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Checklist, functional traits, and conservation status of the Ichthyofauna of rivers in Hu'u District, Sumbawa, Indonesia

KARIZMA FAHLEVY[1,♥], AGUSTINUS SEMBIRING[2], RIAS KAESSARI MAGENTA[2], ADI SUROSO[2], CHARLES P. H. SIMANJUNTAK[3,4], ARIES ASRIANSYAH[3], NURUL WAHIDAH Q. MANIK[5]

[1]Nabat, Abu Dhabi Emirate, United Arab Emirates. Tel./fax.: +971-561892251, ♥email: karizma.fahlevy@nabat.ai
[2]PT Hirax Environmental Indonesia. Jl. Dr. Ide Anak Agung Gde Agung lot 5.1, South Jakarta 12950, Jakarta, Indonesia
[3]Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Institut Pertanian Bogor. Jl. Lingkar Kampus, IPB Dramaga, Bogor 16128, West Java, Indonesia
[4]Eco-Marine and Freshwater Research Institute (EMFRI). Bogor 16118, West Java, Indonesia
[5]Fisheries Resource Center of Indonesia, Rekam Nusantara Foundation. Jl. Sempur Kaler, Bogor 16129, West Java, Indonesia

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Abstract. *Fahlevy K, Sembiring A, Magenta RK, Suroso A, Simanjuntak CPH, Asriansyah A, Manik NWQ. 2026. Checklist, functional traits, and conservation status of the Ichthyofauna of rivers in Hu'u District, Sumbawa, Indonesia. Biodiversitas 27 (4): d270404. https://doi.org/10.13057/biodiv/d270404.* The freshwater fish community of Hu'u District, Sumbawa, Indonesia, remains poorly documented, particularly in rivers outside previously surveyed areas. Rapid assessments were conducted across seven rivers (Hu'u, Lakey, Ncangga, Nangadoro, Puma, Onto, and Tenga) during the wet (February 2023) and dry (July 2023) seasons using cast nets and scoop nets, with two to three hours of sampling effort per site. Fish identification followed standard taxonomic keys, and trait data from available literature were used to classify species into functional entities based on four categorical traits: water column position, substrate preference, feeding habit, and migratory behavior. A total of 17 fish species from seven orders and ten families were recorded. 12 functional entities were recorded. Demersal species were more common across all rivers. Fish species occurred roughly equally across all substrate types. Omnivores were most common. Most species were amphidromous or catadromous. According to IUCN, 13 species are Least Concern, three are Data Deficient, and one is Not Evaluated, and none of the species is protected under Indonesian regulation. These findings provide the first integrated account of species occurrence, functional richness, and conservation status for freshwater fish in Hu'u District rivers. The low species richness and limited functional redundancy suggest potential vulnerability of ecosystem functioning, and the results support the monitoring and prioritization of downstream river conservation in the region.

Keywords: Freshwater fish, functional diversity, functional entities rapid assessment, trait-based ecology

INTRODUCTION

Freshwater ecosystems provide important habitats for a wide diversity of fish species (Muhtadi et al. 2023). Indonesia ranks second globally in freshwater fish biodiversity, with over 1,272 species registered in global databases (Medrano 2023; Froese and Pauly 2024). Extensive studies have been conducted on larger Indonesian islands, including Borneo (Kottelat 2013), Sulawesi (Parenti et al. 2014; Nur et al. 2021), Papua (Ohee 2021), Java (Hasan et al. 2022), and Sumatra (Simanjuntak et al. 2006; Hidayat et al. 2023). However, freshwater fish inventories remain incomplete across many regions of Indonesia (Hutama et al. 2016), particularly in the Lesser Sunda Islands, where ichthyological research lags behind larger islands. Conducting these inventories is crucial for conservation, as species diversity provides data and serves as an indicator of ecosystem condition and environmental impacts (Pathak et al. 2014). Beyond their ecological value, fish are sensitive to water pollution and human pressures, making them effective bioindicators of ecosystem health (Chovanec et al. 2003; Darwall and Vie 2005). The persistent data gap in the Lesser Sunda Islands limits capacity for informed biodiversity assessment and conservation planning at both regional and national scales.

Sumbawa Island, in West Nusa Tenggara Province, Indonesia, hosts river systems whose freshwater fish communities remain largely undocumented. Hu'u District, about 25 km south of Dompu Regency on Sumbawa's southern coast, lies in a geologically active landscape shaped by tectonic processes influencing river morphology, hydrology, and mineral distribution (Intan 2016; Kharistanto et al. 2025). Several studies in Hu'u District were recorded and focused on coastal and marine systems, including marine biota (Putri and Nastiti 2017; Fahlevy et al. 2026; Simanjuntak et al. 2026), fisheries (Yulianto et al. 2016), and hydrodynamics (Hidayat et al. 2025; Havis et al. 2026). Terrestrial environmental quality has also been studied (Kharistanto et al. 2025). However, freshwater fish communities remain poorly characterized. Freshwater fish in island rivers reflect local habitat, watershed features, and connectivity with the sea (Fitzsimons et al. 2002; Iguchi 2007), which are ecologically important in Hu'u. To our knowledge, only one ichthyofaunal survey was conducted in 2019 (SMEC 2019), covering five rivers (Hu'u, Tarolu, Saridi, Onto, and Puma). This survey was limited because it excluded several rivers (Lakey, Ncangga, Nangadoro,

and Tenga) and recorded only species presence, without evaluating functional roles or conservation status.

Characterizing the functional structure of fish communities provides ecological insight that species checklists alone cannot deliver. The functional structure of biological communities is frequently termed functional biodiversity (Mouillot et al. 2011), which comprises three facets: functional richness, functional evenness, and functional divergence. Collectively, these components measure the extent of trait space occupied by species and how species are distributed within that space (Villéger et al. 2008). Our study focuses primarily on functional richness because the available data do not capture all aspects of functional diversity. Classically, functional richness represents the difference in trait values between the two most dissimilar species, reflecting the coverage of trait space and conserving the continuous values of functional traits (Ricotta 2005). In the current study, we lack an integrated metric to represent the full multidimensional scope of functional richness. Consequently, functional richness is defined as the total count of unique functional entities derived from four categorical traits: water column position, substrate preference, feeding habit, and migratory behavior, rather than as a continuous multidimensional niche-space measurement. Functional entities, defined as groups of species with identical trait combinations, quantify the number of distinct ecological roles in a community. Functional redundancy, reflecting the presence of two or more species within the same functional entity, indicates the extent to which ecological functions are buffered against the loss of individual species (McKinley et al. 2022). Additionally, our study includes a conservation status assessment, providing a complementary dimension by identifying species at different extinction risks and highlighting knowledge gaps that limit evidence-based management (Arthington et al. 2016; Darwall and Freyhoff 2016). Building on the 2019 survey, this study expands coverage to seven rivers and includes sampling in both wet and dry seasons to capture a broader range of species. The study aims to: i) document fish species occurrence across seven rivers in Hu'u District; ii) classify species into functional entities using four categorical traits; iii) summarize their conservation status under Indonesian regulations and IUCN criteria.

