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Research Article

Non-native and invasive fish species of Lake Batur in Bali, Indonesia

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Abstract

Lake Batur is one of the priority lakes for the government initiative to control the damage, and to restore the condition and function of the critical lakes. The degradation in biodiversity due to the invasive and non-native species could raise ecological, economic, and socio-cultural problems for the community. In Lake Batur, there are several fish introduction activities since 1935. Many introduced fish species have turned invasive and could alter the structure of fish communities. It is important to have a solid understanding of how invasive species affect an ecosystem and its biodiversity. Despite numerous studies on fish diversity in Lake Batur, the accurate information on fish diversity and the presence of non-native species in Lake Batur is still not completely known. This paper aims to investigate the diversity of fish in Lake Batur to provide accurate information about the composition of fish species and the presence of existing non-native and invasive fish in Lake Batur. We collected fish samples during the dry season from 30 August–5 September 2022. We used experimental gillnets (30 × 2 m, with mesh size of 16 mm; 25 mm; 37.5 mm; 50 mm; 62.5 mm; and 75 mm), fish nets from the fishing communities (mesh size of 50–75 mm), fishing rods, and scoops. Direct identifications were conducted for the fish samples in the location. For unidentified fish, we preserved the fish sample for further identification. A total of 1104 fish samples from lakes and floating net cages with five different stations were collected. In contrast to the others station, station 4 Abangsongan has all fish species. We obtained 17 species distributed among 8 families. Cichlidae is the most dominant fish family, including the non-native species Nile tilapia (*Oreochromis niloticus*) and Midas cichlids (*Amphilophus citrinellus*). Furthermore, Midas cichlid has become invasive with a very rapid increase during the last 10 years in Lake Batur. For Poecilidae family, Bonylip barb (*Cyclocheilichthys apogon*) is clearly identified for the first time in this study. This study concludes that the invasive species, or non-native Indonesian species represented by Cichlidae species, are a significant issue for fish diversity in Lake Batur.

Key words: population, diversity, freshwater, fishes

Introduction

Indonesia has expansive lake system with 1022 natural lakes spread across islands (RCL 2020). These lakes provide various benefits for domestic water source, protein source from aquaculture and fisheries, transportation, energy, irrigation and tourism. Therefore, as part of the ecosystem and water sources, these lakes have socio-economic and ecological values. Despite these benefits, several lakes in Indonesia are currently degraded. To name a few, the damaging of catchment areas and lake boundaries, the declining in water quality and the declining in natural resources and biodiversity due to the extinction of endemic biota species are the example of the lake degradations. These degradations lead to the threat for preserving the lake function and have a detrimental impact on the community.

Since 2009, Indonesia government introduced an initiative National Priority Lake Rescue (GERMADAN) to control the damage, and to restore the condition and function of the critical lakes. Lake Batur is one of these 15 priority lakes for this government initiative (Anonimous 2021). Located within an active caldera, Lake Batur receives its water from neighboring mountains via seepage and rainfall. UNESCO (United Nations Educational, Scientific, and Cultural Organization) recognized Lake Batur region as a part of the World Cultural Landscape, due to the significance role in the culture, economy, and ecology (Putri et al. 2023). One of the 6 indicators for GERMADAN lake restoration is to avoid the degradation in biodiversity that could raise ecological, economic, and socio-cultural problems for the community.

In Lake Batur, fish introductions were started since 1935. Schuster (1953) claimed that common carp (*Cyprinus carpio*), blue panchax (*Aplocheilus panchax*), wrestling halfbeak (*Dermogenys pusilla*), and croaking gourami (*Trichopsis vittata*) were among the first group of fish that were introduced to Bali. According to Wijaya and Tjahyo (2012), several fish species that frequently stocked in Lake Batur are: grass carp (*Ctenopharingodon idella*), common carp (*Cyprinus carpio*), Mozambique tilapia (*Oreochromis mossambicus*), silver barb (*Barbonymus goniotus*), and Nile tilapia (*Oreochromis niloticus*). Recently, Sentosa and Wijaya (2013) and Juliawan et al. (2020) discovered that non-native Nile tilapia (*O. niloticus*), and red devils (*Amphilophus labiatus*), are the leading species followed by small native fish like rasbora (*Rasbora lateristriata*) and swordtail (*Xiphophorus hellerii)*. Aquaculture activities have contributed to the fish introduction in Lake Batur. With the potential of up to 5% of the overall water area for aquaculture and fishery (Budiasa et al. 2018), this region has a potential of 77.07 ha for fisheries growth. Nowadays, fisheries activity is using only 6.28 ha of the lake water area. In Lake Batur, tilapia farming with floating net cages (FNC) technology was economically viable, as shown by the positive Net Present Value (NPV), Internal Rate of Return (IRR) of more than 9%, and

Net Benefit Cost Ratio (Net B/C) of greater than one. However, the water quality was decreasing, with the values of TDS, NO_2, BOD, total P, NH_3, and P-PO_4 exceeding the upper limit of class II water quality criteria. Therefore, The FNC farming should not be expanded in this lake to the water contamination.

