidad	Bega Watershed	2014	sampling survey	6	1
Roque et al.	2019	Bataan		Bagac River Systems		sampling survey	17	5
Quimpong et al.	2020			Matingao River and Marbel River	2012–2013, 2015	sampling survey	6	2
Macalisang et al.	2023	Romblon	San Agustin	Wetland	2016–2017	sampling survey	31	9
Paller et al.	2011	Laguna		Watershed		sampling survey	16	3
Vedra et al.	2022	Misamis Oriental		Talabaan River System	2021	sampling survey	12	4
Ojao et al.	2021	Surigao del Sur	Tandag	Ihawan Spring Community	2018	sampling survey	23	1
Quimpong et al.	2018	Northwestern Mindanao, Philippines		Lake Duminagat	2013	sampling survey	6	0

studies that may introduce bias into our meta-analysis, ensuring that our findings reflect accurate and unbiased trends in goby species richness relative to fish species richness in Philippine freshwater ecosystems.

Each study was critically assessed based on multiple criteria, including study design, data collection methods. Factors such as whether the study provided sufficient details on sampling protocols and included robust statistical analyses were considered in the quality assessment. Additionally, we evaluated whether the studies adhered to standardized ecological survey methodologies, which is crucial for ensuring comparability across different research works. Studies that scored low in ROBITT’s risk assessment were either excluded from the meta-analysis or noted as having potential biases that could influence interpretation. This rigorous assessment process allowed us to refine our dataset, ensuring that our systematic review and meta-analysis were built upon high-quality research, ultimately strengthening the reliability of our conclusions regarding goby biodiversity and its ecological significance in Philippine freshwater habitats. All data were analyzed using JASP Software (Goss-Sampson, 2019).

3. Results

Location of the study: Among the studies included in our systematic review and meta-analysis, the majority were conducted on Luzon Island, with significantly fewer studies focusing on freshwater ecosystems in Mindanao and the Visayas (see Table 1 and Table 2). This geographic disparity highlights a research gap in goby species assessments outside Luzon, where ecological studies on freshwater fish diversity appear to be more concentrated. The scarcity of research in Mindanao and the Visayas suggests their potential underrepresentation in ichthyofaunal studies, possibly resulting in unaddressed critical biodiversity patterns and conservation concerns. Given the unique ecolog-

ical characteristics of freshwater ecosystems on these islands, further research is necessary to provide a more comprehensive understanding of goby species richness and distribution across the Philippine archipelago.

In terms of habitat type, most studies were conducted in river systems, while only a smaller portion focused on lakes. This trend may be attributed to the fact that riverine environments, particularly those with direct connectivity to marine waters, serve as critical habitats for amphidromous goby species, which require both freshwater and marine environments to complete their life cycles. Rivers also provide more accessible sampling sites for researchers, making them the preferred study areas for ichthyofaunal surveys. In contrast, lake ecosystems, though equally important for fish diversity, are less frequently studied, possibly due to logistical challenges or differences in research priorities. This uneven distribution of studies suggests the need for more focused efforts in assessing goby populations in lake ecosystems to ensure a holistic understanding of their ecological roles and conservation needs.

Goby species richness: Overall, this study documented a total of twenty-nine (29) genera of freshwater gobies from the family *Gobiidae*, highlighting the rich diversity of goby species in Philippine freshwater ecosystems (Fig. 2). Among these, the most prevalent genus recorded was *Glossogobius* sp., which appeared in seventeen studies, indicating its widespread distribution and ecological significance. Additionally, other frequently documented genera included *Sicyopterus* sp., *Redigobius* sp., *Rhinogobius* sp., and *Awaous* sp., which were consistently observed across multiple study sites (Table 2; Fig. 2). The dominance of these genera suggests their adaptability to various freshwater habitats, particularly in riverine systems with direct connectivity to marine environments. Their frequent occurrence across different studies underscores their potential role as ecological indicators and emphasizes the need for further research on their population dynamics, habitat preferences, and conservation status.