MATERIALS AND METHODS

Sampling location and sample collection

Freshwater fish sampling was conducted by WSP Indonesia (Golder) in February and July 2023, representing the wet and dry seasons. Seven rivers in Hu'u District, Dompu Regency, West Nusa Tenggara, Indonesia, were included: six downstream rivers (Hu'u, Lakey, Ncangga, Nangadoro, Puma, and Onto) and one midstream river (Tenga) for this rapid assessment (Figure 1). Sites were selected considering accessibility, time constraints, watershed representation, and inclusion of both previously surveyed and undocumented rivers within the district. The sampling design was predominantly downstream-oriented because most accessible river reaches are in lower-gradient zones near the coast. This downstream bias reflects the practical constraints of the rapid assessment framework and is acknowledged as a limitation. General river characteristics, including morphology (based on Matsuda 2004) and streambed composition, were recorded and photographed at each site, with coordinates marked using GPS.

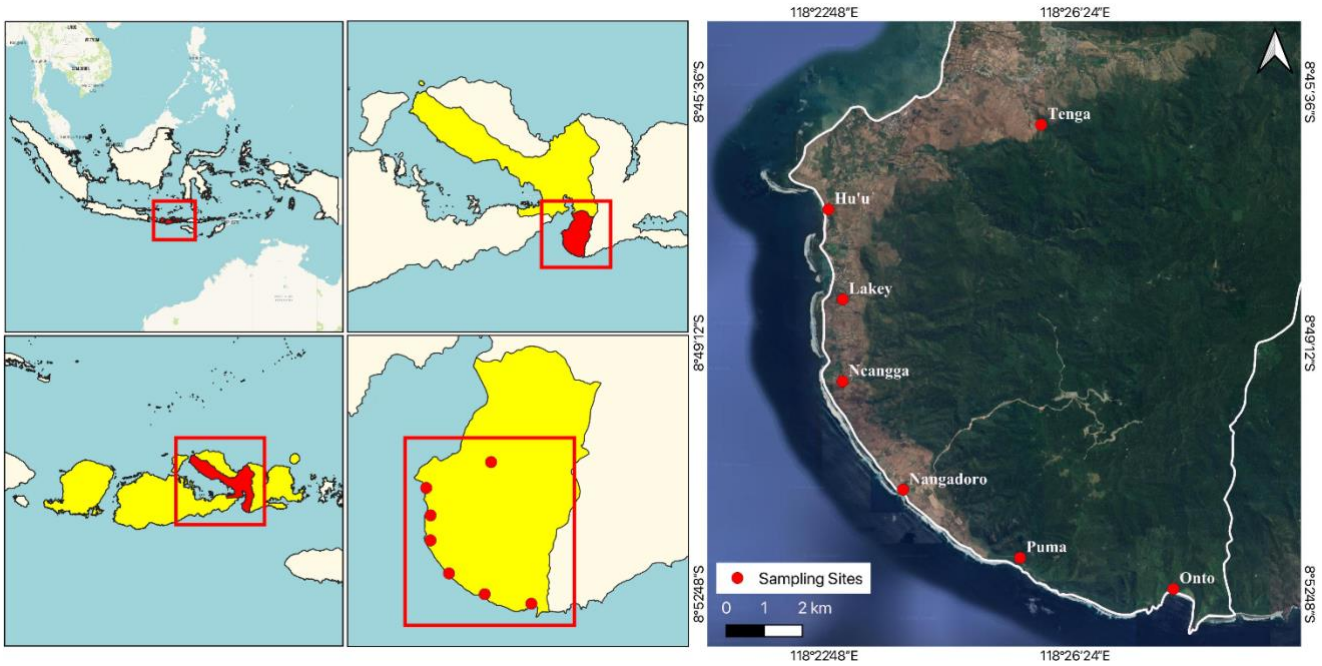

Figure 1. Sampling sites of freshwater rivers in Hu'u District, Dompu Regency, West Nusa Tenggara, Indonesia

Fish were collected using cast nets (2.5 cm mesh) and scoop nets, following Indonesian government guidelines (Djumanto et al. 2020). Scoop nets had a rectangular frame of 40×60 cm with 0.5 mm mesh and were carefully swept along the riverbed and into substrate crevices to capture small-bodied fish hiding among rocks. Sampling at each site lasted two to three hours and was conducted during the daytime between 08:00 and 17:00 local time. The same standardized protocol was applied consistently across all sites and both sampling seasons by the same field team, with each location sampled once per season. As this study was designed as a rapid assessment, sampling effort per site was intentionally limited; therefore, the resulting species lists should be interpreted as minimum estimates of local fish diversity rather than comprehensive inventories of community structure. Captured fish were sorted, photographed, and identified using standard taxonomic keys (Kottelat et al. 1993; Kottelat 2013), with their validity, taxonomic status, and current classification verified using Eschmeyer et al. (2026) and the non-marine category of WoRMS, a highly respected database maintained by a global network of taxonomic experts (WoRMS Editorial Board 2024). If there was a difference between these platforms, we used the most updated one. It might be arguable since the absence of voucher specimens means some taxa may require careful diagnostic confirmation; however, all taxa were carefully identified following established protocols, and this limitation is acknowledged. Local fish names were recorded through community interviews as ancillary ethnobiological information and were not used as the primary basis for species identification.

Traits and conservation status

Fish species' traits were categorized to represent their roles within the habitat (Floyd et al. 2020). Trait data for each species were obtained from FishBase (Froese and Pauly 2024). This approach recognizes that trait categories describe the typical ecological role of each species but may not account for changes with age or differences caused by local environmental conditions. Four categorical traits were used: (i) Water column position, indicates the typical zone where fish are active and feed. Categories include demersal (near the bottom), benthic (on the bottom), and benthopelagic (near the bottom and in midwaters or near the surface) (Zymaroieva et al. 2023). (ii) Substrate preference, shows how species interact with different substrate types. Categories are soft substrates (sand and silt), hard substrates (rocky and pebbly), and both (found across various substrates, McKinley et al. 2022). (iii) Feeding habit, describes the main food source and trophic level: herbivore (plants, algae, phytoplankton), carnivore (insects, small fish, invertebrates), and omnivore (both animal and plant matter). (iv) Migratory behavior, relates to periodic movement between habitats (Chapman et al. 2014). Categories are catadromous (migrate from freshwater to sea to spawn; Bice et al. 2018), amphidromous (regular migration between freshwater and sea not for breeding; Teichert et al. 2012), potamodromous (entirely freshwater; Moreno-Arias et al. 2021), and non-migratory.