Furthermore, the presence of introduced fish in Lake Batur is not accurately known due to the lack of knowledge on the status of fish resources prior to the fish introduction activity (Umar and Sulaiman, 2013). Research on fish biodiversity is necessary due to the important role of biodiversity in the ecological, hydrological, and economic functions of the lake environment. Species richness study from the fish diversity is important for measuring future changes in community structure (Amarasinghe and Welcomme 2002). Studies on the fish communities in numerous lakes in Indonesia reveal that many introduced fish species have turned into "invasive species" and could alter the structure of fish communities (Herder et al. 2012; Sentosa and Wijaya 2013; Atmaja et al. 2014; Ohee et al. 2018; Syahroma et al. 2019; Dina et al. 2022). According to Katsanevakis et al. (2014), before an invasion becomes harmful and difficult to overcomee, it is important to have a solid understanding of how invasive alien species affect an ecosystem and its biodiversity. In contrast to how invasive organisms are typically described, some ecological factors such as salinity, temperature, altitude, distribution, density, microhabitat, and current velocity are more important than biological ones (Devin and Beisel 2006). The state of the waters and the fish resources contained within them are critical for conducting a comprehensive and integrated cross-disciplinary study as mentioned by Dudgeon et al. (2006).

Despite numerous studies on fish diversity in Lake Batur, the accurate information on fish diversity and the presence of non-native species in Lake Batur is still not completely known. Therefore, this paper aims to investigate the diversity of fish to provide accurate information about the composition of fish species and the presence of existing non-native and invasive fish in Lake Batur.

Materials and methods

Lake Batur is the biggest lake in Bali Island. Old Mount Batur, which rises more than 3,000 meters above sea level (asl), erupted twice throughout the process of this lake's development. The summit of the mountain was destroyed when the Batur volcano erupted some 29,300 years ago. At an elevation of 1,050 meters above sea level, Lake Batur is a lake within an active caldera. The lake has a water surface area of 16.05 km^2, an average depth of 50.8 m, and a water volume of 815.38 million m^3 with a catchment area of 105.35 km^2. The lake's water supply is derived from rainfall and water seepage from the nearby mountains. Around 21.4 kilometers of Lake Batur's coastline are covered in land with two distinct topographies: in the