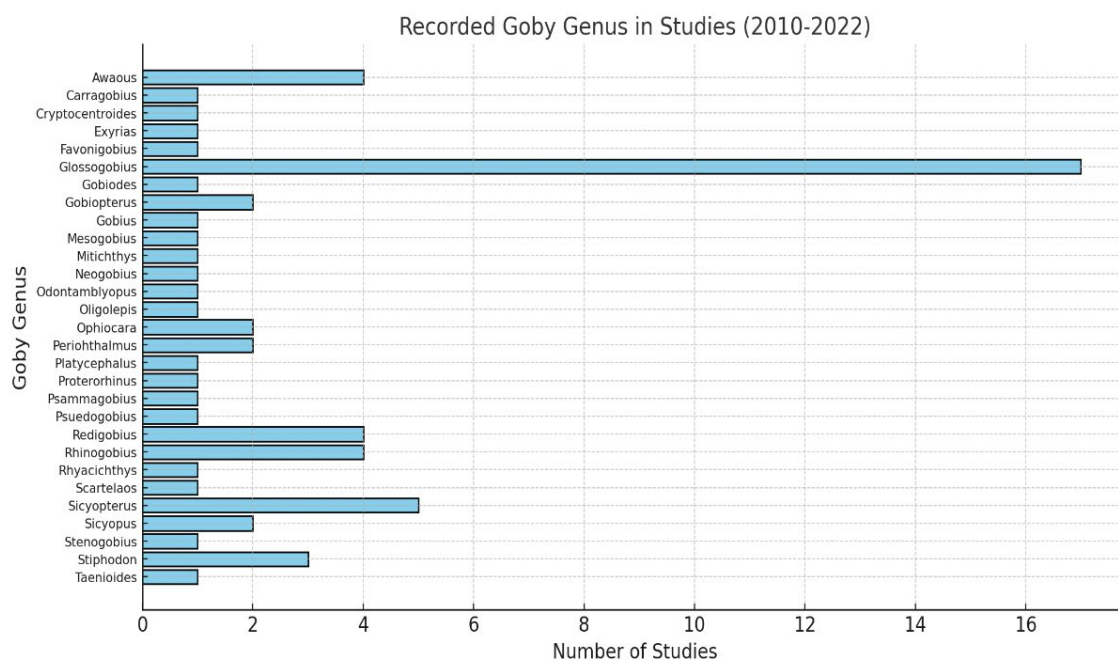


Fig.2. Recorded Goby Genus across studies between 2010 and 2022.

Diversity indices: The diversity indices computed from the analyzed studies reveal considerable variation in goby species richness and distribution across different freshwater ecosystems in the Philippines. $H' = 2.657$ to 0.19 indicated a wide disparity in species diversity among study sites (Table 3). Higher H' values suggest more evenly distributed and diverse goby communities, whereas lower values reflect dominance by a few species or low overall species richness. This variation may be attributed to differences in habitat conditions, environmental disturbances, or anthropogenic impacts such as pollution, habitat fragmentation, and overfishing. Additionally, variations in sampling effort and methodologies may have also influenced the recorded diversity levels across studies.

Similarly, differences in how uniformly goby species are distributed within the studied freshwater systems ($PE = 0.918$ – 0.12). A higher PE Index suggests a more balanced species composition, whereas lower values indicate dominance by certain species, potentially due to ecological competition or environmental stressors. The Simpson's D values ranged from 0.788 to 0.10 , further reinforcing the disparity in community structure across the surveyed sites (Table 3). Higher Simpson's D values indicate a more evenly distributed goby community, while lower values suggest the dominance of a few resilient species that outcompete others

in specific environments. These findings underscore the complexity of goby assemblages in Philippine freshwater ecosystems and emphasize the importance of conservation efforts to protect habitats that support high species diversity and evenness.

Physicochemical analysis: Out of the 23 studies reviewed, only 11 provided data on key physicochemical parameters, namely dissolved oxygen (DO), pH, and water temperature, which are crucial in assessing the environmental conditions of freshwater ecosystems (Table 4). The recorded DO indicated varying oxygen availability across different study sites ($DO = 10.00$ mg/L– 5.42 mg/L). Higher DO values suggest well-oxygenated waters that support diverse aquatic life, while lower values may indicate potential stressors such as organic pollution or eutrophication. pH levels observed across study sites revealed slightly alkaline to near-neutral conditions ($pH = 8.54$ to 7.73), which are generally suitable for freshwater gobies and other fish species. Meanwhile, water temperature (31.50°C to 24.22°C) varied significantly, with the highest temperatures recorded in studies such as Mercado (2018) and the lowest in Paller et al. (2013). These temperature fluctuations may influence metabolic rates, breeding behaviors, and species distribution within these freshwater habitats.

Table 3. Goby species richness and biodiversity indices (Shannon H' , Evenness-PE, and Simpson D).

No.	References	Species richness	Goby species	H'	PE	D
1	Baysa et al., 2022	24	3	1.63	0.56	0.38
2	Bestre et al., 2018	13	3	1.54	0.45	0.22
3	Corpuz et al., 2015a	37	7	2.68	0.78	0.1
4	Corpuz et al., 2015b	29	8	1.65	0.62	0.33
5	Cuadrado et al., 2019	12	2	1.45	0.52	0.34
6	Cui et al., 2022	12	3	1.38	0.73	0.69
7	Denusta et al., 2020	8	1	1.2	0.58	0.62
8	Garcia, 2010	21	2	2.16	0.79	0.85
9	Gonzalez et al., 2023	44	12	1.7	0.65	0.29
10	Jumawan and Seronay, 2017	16	2	1.9	0.69	0.788
11	Labatos and Briones, 2014	9	1	1.87	0.21	0.18
12	Lubos et al., 2020	8	0	1.9	0.2	0.84
13	Masagca et al., 2022	20	3	2.66	0.89	0.92
14	Mercado, 2018	13	2	1.6	0.72	0.78
15	Ojao et al., 2021	23	1	1.88	0.6	0.42
16	Pacalioga and Peralta, 2016	56	11	2.41	0.733	0.85
17	Pacalioga et al., 2010	55	7	1.71	0.45	0.22
18	Paller et al., 2011	16	3	1.04	0.36	0.4
19	Paller et al., 2013	15	6	1.55	0.74	0.26
20	Paller et al., 2017	10	1	1.56	0.68	0.3
21	Romero et al., 2023	8	1	0.19	0.12	0.08
22	Vedra et al., 2022	12	4	1.21	0.74	0.59
23	Visto et al., 2015	6	1	1.22	0.65	0.65

Note: H' = Shannon Index, PE = Pielou's Evenness Index, D = Simpson Index

Table 4. Physicochemical variables found across 23 articles.