Each species was assigned a trait combination across all four categories. Species sharing identical trait combinations were grouped into the same functional entity, representing a distinct ecological role within the community (McKinley et al. 2022). Functional redundancy was recorded when two or more species were assigned to the same functional entity, indicating overlap in trait-based ecological roles. This metric is descriptive and reflects taxonomic redundancy within the applied four-trait classification framework; it does not represent demonstrated functional compensation among species, as abundance and response data were not collected. In this study, functional richness was approximated as the number of unique functional entities derived from the four categorical traits, rather than as a continuous multidimensional niche-space metric (Mason et al. 2005; McKinley et al. 2022).

Additionally, all sampled fish species were classified according to relevant standards to determine their conservation status, using: (i) Minister of Environment and Forestry (MoEF) Regulation No. P.106 Year 2018 (MoEF 2018), (ii) Decree of the Minister of Maritime Affairs and Fisheries (MMaF) No. 1 of 2021 on Protected Fish Species (MMaF 2021), (iii) International Union for Conservation of Nature (IUCN) Red List.

Data analysis

All data analyses were performed using R software version 4.4.1. Functional entities were identified using the *group_by* function in the dplyr package (version 1.1.4; Wickham et al. 2023), which grouped species according to identical combinations of functional traits and counted the number of unique entities per river. Species richness was defined as the total number of species recorded at each river based on pooled wet- and dry-season sampling, while functional richness was defined as the number of unique functional entities recorded at each river. Both metrics were treated as single values per river, resulting in seven observations corresponding to the seven sampled rivers. Within each trait category, the number of species associated with each trait level was summarized for each river to describe patterns of functional trait representation in the assemblage. For example, within the water-column position category, the numbers of benthopelagic and demersal species recorded at each river were compiled to illustrate their relative representation. The same procedure was applied to the other three trait categories. Barplots illustrating the distribution of species across trait levels for each river were generated using the ggplot function from the ggplot2 package version 3.5.1 (Wickham 2016).

RESULTS AND DISCUSSION

River general setting

The seven freshwater rivers sampled in this study exhibited varying morphologies and substrate compositions (Table 1, Figure 1). Six rivers, including Hu'u, Lakey, Ncangga, Onto, Puma, and Tenga, exhibited a meandering morphology, whereas Nangadoro River had a straight morphology. Streambeds varied across sampling locations:

Hu'u, Onto, Puma, and Tenga rivers were characterized by pebbles and rocky substrates; Ncangga River featured sand and rocky substrates; and Lakey and Nangadoro had mixed substrates of sand, rock, and pebbles (Table 1, Figure 1).

Checklist species

A total of 17 fish species, belonging to seven orders and ten families, were identified across the sampling locations (Table 2, Figure 2). Gobiiformes was the most species-rich order, comprising 47.1% of recorded species (8 species), followed by Centrarchiformes at 17.6% (3 species) and Mugiliformes at 11.8% (2 species). The remaining orders, Anabantiformes, Anguilliformes, Ovalentaria, and Siluriformes, each contributed one species, representing 5.9% of the total species recorded (Figure 3).

Notable species presence included *Kuhlia marginata* and *Eleotris melanosoma*, found at five locations, followed by *Kuhlia rupestris* and *Giuris margaritaceus*, observed at four locations (Table 2). In contrast, *Clarias batrachus*, *Pelates quadrilineatus*, *Acentrogobius janthinopterus*, *Glossogobius celebius*, and *Rhyacichthys aspro*, were each recorded at only one location (Table 2). *P. quadrilineatus* was found at Lakey, while *R. aspro* was recorded only at Ncangga. *A. janthinopterus*, *G. celebius*, and *C. batrachus* were found at Tenga, Hu'u, and Tenga, respectively (Table 2). None of the fish species recorded in the rivers of Hu'u District were listed under the protected species regulations of the Government of Indonesia (MoEF 2018; MMaF 2021). Based on the IUCN Red List, 13 species were classified as Least Concern, three as Data Deficient, and one as Not Evaluated (Table 2).

Table 1. General characteristics of freshwater river sampling locations in Hu'u, Sumbawa, Indonesia

River ID	Longitude	Latitude	Watershed	Morphology	Streambed
Hu'u	118°22'51.752" E	8°47'17.033" S	Hu'u	Meandering	Pebbles and rocky
Lakey	118°23'03.971" E	8°48'34.348" S	Lakey	Meandering	Sand, rocky, and pebbles
Nangadoro	118°23'55.961" E	8°51'18.198" S	Doro	Straight	Sand, rocky, and pebbles
Ncangga	118°23'03.911" E	8°49'44.973" S	Ncangga	Meandering	Sand and rocky
Onto	118°27'48.735" E	8°52'43.558" S	Sama	Meandering	Pebbles and rocky
Puma	118°25'36.596" E	8°52'16.772" S	COOI	Meandering	Pebbles and rocky
Tenga	118°25'54.838" E	8°46'04.097" S	Madawa	Meandering	Pebbles and rocky

Table 2. Fishes caught in the freshwater rivers of Hu'u District, Sumbawa, Indonesia

Order/Family	Species	Local name	Conservation status		Locations						
			IUCN	GoI*	1	2	3	4	5	6	7
Anabantiformes											
Anabantidae	*Anabas testudineus*	*Karisa*	LC	NP	+	-	-	-	-	-	+
Anguilliformes											
Anguillidae	*Anguilla marmorata*	*Duna*	LC	NP	-	-	+	+	-	-	-
Centrarchiformes											
Kuhliidae	*Kuhlia marginata*	*Karpe*	LC	NP	-	-	+	+	+	+	+
Kuhliidae	*Kuhlia rupestris*	*Karpe*	LC	NP	+	+	-	+	-	+	-
Terapontidae	*Pelates quadrilineatus*	*Kakero*	NE	NP	-	+	-	-	-	-	-
Gobiiformes											
Eleotridae	*Eleotris melanosoma*	*Kembo'o*	LC	NP	-	+	+	+	+	+	-
Eleotridae	*Giuris margaritaceus*	-	LC	NP	+	-	-	+	+	-	+
Gobiidae	*Acentrogobius janthinopterus*	*Gobi*	LC	NP	-	-	-	-	-	-	+
Gobiidae	*Favonigobius reichei*	*Kembo'o*	LC	NP	-	-	+	-	-	+	-
Gobiidae	*Glossogobius celebius*	*Kembo'o*	LC	NP	+	-	-	-	-	-	-
Gobiidae	*Glossogobius giuris*	-	LC	NP	+	-	-	+	+	-	-
Gobiidae	*Stenogobius blokzeyli*	-	DD	NP	-	-	-	-	-	-	+
Rhyacichthyidae	*Rhyacichthys aspro*	-	DD	NP	-	-	-	+	-	-	-
Mugiliformes											
Mugilidae	*Planiliza subviridis*	*Mpole*	LC	NP	+	-	-	-	+	-	-
Mugilidae	*Moolgarda seheli*	*Mpole*	LC	NP	+	-	-	-	-	-	+
Ovalentaria#											
Ambassidae	*Ambassis buruensis*	*Sabete*	DD	NP	+	-	-	-	+	-	-
Siluriformes											
Clariidae	*Clarias batrachus*	*Simbu*	LC	NP	-	-	-	-	-	-	+
Number of taxa					8	3	4	7	6	4	7

