Romero et al. / The Philippine Journal of Fisheries 30(2): 277-288
DOI: 10.31398/tpjf/30.2.2023-0009

RESEARCH ARTICLE

Diversity, Abundance, and Local Use of Fishes in Lake Danao, Ormoc City, Philippines

Jeremy B. Romero*, **John O. de la Cruz, Maria Elisa B. Gerona-Daga, Racquel U. Tabornal, Rhea Mae S. Dañal, Liza Mae V. Neis**

University of the Philippines Tacloban College, Tacloban City, Leyte 6500 Philippines

ABSTRACT

Lake Danao lies within the Lake Danao Natural Park in Ormoc City, Leyte, Philippines. The lake provides a habitat for various aquatic flora and faunal species. However, existing data on fish assemblage in Lake Danao is scarce and outdated. This study determined Lake Danao's diversity, abundance, and local use of fish. With the help of local fishers, fish samples were collected from different parts of the lake twice a month for 14 months (March 2021 to June 2022). In addition, an ethnoicthyological survey was conducted to supplement the information on the provenance, endemism, and local use of the fish species in Lake Danao. This study recorded eight species of fish in Lake Danao, and only two are considered native (*Anguilla marmorata* and *Clarias batrachus*). Only five species were obtained from the fishers throughout the entire sampling period. On average, *Glossogobius giuris* was the most abundant species (95.96%), while *Channa striata* was the least (0.07%). The low Shannon-Weiner diversity index (mean = 0.19) and high Simpson's dominance index (mean = 0.92) indicate low diversity and dominance of other species (e.g. *G. giuris*). No significant difference was observed in the diversity, dominance, and evenness of fishes between the sampling months. All of the fish species were used as alternative food sources. With the dominance of introduced species, local authorities are strongly encouraged to strictly regulate the entry, possession, and cultivation of exotic fish in Lake Danao and to continue the aquatic biodiversity assessment and monitoring in the area.

*Corresponding Author: *jbromero1@up.edu.ph*
Received: *February 28, 2023*
Accepted*: August 24, 2023*

Keywords: *Lake Danao, fish diversity, upland lake*

1. INTRODUCTION

Lake Danao is a freshwater lake located in the uplands of Ormoc City, Leyte, Philippines. It is part of the Lake Danao Natural Park (LDNP)—a protected area under Republic Act 11038 or the Expanded National Integrated Protected Areas System of the Philippines (E-NIPAS) and under Presidential Proclamation 1155, s. 1998. The natural park was declared a protected area primarily for management, development, and protection because of its massive potential to support and maintain life and other natural processes. Covering the 139.8-ha Lake Danao and the surrounding 2,193 ha of forest lands, LDNP is home to diverse life forms, such as the elusive Philippine tarsier (*Carlito syrichta*), the endemic copepod *Filipinodiaptomus vexillifer* (Li et al. 2019), and different types of freshwater fish (Weliange et al. 2007). Nearby communities rely on LDNP for livelihood through tourism, farming, and fishing.

The diversity and abundance of fish can provide an overview of the health of aquatic ecosystems (Guerrero 2002). For this reason, fish species composition and abundance have helped assess the condition of aquatic ecosystems as they are excellent biological indicators of habitat loss, impacts of invasive alien species (IAS), and effects of climate change (Guerrero 2002; Vescovi et al. 2009). However, Lake Danao's information on fish diversity and abundance is scarce and obsolete. Moreover, the local use of fish in Lake Danao has yet to be described in existing literature. Updating the information on the diversity, abundance, and uses of fish in Lake Danao will help local authorities craft informed policies for

conserving and managing the lake as a natural habitat for commonplace and rare aquatic organisms.

In response, this study was conducted to update the information on the species composition and abundance of fish in Lake Danao. This study also documented the local use of the fishery resources in Lake Danao. It is envisioned that concerned organizations, especially the LDNP Protected Area Management Board (LDNP-PAMB) will be able to draw out appropriate policies for the sustainable development of the protected area from the findings and recommendations of this study.

2. MATERIALS AND METHODS

2.1 Study area

The study was conducted in Lake Danao, Ormoc City, Leyte, Philippines (11°04'14.9"N, 124°41'43.1"E) (Figure 1). Formerly known as Lake Imelda, the guitar-shaped lake lies in the middle of LDNP, around 600 m above sea level (masl) and 15 km northeast of the city.

The lake is utilized primarily for subsistence fishing, tourism, drinking, and utility. Tourism facilities such as floating cottages and stilt cottages were present near Inawasan Creek, the area occupied by the Active Genuine Youth Leaders Association (AGYLA) people's organization, the southmost part of the lake, and below the ecolodge erected by the LDNP-PAMB. Farmlands and human settlements were still present near the lakefront despite the status of LDNP as a protected area. Meanwhile, the Updated LDNP PA Management Plan 2017 revealed that Ormoc City and seven nearby municipalities depend on the lake to meet their daily basic water needs. As such, local authorities prohibited the establishment of aquaculture facilities and the use of motorized boats to help preserve the water quality of Lake Danao.

2.2. Collection and identification of fish samples

Fish samples were obtained from the daily catch of subsistence fishers at Lake Danao twice a month for 14 months, from March to September 2021 and from December 2021 to June 2022. Local fishers used four types of fishing gear, namely 'bingwit' or 'kawil' (simple handline), 'pilot' or 'pukot' (gillnet), 'pana' (speargun), and 'kitang' (longline) to catch specific types of fish from the nearshore (littoral zone), open water (limnetic zone), deep water (profundal zone), and the floor (benthic zone) of Lake Danao.

