

PAPER • OPEN ACCESS

Checklist of endemic (Adrianichthyidae, Gobiidae, Zenarchopteridae) and introduced fish in Lake Poso, Sulawesi, Indonesia

To cite this article: K P Bandjolu *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **869** 012060

View the [article online](#) for updates and enhancements.

You may also like

- [Sulawesi cacao \(*Theobroma cacao*. L.\) performances under two different agricultural system in east coast of Central Sulawesi](#)
Muslimin, W Wijayanti, A Anshary et al.
- [Analysis of fatty acid profile on Rono Lindu \(*Oryzias sarasinorum*\) and Rono Poso \(*Adrianichthys oophorus*\) fishes endemic of Central Sulawesi](#)
A Widodo, R Ummiah, S Anam et al.
- [Eel \(*Anquilla* spp.\) fishing activity in Poso Area Central Sulawesi, Indonesia](#)
L Lukman, T Triyanto, G S Haryani et al.



The Electrochemical Society
Advancing solid state & electrochemical science & technology

241st ECS Meeting

May 29 – June 2, 2022 Vancouver • BC • Canada

Abstract submission deadline: Dec 3, 2021

Connect. Engage. Champion. Empower. Accelerate.
We move science forward



Submit your abstract



Checklist of endemic (Adrianichthyidae, Gobiidae, Zenarchopteridae) and introduced fish in Lake Poso, Sulawesi, Indonesia

K P Bandjolu^{1,2}, E Madiyono², M Herjayanto^{3*}, A Gani⁴, M Nur⁵, S Laheng⁶, M T Gundo^{2,7}

¹ Mosintuwu Institute, Poso Regency 94663, Sulawesi Tengah, Indonesia

² Poso Expedition, Mosintuwu Institute, Poso Regency 94663, Sulawesi Tengah, Indonesia

³ Department of Fisheries Science, Faculty of Agriculture, University of Sultan Ageng Tirtayasa, Serang, Banten 42124, Indonesia

⁴ Aquaculture Study Program, Faculty of Fisheries, Muhammadiyah Luwuk Banggai University, Banggai Regency 94712, Sulawesi Tengah, Indonesia

⁵ Department of Fisheries, Faculty of Animal Husbandry and Fisheries, Sulawesi Barat University, Majene, Sulawesi Barat 91412, Indonesia

⁶ Aquaculture Study Program, Faculty of Fisheries, Madako Tolitoli University, Tolitoli Regency 94514, Sulawesi Tengah, Indonesia

⁷ Biologi Education Program, Faculty of Teaching Education, Sintuwu Maroso University, Poso Regency, Sulawesi Tengah 94612, Indonesia

*Corresponding author: herjayanto@untirta.ac.id

Abstract. Lake Poso is one of the ancient lakes in the world. This lake is known to have high diversity of endemic fish. Several exotic fish species have been introduced to increase the fisheries production in the lake. However, it is reported that the introduced fish is one of the causes of the threat of the existence of endemic fish in this lake. This study aimed to obtain the latest information on endemic (Adrianichthyidae, Gobiidae, and Zenarchopteridae), and introduced fish in Lake Poso. The research was carried out from May to July 2019 at 17 stations on the coast and rivers of Lake Poso. Fish were collected using a seine net, tray net, and hook and line. The results showed that there were 13 species of fish belonging to eight families and 11 genera. A total of six endemic fish species were still found in this study, namely *Adrianichthys oophorus*, *Oryzias nebulosus*, *O. nigrimas*, *O. orthognathus*, *Mugilogobius sarasinorum*, and *Nomorhamphus celebensis*. Seven species of introduced fish were found, namely *Anabas testudineus*, *Aplocheilus panchax*, *Channa striata*, flowerhorn (*Cichlasoma* sp.), *Melanocromis auratus*, *Oreochromis niloticus*, and *Trichopodus trichopterus*. Cichlids (flowerhorn, *M. auratus*, and *O. niloticus*) have the potential to be invasive due to their adaptability and ease of reproduction in Lake Poso. Conservation of the fish endemic to Lake Poso must be a serious



concern for the government, academics, and the community. Ex-situ conservation can be a strategy to conserve the endemic fish of Lake Poso through controlled captivity.

1. Introduction

Lake Poso is one of the tectonic lakes on Sulawesi Island, Indonesia. This lake includes an ancient lake that is 2 million years old with an area of 323 km² and a depth of 450 m [1]. Geological, geographical, and ecological isolation causes Lake Poso to have a uniqueness in aquatic biota [2] mainly because of the abundance of endemic fish. Research that reveals the diversity of fish species in Lake Poso has been carried out for a long time. The first research was conducted by Weber in 1913 which described the endemic fish species of the Gobiidae family, namely *Mugilogobius amadi* [3].