Notes: +: present, -: absent, *: protected species status under Government of Indonesia regulations (MoEF 2018; MMaF 2021), #: order-level placement in WoRMS Editorial Board (2024) is currently unreviewed, LC: Least Concern, DD: Data Deficient, NE: Not Evaluated, NP: Not Protected, 1: Hu'u, 2: Lakey, 3: Nangadoro, 4: Ncangga, 5: Onto, 6: Puma, 7: Tenga

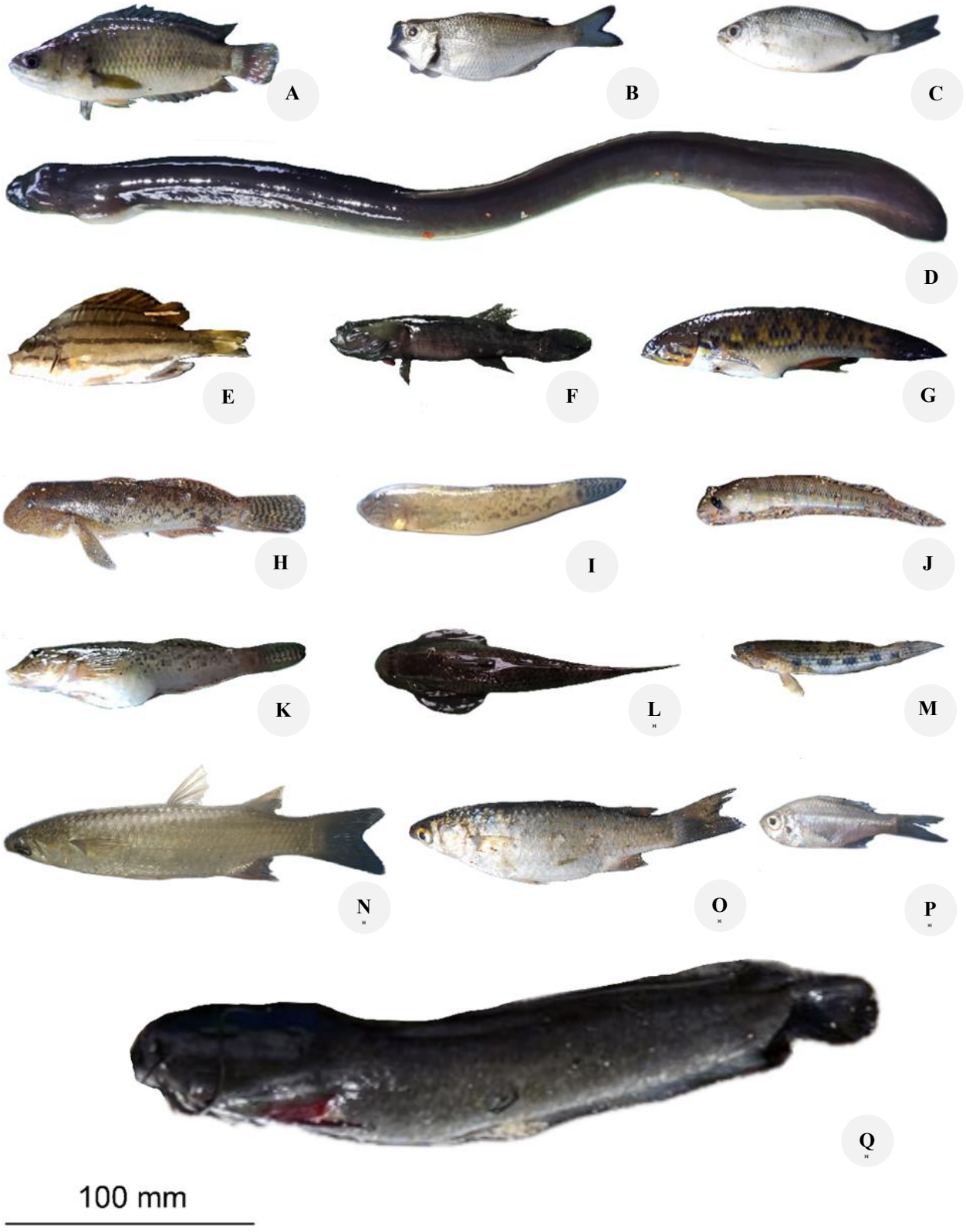

Figure 2. Fishes of the freshwater rivers of Hu'u District, Sumbawa, Indonesia. All specimens were photographed in the field immediately after capture. Total length measurements were taken directly from each specimen in the field. As this study was conducted as a rapid assessment, physical voucher specimens were not retained. A. *Anabas testudineus*, 150 mm TL; B. *Kuhlia marginata*, 90 mm TL; C. *Kuhlia rupestris*, 79 mm TL; D. *Anguilla marmorata*, 360 mm TL; E. *Pelates quadrilineatus*, 93 mm TL; F. *Eleotris melanosoma*, 156 mm TL; G. *Giuris margaritaceus*, 121 mm TL; H. *Acentrogobius janthinopterus*, 135 mm TL; I. *Favonigobius reichei*, 150 mm TL; J. *Stenogobius blokzeyli*, 95 mm TL; K. *Glossogobius giuris*, 120 mm TL; L. *Rhyacichthys aspro*, 120 mm TL; M. *Glossogobius celebius*, 95 mm TL; N. *Planiliza subviridis*, 155 mm TL; O. *Moolgarda seheli*, 125 mm TL; P. *Ambassis buruensis*, 75 mm TL; Q. *Clarias batrachus*, 290 mm TL

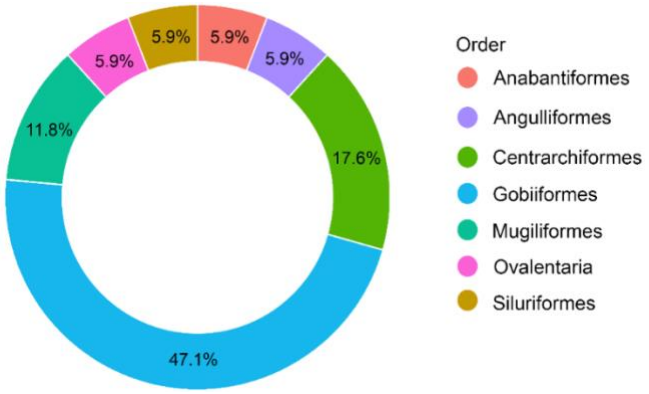

Figure 3. Composition of fish species by order in Hu'u freshwater rivers

Functional entities, species richness, and functional richness

The 17 sampled fish species were classified into 12 functional entities (Table 3 and Table 4). Four functional entities exhibited redundancy, with three entities represented by two species each and one entity represented by three species (Table 4). Species richness across sampling locations ranged from 3 species (Lakey) to 8 species (Hu'u), while functional richness ranged from 3 functional entities (Lakey and Puma) to 8 (Hu'u; Figure 4). Hu'u recorded equal values of species richness and functional richness (8 each), indicating that no functional redundancy under the four-trait classification used was detected at this site. In contrast, Ncangga (7 species, 5 functional entities), Onto (6 species, 5 functional entities), and Tenga (7 species, 5 functional entities) showed higher species richness relative to functional richness, indicating that multiple species share some ecological roles at these sites. Lakey and Puma recorded the lowest functional richness (3 each), corresponding to their lower species richness compared with other sampled rivers (Figure 4).