The samples were placed in adequately labeled polyethylene bags. Samples were stored at 4°C and transported immediately to the Wet Laboratory of the University of the Philippines Tacloban College (UPTC) in Tacloban City for morphometric analysis. The total length (measurement from the mouth to the tip of the tail; cm) and wet weight (g) of individual samples were measured (Phan et al. 2021). The total length was measured using a ruler or caliper to the nearest 0.1 cm, while the wet weight was measured using a digital platform scale to the nearest 0.01 g.

The samples' endemism and initial taxonomic classification were identified using FishBase (www.fishbase.se) and other available taxonomic guides (Allen et al. 2003; Froese and Pauly 2016). A voucher specimen was selected from each fish caught in the lake and photographed for validation. Photos of voucher specimens were sent to the College of Fisheries and Ocean Sciences at the University of the Philippines Visayas in Miagao, Iloilo for validation purposes. The voucher specimens were donated to the Natural History Museum and Herbarium of UPTC.

2.3 Ethnoicthylogical survey

A guided interview of the fisherfolk in Lake Danao was conducted from 29–30 July 2022 using a

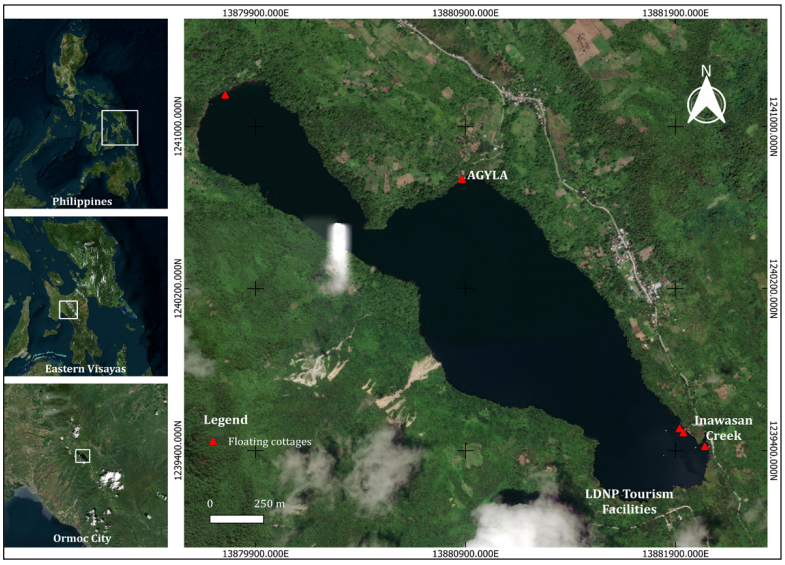

Figure 1. Map showing Lake Danao, Ormoc City, Leyte.

qualitative survey questionnaire. The semi-structured interview was administered with an Open Data Kit (ODK) tool. Only those local subsistence fishers who were 18 years old and above and have signed the Free and Prior Informed Consent (FPIC) form were considered respondents. The FPIC included an easy-to-comprehend information sheet with a Cebuano translation.

The survey started with the four LDNP-PAMB registered subsistence fishers in Lake Danao. Based on actual fieldwork, more than four fishers were operating in the area. Hence, the study used a snowball sampling technique beginning with the four registered fishers and continuing with all 21 fishers who were interviewed.

The ethnoichthyological survey instrument was designed to complement the information on the fish diversity in Lake Danao based on the fishers' knowledge. For the first part, each participant was asked to name the photos of the fish species. The photos were taken from actual fish samples from Lake Danao. Then, the participants were asked to enumerate other fish species apart from the photos in the survey instrument. Next, the respondents were asked to validate the presence of common carp and walking catfish by showing them representative photos of the said fishes and asking if they had encountered such fish species in their entire fishing operations at Lake Danao. Anecdotal reports and Weliange et al. (2007) reported the presence of the two fishes in the lake.

In addition, the respondents were asked to provide information on the endemism, spawning seasons, and the traditional preparations and uses of the fish they identified. Using a satellite image of Lake Danao, each respondent was asked to identify the fishing areas for a particular fish.

To determine the degree of importance locals place on each fish species, the Relative Frequency of Citation (RFC) index was determined by dividing the number of informants mentioning a species by the total number of informants who participated in the survey (Vitalini et al. 2013). Values closer to 1 mean that the fish is more important than the rest (Mohomodly and Mootsamy 2014).

Since this component employed a non-probability sampling approach, the data were processed using descriptive statistics and thematic analysis (Braun and Clark 2006).

2.4. Data analysis

The ethnoicthyological survey and the daily catch of fishers were used to generate an inventory of the fish species in Lake Danao. Meanwhile, the abundance of fish was expressed as relative abundance (in percentage) of the total number of individuals per species to the total number of individuals caught (Corpuz et al. 2016). On the other hand, the diversity of fish was determined using the following indices:

Shannon-Wiener Index (H'), which is commonly used to characterize species diversity in a community and accounts for both the abundance and evenness of the species present (Spellerberg and Fedor 2003), was computed using the formula:

$$H' = -\Sigma[(p_i) \times ln(p_i)]$$

where H'= Shannon-Wiener Index

p_i = proportion of total abundance represented by species

Building on the Shannon-Wiener Index, Pielou's Evenness Index (J') measures how evenly the individuals in a community are distributed among the different species (Pielou 1966) and was determined using the formula:

$$J' = H'/ln(S)$$

where S = number of species in a community

The Simpson's Diversity Index (D) measures diversity by considering the number of species present, as well as the relative abundance of each species. According to Simpson (1949), species diversity increases as species richness and evenness increase. The Simpson's Diversity Index was computed using this formula:

$$D=1-(\Sigma n(n-1))/(N(N-1))$$

where N = total number of individuals of all species

n = the number of individuals for a particular species

The Simpson's Dominance Index is the degree to which one or more species have a significant influence in controlling the other species within a community. It is measured by subtracting Simpson's diversity index from 1 (Lande 1996), as shown below.

$$\textit{Simpson's Dominance Index} = 1 - D$$

Since data were not normally distributed, a Kruskal-Wallis test was conducted to determine the significant difference in the diversity indices between and among the sampling months. The diversity indices were calculated using PAST 4.03.

