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Habitat characteristics of Lake Towuti, South Sulawesi, Indonesia - the home of endemic fishes

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Abstract. The aim of this study was to examine the habitat characteristic features of Lake Towuti, a home for several endemic fish species. The sampling was conducted from June to October 2009 at seven sampling locations in the Lake Towuti, namely Tominanga, Manu Cape, Loeha Island, Hola-hola downstream, Kawatang downstream, Beau and Bakara Cape. The water quality parameters were recorded *in situ* and *ex situ* while the fish samples were caught using gill net with four mesh size (0.75, 1.0, 1.25 and 1.5 inches). The relationship between the fishery resources and the ecological parameters were analyzed using principal components analysis (PCA). The results showed that pH, total phosphorus, total organic matter (TOM) and suspended solid (SS) are the important components of water quality studies, thus playing a major role in fish distribution. Moreover, *Borreria* sp. distribution and other crucial factors including pH, SS, TOM and sediment play a critical role to determine the *Glossogobius flavipinnnis* distribution. Also, the results showed that the single important factor, ammonia plays an important role for the determination of *Glossogobius matanensis* distribution in Lake Tuwoti. A total of 11 fish species were recorded in this study where seven species are endemic to this lake. In addition, Tominanga and Hola-hola have high fish diversity compare to other locations.
Key Words: distribution, abundance, aquatic plant, freshwater fish, ancient Lake Towuti.

Introduction. In South Sulawesi of Indonesia, three lakes are connected in a cascade as Malili Lakes Complex; the uppermost is Lake Matano and Lake Mahalona which are from Nuha District and the lowermost is Lake Towuti from Towuti District. Lake Towuti is located in Malili Complex, East Luwu Regency, South Sulawesi, Indonesia. Lake Towuti and Lake Matano are ancient lakes in Indonesia. Lake Towuti is a tectonic lake which covered 56,000 ha total areas, maximum depth of 203 m and it was classified as oligotropic lake (Haffner et al 2001). Lake Towuti is also used for hydro-electric power plant, fishing ground for artisanal fishermen, ecotourism and source of water for domestic uses (Nasution 2006). In addition, there was an indication that the Lake Towuti has been polluted and threatened by alien fish species (Nasution et al 2009).

Wirjoatmodjo et al (2003) reported that there are 29 species of fish belonging to 13 families which were recorded in this lake. Of these, 19 species are endemic to the lake and red listed by IUCN (IUCN 2003; Froese & Torres 1999). The total endemic fishes of Lake Towuti is higher compared to other Indonesian lakes, for example Lake Matano and Lake Poso have 14 species and 8 endemic fishes, respectively (Wirjoatmodjo et al 2003), and Lake Laut Tawar has only 2 endemic fishes (Muchlisin et al 2010a; Muchlisin et al 2010b; Muchlisin et al 2011a). Therefore, the Lake Towuti is an important habitat for endemic fish species in Indonesia.

However, the fish populations form Lake Towuti were sharply declined during the last decade due to over exploitation, habitat perturbation, introduction of alien species and destrustive fishing practices. According to Samuel et al (2005), a total of 4 dipnets were operated in Lake Towuti in 2003, and it was increased to 19 dipnets in 2007 (Nasution 2008). The dipnet is one of unselective fishing gear, and a potentially threat to the fish population in the lake.

It was suspected that anthropogenic perturbation gave a negative impact on water quality of Lake Towuti. Presently, no study was done on the water quality of Lake Towuti as important habitat for endemic fish species herein. Hence, the objective of the present study was to examine the habitat characteristics of fishes in Lake Towuti as a basic information to plan a better conservation strategy, especially for endemic fish species in Lake Towuti.

Material and Method. The study was conducted in Lake Towuti, South Sulawesi (Figure 1) from June to October 2009. Seven sampling stations were selected based on characteristic of the lake, namely; (A) Tominanga, (B) Cape of Manu, (C) Loeha Island, (D) Hola-hola, (E) Kawatang, (F) Beau, and (G) Cape of Bakara (Figure 1). The GPS coordinates and each sampling location description are presented in Table 1. Measurement of environmental parameters such as water temperature, turbidity, conductivity, dissolved oxygen and pH were conducted *in situ*, while nuisance parameters ($N\text{-}NO_2$, $N\text{-}NH_4$), nutrients (Total Nitrogen - TN, $N\text{-}NO_3$, Total Phosphorous - TP, $P\text{-}PO_4$) and chlorophyll-a were performed *ex situ*, for this proposes approximately two liters of water sample being collected using Vandorm bottle sampler and then preserved following the method of Greenberg et al (1998). The methods of analysis were presented in Table 2.