Within the water column position category, demersal species were more common than benthopelagic species across all sampled rivers (Figure 5.A). Only one benthopelagic species was recorded, occurring at Hu'u, Ncangga, and Onto, whereas the number of demersal species ranged from 3 at Lakey to 7 at Hu'u and Tenga. For substrate preference, species associated with soft substrates ranged from 1 at Lakey and Nangadoro to 5 at Tenga; species associated with hard substrates ranged from 1 at Lakey and Onto to 3 at Ncangga; and species associated with both hard and soft substrates ranged from 1 at Hu'u, Nangadoro, and Ncangga to 2 at Lakey, Onto, and Puma (Figure 5.B). Regarding feeding habits, omnivorous species were the most represented, ranging from 2 at Lakey and Nangadoro to 6 at Tenga; carnivorous species ranged from 1 at Lakey, Puma, and Ncangga to 3 at Hu'u; and herbivorous species were recorded as a single species at sites where they occurred (Figure 5.C). In terms of migratory behavior, amphidromous species ranged from 1 at Lakey to 4 at Hu'u and Ncangga; catadromous species ranged from 1 at Lakey, Nangadoro, Onto, and Puma to 3 at Hu'u; potamodromous species ranged from 1 at Lakey to 2 at Tenga; and non-migratory species were recorded only at Lakey as a single species (Figure 5.D).

Comparison of fish occurrences: 2019 and 2023

The 2019 survey recorded a total of 27 taxa, including 24 species and three identified only to genus (Table 5, Table S1), whereas the 2023 survey documented 17 species (Table 5). Eight species, *Anabas testudineus*, *Anguilla marmorata*, *Kuhlia marginata*, *Kuhlia rupestris*, *Eleotris melanosoma*, *Acentrogobius janthinopterus*, *Planiliza subviridis*, and *Ambassis buruensis*, were shared between both surveys. 16 taxa recorded in 2019 were not detected in 2023, including 13 species and 3 genus-level records, while 9 species documented in 2023 had not been previously recorded in 2019 (Table 5).

Discussion

This study represents a rapid assessment of freshwater fish diversity in Hu'u District, Sumbawa. All rivers observed had rocky substrates, and the meandering morphology of most rivers (Table 1). This study recorded *K. marginata* and *K. rupestris* (order Centrarchiformes) and *E. melanosoma* and *G. margaritaceus* (order Gobiiformes) at four to five locations. The prevalence of these orders may reflect favorable habitat conditions in downstream rocky reaches. Furthermore, Gobiiformes fishes are well adapted to fast-flowing rocky substrates, using their fins to grip rocks and other substrates to avoid being carried away by river currents (Patzner et al. 2011).

Compared with freshwater fish studies in other Indonesian rivers, this study recorded 17 species, which is lower than in the Brantas River, East Java (42 species; Hasan et al. 2022), the Merbau River, Sumatra (21 species; Hidayat et al. 2023), and the Mahakam River, East Kalimantan (28 species; Jusmaldi et al. 2025), but slightly higher than in the Batetangnga River, West Sulawesi (14 species; Nur et al. 2021). Dominant orders also differed markedly: Cypriniformes prevailed in the Brantas and Merbau rivers, Cypriniformes and Siluriformes dominated the Mahakam River, whereas Gobiiformes and Centrarchiformes were dominant in this study. The higher species richness in those systems likely reflects their greater habitat heterogeneity (Shi and Czerniawski 2025) and broader environmental gradients spanning multiple river segments from upstream to downstream (Hasan et al. 2022; Hidayat et al. 2023; Jusmaldi et al. 2025), compared to this study, where sampling was predominantly confined to downstream reaches, which reduces the likelihood of detecting upstream-associated species.

Fish in Hu'u rivers showed low trait-combination redundancy under the applied classification, with most functional entities represented by only one species. This outcome is likely due to the limited species richness across sites. Increasing species numbers could improve the likelihood of multiple species fulfilling the same functional roles (McKinley et al. 2023). Functional entities are closely linked to species richness, as low species richness reduces the number of species occupying ecological niches, thereby limiting functional redundancy (Parravicini et al. 2014). In

ecosystems with low functional redundancy, the ecological roles of functionally unique species may not be readily compensated by other species, potentially reducing key ecosystem processes such as nutrient cycling, prey regulation, and organic matter processing (Mouillot et al. 2014; Parravicini et al. 2014). In the context of this study, where eight of the twelve functional entities are represented by only one species, the results suggest a potential early indicator that disturbances affecting these species might influence their associated ecological functions in these river systems.

Table 3. Functional trait of 17 fish caught in the freshwater rivers of Hu'u, Sumbawa, Indonesia

Order/Family	Species	Local name	Water column position	Substrate preference	Feeding habit	Migratory behavior
Anabantiformes						
Anabantidae	*Anabas testudineus*	*Karisa*	Demersal	Soft	Omnivore	Potamodromous
Anguilliformes						
Anguillidae	*Anguilla marmorata*	*Duna*	Demersal	Hard and soft	Carnivore	Catadromous
Centrarchiformes						
Kuhliidae	*Kuhlia marginata*	*Karpe*	Demersal	Hard	Omnivore	Catadromous
Kuhliidae	*Kuhlia rupestris*	*Karpe*	Demersal	Hard	Omnivore	Catadromous
Terapontidae	*Pelates quadrilineatus*	*Kakero*	Demersal	Soft	Carnivore	Non-migratory
Gobiiformes						
Eleotridae	*Eleotris melanosoma*	*Kembo'o*	Demersal	Soft	Omnivore	Amphidromous
Eleotridae	*Giuris margaritaceus*	-	Demersal	Soft	Omnivore	Amphidromous
Gobiidae	*Acentrogobius janthinopterus*	*Gobi*	Demersal	Soft	Omnivore	Amphidromous
Gobiidae	*Favonigobius reichei*	*Kembo'o*	Demersal	Hard and soft	Carnivore	Amphidromous
Gobiidae	*Glossogobius celebius*	*Kembo'o*	Demersal	Hard	Carnivore	Amphidromous
Gobiidae	*Glossogobius giuris*	-	Benthopelagic	Hard and soft	Carnivore	Amphidromous
Gobiidae	*Stenogobius blokzeyli*	-	Demersal	Hard	Omnivore	Amphidromous
Rhyacichthyidae	*Rhyacichthys aspro*	-	Demersal	Hard	Herbivore	Amphidromous
Mugiliformes						
Mugilidae	*Planiliza subviridis*	*Mpole*	Demersal	Soft	Omnivore	Catadromous
Mugilidae	*Moolgarda seheli*	*Mpole*	Demersal	Soft	Herbivore	Catadromous
Ovalentaria[1]						
Ambassidae	*Ambassis buruensis*	*Sabete*	Demersal	Hard and soft	Carnivore	Amphidromous
Siluriformes						
Clariidae	*Clarias batrachus*	*Simbu*	Demersal	Soft	Omnivore	Potamodromous