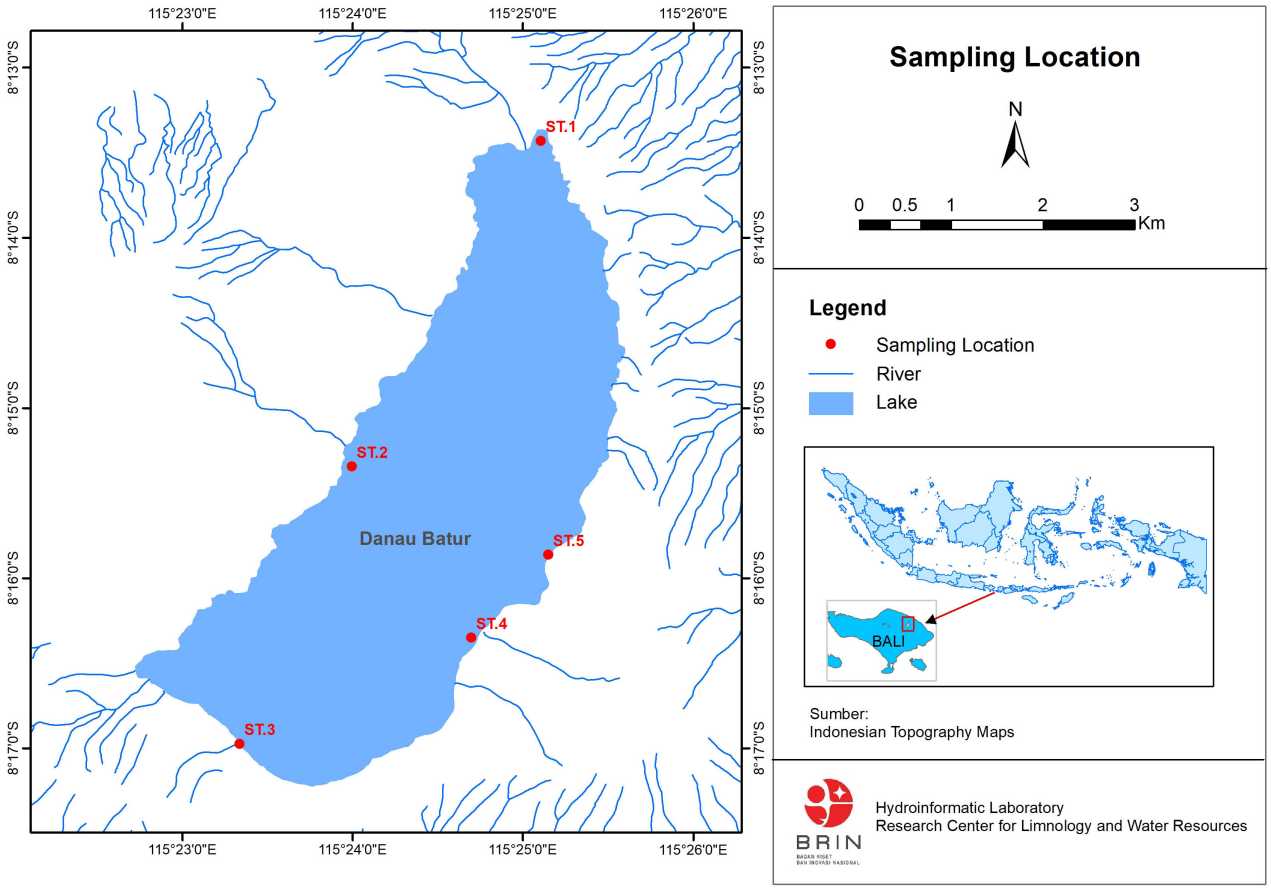

Figure 1. Sampling location in Lake Batur, Bangli Regency, Bali Province. Villages are represented as Station 1 = Songan; 2 = Toya bungkah; 3 = Kedisan; 4 = Abangsongan; 5 = Cemara Landung (for details see Table 1).

Table 1. Details of station sampling locations in Lake Batur, Bali Province in Indonesia

Station	Sampling sites/Villages	S	E	Altitude	Land use types
1	Songan	−8.1362	115.2491	1033 m a.s.l	Agricultural area
2	Toya Bungkah	−8.1511	115. 2492	1057 m a.s.l	Floating net cage activities and tourism
3	Kedisan	−8.1652	−115.2281	488 m a.s.l	Dock area and community activities
4	Abangsongan	−8.1641	115. 2452	1200 m a.s.l	Aquatic plant area
5	Cemara Landung	−8.1545	115. 2588	1200 m a.s.l	Floating net cage activity areas and fishing areas

west, an undulating lowland to mountains (Mount Batur, which is 1,717 m asl) and in the north, east, and south, steep hilly terrain to mountains (Mount Abang with an altitude of 2,172 m asl).

We collected fish sample from five stations based on previous research by Juliawan et al. (2020) (Figure 1). The detail information related to the sampling location, the coordinates, the altitude of the location and type of land use are presented in Table 1. Fish collections were conducted during the dry season from 30 August–5 September 2022. To collect fish samples, we used experimental gillnets (30 × 2 m, with mesh size of 16 mm; 25 mm; 37.5 mm; 50 mm; 62.5 mm; and 75 mm), fish nets from the fishing communities (mesh size of 50–75 mm), fishing rods, and scoops. We conducted direct identification for fish samples in the location. For unidentified fish, we preserved the fish sample for further identification process based on protocol by Kottelat et al. (1993) and Kullander (2003). The data was tabulated based on

Table 2. Fish diversity at Lake Batur in Bali, Indonesia during sampling from 28 August to 5 September 2022.