No.	References	Water Temperature	pH	DO
1	Baysa et al., 2022	27.765	7.6	27.765
3	Corpuz et al., 2015a	28.14	7.62	28.14
4	Corpuz et al., 2015b	28.178	7.976	28.178
13	Masagca et al., 2022	28.73	7.91	28.73
14	Mercado, 2018	31.503	7.68	31.503
15	Ojao et al., 2021	28.873	7.367	28.873
17	Pacalioga et al., 2010	24.971	7.699	24.971
18	Paller et al., 2011	26.287	8.539	26.287
19	Paller et al., 2013	24.225	7.315	24.225
20	Paller et al., 2017	27.755	7.825	27.755
23	Visto et al., 2015	25.625	7.375	25.625

Table 4 highlighted site-specific variations in water quality, which can be influenced by factors such as seasonal changes, geographic location, and anthropogenic activities. For instance, studies conducted in urbanized or disturbed environments may exhibit higher temperatures and lower DO levels due to increased runoff, reduced vegetation cover, and pollution. Conversely, sites in relatively undisturbed areas with stable riparian vegetation and minimal human impact tend to maintain more favorable water quality parameters. The variations observed emphasize the need for continued monitoring and assessment of freshwater ecosystems, as physicochemical factors play a vital role in maintaining the health and stability of goby populations. Understanding these environmental parameters can provide valuable insights into habitat suitability, species adaptability, and potential threats to freshwater biodiversity in the Philippines.

Relationship among variables from the pool of publications: A strong positive relationship was observed between goby species richness and overall fish species richness, suggesting that areas with higher fish diversity also tend to support a greater number of goby species ($r=0.846$, $p<.001$; Table 5). This finding indicates that gobies, as a taxonomic group, thrive in

ecologically rich freshwater systems where fish communities are more diverse, possibly due to favorable environmental conditions such as habitat complexity, resource availability, and stable water quality parameters. The significant correlation also suggests that gobies may serve as an important ecological indicator of freshwater biodiversity, with their presence reflecting overall ecosystem health. Furthermore, since gobies exhibit amphidromous life cycles requiring both freshwater and marine environments, the observed correlation may highlight the importance of hydrological connectivity in sustaining both goby and broader fish assemblages.

Apart from the strong goby-fish species richness correlation, additional positive relationships were observed between fish species richness and H' , indicating that higher fish species richness contributes to greater species diversity and evenness in freshwater ecosystems ($r=0.487$, $p=0.019$). Similarly, PE showed significant correlations with both H' and Simpson D, reinforcing the idea that ecosystems with a balanced distribution of species tend to exhibit greater overall diversity ($r=0.611$, $p=0.002$; $r=0.657$, $p<0.001$, Table 5). This implies that in areas where fish species are more evenly distributed, goby species also benefit

Table 5. Pearson correlation (r) of variables from the final selection of studies.

Variable		Goby species richness	Fish species richness	Shannon Index	Simpson Index	Evenness Index
1. Goby species richness	Pearson's r p-value	— —				
2. Fish species richness	Pearson's r p-value	0.846 < .001	— —			
3. Shannon Index	Pearson's r p-value	0.327 0.128	0.487 0.019	— —		
4. Simpson Index	Pearson's r p-value	-0.170 0.438	-0.098 0.656	0.330 0.124	— —	
5. Evenness Index	Pearson's r p-value	0.161 0.462	0.118 0.591	0.611 0.002	0.657 < .001	— —

from reduced interspecific competition and more stable ecological conditions. The presence of strong evenness and diversity relationships further highlights the role of habitat conservation in maintaining the structural integrity of fish communities, as disturbances such as habitat fragmentation and pollution can disrupt these ecological balances.

Conversely, the Simpson D in Table 5 displayed weak and non-significant correlations with goby species richness ($r = -0.170$, $p = 0.438$) and fish species richness ($r = -0.098$, $p = 0.656$), due to the dominance by several species that does not necessarily correspond with higher goby or fish diversity. This may indicate that in some freshwater habitats, a few dominant species outcompete others, leading to lower overall diversity despite relatively high species richness. Such findings highlight the complexity of species interactions in freshwater ecosystems, where diversity indices alone may not fully capture the ecological dynamics at play. Ultimately, these results emphasize the importance of taking into account multiple biodiversity metrics when assessing freshwater fish communities, as well as the need for conservation strategies that maintain both species richness and community evenness to support long-term ecological stability.

Meta-analysis, forest plot, and residual heterogeneity across study sites and publications: The forest plot analysis revealed that all studies included in the meta-analysis are positioned entirely on the positive side of zero, indicating a consistent trend in the relationship between goby species richness and overall fish species richness (Fig. 3). Among the studies, Study 16 exhibited the highest effect size (0.69), suggesting that goby richness in this dataset has a relatively strong association with fish species richness. This may be due to favorable environmental conditions, such as well-preserved freshwater habitats, optimal water quality parameters, or higher habitat complexity, which support diverse goby and fish populations. Conversely, Study 12 recorded the lowest effect size (0.0), indicating little to no measurable relationship between goby richness and overall fish species richness in that study (Fig. 3). This could be attributed to various ecological factors, such as habitat degradation, pollution, or methodological inconsistencies in species sampling and identification.

The combined effect size across all studies falls within the range of a low but statistically significant effect ($g = 0.46$; 0.34–0.57). This suggests that although goby species richness positively correlates with total fish species richness, this association is not very substantial. Several factors could contribute to this low effect size, including ecological niche differentiation, varying habitat preferences among fish species, or site-specific environmental conditions that influence community structure. Additionally, differences in survey methodologies, seasonal variations, and geographical distribution may also play a role in moderating the observed relationship. Despite the relatively low effect size, the positive direction of the results reinforces the idea that freshwater ecosystems with greater fish diversity tend to support higher goby richness, albeit to varying degrees.