Note: *: order-level placement in WoRMS Editorial Board (2024) is currently unreviewed. Trait categories show the main ecological characteristics of each species but may not reflect changes with age or differences in habitat and feeding behavior

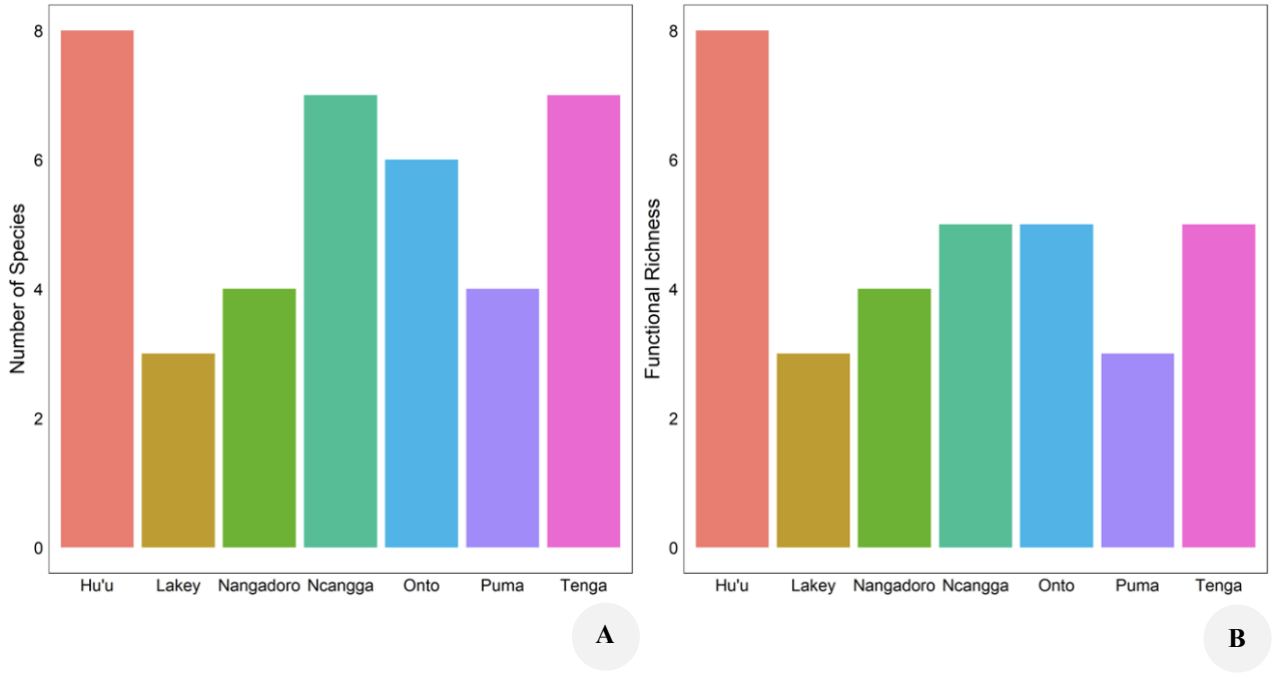

Figure 4. Barplots of (A) species richness and (B) functional richness of fish caught in the seven freshwater rivers of Hu'u, Sumbawa, Indonesia

Table 4. Functional entities identified from the 17 fish species caught in the seven freshwater rivers of Hu'u, Sumbawa, Indonesia

Functional entity	Functional traits				Species	No. of species
	Water column position	Substrate preference	Feeding habit	Migratory behavior		
1	Benthopelagic	Hard and soft	Carnivore	Amphidromous	*Glossogobius giuris*	1
2	Demersal	Hard	Carnivore	Amphidromous	*Glossogobius celebius*	1
3	Demersal	Hard	Herbivore	Amphidromous	*Rhyacichthys aspro*	1
4	Demersal	Hard	Omnivore	Amphidromous	*Stenogobius blokzeyli*	1
5	Demersal	Hard	Omnivore	Catadromous	*Kuhlia marginata*, *Kuhlia rupestris*	2
6	Demersal	Hard and soft	Carnivore	Amphidromous	*Favonigobius reichei*, *Ambassis buruensis*	2
7	Demersal	Hard and soft	Carnivore	Catadromous	*Anguilla marmorata*	1
8	Demersal	Soft	Carnivore	Non-migratory	*Pelates quadrilineatus*	1
9	Demersal	Soft	Herbivore	Catadromous	*Moolgarda seheli*	1
10	Demersal	Soft	Omnivore	Amphidromous	*Eleotris melanosoma*, *Giuris margaritaceus*, *Acentrogobius janthinopterus*	3
11	Demersal	Soft	Omnivore	Catadromous	*Planiliza subviridis*	1
12	Demersal	Soft	Omnivore	Potamodromous	*Anabas testudineus*, *Clarias batrachus*	2