No	Species & origin	Common name	Family	Station				
				1	2	3	4	5
1	*Amphilophus citrinellus* (non-native)	Midas cichlid	Cichlidae	+++++	+++++	+++++	+++++	+++++
2	*Anabas testudineus* (non-native)	Climbing perch	Anabantidae	–	–	–	+	–
3	*Barbodes binotatus* (native)	Spotted barb	Cyprinidae	–	–	+++	+++	–
4	*Barbonymus goniotus* (native)	Silver barb	Cyprinidae	–	–	++	+++	–
5	*Channa striata* (native)	Snakehead	Channidae	+	–	++	–	–
6	*Clarias gariepinus* (non-native)	African catfish	Clariidae	–	–	–	+	–
7	*Ctenopharingodon Idella* (non-native)	Grass carp	Cyprinidae	–	–	–	+	–
8	*Oreochromis niloticus* (non-native)	Nile tilapia	Cichlidae	++++	++++	+++	+++	++++
9	*O. mossambicus* (non-native)	Mosambique tilapia	Cichlidae	–	–	++	++	–
10	*Cyclocheilichthys apogon* (native)	Beardless barb	Cyprinidae	–	+	+++	++++	–
11	*Poecillia reticulata* (non-native)	Guppy	Poecillidae	+	–	+	–	–
12	*Gambusia affinis* (non-native)	Mosquito fish	Poecillidae	++++	++++	++++	++++	++++
13	*Rasbora lateristriata* (native)	Yellow rasbora	Danionidae	–	–	–	+	–
14	*Trichopodus pectoralis* (non-native)	Snakeskin gourami	Osphronemidae	–	–	–	+	–
15	*Trichopodus trichopterus* (native)	Blue gourami	Osphronemidae	–	–	+	–	–
16	*Xiphophorus helleri* (non-native)	Green swordtail	Poecillidae	–	+	+	+	–
17	*Xiphophorus maculatus* (non-native)	Southern platyfish	Poecillidae	–	–	++	–	–

Note: 1 = + (very rare, found only 1 specimen), 2 = ++ (rare, found more than 2 specimens), 3 = +++ (found more than 10 specimens), 4 = ++++ (always found as the second dominant specimen), 5 = +++++ (60–70% of captured specimen at each station), – = not occurred in sample

the fish species caught, and the percentage was calculated to determine the dominance of the fish species. Detailed observations of existing species were made for several dominant fish families.

Results and discussion

Fish diversity

In this study, we collected 1,104 fish samples from five stations. In contrast to the others four stations, station 4 Abangsongan has all fish species. In total, we obtained 17 species distributed among 14 genera and 8 families (Table 2). Among these, there are six native species and 11 introduction species. Based on this study, Cichlidae is the most dominant fish family with including the non-native species, Nile tilapia (*Oreochromis niloticus*) and Midas cichlids (*Amphilophus citrinellus*). Furthermore, we found the beardless (*Cyclocheilichthys apogon*) and the "spotted barb complex" (*Barbodes binotatus*) from Family Cyprinidae. In addition, Guppy (*Poecillia reticulata*), mosquito fish (*Gambusia affinis*), and green swordtail (*Xiphophorus hellerii*) from

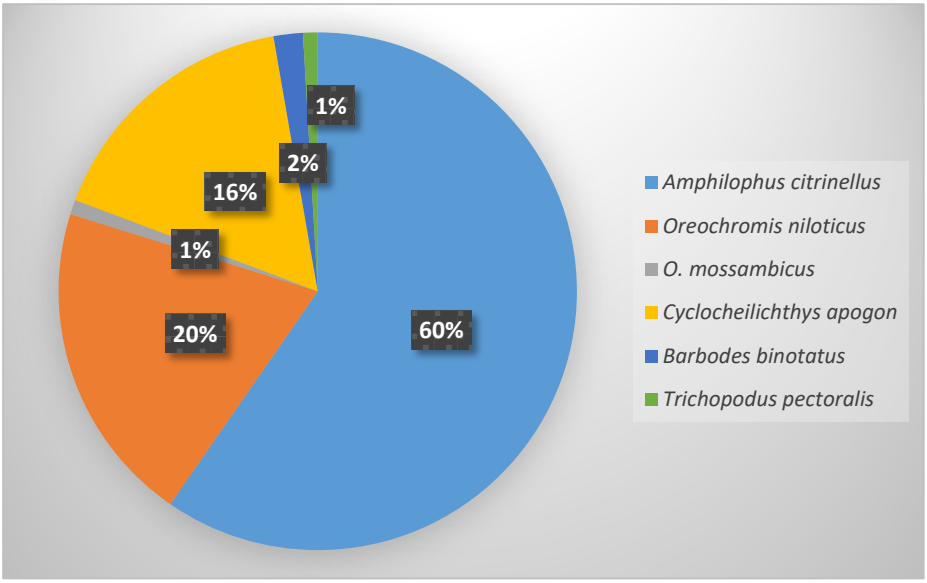

Figure 2. Main fish composition in Lake Batur based on 1,104 samples collected at five stations. Note: Visual observation was used to determine the abundance of Poeciliidae.