Furthermore, a low heterogeneity index was recorded across publications (Fig. 3), indicating minimal variability among the included studies ($I^2 = 14.74\%$; $H^2 = 1.173$). This suggests that the relationship between goby species richness and fish species richness is consistent across different research locations, with little variation associated with methodological differences or external environmental factors. A low heterogeneity value strengthens the reliability of the meta-analysis findings, implying that outliers or conflicting results from individual studies do not significantly influence the observed trend. However, the relatively low effect size highlights the need for further investigations into additional ecological factors that may influence goby species distribution, such as hydrological connectivity, competition, and habitat fragmentation. Future research should consider a broader range of environmental variables and explore potential interactions that may contribute to variations in goby and fish diversity patterns across different freshwater ecosystems.

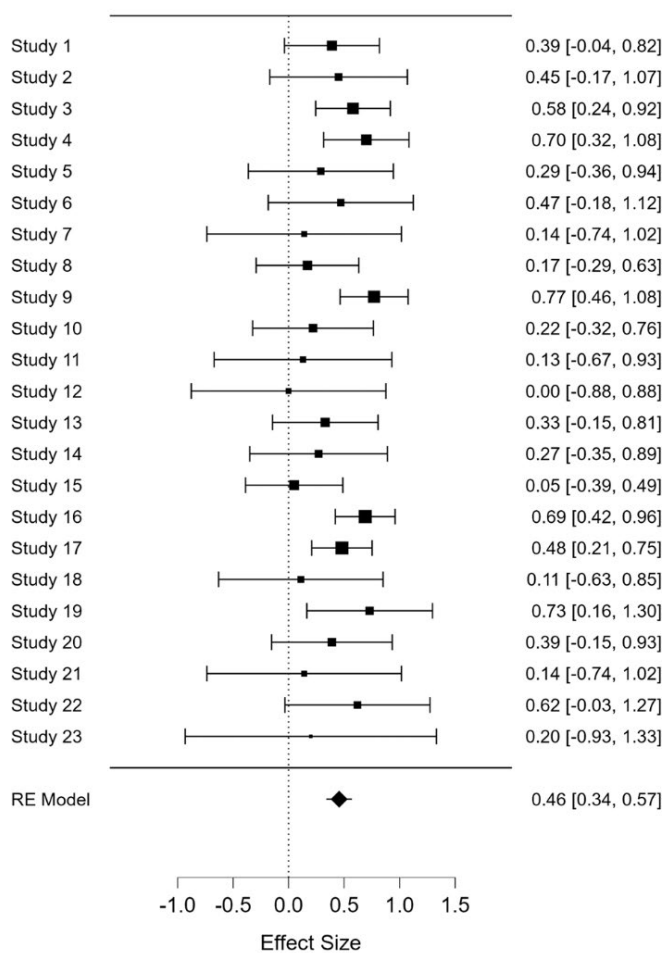


Fig.3. Forest plot.

Table 6. Residual heterogeneity estimates.

	Estimate
τ^2	0.010
τ	0.102
I^2 (%)	14.737
H^2	1.173

The funnel plot in Figure 4 provided a visual assessment of potential publication bias among the studies included in the meta-analysis of freshwater goby species from recent ichthyofaunal surveys in the Philippines (2010–2022). Ideally, in the absence of publication bias, the data points representing individual studies should be symmetrically distributed around the central effect size, forming an inverted funnel shape. This symmetrical pattern indicates that studies with both large and small effect sizes are equally reported, reducing the likelihood of selective publication and ensuring a more balanced representation of available data.

However, the observed funnel plot displays noticeable asymmetry, suggesting a significant deviation from the expected distribution. This pattern demonstrates the potential presence of publication bias, where studies with smaller effect sizes or non-significant results may be underreported or unpublished. Several factors could contribute to this asymmetry, including selective reporting, variations in sampling methodologies, or geographical disparities in research focus. Additionally, differences in study quality, sample sizes, or ecological conditions across study sites may also influence the distribution of effect sizes. Taking into account this deviation, further statistical analyses, such as Egger's regression test, are necessary to quantitatively assess the extent of publication bias and evaluate its potential impact on the overall findings of the meta-analysis.

Publication bias in freshwater goby studies:

Egger's regression test for funnel plot yielded a statistically strongly significant result, indicating the presence of publication bias ($sei = -2.749$, $p = 0.006$). A p -value below 0.05 suggests that smaller studies with non-significant or negative findings may be underreported or unpublished, leading to an overestimation of the overall effect size in the meta-analysis.

The result of the funnel plot in Figure 4 revealed an asymmetrical pattern among studies' standard error over effect sizes, indicating a strong publication bias. Moreover, the Egger's test further confirmed a publication bias ($p = 0.006$). The presence of publication bias in this study may stem from multiple factors, including selective reporting of studies with significant findings, variations in survey methodologies, or regional biases in freshwater goby research across the Philippines. Given these findings, sensitivity analyses such as the trim-and-fill method or fail-safe N tests could be explored to adjust for bias and assess the robustness of the meta-analytic conclusions. While publication bias does not invalidate the primary conclusions, it underscores the need for cautious interpretation of the results. Future ichthyofaunal surveys should aim for comprehensive reporting, including non-significant findings, to ensure a more balanced representation of freshwater goby diversity in the region.