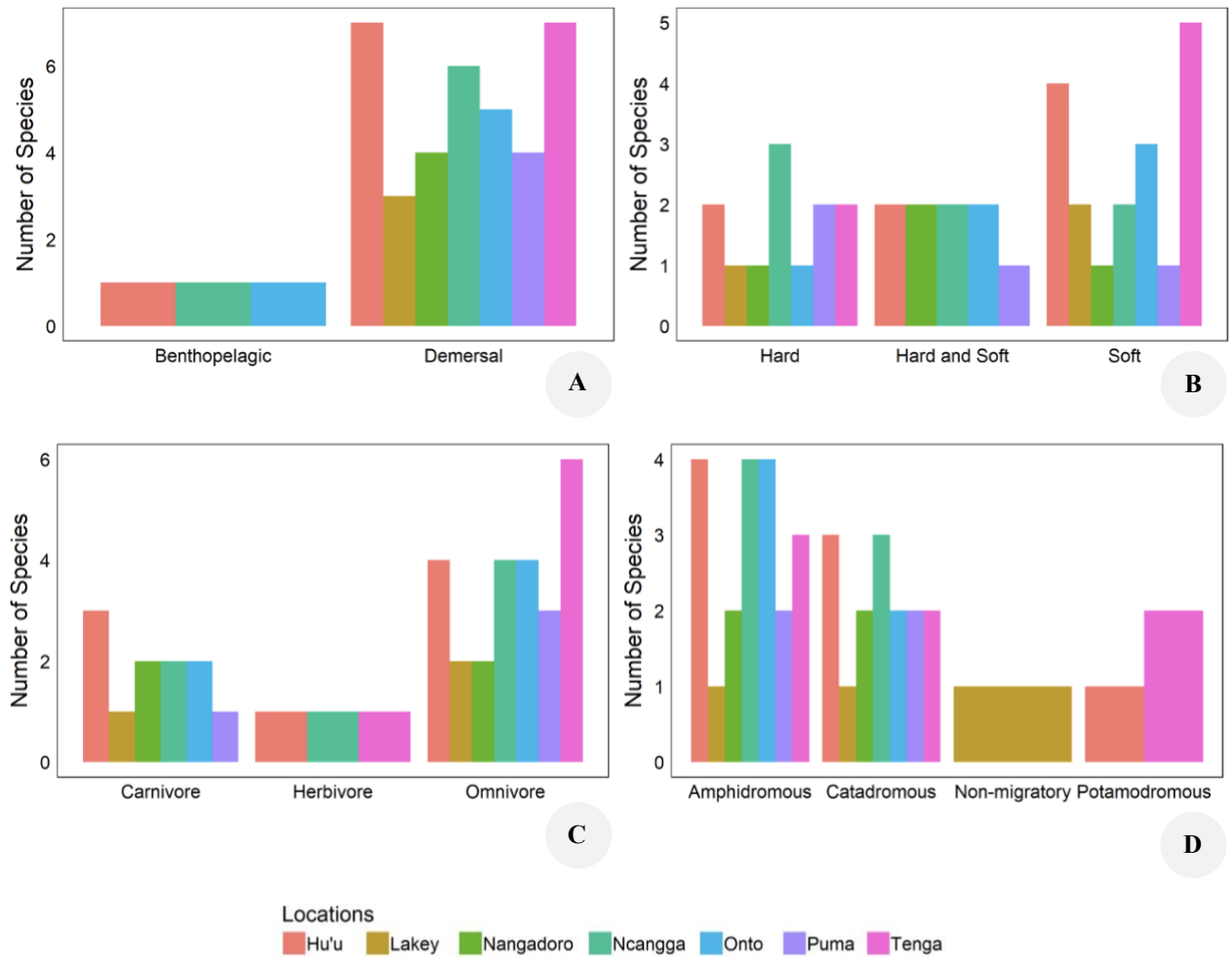

Figure 5. Barplots of the four functional traits, including (A) water column position, (B) substrate preference, (C) feeding habit, and (D) migratory behavior of fish caught in the seven freshwater rivers of Hu'u, Sumbawa, Indonesia

Table 5. Comparison of fish species recorded in the rivers of Hu'u District in 2019 (SMEC 2019) and 2023 (Present study)

Order/Family	Species	2019	2023
Anabantiformes			
Anabantidae	*Anabas testudineus*	+	+
Anguilliformes			
Anguillidae	*Anguilla marmorata*	+	+
Beloniformes			
Belonidae	*Tylosurus crocodilus*	+	-
Centrarchiformes			
Kuhliidae	*Kuhlia marginata*	+	+
Kuhliidae	*Kuhlia rupestris*	+	+
Terapontidae	*Terapon jarbua*	+	-
Terapontidae	*Pelates quadrilineatus*	-	+
Cichliformes			
Cichlidae	*Oreochromis niloticus*	+	-
Eupercaria			
Gerreidae	*Gerres filamentosus*	+	-
Gerreidae	*Gerres* sp.	+	-
Gobiiformes			
Eleotridae	*Belobranchus* sp.	+	-
Eleotridae	*Butis butis*	+	-
Eleotridae	*Eleotris melanosoma*	+	+
Eleotridae	*Giuris margaritaceus*	-	+
Eleotridae	*Ophiocara porocephala*	+	-
Gobiidae	*Acentrogobius audax*	+	-
Gobiidae	*Acentrogobius janthinopterus*	+	+
Gobiidae	*Favonigobius reichei*	-	+
Gobiidae	*Glossogobius celebius*	-	+
Gobiidae	*Glossogobius giuris*	-	+
Gobiidae	*Periophthalmus argentilineatus*	+	-
Gobiidae	*Pseudogobius poicilosoma*	+	-
Gobiidae	*Schismatogobius marmoratus*	+	-
Gobiidae	*Sicyopterus micrurus*	+	-
Gobiidae	*Sicyopus* cf. *rubicundus*	+	-
Gobiidae	*Stenogobius* sp.	+	-
Gobiidae	*Stenogobius blokzeyli*	-	+
Gobiidae	*Stiphodon ornatus*	+	-
Rhyacichthyidae	*Rhyacichthys aspro*	-	+
Gonorynchiformes			
Chanidae	*Chanos chanos*	+	-
Mugiliformes			
Mugilidae	*Planiliza subviridis*	+	+
Mugilidae	*Moolgarda seheli*	-	+
Ovalentaria*			
Ambassidae	*Ambassis buruensis*	+	+
Siluriformes			
Clariidae	*Clarias batrachus*	-	+
Tetraodontiformes			
Tetraodontidae	*Arothron hispidus*	+	-
Tetraodontidae	*Arothron manilensis*	+	-
Total species		27	17
Present in both surveys		8	8
Distinct species		19	9

Note: *order-level placement in WoRMS Editorial Board (2024) is currently unreviewed

In the rivers of Hu'u District, demersal and omnivorous species were the most frequently recorded, whereas herbivorous species were relatively rare across sampling sites. This observed pattern may correspond to the rivers' substrate, which is mostly rocky. Complex substrates with varying rock sizes and soft sediments may provide shelter and feeding opportunities, potentially favoring species that exploit benthic resources and ambush prey (Flynn and Ritz 1999). This structural complexity also likely limits the presence of herbivorous fish, which tend to avoid areas with higher predation risk (González-Murcia et al. 2020).

The presence of amphidromous and catadromous species in Hu'u rivers is consistent with the downstream position of most sampling locations and their proximity to Cempi Bay. These species belong to the broader group of diadromous fish, which migrate between freshwater and marine environments to complete their life cycles (Fitzsimons et al. 2002; Iguchi 2007; Silva et al. 2015; Simanjuntak et al. 2021). Their euryhaline physiology enables them to occupy niches across the freshwater-marine gradient (Hayashi et al. 1992; Natsumeda and Seya 2012), and their prevalence in the recorded assemblage reflects the strong influence of river-sea connectivity on fish community composition in the downstream reaches sampled in this study.