Poecilidae family were among other species we found in this study (Figure 2). According to Joanna (2021) most Cichlidae species live in flooded ecosystems, but some have adapted to flowing waters. Cyprinidae and Poeciliidae have been noted as invasive species (Tamaru et al., 2001; Karahan and Ergene 2010).

We assumed the flora and fauna in Bali Island were originated from Java based on the geographic background. Bali island is located at the eastern end of the Sunda Shelf, next to the Wallace line, while the western end is located on the island of Lombok. Bali island is often connected and disconnected with the island of Java due to the rise and fall of sea level during the last glacial maximum period (Voris 2000; Bird et al. 2005). Therefore, the level of flora and fauna endemicity is low in Bali Island (Tanzler et al. 2014). Fish diversity in Lake Batur is higher compared to Lake Buyan, another lake in Bali Island. In Lake Buyan, there are two native fish species from seven species that belong to five genera and four families were identified. Cichlidae is the most dominant family in Lake Buyan (Taradipha et al. 2018). Study from Wargasasmita (2001) showed that less than 20 fish species of fish can be found in most volcanic lakes throughout Indonesia, such as Lake Toba, Lake Singkarak, Lake Maninjau, and Lake Kerinci.

Lake Sentarum is one of the non-volcanic lake with a high number of fish species. Around 220 fish species were found in Lake Sentarum (Kottelat and Widjanarti 2005). Lake Sentarum National Park is in the Kapuas basin of West Kalimantan region. This lake is part of the Kapuas floodplain that is surrounded by hills. The Kapuas main river is characterized by the complex network of seasonal lakes, permanent or non-permanent submerged forests, and swamp forests. These complex networks are crucial in dampening the fluctuations in water level.

Figure 3. Two different Nile tilapia (*Oreochromis niloticus*) phenotypes in Lake Batur, Bali, Indonesia. 70 = wild population of type 2; 71 = cage culture population. Photographs by Rudhy Gustiano.

Analysis of the populations

The most dominant fish family with nearly 90% of the fish population in Lake Batur is Cichlidae, including Nile tilapia and Midas cichlid. The Midas cichlid is increasingly dominating the population with 60% of the total of the fish population. In 10 years, Midas cichlid replaced Nile tilapia as the most dominant fish species in Lake Batur. In 2013, Nile tilapia dominated the total fish population with 63% compared to 0.4% contribution of Midas cichlid of the total population (Sentosa and Wijaya 2013). Currently, this study showed that nile tilapia is contributed 20%, while the number of Midas cichlid contributed to 60% of the total of the population in Lake Batur. This condition could lead to the disruption of the ideal composition of the fish community in Lake Batur. Further study related to the biological, environmental, and genetic factors is needed to explore the background of this immense increase for Midas cichlid population in Lake Batur.

The biological invasion is a common phenomenon for freshwater ecosystem all over the world. At least, hundreds of freshwater species have been displaced from their native habitat due to the several vectors e.g., ballast water, canals, and intentional release from aquariums, gardens, and fishing activity (Gozlan et al. 2010). As a result, dozens of alien species have been established in many freshwater bodies (Strayer 2010). Control and awareness for the are needed to avoid the increasing number of introduced and invasive fish species. Several introduced and invasive fish species among families will be discussed in this study.

Cichlidae

The populations of wild and cultured Nile tilapia populations were found only at Station 4 in Lake Batur (Figure 3). We assumed that the alleged changes in color patterns occurred because of the differences in the natural hybridization within or between species, or genetic color polymorphisms due to the environmental adaptation. Several studies extensively documented the natural hybridization between Cichlidae species (Amarasinghe and De Silva 1996; Agnèse et al. 1998; Noëlla et al. 2021). We will validate the population difference based on the following morphogenetic observations with biometric and molecular DNA measurements from the populations. The most dominant fish species in Lake Batur are Midas cichlids, which contributed to the 60%

Figure 4. Three different wild populations of midas cichlid (*Amphilophus citrinellus*) phenotypes in Lake Batur, Bali, Indonesia. Photographs by Rudhy Gustiano.

of the total catch in this study (Figure 4). Several colors of Midas cichlids were revealed in this study: uniform background of red/orange or pale/opaque, black spots extending down the back, vertically striped from the back to the abdomen, and reddish, yellowish, and black eyes.