Until now, there are 10 species of fish endemic to Lake Poso, which consist of 3 families (Adrianichthyidae, Gobiidae, and Zenarchopteridae) [4]. Adrianichthyidae consists of two genera *Adrianichthys* and *Oryzias* [5] has seven species, namely *Adrianichthys kruyti*, *A. oophorus*, *A. poptae*, *A. roseni*, *Oryzias nebulosus*, *O. nigrimas*, and *O. orthognathus* [5, 6, 7]. Gobiidae one genus, namely *Mugilogobius* has two species *Mugilogobius amadi* and *M. sarasinorum* [3]. One genus and species of Zenarchopteridae, *Nomorhamphus celebensis* [8]. In addition, in the Lake Poso system, there are also native fish species which are tropical anguillid eels, namely *Anguilla bicolor*, *A. borneensis*, *A. celebesensis*, *A. interioris*, and *A. marmorata* which are catadromous [9] and *N. towoetii* [3]. Two of the native species of Lake Poso (*A. celebesensis* and *N. towoetii*) are endemic to Sulawesi Island [4].

Fish introductions have been carried out in Lake Poso to increase fishery production. In 1978 it was reported that nine introduced species of fish were found in Lake Poso, namely *Anabas testudineus*, *Barbonymus gonionotus*, *Channa striata*, *Clarias* sp., *Cyprinus carpio*, *Osteochilus vittatus*, *Oreochromis niloticus*, *O. mossambicus*, and *Trichopodus trichopterus* [10, 11]. Furthermore, in 2015 seven new introduced fish species were reported, namely *Aplocheilichthys pancax*, *Collosoma* sp., *Cichlasoma* sp., *Melanochromis auratus*, *Pangasianodon* sp., *Poecilia reticulata*, and *Pterygoplichthys paradis* [12]. So as a summary, currently there are 16 species of alien fish that have been introduced in Lake Poso. The existence of the introduction of alien fish is a major threat to biodiversity in Lake Poso, mainly in the form of population decline and the extinction of endemic fish species.

Currently, several species of fish endemic to Lake Poso are thought to have become extinct. Native fish in Lake Poso began to disappear after the introduction of catfish *Clarias* sp. in the early 1980s in Pendolo (southern area of the lake) [6]. The catfish is suspected to be a predator for endemic fish in Lake Poso. Since 1983 the endemic species *A. kruyti* has never been found [7]. In addition, another endemic fish species has also been reported as rare, namely *M. amadi* since 1985. The last reported specimen of this species was in February 1987 [6]. Two types of fish introduced into Lake Poso, namely *Channa striata* (predatory snakehead) and *Oreochromis mossambicus* caused a decrease in the population of *A. kruyti*, *A. poptae*, and *M. amadi* [11]. Based on this, the impact of the introduction of introduced species has occurred and is felt, so the number of species that are threatened with degradation to extinction may continue to increase. In 2019 ichthyofauna in several Central Sulawesi lakes, including Lake Poso was reported [13], but the results have not been maximized due to limited observation stations. Therefore, it is necessary to conduct research that aims to obtain the latest information on endemic fish and introduced fish in Lake Poso. It is hoped that the results of this study will become one of the bases for the conservation and sustainable management of fish resources in Lake Poso.

2. Material and Methods

2.1. Samples Collection

The study was conducted in Lake Poso, Central Sulawesi, Indonesia from May 16 to July 28, 2019. Sampling was carried out at 17 stations, namely 12 at the lakeshore, four at the inlet river, and one station at the Lake Poso outlet (Table 1). The research location is based on information on endemic fish habitats and information on fishermen. Samples were collected using a seine net, tray net, and hook and line. The seine net measures 8 m long, 1 m wide, and mesh size 5 mm. Tray net is 1 m long, 0.5 m wide,

and mesh size 5 mm. At each location, water quality parameters (temperature and brightness) were measured, and habitat was observed (substrate type, and the presence of aquatic plants). The temperature was measured in situ using a thermometer. The brightness (clear or murky) and the presence of aquatic plants (present or absence) were observed qualitatively. In addition, location coordinates were taken using the Global Positioning System.

Table 1. Research stations.