4. Discussion

Across 23 studies, Luzon emerges as the predominant locus of research on Philippine freshwater gobies, corroborating earlier evidence that it is the country's

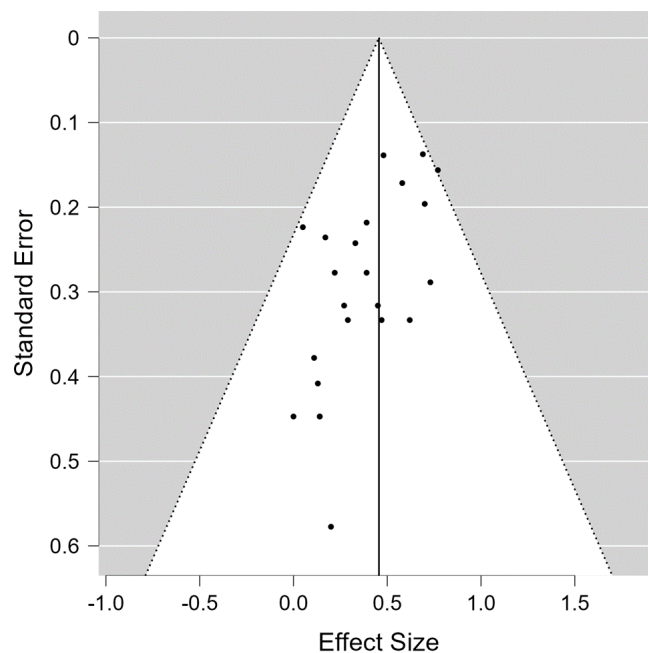


Fig.4. Funnel plot asymmetry.

Table 7. Regression test for funnel plot asymmetry ("Egger's test").

	z	p
sei	-2.749	0.006

most intensively studied freshwater region (Magbanua et al., 2017). This concentration of effort has yielded a comparatively coherent picture of gobiid diversity and assemblage structure in Luzon's riverine systems, but it also risks entrenching a geographic bias in our national understanding of freshwater fish ecology. Although the available is sufficient for robust inferences about Luzon, it also emphasizes the limited generalizability of these insights to the rest of the archipelago.

By contrast, freshwater systems in the Visayas and Mindanao remain poorly studied, creating a significant knowledge gap in goby species distributions, assemblage composition, and biodiversity processes in these regions. The observed disparity mirrors the broader pattern identified by Magbanua et al. (2017) for freshwater ecosystem research in the Philippines, reinforcing the need for spatially balanced sampling. Targeted, stratified ichthyofaunal surveys—designed to capture habitat gradients, hydrological seasonality, and watershed-level landuse pressures—are therefore essential to develop a comprehensive, archipelagowide baseline.

Taxonomically, the compiled records converge on the prominence of *Glossogobius*, with *Glossogobius* spp. as the most prevalent gobies across studies, which is consistent with the genus's recognition as one of the most speciose gobioid lineages (Agorreta et al., 2013). Comparative biogeographic work supports ongoing species radiation within *Glossogobius* across Papua New Guinea, Sulawesi, Madagascar, and the Philippines (Hoese and Allen, 2009). Within the Philippines, eight

Glossogobius spp. have been documented to date, with *G. aureus* as the most abundant and commercially salient, a pattern aligned with the genus's ecological versatility and capacity to occupy a range of lowland freshwater habitats.

Across studies reporting community metrics, diversity indices (Shannon, Evenness, and Simpson) normally fall within low to medium ranges (Magurran, 2021). This is consistent with theory and empirical patterns, demonstrating that insular tropical rivers typically support lower fish diversity than their continental tropical counterparts (Smith et al., 2003). Insular stream fish assemblages are shaped by dispersal from multiple sources, including adjacent islands, producing species pools constrained by overwater colonization and habitat connectivity (Covich, 2006). Notably, introduced species were recorded in all studies; while their ecological impacts warrant focused assessment, they have—at least numerically—contributed to higher local species counts in some Philippine freshwater systems (Guerrero, 2014).

Physicochemical data from 11 studies indicate that dissolved oxygen, pH, and water temperature generally meet thresholds that were established by the Department of Environment and Natural Resources Administrative Order (DAO) No. 201608 on Water Quality Guidelines and General Effluent Standards. These conditions are broadly suitable for sustaining freshwater fish communities, including gobiids, which often exhibit finescale microhabitat specialization. Nevertheless, maintaining water quality is critical: fluctuations in oxygen dynamics, thermal regimes, and acidity can reshape trophic interactions, alter recruitment, and precipitate shifts in community composition. Sustained, watershed-scale monitoring is therefore warranted to detect and mitigate degradation arising from pollution, deforestation, sedimentation, and landuse change under DAO 201608 compliance frameworks.

Correlation analyses reveal a strong positive relationship between goby species richness and overall fish species richness, reinforcing the ecological expectation that in oceanic islands—where diadromous and amphidromous lineages frequently dominate—peripheral freshwater fishes such as Gobiidae are naturally prevalent (Leveque et al., 2008). Concordantly, fish species richness is positively associated with the Shannon Index, which integrates both richness and evenness; as richness rises, Shannon entropy typically increases, provided dominance does not intensify. By contrast, the strong positive correlation between Simpson and Evenness indices, coupled with the absence of a direct richness–Simpson correlation, underscores Simpson's sensitivity to dominance structure rather than to richness per se, highlighting the importance of balanced relative abundances for community stability.

The metaanalysis (Forest Plot) places all studies on the positive side of zero, yielding a combined effect size of 0.46, indicative of a moderate yet statistically meaningful association between goby richness and total fish richness. Low heterogeneity ($I^2 = 14.74\%$) suggests broadly comparable methodologies across studies, with only minor differences in sampling gear, effort,

or habitat coverage. Two caveats deserve attention. First, introduced species in total richness may inflate effect sizes by adding taxa independent of native community assembly processes; sensitivity analyses excluding nonnative species would clarify this influence. Second, the funnel plot shows asymmetry, and Egger's test indicates potential publication bias—an unsurprising outcome given the topic's specificity and a literature base that already emphasizes gobiid dominance in Philippine freshwaters (Herre, 1953; Leveque et al., 2008). Addressing these biases will require broader geographic coverage and systematic inclusion of gray literature and null results.