We found three different populations of Midas cichlid in Lake Batur at Station 4, Abangsongan Village. Natural hybridization of Midas cichlid with other species within cichlidae could leads to the increasing diversity of Midas cichlid populations in Lake Batur. The hybridization also contributes to the black color of Red Devil fish populations. The differences in color background and pattern in fish were controlled by the different genes. Cichlidae family can easily breed within and between-species and allows for the emergence of hybrids with a wide range of patterns and colors (Rajaee 2011; Maan and Sefc 2013; Wang et al. 2021).

Cyprinidae

This study showed that the beardless barb (*Cyclocheilichthys apogon*) is the most dominant species for cyprinids in Lake Batur (Figure 5). This species was not identified in previous research in Lake Batur. The other species from the cyprinids family that we found in this study are silver barb (*Barbonymus goniotus*) and spotted barb (*Barbodes binotatus*). According to Kottelat et al. (1993), spotted barb (*B. binotatus*) is not only consist of a single species. The species complexity of *B. binotatus* is complicated due to the various morphotypes within this single group. However, the morphological variations such as patches, bands and spots are not a valid basis to differentiate the species within *B. binotatus*. These morphological variations can appear in the same species of *B. binotatus.* Meristic characterization is a more valid basis compared to the morphological variations to differentiate the species within *B. binotatus.*

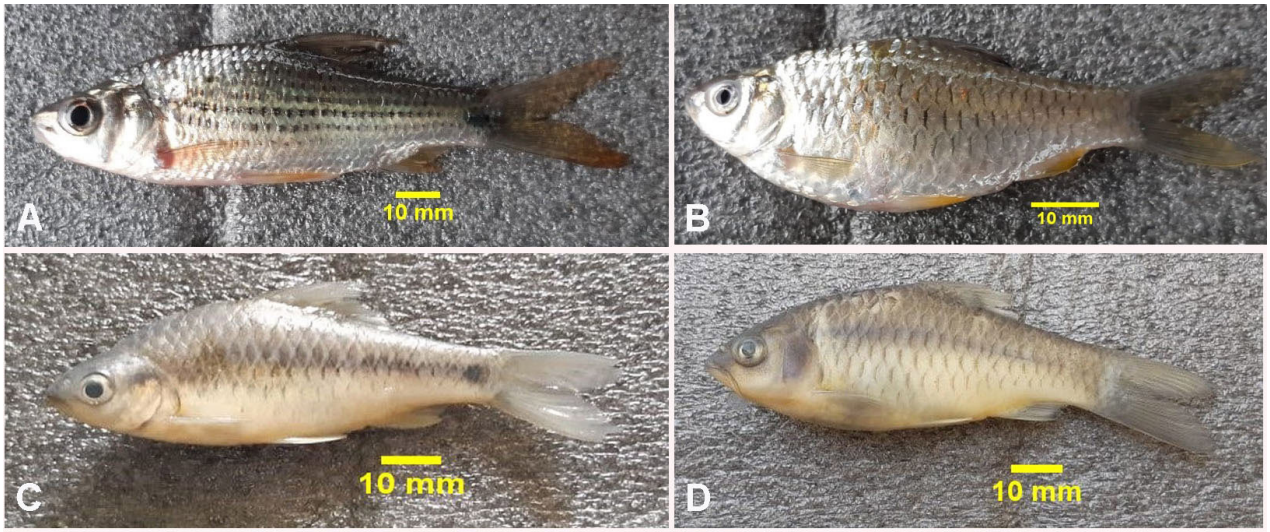

Figure 5. Cyprinid species in Lake Batur, Bali, Indonesia. Beardless barb (*Cyclocheilichthys apogon*) (A), silver barb (*Barbonymus goniotus*) (B), preserved spotted barb (*Barbodes binotatus*) with spot on the caudal fin C), preserved spotted barb with spot on the anal fin (D). Photographs by Rudhy Gustiano.

Due to the age, sexual dimorphism, polymorphism, and biophysical adaptation to ecological pressure, individuals from the same fish species can exhibit variations in morphology and pigmentation. Ng and Tan (2021) showed the variations of pigmentation within *B.* aff. *binotatus* from "Malay Peninsula" during ontogeny period.