Station	Station name	Coordinate
1	River from Kandela Falls, Tindoli Village	1°59'15.6"S 120°41'39.2"E
2	Lakeshore in Tolambo Village	1°57'30.8"S 120°40'42.3"E
3	Tindoli Village Harbor	1°59'15.3"S 120°41'08.9"E
4	River in Bo'e Village	2°04'11.2"S 120°38'34.7"E
5	Lakeshore in Bancea Village 1	1°59'28.8"S 120°35'06.8"E
6	Lakeshore in Bancea Village 2	1°59'04.9"S 120°34'50.7"E
7	Lakeshore at Bancea Orchid Garden	1°58'53.2"S 120°34'45.0"E
8	Lakeshore in Taipa Village	1°55'16.7"S 120°32'54.3"E
9	River in Meko Village	1°52'59.1"S 120°31'29.7"E
10	Lakeshore in Toniasa Village	1°50'38.2"S 120°32'00.7"E
11	Lakeshore in Siuri	1°48'35.8"S 120°31'31.0"E
12	River from Saluopa Falls	1°45'07.3"S 120°32'28.0"E
13	Lakeshore in Yosi, Pamona Village	1°46'13.3"S 120°38'14.5"E
14	Kompo Dongi, Tentena	1°44'44.5"S 120°39'03.3"E
15	Lakeshore at Watu Pangasa Angga, Sangele	1°46'22.2"S 120°38'19.8"E
16	Lakeshore in Peura Village	1°51'28.3"S 120°38'55.4"E
17	Lakeshore in Dulumai Village	1°54'56.2"S 120°39'55.6"E

2.2. Species Identification

The fish samples obtained were separated for each station. Live fish are documented for species identification. In addition, fish were also preserved in 1 L sample bottles containing 70% alcohol, labeled with the fish species name, collection location or station, collection date, and collector's name. The fish were then analyzed at the Animal Biosystematics and Evolution Laboratory, Department of Biology, Faculty of Mathematics and Natural Sciences, Tadulako University, Palu, Indonesia. Fish identification was carried out based on morphology characters [3, 6-8].

3. Result and Discussion

The fish collected consisted of 13 species belonging to 8 families and 11 genera. In the collection, six species are endemic to Lake Poso, and seven species of fish are introduced (Table 2). The highest number of fish species was found in the lakeshore location in Yosi, Pamona Village, namely five species (*O. nigrimas*, *M. sarasinorum*, *C. striata*, flowerhorn, and *M. auratus*) (Figure 1).

Only one species of *Adrianichthys* was found in the study, namely *A. oophorus* or known as vernacular name 'rono' (Figure 2). The rono is a consumption species that are caught at night. The fisherman who catches the rono is known as 'toperono' in the Pamona language. Toperono catches this fish by turning on a light near the surface of the water and then the rono fish will gather near the light. This is thought to be related to the positive phototaxis nature of the fish. The population of rono fish is still stable because it is still found and abundant.

Mugilogobius sarasinorum (Figure 3) is the most commonly found species in the family Gobiidae. The distribution of this species includes the coast and the inlet river of Lake Poso (Fig. 1). This fish is known by the vernacular name 'bungu masiwu' and is also used by the community as a consumption fish. The total length (TL) of the male bungu masiwu reached 5.3 cm and the female 4.7 cm. Anasa or

N. celebensis (Figure 4) is a fish found in waters with clear water habitat characteristics. This fish is commonly found inlet river of Lake Poso. The use of anasa fish is an export ornamental fish favored by ornamental fish collectors in foreign countries.

Table 2. Fish species were obtained during research.

Family	No.	Species	English name	Vernacular name
Adrianichthyidae	1	<i>Adrianichthys oophorus</i> *	Egg-carrying Buntingi	Rono
	2	<i>Oryzias nebulosus</i> *	Nebulous ricefish	Rono
	3	<i>O. nigrimas</i> *	Black buntingi	Rono pahit
	4	<i>O. orthognathus</i> *	Sharpjawed buntingi	Rono
Anabantidae	5	<i>Anabas testudineus</i> **	Climbing perch	Betok/kosa
Aplocheilidae	6	<i>Aplocheilus panchax</i> **	Blue panchax	Kepala timah
Chanidae	7	<i>Channa striata</i> **	Snakehead fish	Gabus
Cichlidae	8	<i>Cichlasoma</i> sp. **	Flowerhorn	Louhan
	9	<i>Melanochromis auratus</i> **	Golden mbuna	Niasa
	10	<i>Oreochromis niloticus</i> **	Nile tilapia	Nila
Gobiidae	11	<i>Mugilogobius sarasinorum</i> *	Sarasin's Goby	Bungu masiwu
Osphronemidae	12	<i>Trichopodus trichopterus</i> **	Three spot gouramy	Sepat
Zenarchopteridae	13	<i>Nomorhamphus celebensis</i> *	Poso Halfbeak	Anasa/didisa