3. RESULTS AND DISCUSSION

3.1 Species composition and abundance

Based on the ethnoicthyological survey and actual fish catch, eight species of freshwater fish were found in Lake Danao (Table 1). These species include tank goby (*Glossogobius giuris*), Nile tilapia

(*Oreochromis niloticus*), giant mottled eel (*Anguilla marmorata*), snakehead murrel (*Channa striata*), three spot gourami (*Trichopodus trichopterus*), common carp *(Cyprinus carpio)*, koi (*Cyprinus rubrofuscus*), and walking catfish (*Clarias batrachus*). Only *A. marmorata* and *C. batrachus* are considered native**,** while the rest are introduced into Lake Danao. On the other hand, all of these species are currently listed as "Least Concern" by the International Union for Conservation of Nature (IUCN 2022).

However, only five species were observed and collected from the daily catch of fishers throughout the entire sampling period. *Glossogobius giuris* was the most abundant fish species with a relative abundance of 95.96%**,** and the least was *Channa striata* (0.07%) (Table 2).

Regarding RFC, *O. niloticus* and *G. giuris* had the highest values of 0.86 and 0.81, respectively. This result can be explained by the fact that these two species were the most commonly caught fish, becoming a common food source for locals. The low RFC values for *T. trichopterus*, *C. carpio*, and *C. rubrofuscus* can be attributed to the local's low consumption of these fish species due to their rarity resulting from low population or seasonality. While *A. marmorata* and *C. batrachus* incurred low RFC values, local fishers placed a high value on these species because of their rarity resulting from their seasonality, high nutritional value, and increased demand, not just in the area but also in the city.

The high abundance of *G. giuris* can be attributed to the fish's invasive and cannibalistic tendencies (Figure 2). This fish is a carnivore that feeds mainly on insects, smaller crustaceans, and other fish species. It has been observed to manifest cannibalism by feeding on smaller tank gobies (Islam et al. 2014), which was also recorded in Lake Danao on several occasions. This fish is considered invasive and can wipe out native species like Lake Lanao where 15 endemic fish species vanished after the introduction of *G. giuris* (Juliano et al. 1989). In Lake Danao, locals observed the decline of the *C. carpio* population after the introduction of *G. giuris,* believing that the fish is preying on carp's eggs.

Widely distributed in both coastal and estuarine waters in the Indo-Pacific region (Froese and Pauly 2023), G. giuris has been recorded in Taal Lake in Batangas (Masagca and Ordoñez 2003), Lake

Table 1. List of fish species present in Lake Danao, Ormoc City based on the ethnoichthyological survey conducted last 29–30 July 2022, and the fishers' catch from March to September 2021 and from December 2021 to June 2022.

Common Name (Local Name)	Scientific name	Endemism	Year Introduced	Fishing area	Fishing gear	RFC
Nile tilapia (tilapia)	*Oreochromis niloticus* (Linnaeus 1758)	Introduced	1940s	Nearshore, deep water	Simple handline, speargun, gillnet	0.86
Tank goby (bul-a)	*Glossogobius giuris* (Hamilton 1822)	Introduced	1970s	Nearshore	Simple handline	0.81
Giant mottled eel (kasili)	*Anguilla marmorata* (Quoy and Gaimard 1824)	Native		Deep water (adult), Nearshore (young)	Longline	0.57
Common carp (karpa)	*Cyprinus carpio* (Linnaeus 1758)	Introduced	1960s	Open and deep waters	Speargun	0.33
Snakehead murrel (haru-an or hal-wan)	*Channa striata* (Bloch 1793)	Introduced	Unknown	Nearshore	Simple handline, speargun	0.29
Walking catfish (agok-ok)	*Clarias batrachus* (Lacepède 1803)	Native		Nearshore, shallow parts	Simple handline	0.24
Three spot gourami (gourami)	*Trichopodus trichopterus* (Pallas 1770)	Introduced	Unknown	Nearshore	Simple handline	0.14
Amur carp (koi)	*Cyprinus rubrofuscus* (Linnaeus 1758)	Introduced	2013	Deep water	Speargun	0

Table 2. Composition and relative abundance of fish species in Lake Danao, Ormoc City based on the fishers' catch from March to September 2021 and from December 2021 to June 2022.

Species	No. of individuals	Relative Abundance (%)	Length (cm)		Weight (g)	
			Mean	Range (Min, Max)	Mean	Range (Min, Max)
Glossogobius giuris	1403	95.96%	10.72	3 - 30	12.06	2 - 134
Oreochromis niloticus	53	3.63%	33.52	7.7 - 271	98.41	8 - 400
Trichopodus trichopterus	3	0.21%	10.15	10 - 10.5	13.27	9 - 16
Anguilla marmorata	2	0.14%	75.50	57 - 94	1,825.15	475-3,175
Channa striata	1	0.07%	249.00	-	147.48	-

Figure 2. Photograph of tank goby (*Glossogobius giuris*) voucher specimen collected from Lake Danao, Ormoc City in 2022.