These findings motivate a forward agenda grounded in geographic rebalancing, methodological standardization, and data transparency. Priorities include (i) expanding surveys in the Visayas and Mindanao with stratified designs across watershed types and disturbance gradients; (ii) coupling morphology with molecular barcoding to resolve cryptic *Glossogobius* lineages (cf. Hoese and Allen, 2012); (iii) harmonizing protocols for effort, gear, and index calculation to reduce residual heterogeneity; (iv) conducting sensitivity analyses that partition native versus introduced assemblage components (Guerrero, 2014); and (v) integrating longterm waterquality monitoring within the DAO 201608 framework to link community responses with environmental change (DENRBMB, 2016). Such steps will strengthen inference on gobiid biogeography and community ecology, enhance the robustness of future metaanalyses, and generate the evidence base needed to identify endemism, assess ecosystem health, and design effective, regionappropriate conservation strategies (Herre, 1953; Smith et al., 2003; Leveque et al., 2008; Covich, 2006; Magbanua et al., 2017).

5. Conclusion

Goby diversity in the Philippines, as measured by species richness, remains notably high, with *Glossogobius* sp. emerging as the most prevalent genus across the studies. However, a significant geographical disparity exists in ichthyofaunal surveys, as most studies were conducted in Luzon, while freshwater systems in the Visayas and Mindanao remain underrepresented in published literature. This research gap underscores the need for further exploration in these regions to obtain a more comprehensive picture of goby species distribution and diversity. The diversity index scores from the studies revealed low to medium diversity, which is consistent with the general understanding that tropical insular streams have fewer fish species compared to continental rivers. Additionally, the presence of introduced fish species contributed to an increase in overall biodiversity scores, although their ecological impacts on native goby populations require further investigation. Understanding whether these introduced species compete with, displace, or coexist with native gobies is critical for future conservation and management strategies (Patzner et al., 2011).

The strong positive correlation between goby species richness and total fish species richness suggests that gobies are a dominant and ecologically significant group within Philippine freshwater habitats. Meta-analysis results further supported this finding, with a combined effect size of 0.46, indicating a moderate but notable influence of goby richness on overall fish diversity. This highlights the ecological importance of gobies in structuring freshwater communities, particularly in insular environments where they thrive as peripheral freshwater species. Given their adaptability and prevalence, gobies may serve as reliable indicators of freshwater ecosystem health. However, publication bias, as detected in the funnel plot and Egger's test, suggests that existing studies may not fully capture the diversity and ecological roles of gobies across all freshwater systems in the Philippines. Addressing these gaps through expanded research efforts in understudied regions, along with standardized methodologies, will enhance our understanding of goby diversity and its broader ecological implications.

Taking into account the high publication bias observed in this study, future research studies should expand their focus beyond the Philippines to include goby diversity across Southeast Asian nations. A broader regional approach will provide a more comprehensive understanding of goby distribution patterns, reduce bias, and allow for comparisons between different freshwater ecosystems. Moreover, there is a critical need to increase ichthyofaunal surveys in the Visayas and Mindanao regions, as these areas remain underrepresented in published literature. Expanding research efforts in these regions will not only help address publication bias but also contribute valuable data on goby diversity and freshwater fish assemblages in lesser-studied habitats.

Furthermore, a meta-analysis comparing native fish species richness with introduced fish species richness would be highly beneficial in assessing the ecological impact of non-native species on freshwater biodiversity. This analysis could determine whether introduced species significantly influence overall species richness and whether their presence alters native fish communities, including goby populations. Understanding these effects is crucial for developing informed conservation and management strategies aimed at preserving native biodiversity while mitigating the potential ecological disruptions caused by introduced species.

Acknowledgements

The authors extend heartfelt appreciation to the anonymous reviewers for their constructive comments and critical insights, which helped improve the clarity, rigor, and overall impact of this manuscript. CTB contributed to the conceptualization and methodology of the study. JJCG handled software implementation, data validation, and formal analysis. Investigation and resource acquisition were carried out by CTB, while data curation was managed by both authors. The original draft was written by CTB, with review and final editing performed by JJCG. Visualization and figure

preparation were handled by JJCG. Supervision and administration of the paper were overseen by JJCG.