*endemic, **introduced

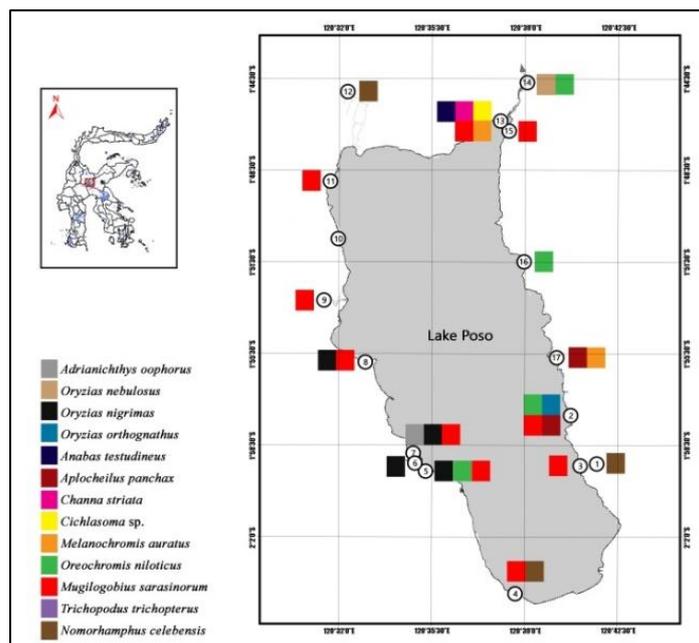


Figure 1. Map of Lake Poso and fish species at each observation location (Map edited by M. Juraid, H. Priyana and E. M. Rizki).



Figure 2. *Adrianichthys oophorus* caught by fisherman for consumption (Photograph by © K P Bandjolu).

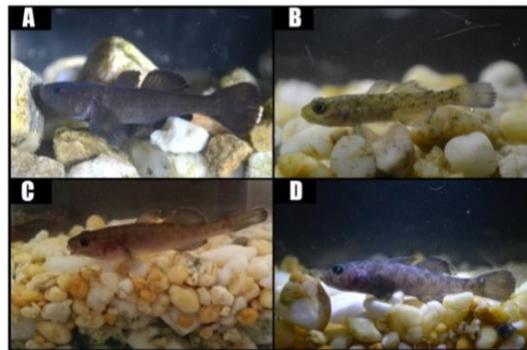


Figure 3. Color variation of *Mugilogobius sarasinorum*, A. male 5.3 cm TL, B. male 3.5 cm TL, C. female 4.7 cm TL, D. male 4.4 cm TL, (Photograph A-B by ©E Madiyono, and C-D by © K P Bandjolu).



Figure 4. Female *Nomorhamphus celebensis* 5.3 cm TL (Photograph ©K P Bandjolu).

Most introduced fish species from the Cichlidae in Lake Poso (three species). These fish were *Cichlasoma* sp. or flowerhorn, *O. niloticus*, and *M. auratus* (Figure 5). Other introduced fish species found were from the Anabantidae, Aplocheilidae, and Chanidae families, each consisting of only one species. The introduced species used as consumption fish and the main catch of fishermen is tilapia. *Channa striata* and *A. testudineus* are also consumed by the public but are less popular.



Figure 5. Cichlids species in Lake Poso, A. flowerhorn 13.5 cm TL, B. *Oreochromis niloticus* 7.1 cm TL, and C. *Melanochromis auratus* 6.3 cm TL (Photograph A & B by ©K P Bandjolu, and C by ©E Madiyono).

In general, the habitat characteristics of fish sampling location in Lake Poso have five types of basic substrates, namely boulder, pebble, mud, coarse sand, and fine sand. The Lake Poso inlet river has four basic substrate types, namely cobble, pebble, coarse sand, and fine sand. Habitat temperatures range from 21-29°C. Several locations of fish habitat found macrophytes and *Mimosa* sp. Information on the characteristics of the habitat types for environmental manipulation activities for the Lake Poso endemic fish in aquaculture in the future.

Table 3. List of fish that have been reported to be in the Lake Poso system.