Buluan in Sultan Kudarat (Dorado et al. 2012), Lake Lanao in Lanao del Sur (Mahilum et al. 2013), and Lake Mainit in Surigao del Norte (Joseph et al. 2016). Fishers in Lake Danao intimated that the G. giuris population dominating the lake may have descended from the eggs that were incorporated into the river sand from Paridahan, Brgy. Ipil, Ormoc City, which was used in constructing the Inawasan bridge. Only during the construction did the fish start being caught as by-catch and eventually as target catch. However, this claim warrants further investigation.

The second most abundant fish species was *O. niloticus* (Figure 3). Part of the Cichlidae family, *O. niloticus* is native to Africa and the Middle East and was first introduced in the Philippines in the 1970s. Locals believe that the present population of *O. niloticus* in Lake Danao may have descended from the tilapias cultured in fish pens by the Department of Agriculture in the 1970s. On the other hand, some fishers reported that tilapia has already been inhabiting the lake since the 1950s or even earlier. This type of tilapia could be *O. mossambicus*, which was first introduced into the country around the same period (Guerrero 2014). However, no such specimen was collected throughout the sampling period.

Within the last ten years, fingerlings of *O. niloticus* were introduced into the lake to enhance the fish catch. The most recent seeding of *O. niloticus*

Figure 3. Photograph of Nile tilapia (*Oreochromis niloticus*) voucher specimen collected from Lake Danao, Ormoc City in 2022.

in Lake Danao happened in 2018 with over 20,000 fingerlings. Nile tilapia seeding is often associated with severe environmental change because of tilapia's ability to outcompete local fish species in terms of food and habitat (Canonico et al. 2005). More specifically, tilapias prey on eggs, fry, and smaller fish, and these feeding and excretion habits can cause eutrophication that can adversely affect the population of other organisms (Peterson et al. 2005; Vicente and Fonseca-Alves 2013).

The third most abundant species was *T. trichopterus* (Figure 4), a member of the Osphronemidae family and commonly feeds on crustaceans, zooplankton, and insect larvae. They are considered popular ornamental fish and are deemed to have high economic value as they can be used as an additional source of protein in rural areas (Kottelat 2013). Native to Thailand, *T. trichopterus* was first introduced into the country in 1938 (Cagauan 2007). In Lake Danao, *T. trichopterus* is commonly found on the lakeshore and caught mostly as by-catch.

Also known as the marbled eel, *A. marmorata* (Figure 5) is one of the most widely distributed freshwater eels in Southeast Africa, Asia, and Polynesia (Ege 1939; Marquet and Galzin 1991; Marquet 1996). It is considered one of the native freshwater eels of the Philippines and has been observed naturally in Ibulao River in Ifugao (Tauli et al. 2022), Lake Duminagat in Misamis Occidental (Quimpang et al. 2018), Bago River in Negros Occidental (Bucol et al. 2010), and Cagayan River in Cagayan Valley (Piper et al. 2022). The fishers in Lake Danao revealed that the peak season for *A. marmorata* is during the rainy seasons, particularly in October and November.

Channa striata originated from Malaysia and are considered one of the earliest species introduced in the Philippines, dating back to 1908 (Cagauan 2007) (Figure 6). This fish thrives in still and muddy portions of ponds, rivers, streams, swamps, lakes, flooded fields, and even in slow-flowing canals. This fish usually prey on small animals like frogs, fish, freshwater prawns, and aquatic insects. Unfortunately, the survey respondents were unable to determine when and how this fish found its way to Lake Danao.

Three other fish species were recorded in Lake Danao based on the respondents' knowledge, and these fishes were *C. carpio*, *C. rubrofuscus*, and *C. batrachus*.

Figure 4. Photograph of three spot gourami (*Trichopodus trichopterus*) voucher specimen collected from Lake Danao, Ormoc City in 2022.

Figure 5. Photograph of giant mottled eel (*Anguilla marmorata*) voucher specimen of collected from Lake Danao, Ormoc City in 2023.

Figure 6. Photograph of snakehead murrel (*Channa striata*) voucher specimen collected from Lake Danao, Ormoc City in 2022.

The common carp (*C. carpio*) was introduced to the country from Hong Kong, China in 1910 (Cagauan 2007). According to the respondents, *C. carpio* was introduced into the lake as early as the 1950s. This carp species usually thrives in slow-moving freshwater habitats like well-vegetated lakes and feeds on benthic organisms, phytoplankton, and macrophytes (Froese and Pauly 2023). *Cyprinus carpio* is one of the widely-cultured commercially important freshwater fish species worldwide due to its fast reproduction rate. However, *C. carpio* may compete with indigenous fish species and destroy submerged macrophyte vegetation (Cagauan 2007). Fishers in Lake Danao seldom target common carp because of its rarity and they observed a waning catch rate after the introduction of tank gobies. Some of the fishers believe that tank gobies feed on the eggs of *C. carpio* resulting in the decline of its population. Though no actual common carp specimen was caught from Lake Danao during the sampling period, the study of Weliange et al. (2007) confirms the presence of *C. carpio* in the lake.