Based on molecular analysis from Ng and Tan (2021), *B.* aff. *binotatus* from Malaysia, Sumatra, Kalimantan (Borneo) and the Philippines is an undescribed species and different from *B. binotatus* from Java. This is important evidence to support the assumption that speciation is not always followed by morphological changes. These cryptics species are likely undescribed and they are maybe currently rare, threatened, or endemic. Roux et al. (2016) explained that genetic markers do not necessarily diverge at the same level of morphological divergence. In addition, several species in the Barbodes genus of Sundaland exhibit morphological similarity to *B. binotatus*. The species complexity in *B. binotatus* could be explained by the typical morphology and molecular character for the "cryptic species".

Danionidae

During the survey, *Rasbora lateristriata* (Figure 6) is the only species from Danionidae that we found in Buyan Lake. This result is in agreement with the previous study from Taradipha et al. (2018). In this study, we found *R. latestriata* at station 4 and it is possible to find this species in all station. *R. latestriata* can be distinguished from *R. baliensis* with the number of lateral line scales and total length; *R. baliensis* has 26–28 lateral line scales with the total length of 3.5 cm and *R. latesriata* has 29–33 lateral line scales with the total length 12 cm (Kottelat et al. 1993). According to Hasan et al. (2021), *R. baliensis* is an endemic species in Indonesia that can be found in the central region of Java island.

Figure 6. Preserved specimen of *Rasbora lateristriata* in Lake Batur, Bali, Indonesia. Photograph byRudhy Gustiano.

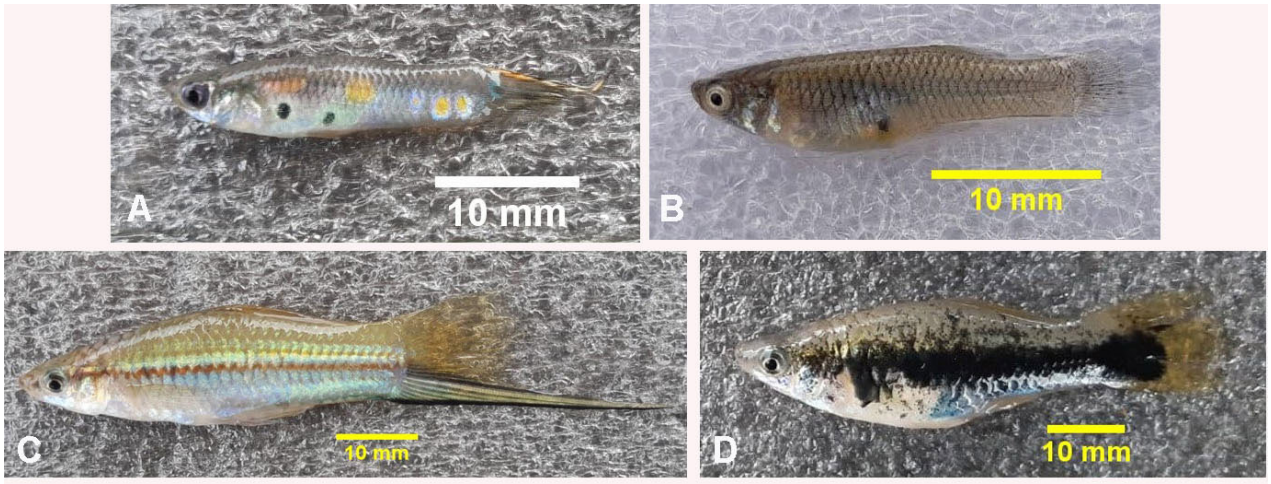

Figure 7. Poecilidae species in Lake Batur, Bali, Indonesia. Guppy (*Poecilia reticulata*) (A), mosquito fish (*Gambusia affinis*) (B), male swordtail (*Xiphophorus hellerii*) (C), Southern platyfish (*Xiphophorus maculatus*) (D). Photographs by Rudhy Gustiano.

Poeciliidae

Guppy (*Poecilia reticulata*), mosquito fish (*Gambusia affinis*), swordtail (*Xiphophorus helleri*), and Southern platyfish (*Xiphophorus maculatus*) are species from Poeciliidae family that we found in Lake Batur during the study (Figure 7). Mosquito fish can be found in all stations, despite the fact that each station had a unique aquatic substrate, such as sandy mud at station 1, mountain rocks at station 2, and vegetated mud at stations 3, 4, and 5. In the previous study from Sentosa and Wijaya (2013) showed that only guppy were present from family Poecilidae. In this study, we found more abundance of mosquito fish compared to guppy. Mosquito fish are the most numerous and widespread species for Poeciliidae family. Mosquito fish is known for their capability to adapt to harsh conditions. The global introduction of mosquitos fish to control the mosquitos leads to the fact that the mosquito fish is the most widespread freshwater fish in the world (Pyke 2005). The absence of their natural predators including bass, catfish and bluegill is another reason for the above phenomenon. In Indonesia, mosquito fish were originally imported and can only be found in West Java, but currently this species are spread throughout Indonesia (Wahyudewantoro and

Rachmatika 2016; Dina et al. 2022). Species from this family have been discovered co-existing in areas where many small fish live. Furthermore, *X. helleri* was discovered as the invasive-potential fish in Lake Buyan (Dina et al. 2022).