No.	Species	1987 [10]	2001 [8]	2011 [14]	2015 [12]	2016 [9]	This study
Endemic							
1	<i>Adrianichthys kruyti</i>	+	-	-	-	-	-
2	<i>Adrianichthys oophorus</i>	-	-	-	+	-	+
3	<i>Adrianichthys poptae</i>	+	-	-	-	-	-
4	<i>Adrianichthys roseni</i>	-	-	-	-	-	-
5	<i>Mugilogobius amadi</i>	+	-	-	-	-	-
6	<i>Mugilogobius sarasinorum</i>	-	-	+	-	-	+
7	<i>Nomorhamphus celebensis</i>	+	+	+	-	-	+
8	<i>Oryzias nebulosus</i>	-	-	-	-	-	+
9	<i>Oryzias nigrimas</i>	-	-	+	-	-	+
10	<i>Oryzias orthognathus</i>	-	-	-	-	-	+
Native							
11	<i>Anguilla bicolor</i>	-	-	-	-	+	-
12	<i>Anguilla borneensis</i>	-	-	-	-	+	-
13	<i>Anguilla celebesensis</i> *	-	-	-	-	+	-
14	<i>Anguilla interioris</i>	-	-	-	-	+	-
15	<i>Anguilla marmorata</i>	-	-	+	-	+	-
16	<i>Nomorhamphus towoetii</i> *	-	+	-	-	-	-
Introduced							
17	<i>Anabas testudineus</i>	+	-	+	-	-	+
18	<i>Aplocheilus pancax</i>	-	-	-	+	-	+
19	<i>Barbonymus gonionotus</i>	+	-	-	-	-	-
20	<i>Channa striata</i>	+	-	+	-	-	+
21	<i>Cichlasoma</i> sp.	-	-	-	+	-	+
22	<i>Clarias</i> sp.	+	-	+	-	-	-
23	<i>Collosoma</i> sp.	-	-	-	+	-	-
24	<i>Cyprinus carpio</i>	+	-	+	-	-	-
25	<i>Melanochromis auratus</i>	-	-	-	+	-	+
26	<i>Osteochilus vittatus</i>	+	-	+	-	-	-
27	<i>Oreochromis niloticus</i>	+	-	+	-	-	+
28	<i>Oreochromis mossambicus</i>	+	-	-	-	-	-
29	<i>Pangasianodon</i> sp.	-	-	-	+	-	-
30	<i>Poecilia reticulata</i>	-	-	-	+	-	-
31	<i>Pterygoplichthys paradis</i>	-	-	-	+	-	-
32	<i>Trichopodus trichopterus</i>	+	-	-	-	-	+

+ : presence, - : absence, *endemic to Sulawesi Island [4]

Fish record that have been reported in Lake Poso based on several studies are 32 species (Table 3) consisting of 10 endemic species of Lake Poso, 6 native species, and 16 species or 50% are introduced fish [8, 9, 10, 12, 14]. Fish families endemic to Lake Poso are Adrianichthyidae or ricefishes [5], Gobiidae [3], and Zenarchopteridae, or halfbeaks [8]. Species *Anguilla celebesensis* and *Nomorhamphus towoetii* are endemic species to Sulawesi Island [4] because they can be found in other waters of Sulawesi Island apart from Lake Poso.

The population of species *A. oophorus* is currently still stable [15]. Lake Poso fisherman catch this fish and sell it as fish for consumption. The other three species of *Adrianichthys* have long been hard to find. The species *A. kruyti* was last reported in 1983 [7]. Its habitat is at the Lake Poso outlet north of Tentena. Then the species *A. poptae* reported by [6] at the Lake Poso outlet, was last collected in March 2003 in Pendolo, south of Lake Poso [7]. The last species, *A. roseni*, was described in 2004 by Parenti & Soeroto using a sample (holotype) collected on 4-5 September 1978. The existence of the three 'buntingi' or 'buntinge' species (the vernacular name of three species of *Adrianichthys*) is difficult to found may be related to the habitat of these fish in the deep lake. Buntingi lives at a depth of 4-6 m [6]. Therefore, further exploration using better observation and capture techniques in the deep part of the lake is needed to reveal the presence of the three *Adrianichthys* species. Currently, living specimens of *A. poptae* can be found at the World Medaka Aquarium, Japan (personal communication with Mr. Shinzo Miwa). The three species of *Oryzias* still found in Lake Poso are good information. However, the existence of the *Oryzias* species endemic to Lake Poso is also inseparable from threats to its sustainability.

The last specimen of *M. amadi* was reported in February 1989. The species reported by the community of Dulumai Village has been rare since 1985 [6]. The species that is still easy to find is *M. sarasinorum*. Further studies on the endemic *Mugilogobius* of Lake Poso need to be carried out regarding its molecular identification because this fish can be found in inlet rivers, lakeshores, and deep lake sections on rock cliffs. The pattern of reproduction still needs to be studied, whether these fish migrate from the lake to the Lake Poso inlet river or vice versa to reproduce.

Halfbeak reported in Lake Poso as many as two species [8]. *Nomorhamphus towoetii* is an endemic species of Sulawesi Island [4]. This species is not endemic to Lake Poso because it was also found in Lake Towuti. Its habitat records in Lake Poso are in the Sangele area, the western shore of Lake Poso where it empties at Tentena in August 1995 [8]. Information about halfbeaks at Lake Poso is very limited. The study of halfbeak in Lake Poso is important to obtain information on diversity, habitat, and life cycle.