C. rubrofuscus, widely known as 'koi,' is a selectively bred carp species with unique, vibrant colors introduced in Philippine waters. According to a local fisher, the introduction of *C. rubrofuscus* to the lake was brought about by the flooding of a koi pond near the lake in 2013 because of Super Typhoon Haiyan (local name: Yolanda). In 2022, a fisher reported two koi individuals caught from the lake weighing 9 kg and 16 kg. Koi favors calm and slow-moving freshwater habitats with a natural benthic community. They feed on any available food sources, such as algae, plants, fish eggs, juvenile fish, and insects, among others (Froese and Pauly 2016), enabling them to survive in the lake.

Meanwhile, *C. batrachus* was first thought to be an introduced fish species that originated in Thailand and came to the country through aquaculture in 1972 (Juliano et al. 1989). However, long before its supposed introduction, the natural occurrence of *C. batrachus* was already recorded in Laguna de Bay (Herre 1953; Delmendo and Bustillo 1968) and Taal Lake in Batangas (Herre 1927) as well as in other parts of the country (Herre 1953). During the sampling period, no specimen of *C. batrachus* was obtained from the fishers, however, the respondents were unanimous in identifying the photo of the said fish among the other types of catfish native to the Philippines that were shown in the ethnoichthyological survey. Moreover, the study by Weliange et al. (2007) confirmed the presence of *C. batrachus* in Lake Danao.

3.2 Fish diversity in Lake Danao

The fish species diversity in Lake Danao is generally low due to the low number of species caught in each sampling (Table 3). The Shannon-Wiener diversity index of the fish in the lake was low (mean = 0.19) and ranged from 0.03 to 0.38 over the sampling period. Moreover, the study also generated a low Simpson's diversity index (mean = 0.08) and the values varied over the months from 0.01 to 0.22. Meanwhile, the average Pielou's equitability index (0.12) was also found to be low, indicative of uneven species distribution. Consequently, an extremely high average Simpson's dominance index (0.92) was observed in Lake Danao indicating the presence of a dominant species. A Kruskal-Wallis test showed no significant difference in the diversity indices of the fish species in the lake over the sampling months (H (13) = 8.02, p = 0.84).

Low diversity is common in upland lakes (Amarasinghe and Welcomme 2002; Raburu et al. 2022). However, the introduction and dominance of non-native or invasive species may lead to decreased diversity (Charles and Dukes 2008). The assessment in Lake Danao showed that most of the fish species are introduced**,** and two of which (*G. giuris* and *O. nilocticus*) are considered IAS. *Glossogobius giuris* exhibit their dominance and invasiveness by feeding on juveniles of other fish and through their cannibalistic feeding habits (Islam 2002; Achakzai et al. 2015). Cannibalism in fish is linked with low species richness in freshwater ecosystems (Pereira et al. 2017). Meanwhile, the low diversity and high dominance indexes can be attributed to the high relative abundance of *G. giuris*. Other factors that may contribute to low values include the fishing area of the fishers, the seasonality, the species' inherent elusiveness, or the dwindling population of the fish (Torres et al. 2013; Luo et al. 2022).

The observed low fish diversity and prevalence of invasive species in the lake are concerning issues. The presence of IAS could wipe out other native species and could lead to lower diversity, like in the case of Lake Lanao, where the fish diversity was reduced after the introduction of gobies, mudfish, and tilapia (Juliano et al. 1989; Ismail et al. 2014). Thus, continued monitoring and evaluation of aquatic biodiversity using conventional and emerging methods (e.g. environmental DNA) (Aquilino et al. 2011; Abdulmalik-Labe and Quilang 2019) must be done to provide a better understanding of the state of

Table 3. Fish diversity in Lake Danao, Ormoc City, based on the fishers' catch from March 2021 to September 2021 and December 2021 to June 2022.

Year	Month	No. of Spp Caught	No. of Individuals	Shannon-Wiener Index (H')	Pielou's Equitability Index (J')	Simpson's Diversity	Simpsons Dominance
2021	March	2	62	0.14	0.21	0.06	0.94
	April	2	124	0.05	0.07	0.02	0.98
	May	2	80	0.38	0.54	0.22	0.78
	June	2	30	0.15	0.21	0.06	0.94
	July	2	82	0.11	0.17	0.05	0.95
	August	2	131	0.21	0.3	0.1	0.9
	September	3	244	0.17	0.16	0.07	0.93
	December	2	18	0.21	0.31	0.1	0.9
2022	January	2	130	0.25	0.36	0.13	0.87
	February	2	39	0.12	0.17	0.05	0.95
	March	2	127	0.14	0.2	0.06	0.94
	April	2	188	0.03	0.05	0.01	0.99
	May	2	64	0.31	0.45	0.17	0.83
	June	3	143	0.17	0.15	0.07	0.93
Overall		**5**	**1462**	**0.19**	**0.12**	**0.08**	**0.92**

aquatic biodiversity in Lake Danao. Scholars and local authorities will be able to use the knowledge from these monitoring activities for informed management and conservation of the protected area.

3.3. Local use of fish in Lake Danao

All freshwater species caught in Lake Danao were used as a local food source. Meanwhile, *G. giuris* was sometimes used as bait for catching other types of fish, i.e., marbled eel fishing, while *T. trichopterus* and *Channa striata* were also captured for pet trade. Some of the fishers retained their catch for household consumption, while some folks preferred selling their catch, especially if the fish was of high value, like *A. marmorata, O. niloticus, C. batrachus,* and *C. rubrofuscus.* The high-value catch was sometimes sold directly as fresh or cooked to buyers like neighbors or tourists, while some were peddled to the city market at a reasonable price. Occasionally, the fishers trade catch with their neighbors or friends with other goods or food items like rice or other types of fish or meat. Locals prepare the fish in various ways such as 'prinito' (fried), 'tinola' (fish soup), 'ginataan' (cooked in coconut milk and other herbs and spices), 'paksiw' (poached in vinegar with herbs and spices), or 'eskabetse' (fried and drenched in sweet and sour sauce).