Conflict of Interest

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

References

- Agorreta A., San Mauro D., Schliewen U. et al. 2013. Molecular phylogenetics of *Gobioidei* and phylogenetic placement of European gobies. *Molecular phylogenetics and evolution* 69(3): 619–633. DOI: [10.1016/j.ympev.2013.07.017](https://doi.org/10.1016/j.ympev.2013.07.017)
- Baysa R.P., Mendoza D.M., Villanueva G.A. et al. 2022. Fish diversity and physico-chemical characteristics of the Minalin Channel–Pampanga River Basin during dry and wet season, Minalin, Pampanga, Philippines. *International Journal of Recent Scientific Research* 10(7): 33786–33792. DOI: [10.24327/ijrsr.2019.1007.3749](https://doi.org/10.24327/ijrsr.2019.1007.3749)
- Benstead J.P., De Rham P.H., Gattolliat J.L. et al. 2003. Conserving Madagascar's freshwater biodiversity. *BioScience* 53(11): 1101–1111. DOI: [10.1641/0006-3568\(2003\)053\[1101:CMFB\]2.0.CO;2](https://doi.org/10.1641/0006-3568(2003)053[1101:CMFB]2.0.CO;2)
- Bestre E.C., Lumiquio A.M., Napaldet J.T. 2018. Fishes and shell diversity of major rivers of Benguet, Philippines. *Journal of Wetlands Biodiversity* 8: 59–85.
- Blanco G.J. 1956. Assay of the goby fry (*ipon*) fisheries of the Laoag River and its adjacent marine shores, Ilocos Norte Province. *Philippine Journal of Fisheries* 4(1): 31–78.
- Boyd R.J., Powney G.D., Burns F. et al. 2022. ROBITT: A tool for assessing the risk of bias in studies of temporal trends in ecology. *Methods in Ecology and Evolution* 13(7): 1497–1507. DOI: [10.1111/2041-210X.13857](https://doi.org/10.1111/2041-210X.13857)
- Corpuz M.N.C., Paller V.G.V., Ocampo P.P. 2015. Environmental variables structuring the stream gobioid assemblages in three protected areas in Southern Luzon, Philippines. *Raffles Bulletin of Zoology* 63: 357–365.
- Corpuz M.N.C., Paller V.G.V., Ocampo P.P. 2015. Ichthyofaunal survey in selected freshwater habitats in Camarines Sur, Philippines. *Asian Journal of Biodiversity* 6(1): 80–99. DOI: [10.7828/ajob.v6i1.696](https://doi.org/10.7828/ajob.v6i1.696)
- Covich A.P. 2006. Dispersal limited biodiversity of tropical insular streams. *Polish Journal of Ecology* 54(4): 523–547.
- Cuadrado J.T., Lim D.S., Alcontin R.M.S. et al. 2019. Species composition and length–weight relationship of twelve fish species in the two lakes of Esperanza, Agusan del Sur, Philippines. *FishTaxa* 4(1): 1–8.
- Cui L.E., Guerrero III R.D., De Lara A.V. et al. 2022. Diminutive freshwater fish in the Santa Cruz River System, Laguna, Philippines. *Journal of Environmental Science and Management* 25(1): 48–56. DOI: [10.47125/jesam/2022_1/06](https://doi.org/10.47125/jesam/2022_1/06)
- Denusta P.J.T., Maliao B.P., Mendoza J.T.P. et al. 2020. Species composition and length–weight relationship of fishes in Tigum River, Iloilo, Philippines. *Philippine Journal of Science* 149(3): 491–493.
- Department of Environment and Natural Resources—Biodiversity Management Bureau (DENRBMB). 2016. The National Invasive Species Strategy and Action Plan 2016–2026 (Philippines). Quezon City, Philippines: Department of Environment and Natural Resources—Biodiversity Management Bureau.