Cichlids (flowerhorn, *O. niloticus*, and *M. auratus*) are very adaptable, grow and reproduce in Lake Poso. Flowerhorn and *M. auratus* are thought to have entered accidentally with the introduction of *O. niloticus* in 2009 [12]. The existence of these foreign species has threatened the existence of endemic fish in Lake Poso. According to several researchers, the entry of foreign fish species into freshwater ecosystems has major consequences, including loss of species diversity, extinction of endemic species, distortion of food web function, and changes in ecosystem productivity [16]. The introduction of the tilapia *O. mossambicus* in Lake Lindu is the cause of the reduced population of endemic biota because adult fish feed fish fry. This fish has also been introduced to Lake Poso and has caused a decline in the populations of *A. kruyti*, *A. poptae*, and *M. amadi* [11].

Competition for occupying the same habitat niche as endemic fish has the potential to threaten the sustainability of endemic fish. The large adult size of introduced fish and the carnivorous nature of several introduced species in Lake Poso cause them to become predators for the larval, juvenile, and adult stages of fish endemic to this lake. For example, a threat case by introduced flowerhorn species has occurred in Lake Matano which is also known for its endemic fish diversity. Observation of gastric contents in flowerhorn shows that this fish is an invasive predator [16].

Tilapia is a consumption fish that is widely introduced together and is a common carp in the lakes of Central Sulawesi [13]. Tilapia has long been known to cause a decline in the population and diversity of native fish species in some of the world's freshwaters. This is because these fish have a high level of competition for food resources, lack of predation, and high adaptation to changing environmental

conditions, so this species develops very quickly [17]. This fish was deliberately introduced into Lake Poso to increase the production of lake fisheries [10]. Tilapia is still a mainstay for fisheries activities in Lake Poso, namely as a consumption fish.

A recently reported Cichlid species in Lake Poso is *M. auratus*. The male and female fish caught in Lake Poso was 9.5 cm and 7.5 cm respectively. This fish occupies habitats associated with massive rocks in shallow areas and steep bottom slopes north of Lake Poso [12]. Ecologically, this area plays an important role for the endemic fish *A. oophorus* to find food and shelter for adult fish and newly hatched larvae.

The decline in endemic fish populations can be caused by many factors, including: (1) the presence of foreign species [7, 10, 11, 16]; (2) diseases and parasites [6]; (3) pollution and overfishing [7]; (4) use of unfriendly fishing gear and habitat change [18]. Conservation of endemic fish in Lake Poso is very important and urgent to do. The population of Lake Poso endemic species has decreased due to alien species, development on the lakeshore, and changes in watershed land use [19]. The conservation status of endemic fish in Lake Poso (Table 5) needs attention to be immediately protected nationally.

Table 4. Conservation status of endemic fish in Lake Poso.

Species	Status at IUCN	Last Collected
<i>Adrianichthys kruyti</i>	Critically Endangered	1983
<i>Adrianichthys oophorus</i>	Least Concern	On This Study
<i>Adrianichthys poptae</i>	Endangered	2003
<i>Adrianichthys roseni</i>	Critically Endangered	1978
<i>Mugilogobius amadi</i>	Critically Endangered	1987
<i>Mugilogobius sarasinorum</i>	Endangered	On This Study
<i>Nomorhamphus celebensis</i>	Endangered	On This Study
<i>Oryzias nebulosus</i>	Near Threatened	On This Study
<i>Oryzias nigrimas</i>	Near Threatened	On This Study
<i>Oryzias orthognathus</i>	Near Threatened	On This Study

Conservation aims to protect endemic fish species that are threatened with extinction, maintain the diversity of endemic fish species, maintain the balance and stability of the ecosystem, and sustainably utilize endemic fish resources. The conservation strategy for endemic fish in Lake Poso according to [12] is to protect lake water bodies against the introduction of foreign species, physical habitat protection, regulation of fishing gear and fishing season, and closure of fishing areas. Another thing that can be adopted is by making regulations prohibiting the use of destructive fishing gear in the form of electric fishing or poisons/chemicals to catch fish, this has proven to be effective in maintaining the diversity of fish species in the waters of the Menoreh Karst Region, Central Java [20]. In addition, the preservation of local wisdom in the form of village regulations only tolerates traditional fishing can be applied in Lake Poso.

The coastal area of Lake Poso has long been used by the community for household activities, the fisheries sector, livestock, and agriculture. These activities are very likely to be a source of pollution that will affect the condition of Lake Poso. In addition, several areas of Lake Poso are also used as tourist attractions, including waterfalls located on the inlet river. Conservation of the Poso Lake inlet river is very important because there are endemic fish, namely *M. sarasinorum* and *N. celebensis*. The determination of these endemic fish as mascots or ambassadors for clean water in the Lake Poso inlet is one way of socializing the importance of preserving fish and their habitats.