Fish research in Hu'u District has focused primarily on coastal and marine species in Cempi Bay (Yulianto et al. 2016; Simanjuntak et al. 2026). Consequently, information on the conservation status of freshwater fish in the district's rivers remains limited. Most species recorded in this study are classified as Least Concern or other lower-risk categories, although their status may change over time (Hasan et al. 2022). Since 2004, the IUCN has conducted global freshwater fish assessments (Arthington et al. 2016), yet many regions in Indonesia remain poorly assessed (Darwall and Freyhoff 2016). The presence of three Data Deficient species and one Not Evaluated species in this study highlights that available information makes it challenging to develop informed future management strategies. Species lacking adequate data are not necessarily of low ecological importance, as their true conservation risk cannot be determined without further investigation (Jusmaldi et al. 2025). Therefore, further research is needed to update the conservation status of poorly known species.

Compared with the 2019 study (SMEC 2019), which recorded 27 taxa across five rivers, the present study documented 17 species across seven rivers and shows lower species occurrences than 2019. This study recorded fewer species, possibly due to the type of fishing gear used, limited time, effort, and sampling area. Rocky substrates made it difficult to use cast nets effectively, causing small fish hiding between rocks to be overlooked (González-Murcia et al. 2020). Sampling larger areas may have increased the likelihood of finding more species because larger areas tend to yield more individuals, increasing the chance of encountering additional species (Paller 2018). The higher number of species detected in 2019 may also be due to the use of more diverse gear to catch fish in complex habitats, longer sampling time, and the greater total sampling area; however, the lack of methodological documentation in 2019, including no description of sampling methods, identification methods, gear used, effort, and full photo-documentation of the rivers and species caught, limits direct comparison between the two datasets. Despite this,

the results of the present study enriched the ichthyofauna database in the rivers of Hu'u District by detecting nine species in 2023 (*Giuris margaritaceus*, *Favonigobius reichei*, *Glossogobius celebius*, *Glossogobius giuris*, *Stenogobius blokzeyli*, *Rhyacichthys aspro*, *Pelates quadrilineatus*, *Moolgarda seheli*, and *Clarias batrachus*) that were absent from the 2019 list.

This study had several methodological limitations that should be considered: (i) sampling was largely limited to downstream reaches, with each site visited only once per season for two to three hours using cast nets and scoop nets, (ii) the downstream-focused design, limited temporal replication, reduced gear efficiency on rocky substrates, and daylight-only sampling suggest that the species lists represent minimum estimates of local fish diversity rather than complete community inventories, (iii) fish assemblages in upstream and midstream sections remain largely undocumented and may differ substantially from downstream assemblages, and (iv) small-bodied and cryptic species sheltering in rocky crevices or active at night may have been under-detected under this rapid assessment campaign. Despite these limitations, this study provides a descriptive list of updated freshwater fish species in rivers of Hu'u District, along with information on their occurrence and habitat associations based on the four trait categories examined, offering a baseline for future monitoring and conservation planning.

However, several limitations should be acknowledged. The sampling design was downstream-biased and based on single visits per site per season, which may not fully capture spatial and temporal variability. In addition, the absence of abundance data restricts interpretation to presence-based patterns, and the analysis remains descriptive without inferential or multivariate testing, limiting deeper ecological inference. These limitations offer a preliminary assessment for seven sampled rivers and contribute to the limited knowledge of freshwater fish diversity in the Lesser Sunda Islands. Future studies should incorporate replicated and longitudinal sampling, include abundance-based metrics, and apply multivariate analyses (e.g., PCA or trait-environment modeling) to understand ecological relationships better. Expanding sampling to upstream habitats and integrating environmental variables will be essential to validate the observed patterns and to support more robust monitoring and conservation planning for freshwater ecosystems in Hu'u District.

In conclusion, the rivers in the Hu'u District exhibit meandering morphology and predominantly rocky substrates. A total of 17 species, spanning 7 orders and 10 families, were recorded, with Gobiiformes and Centrarchiformes being the most frequently observed. Fish species were classified into 12 functional entities based on 4 categorical traits, and functional richness from 3 to 8 entities. Functional redundancy was low, with most functional entities represented by a single species, indicating limited overlap in ecological roles and suggesting potential functional vulnerability of these river ecosystems. Observed species were predominantly demersal, showed roughly equal occurrences across soft, mixed, and hard substrate types, and were primarily omnivorous and amphidromous. Conservation assessments showed that most species are currently categorized as Least Concern, while a few were Data Deficient or Not Evaluated.

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Table S1. List of fish species in the freshwater rivers of Hu'u District, Sumbawa, Indonesia (SMEC 2019)

Order/Family	Species	Local name	Locations				
			Hu'u	Onto	Puma	Saridi	Tarolu
Anabantiformes							
Anabantidae	*Anabas testudineus*	*Krysa*			+		
Anguilliformes							
Anguillidae	*Anguilla marmorata*	*Duna*		+	+		
Beloniformes							
Belonidae	*Tylosurus crocodilus*	*Uta kajuru*	+				
Centrarchiformes							
Kuhliidae	*Kuhlia marginata*	-					+
Kuhliidae	*Kuhlia rupestris*	-					+
Terapontidae	*Terapon jarbua*	*Kakero*	+				
Cichliformes							
Cichlidae	*Oreochromis niloticus*	*Nila*	+				
Eupercaria							
Gerreidae	*Gerres filamentosus*	-	+				
Gerreidae	*Gerres* sp.	-	+				
Gobiiformes							
Eleotridae	*Belobranchus* sp.	-	+				
Eleotridae	*Butis butis*	*Kambo'o*	+				
Eleotridae	*Eleotris melanosoma*	*Kambo'o*	+				
Eleotridae	*Ophiocara porocephala*	-	+				
Gobiidae	*Acentrogobius audax*	-	+				
Gobiidae	*Acentrogobius janthinopterus*	-	+				+
Gobiidae	*Periophthalmus argentilineatus*	*Kenaca*	+				
Gobiidae	*Pseudogobius poicilosoma*	-	+				
Gobiidae	*Schismatogobius marmoratus*	-		+			+
Gobiidae	*Sicyopterus micrurus*	-		+			
Gobiidae	*Sicyopus* cf. *rubicundus*	*Kambo'o*				+	
Gobiidae	*Stenogobius* sp.	-	+				
Gobiidae	*Stiphodon ornatus*	-					+
Gonorynchiformes							
Chanidae	*Chanos chanos*	-	+				
Mugiliformes							
Mugilidae	*Planiliza subviridis*	*Tampole*	+				
Ovalentaria							
Ambassidae	*Ambassis buruensis*	-	+				
Tetraodontiformes							
Tetraodontidae	*Arothron hispidus*	-	+				
Tetraodontidae	*Arothron manilensis*	-	+				

Notes: +: present