This study showed that the fish diversity in Lake Batur is dominated by the introduced fish species, with approximately 70% of total fish populations. This introduction are on intentional or unintentional purpose. One of the example is the fish transportation for aquaculture purpose to the floating net cages (FNC). Currently, FNC farming business are importing seeds from various sources in Java Island. This activities potentialy increase fish diversity in Lake Batur due to the fish introduction. Therefore, the potential threat of this introduced species to replace native fish species should be avoided.

Station 4 is an ideal location to support the diversity of existing fish species due to the several reasons: 1) relatively close to the dense population of residential areas, 2) located in an agricultural area with the presence of floating net cages, and 3) a location with the sloping muddy edge and more protected by many aquatic plants that can support fish habitat compared to other observation sites. Budiasa et al. (2018) conducted research on the carrying capacity of the waters in the presence of FNC.

The validation of fish species in Lake Batur requires in-depth research based on the taxonomy, biology, and molecular approaches to obtain precise result. Specific types of samples are required to complete the collected test materials. The documentation of fish diversity in Lake Batur will provide a strong recommendations for the management and utilization of Lake Batur. A successful lake management plan based on sustainable fish diversity can improve the regional income and community welfare and also provide nutrition for the residents around Lake Batur.

Cichlidae species as invasive or non-native species is a major issue for the productivity, natural resources, and tourism of Lake Batur. Therefore, the presence of the introduced and invasive fish needs a proper control. The introduced and invasive fish should not be released into public waters outside Lake Batur. Several introduced fish species such as *O. mossambica* and *O. niloticus* have been widely used for human consumption. However, these species should be reared in a controlled environment to avoid the escape to the public waters. Invasive fish species should be strictly prohibited and the strong regulations are required to control the spread of the invasive species in public waters. In accordance to the convention on biological diversity, Gherardi (2010) mentioned three steps to manage the non-native species: 1) the prevention of introductions or translocations, 2) the eradication of invasive species that are already established, and 3) if the available resources are limited and immediate eradication is not feasible, efforts should be made to gradually reduce the population of the invasive species.

Lake Batur showed lower taxonomic richness and more simple community structures of fishes compared to several ancient lake in

Indonesia, similar with Lake Matano in Sulawesi (Hadiaty and Wirjoatmojo 2002; Sulastri et al. 2020), Lake Malili (Vaillant et al. 2011), and Lake Poso (Herder et al. 2022). Lake Maninjau in Sumatra and Lake Sentarum in Kalimantan have a higher diversity of fish compared to Lake Batur (Roesma et al. 2021; Haryani et al. 2020). There are two main issues that threaten the sustainability of the fish diversity in most of the lake in Indonesia: 1) the high rate of land conversion and 2) the occurrence of invasive fish species lead to the presence of more non-native species than indigenous (Sulastri et al. 2020; Herder et al. 2022).

Conclusions

We found 17 species belonging to 8 families in Lake Batur. The most dominant fish family in Lake Batur is Cichlidae, represented by non-native species Nile tilapia and Midas cichlids. Furthermore, Midas cichlid become invasive with a very rapid increased number in population during last 10 years in Lake Batur. For Poecilidae family, Bonylip barb (*Cyclocheilichthys apogon*) is clearly identified for the first time in this study. The spotted barb (*Barbodes binotatus*) showed a species complexity that still needs to be resolved. Poeciliidae species were found in a shared habitats with small Midas cichlids. This location is presumably identified as spawning area and nursery ground for Midas cichlids. A holistic and comprehensive study of fish diversity in Lake Batur will improve the results of previous research and provide a complete picture of fish diversity in Lake Batur.

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Authors' contribution

All authors are responsible for the general design of the manuscript. RG, GSH, IWA, TN, SA, SL, GW,GRA, and MHFA conducted the research, collected samples and analyzed data. RG wrote the first draft and completed the manuscript. All authors had equal contribution.

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