Maintenance and breeding can also be carried out outside the habitat through aquaculture as a form of ex situ conservation [21]. Fish from aquaculture can be re-stocked in their natural habitat. Research and development activities can be carried out through the collaboration of various parties, namely the government, institutions, researchers, and the community. The collaboration is carried out in the form of research and development to manage endemic fish resources in Lake Poso so that their existence is maintained and sustainable. Counseling on the biodiversity of endemic fish in Lake Poso, the impact of the introduction of alien species into Lake Poso, and the importance of maintaining the diversity of

endemic fish in Lake Poso is urgently needed. The availability of data on the collection of fish endemic to Lake Poso at the museum that can be accessed as scientific reference material, and compiled with other data such as habitat, geography, and the environment is an integrated component of the conservation strategy. The status of Lake Poso is an ancient lake that can be used as a natural laboratory where to study various ecological and biological processes of aquatic life is an opportunity that must be captured wisely. Stakeholders must take important steps regarding the future use of the Lake Poso ecosystem [12] for the preservation of the endemic fish of Lake Poso.

4. Conclusion

Six endemic fish species are still found in Lake Poso, namely *Adrianichthys oophorus*, *Oryzias nebulosus*, *O. nigrimas*, *O. orthognathus*, *Mugilogobius sarasinorum*, and *Nomorhamphus celebensis*. Seven species of introduced fish were found in Lake Poso, namely *Anabas testudineus*, *Aplocheilus panchax*, *Channa striata*, *Cichlasoma* sp., *Melanocromis auratus*, *Oreochromis niloticus*, and *Trichopodus trichopterus*. The existence of Cichlids (flowerhorn, *M. auratus*, and *O. niloticus*) has the potential to become invasive fish in Lake Poso because of their adaptability and reproduction. Several conservation strategies for endemic fish in Lake Poso are protecting lake water bodies against the introduction of alien species and essential habitats (in situ conservation), physical protection of habitats, regulation of fishing gear, and fishing seasons, as well as the closure of fishing areas, ex situ conservation and preservation of local wisdom. These various conservation strategies must be a serious concern from the government, academics, and the community to save the spectacular endemic fish in ancient Poso Lake from extinction.

Acknowledgement

Many thanks to Mrs. Lian Gogali (Director of Mosintuwu Institute), Aswadi, and the entire of first Poso Expedition team for their help and support during research activities. Head of the Laboratory of Animal Biosystematics and Evolution, Department of Biology, FMIPA Tadulako University. To Mr. Shinzo Miwa (Chairman of Japan Killifish Fan Club) for the information regarding the fish endemic to Lake Poso. To Muh. Juraid, Muammar, Abd. Waris, Haris Priyana, Exel Muhamad Rizki, and all Ekspedisi Riset Akuatika (ERA) Team for their good cooperation.

References

- [1] Vaillant J J, Haffner G D and Cristescu M E 2011 The ancient lakes of Indonesia: Towards integrated research on speciation. *Integrative and Comparative Biology*, **51** (4): 634-643. doi: 10.1093/icb/icr101.
- [2] Cristescu M E, Adamowicz S J, Vaillant J J and Haffner D G 2010 Ancient lakes revisited: from the ecology to the genetics of speciation. *Molecular Ecology*, **19** (22): 4837-4851. doi: 10.1111/j.1365-294X.2010.04832.x.
- [3] Larson H 2001 A revision of the gobiid fish genus *Mugilogobius* (Teleostei: Gobioidae), and its systematic placement. *Records of the Western Australian Museum, Supplement* (**62**): 1-233. doi: 10.14264/uql.2016.748.
- [4] Hadiaty R K 2018 Status taksonomi iktiofauna endemik perairan tawar Sulawesi. *Jurnal Iktiologi Indonesia*, **18** (2): 175-190. (in bahasa Indonesia)
- [5] Mokodongan D F and Yamahira K 2015 Origin and intra-island diversification of Sulawesi endemic *Adrianichthyidae*. *Molecular Phylogenetics and Evolution* **93**:150– 160.
- [6] Kottelat M 1990 Synopsis of the endangered Buntingi (Osteichthyes: *Adrianichthyidae* and *Oryziidae*) of Lake Poso, Central Sulawesi, Indonesia, with a new reproductive guild and descriptions of three new species. *Ichthyological Exploration of Freshwaters*, **1** (1): 49-67.
- [7] Parenti L R, Soeroto B 2004 *Adrianichthys roseni* and *Oryzias nebulosus*, two new ricefishes (Atherinomorpha: Beloniformes: *Adrianichthyidae*) from lake Poso, Sulawesi, Indonesia. *Ichthyological Research* **51** (1): 10-19. doi: 10.1007/s10228-003-0187-1.
- [8] Meisner A M 2001 Phylogenetic systematics of the viviparous halfbeak genera *Dermogenys* and