4. CONCLUSION

This study provided clear evidence that most fish species observed in Lake Danao were introduced and dominated the fish community in the lake. Eventually, nearby communities, especially fishing households, learned to use these introduced fish as alternative food sources and placed them with high importance. Despite the economic benefits of introducing non-native fish, the high abundance and dominance of exotic species raise the alarm for the fate of other species, particularly the native ones, and the condition of the whole ecosystem structure and dynamics in Lake Danao. Therefore, local authorities must stringently regulate the entry, possession, and cultivation of non-native finfish and shellfish on the lake and within the vicinity of the protected area. Moreover, the management of the protected area must strictly enforce existing policies regarding lake conservation and management**,** including the regular assessment of aquatic biodiversity and water quality. All of these measures will help prevent the ill effects of IAS and, at the same time**,** maintain and improve the ecosystem services of Lake Danao. Local authorities may use the findings of this study as a guide in revisiting and improving the existing conservation and management plan of LDNP.

ACKNOWLEDGMENT

This study was implemented under the Fish and Aquatic Biodiversity Resource Evaluation and Monitoring in Lake Danao, Ormoc City (FiBRE Project) of the LAKES Danao Program, which stands for Lake Assessments for Key Ecosystem Services in Lake Danao Program. With funding support from the National Research Council of the Philippines of the Department of Science and Technology (DOST-NRCP), the research program is implemented by the University of the Philippines Tacloban College and in partnership with the DENR Regional Office 8 through the LDNP-PAMB, Environmental Management Bureau Regional Office 8, LGU Ormoc, and the Leyte Normal University. The team would also like to thank Ms. Roxanne Cabebe at the College of Fisheries and Ocean Sciences at UPV for the taxonomic validation of all fish species collected from the lake. The team would also like to thank Ma. Salvacion Pantino, Mr. Eugie V. Cinco, Ms. Maria Niña Gaut, LDNP-PAMO, boatmen, and the fishers for their contributions.

AUTHOR CONTRIBUTIONS

Romero JB: Formal analysis, Investigation, Data Curation, Visualization, Writing - Original Draft. **de la Cruz JO:** Conceptualization, Methodology, Supervision, Investigation, Formal Analysis, Project administration, Funding acquisition. **Gerona-Daga MEB:** Supervision, Formal analysis, Investigation, Data Curation. **Tabornal RU:** Supervision, Investigation, Data Curation. **Dañal RMS:** Formal analysis, Investigation, Data Curation. **Neis LMV**: Formal analysis, Investigation, Data Curation.

CONFLICTS OF INTEREST

All authors declare that they have no conflicts of interest.

ETHICS STATEMENT

Before the conduct of the study, a gratuitous permit was secured from the Department of Environment and Natural Resources Regional Office 8 through the LDNP-PAMB. The researchers also followed all institutional and national guidelines for the care and use of laboratory animals. A research ethics clearance was secured from the UP Visayas Research Ethics Board (UPV REB) before the ethnoicthyological survey was conducted. In compliance with the research ethics guidelines of UPV REB and the Philippine Health Research Ethics Board, the authors obtained informed consent from all participants for inclusion in the study.

REFERENCES

Abdulmalik-Labe, OP, Quilang, JP. 2019. DNA barcoding of fishes from Lake Lanao, Philippines. Mitochondrial DNA B. 4(1):1890–1894. https://doi.org/10.1080/23802359.2019.1614890

Achakzai WM, Saddozai S, Baloch WA, Massod J, Rehman HU, Ain MU. 2015. Food and feeding habits of *Glossogobius giuris* (Hamilton and Buchannan, 1822) collected from Manchar Lake distt. Jamshoro, Sindh, Pakistan. Glob Vet. 14(4):613–618. https://doi.org/10.5829/idosi.gv.2015.14.04.9465

Allen G, Steene R, Humann P, Deloach N. 2003. Reef fish identification: Tropical Pacific. Jacksonville, Florida, USA: New World Publications Inc.

Amarasinghe US, Welcomme RL. 2002. An analysis of fish species richness in natural lakes. Environ Biol Fishes. 65(3):327–339. https://doi.org/10.1023/A:1020558820327

Aquilino SV, Tango JM, Fontanilla IK, Pagulayan RC, Basiao ZU, Ong PS, Quilang JP. 2011. DNA barcoding of the ichthyofauna of Taal Lake, Philippines. Mol Ecol Resour. 11(4):612–619. https://doi.org/10.1111/j.1755-0998.2011.03000.x

Bloch, ME. 1793. Naturgeschichte der ausländischen Fische. Berlin. v. 7: i-xiv + 1-144, Pls. 325–360.

Braun V, Clarke V. 2006. Using thematic analysis in psychology. Qual Res Psychol. 3(2):77–101. https://doi.org/10.1191/1478088706qp063oa

Bucol A, Menes C, Linaugo J. 2010. An annotated checklist of eels in Bago River, Negros Occidental, Philippines. Asian Journal of Biodiversity. 1:126–138. https://doi.org/10.7828/ajob.v1i1.105

Cagauan AG. 2007. Exotic aquatic species introduction in the Philippines for aquaculture- A threat to

biodiversity or a boon to the economy. Journal of Environmental Science and Management. 10(1):48–62.