- Estal-Mercado R. 2018. A freshwater fish inventory of Daniog River, Lanuza, Surigao del Sur, Philippines. *Science International (Lahore)* 30(1): 141–145.
- Garcia L.M.B. 2010. Species composition and length-weight relationship of fishes in the Candaba wetland on Luzon Island, Philippines. *Journal of Applied Ichthyology* 26(6): 946–948. DOI: [10.1111/j.1439-0426.2010.01516](https://doi.org/10.1111/j.1439-0426.2010.01516)
- Goss-Sampson M. 2019. *Statistical analysis in JASP: A guide for students*.
- Gonzalez J.B., Gado V.J.H., Mantes B.G. 2023. Freshwater ichthyofauna of wetlands in Tablas Island, Romblon, the Philippines. *Academia Journal of Biology* 45(1): 121–138. DOI: [10.15625/2615-9023/17521](https://doi.org/10.15625/2615-9023/17521)
- Guerrero III R.D. 2014. Impacts of introduced freshwater fishes in the Philippines (1905–2013): A review and recommendations. *Philippine Journal of Science* 143(1): 49–59.
- Guo Z., Cucherousset J., Lek S. et al. 2013. Comparative study of the reproductive biology of two congeneric and introduced goby species: Implications for management strategies. *Hydrobiologia* 709: 89–99. DOI: [10.1007/s10750-012-1439-8](https://doi.org/10.1007/s10750-012-1439-8)
- Hak T., van Rhee H., Suurmond R. 2016. How to interpret results of metaanalysis. SSRN. Available at SSRN: 3241367.
- Herre A.W. 1953. Check list of Philippine fishes (Vol. 20). Washington, DC: U.S. Government Printing Office.
- Herre A.W.C.T. 1927. A new genus and three new species of Philippine fishes. *Philippine Journal of Science* 32(3): 413–419.
- Hoese D.F., Allen G.R. 2009. Description of three new species of *Glossogobius* from Australia and New Guinea. *Zootaxa* 1981(1): 1–14.
- Hoese D.F., Allen G.R. 2012. A review of the amphidromous species of the *Glossogobius celebius* complex, with description of three new species. *Cybius* 35(4): 269–284.
- Kornis M.S., Sharma S., Jake Vander Zanden M. 2013. Invasion success and impact of an invasive fish, round goby, in Great Lakes tributaries. *Diversity and Distributions* 19(2): 184–198.
- Jumawan J.C., Seronay R.A. 2017. Length-weight relationships of fishes in eight floodplain lakes of Agusan Marsh, Philippines. *Philippine Journal of Science* 146(1): 95–99.
- Labatos B.V., Jr., Briones N.D. 2014. Freshwater fishes of Tikub Lake, Tiaong, Quezon, Philippines. *Asian Journal of Biodiversity* 5(1): 41–53.
- Levêque C., Oberdorff T., Paugy D. et al. 2008. Global diversity of fish (Pisces) in freshwater. *Freshwater animal diversity assessment* 595: 545–567. DOI: [10.1007/s10750-007-9034-0](https://doi.org/10.1007/s10750-007-9034-0)
- Lubos L.C., Barroso C.J.V., Tantoy O.A. et al. 2020. Diversity of freshwater fish in Sawaga River, Malaybalay City, Bukidnon, Philippines. *Asian Journal of Biodiversity* 11(1): 126–136. DOI: [10.7828/ajob.v11i1.1391](https://doi.org/10.7828/ajob.v11i1.1391)
- Magbanua F.S., Fontanilla A.M., Ong P.S. et al. 2017. 25 years 1988–2012 of freshwater research in the Philippines: What has been done and what to do next? *Philippine Journal of Systematic Biology* 11(1): 1–15.
- Magurran A.E. 2021. Measuring biological diversity. *Current Biology* 31(19): 1174–1177.
- Masagca J.T., Latorre I.T., Trinidad M.L.S. 2022. Freshwater fishes found in Pajo–Sto. Domingo River system in Catanduanes Island, Philippines. *Aquaculture, Aquarium, Conservation & Legislation* 15(2): 878–884.
- Millennium Ecosystem Assessment. 2005. *Ecosystems and human wellbeing: Wetlands and water synthesis*. Washington, DC: World Resources Institute.
- N'Guyen A., Hirsch P.E., Bozzuto C. et al. 2018. A dynamical model for invasive round goby populations reveals efficient and effective management options. *Journal of Applied Ecology* 55(1): 342–352. DOI: [10.1111/1365-2664.12934](https://doi.org/10.1111/1365-2664.12934)
- Ojao M.D., Manatad E.E., Logronio P.A. et al. 2021. Physicochemical properties and fish composition of Ihawan Spring Community Watershed, Tandag, Surigao del Sur, Philippines. *Journal of Tropical Life Sciences* 11: 367–374.
- Pacalioga J.O., Peralta A. 2016. Fish species abundance and species richness in a diverted channel in Ilog, Negros Occidental, Philippines. *Manila Journal of Science* 9: 91–104.
- Pacalioga J.O., Bucol A.A., Linaugo J.D. et al. 2010. Fishes and macroinvertebrates of Bago River, Negros Occidental, Philippines. *Silliman Journal* 51(1).
- Page M.J., McKenzie J.E., Bossuyt P.M. et al. 2021. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* 372. DOI: [10.1136/bmj.n71](https://doi.org/10.1136/bmj.n71)
- Paller V.G.V., Corpuz M.N.C., Bandal M.J.Z. 2017. Freshwater fish assemblages and water quality parameters in seven lakes of San Pablo, Laguna, Philippines. *Asian Journal of Biodiversity* 8(1): 1–22. DOI: [10.7828/ajob.v8i1.995](https://doi.org/10.7828/ajob.v8i1.995)
- Paller V.G.V., Corpuz M.N.C., Ocampo P.P. 2013. Diversity and distribution of freshwater fish assemblages in Tayabas River, Quezon (Philippines). *Philippine Journal of Science* 142(1): 55–67.
- Paller V.G.V., Labatos B.V., Lontoc B.M. et al. 2011. Freshwater fish fauna in watersheds of Mt. Makiling forest reserve, Laguna, Philippines. *Philippine Journal of Science* 140(2): 195–206.
- Patzner R.A., Van Tassell J.L., Kovacic M. 2011. The biology of gobies. In Kapoor B.G. (Ed.), *The biology of gobies*. Enfield, NH: Science Publishers, pp. 3–138.
- Reichenbacher B., Příkryl T., Cerwenka A.F. et al. 2020. Freshwater gobies 30 million years ago: New insights into character evolution and phylogenetic relationships of †Pirskeniidae (Gobioidei, Teleostei). *PLoS ONE* 15(8): e0237366. DOI: [10.1371/journal.pone.0237366](https://doi.org/10.1371/journal.pone.0237366)
- Romero J.B., de la Cruz J.O., Gerona-Daga M.E.B. et al. 2023. Diversity, abundance, and local use of fishes in Lake Danao, Ormoc City, Philippines.
- Smith G.C., Covich A.P., Brasher A.M. 2003. An ecological perspective on the biodiversity of tropical island streams. *BioScience* 53(11): 1048–1051. DOI: [10.1641/0006-3568\(2003\)053\[1048:AEPOTB\]2.0.CO;2](https://doi.org/10.1641/0006-3568(2003)053[1048:AEPOTB]2.0.CO;2)
- van Rhee H., Suurmond R., Hak T. 2015. *User manual for MetaEssentials: Workbooks for metaanalysis*. SSRN. Available at SSRN: 3241355.
- Vedra S.A., Padilla R.F.Q., Vicente R.J. 2022. Indigenous fishes inhabiting the Talabaan River system of Naawan, Misamis Oriental, Northern Mindanao, Philippines.
- Vié J.C., Hilton-Taylor C., Stuart S.N. 2009. *Wildlife in a changing world: An analysis of the 2008 IUCN Red List of Threatened Species*. Gland, Switzerland: IUCN.
- Visto L.M., Nuñez O.M., Magdamit A.D. 2015. Diversity of ichthyofauna in freshwater system in Bega Watershed, Prosperidad, Agusan del Sur, Philippines. *Journal of Biodiversity and Environmental Sciences* 7(1): 262–271.