- Nomorhamphus* (Teleostei: Hemiramphidae: Zenarchopterinae). *Zoological Journal of the Linnean Society*, **133** (2): 199-283. doi: [10.1006/zjls.2000.0281](https://doi.org/10.1006/zjls.2000.0281).
- [9] Miller M J, Wouthuyzen S, Sugeha H Y, Kuroki M, Tawa A, Watanabe S, Syahailatua A, Suharti S, Tantu F Y, Otake T, Tsukamoto K and Aoyama J 2016 High biodiversity of leptocephali in Tomini Bay Indonesia in the center of the Coral Triangle. *Regional Studies in Marine Science* **8**. 99-113. doi :10.1016/j.rsma.2016.09.006.
- [10] Whitten A J, Mustafa M and Henderson G S 1987 *The ecology of Sulawesi*. Gadjah Mada University Press. 777p.
- [11] Whitten A J, Bishop K D, Nash S V and Clayton L 1987 One or more exticnt from Sulawesi, Indonesia ?. *Conservation Biology*, **1** : 42-48.
- [12] Gundo M T 2015 Konservasi ikan endemik rono, *Xenopoecilus oophorus*, Kottelat 1990 di Danau Poso, Sulawesi Tengah. *Disertasi*. Bogor: Sekolah Pascasarjana, Institut Pertanian Bogor. (in bahasa Indonesia)
- [13] Herjayanto M, Gani A, Adel Y S and Suhendra N 2019 Freshwater fish of lakes and it's inlet rivers in Sulawesi Tengah Province, Indonesia. *Journal of Aquatropica Asia*. **4** (1): 1-9 (in bahasa Indonesia).
- [14] Makmur S, Sawestri S, Atminarso D, Pongmasak P R, Selamet S, Jahri M and Irawan B 2011 Ekobiologi dan kegiatan perikanan di perairan Danau Poso Sulawesi Tengah. *Laporan teknis*. Kementerian Kelautan dan Perikanan, Badan LITBANG Kelautan dan Perikanan, Balai Penelitian Perikanan dan Perairan Umum. (in bahasa Indonesia).
- [15] Mokodongan, D F 2019 *Xenopoecilus oophorus*. The IUCN Red List of Threatened Species 2019: e.T23121A90980873. <https://dx.doi.org/10.2305/IUCN.UK.2019-2.RLTS.T23121A90980873.en>. Downloaded on 22 August 2021.
- [16] Herder F, Schliewen U K, Geiger M F, Hadiaty R K, Gray S M, McKinnon J F, Walter R P and Pfaender J 2012 Alien invasion in Wallace's Dreamponds: records of the hybridogenic "flowerhorn" cichlid in Lake Matano, with an annotated checklist of fish species introduced to the Malili Lakes system in Sulawesi. *Aquatic Invasions*, **7** (4): 521-535. doi: 10.3391/ai.2012.7.4.009.
- [17] Vicente I S T and Alves C E F 2013 Impact of intoduced nile tilapia (*Oreochromis niloticus*) on alienaquatic ecosystem. *Pakistan Journal of Biological Science*, **16** (3):121-126. doi:10.3923/pjbs.2013.121.126.
- [18] Tweedley J R, Bird D J, Potter I C, Gill H S, Miller P J, O'Donovan G and Tjakrawidjaja A H 2013 Species compositions and ecology of the riverine ichthyofaunas in two Sulawesian Islands in the biodiversity hotspot of Wallacea. *Journal of Fish Biology*. **82** (6):1916–1950.
- [19] Serdiati N, Arfiati D, Widodo M S, Lelono T D and Gosari B A J 2019 Food habits of the endemic ricefishes (*Oryzias nigrimas*, Kottelat 1990) in Poso Lake, Central Sulawesi of Indonesia. *Russian Journal of Agricultural and Socio-economic Sciences*, **3** (87): 125-130. doi: 10.18551/rjoas.2019-03.16.
- [20] Hadiaty R K 2016 Iktiofauna di kawasan Karst Menoreh, Jawa Tengah dan upaya konservasinya. *Jurnal Iktiologi Indonesia*, **16** (2): 199-210. doi: [10.32491/jii.v16i2.41](https://doi.org/10.32491/jii.v16i2.41). (in bahasa Indonesia).
- [21] Jayadi J, Husma A, Nursahran, Ardiansyah and Sriwahidah 2016 Domestication of celesbes rainbow fish (*Marosatherina ladigesii*). *Aquaculture, Aquarium, Conservation & Legislation Bioflux*, **9** (5): 1067-1077.