Canonico GC, Arthington A, McCrary JK, Thieme ML. 2005. The effects of introduced tilapias on native biodiversity. Aquat Conserv. 15(5):463–483. https://doi.org/10.1002/aqc.699

Charles H, Dukes JS. 2008. Impacts of invasive species on ecosystem services. In: Nentwig W, editor. Biological invasions. Ecological studies, Vol 193. Berlin, Heidelberg: Springer. p. 217–237. https://doi.org/10.1007/978-3-540-36920-2_13

Corpuz MN, Paller VG, Ocampo P. 2016. Diversity and distribution of freshwater fish assemblages in Lake Taal river systems in Batangas, Philippines. Journal of Environmental Science and Management. 19(1):85–95. https://doi.org/10.47125/jesam/2016_1/09

Delmendo MN, Bustillo RN. 1968. Studies on fish population of Laguna de Bay. FAO Occas. Pap. 69/12, IFPC/C68/Technical 30.

Dorado EL, Torres MA, Demayo CG. 2012. Describing body shapes of the white goby, *Glossobius giuris* of Lake Buluan in Mindanao, Philippines using landmark-based geometric morphometric analysis. Int Res J Biological Sci. 1(7):33–37.

Ege V. 1939. A revision of the genus *Anguilla* Shaw, a systematic, phylogenetic and geographical study. Dana Rep. 16:1–256.

Expanded National Integrated Protected Areas System Act of 2018. 2018.

Froese R, Pauly D. 2023. FishBase. World Wide Web Electronic Publication. Available from: www.fishbase.org

Guerrero III RD. 2002. Invasive aquatic animals in the Philippines. In: [editor unknown] Special Report on Their Impacts and Management. Philippines: ASEAN Biodiversity (Oct-Dec 2002). p. 2–15.

Guerrero III RD. 2014. Impacts of introduced freshwater fishes in the Philippines (1905-2013): A review and recommendations. Philipp J Sci. 143(1):49–59.

Hamilton F. 1822. An account of the fishes found in the River Ganges and its branches. Edinburg, Scotland: Archibald Constable and Company.

Herre A. 1927. The fisheries of Lake Taal (Bombon), Luzon and Lake Naujan (Mindoro). Philipp J Sci. 34:287–315.

Herre A. 1953. Check list of Philippine fishes. Washington, DC: United States Government Printing Office.

Islam MN. 2002. Cannibalism of freshwater gobi, *Glossogobius giuris* (Hamilton) in relation to its size, sex and season from the river Padma. Univ J Zool. 21:63–64.

Ismail GB, Sampson DB, Noakes DL. 2014. The status of Lake Lanao endemic cyprinids (*Puntius* species) and their conservation. Environ Biol Fishes. 97(4):425–434. https://doi.org/10.1007/s10641-013-0163-1

IUCN. 2022. The IUCN Red List of Threatened Species. Version 2022-2. https://www.iucnredlist.org.

Joseph CCD, Jumawan JH, Hernando BJ, Boyles LZ, Jumawan JC, Velasco JB, Cabuga CC, Abastillas S, Requieron EA, Torres MA. 2016. Fluctuating asymmetry in evaluating the developmental instability of *Glossogobius giuris* (Hamilton, 1822) from Lake Mainit, Surigao del Norte, Philippines. Computational Ecology and Software. 6(2):55–65.

Juliano RO, Guerrero III R, Ronquillo I. 1989. The introduction of exotic aquatic species in the Philippines. In: De Silva SS, editor. Exotic aquatic organisms in Asia. (19-21 June 1981) Proceedings of the Workshop on Introduction of Exotic Aquatic Organisms in Asia. Asian Fish Soc Spec Publ. Vol 3, p. 83–90.

Kottelat M. 2013. The fishes of the inland waters of Southeast Asia: A catalogue and core bibliography of the fishes known to occur in freshwaters, mangroves and estuaries. Raffles Bull Zool. 27:1-663.

Lacepède BGE. 1803. Histoire naturelle des poissons. Tome Cinquieme. 5(1-21)

Lande R. 1996. Statistics and partitioning of species diversity, and similarity among multiple communities. Oikos. 76(1):5–13. https://doi.org/10.2307/3545743

Li H, Guinto SK, Papa RD, Han BP, Magbanua FS, Rizo EZ, Dumont HJ, Lin Q. 2019. On *Filipinodiaptomus* Lai, Mamaril Sr. and Fernando, 1979 (Calanoida, Diaptomidae): Redescription and re-allocation of the Philippine endemic *Diaptomus vexillifer* Brehm, 1933. Crustaceana. 92(5):513–536. https://doi.org/10.1163/15685403-00003880

Linnæus C. 1758. Systema naturæ per regna tria naturæ, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis.

Luo D, Wan Z, Jia C, Zhu Y, Zou Q, Ye F, Feng Y, Zhang M, Wu X, Liu X, Ouyang S. 2022. Temporal Changes of Fish Diversity and Driver Factors in a National Nature Reserve, China. Animals. 12(12):1544. https://doi.org/10.3390/ani12121544

Mahilum,JJ, Camama C, Lalisan JA, Vedra SA. 2013. Morphology of goby species, *Glossogobius celebius* (Valenciennes 1837) and *Glossogobius giuris* (Hamilton 1822) in Lake Lanao Mindanao, Philippines. Int J Res Biosci. 2(3):66–78. https://www.ijrbs.in/index.php/ijrbs/article/view/89

Masagca J, Ordonez J. 2003. Karyomorphology of the Philippine Rock Goby, *Glossogobius Giuris* (Gobiidae) from Lake Taal and some rivers of Cavite, Luzon Island. Biotropia. 21: 11–18. https://doi.org/10.11598/btb.2003.0.21.185

Marquet G. 1996. The freshwater eels (Anguillidae) of New Caledonia: taxonomy and distribution. Vie Milieu. 46(1):65–71. https://hal.sorbonne-universite.fr/hal-03100550

Marquet G, Galzin R. 1991. The eels of French Polynesia: Taxonomy, distribution and biomass. Bull Soc Franco-jap Océanogr. 29(1):8–17.

Mootoosamy A, Mahomoodally MF. 2014. Quantitative ethnozoological assessment of traditional used animals based therapies in the island of Mauritius. J Ethnopharmacol. 154(3):847–857. https://doi.org/10.1016/j.jep.2014.05.001

Pallas PS. 1770. Spicilegia Zoologica quibus novae imprimis et obscurae animalium species iconibus, descriptionibus atque commentariis illustrantur. Berolini, Gottl. August. Lange.

Pereira LS, Keppeler FW, Agostinho AA, Winemiller KO. 2017. Is there a relationship between fish cannibalism and latitude or species richness?. PloS one. 12(1):e0169813. https://doi.org/10.1371/journal.pone.0169813

Peterson MS, Slack WT, Woodley CM. 2005. The occurrence of non-indigenous Nile tilapia, *Oreochromis niloticus* (Linnaeus) in coastal Mississippi, USA: ties to aquaculture and thermal effluent. Wetlands. 25(1):112–121. https://doi.org/10.1672/0277-5212(2005)025[0112:TOONNT]2.0.CO;2

Phan GH, Dinh QM, Truong NT, Nguyen THD, Nguyen TTK. 2021. The intraspecific and spatio-temporal changes in growth pattern and condition factor of *Glossogobius aureus* inhabiting in the Mekong Delta, Vietnam. Egypt J Aquat Biol Fish. 25(2):591–599. https://doi.org/10.21608/EJABF.2021.166984

Pielou EC. 1966. The measurement of diversity in different types of biological collections. J Theor Biol. 13:131–144. https://doi.org/10.1016/0022-5193(66)90013-0

Piper A, Belen A, Villanueva B, Gollock M. 2022. Residence, activity patterns and behaviour of the giant mottled eel (*Anguilla marmorata*) in two freshwater protected areas in the Philippines. Aquat Conserv. 32(10):1606–1617. https://doi.org/10.1002/aqc.3870

Quimpang VT, Cudal MG, Leaño EP, Opiso EM, Calunsag VLB, Amoroso VB. 2018. Physicochemical characteristics and fish fauna composition of Lake Duminagat, Mt. Malindang Range Natural Park, Philippines. Journal of Multidisciplinary Studies. 7(2):60–81.

Quoy JRC, Gaimard JP. 1824. Description des Poissons. Chapter IX. In: Freycinet, L. de, Voyage autour du Monde...exécuté sur les corvettes de L. M. 192-401 [1-328 in 1824; 329-616 in 1825], Atlas pls. 43-65.

Raburu PO, Masese FO, Mwasi BN. 2022. Low diversity of fishes in high elevation Afrotromontane streams renders them unsuitable for biomonitoring. Afr J Ecol. 60(4):1029–1042. https://doi.org/10.1111/aje.13056

Simpson E. 1949. Measurement of diversity. Nature. 163: 688. https://doi.org/10.1038/163688a0

Spellerberg I, Fedor P. 2003. A tribute to Claude Shannon (1916–2001) and a plea for more rigorous use of species richness, species diversity and the 'Shannon–Wiener' Index. Glob Ecol Biogeogr. 12(3):177–179. https://doi.org/10.1046/j.1466-822X.2003.00015.x

Tauli M, Garcia MP, Podeque JR, Signey L, Sarmiento K, Santos M. 2022. Fish Species Composition and Distribution from 2015 to 2019 in the Ibulao River, Ifugao, Cordillera, Philippines. Philipp J Fish. 29(1):90-95. https://doi.org/10.31398/tpjf/29.1.2020C0016

Torres M, Coll M, Heymans J, Christensen V, Sobrino I. 2013. Food-web structure of and fishing impacts on the Gulf of Cadiz ecosystem (Southwestern Spain). Ecol Modell. 265:26–44. https://doi.org/10.1016/j.ecolmodel.2013.05.019

Updated Lake Danao Natural Park Protected Area Management Plan 2017. 2017. Ormoc City, Leyte, Philippines: Lake Danao Natural Park Protected Area Management Board

Vicente IS, Fonseca-Alves CE. 2013. Impact of introduced Nile tilapia (*Oreochromis niloticus*) on non-native aquatic ecosystems. Pak J Biol Sci. 16(3):121–126. https://doi.org/10.3923/pjbs.2013.121.126

Vescovi LD, Berteaux D, Bird D, Sylvie DB. 2009. Freshwater biodiversity versus anthropogenic climate change. France: UNESCO-WWAP.

Vitalini S, Iriti M, Puricelli C, Ciuchi D, Segale A, Fico G. 2013. Traditional knowledge on medicinal and food plants used in Val San Giacomo (Sondrio, Italy)—an alpine ethnobotanical study. J Ethnopharmacol. 145(2):517–529. https://doi.org/10.1016/j.jep.2012.11.024

Weliange WS, Pogosa J, Lankaadikara C, Leichtfried M, Göltenboth F. 2007. Guide to he fresh water fishes in Tubod River, Lake Danao and its outlet, Inawasan River in Leyte, Philippines. Annals of Tropical Research. 29(1):1–13. https://doi.org/10.32945/atr2921.2007