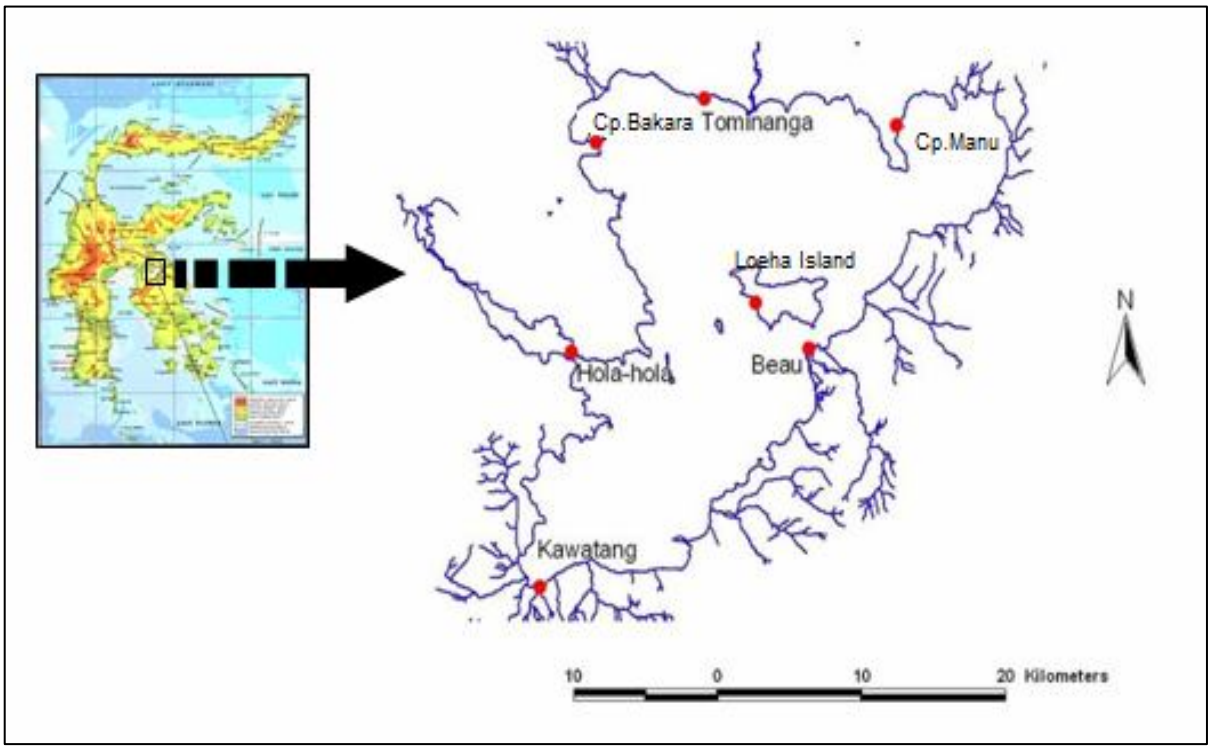

Figure 1. The map of Lake Towuti in South Sulawesi, Indonesia showing sampling locations (red cicles).

The vegetations were sampled using 10 x 10 m quadratic transects which were placed parallel to the coast with two replications. The samples were stored in 70% alcohol solution, then dried in an oven at a temperature of 70^{o}C. Samples were identified based on Backer & Van den Brink (1968), Hidayat et al (2004), and Pancho & Soerjani (1978) at the Herbarium Bogoriense, Research Center for Biology-Indonesian Institute of Sciences, Cibinong.

The sediment samples were taken using Ekman grab. The samples were put into plastic containers which have been labeled and then transported to laboratory for further analysis. The samples were dried in oven at 105^{o}C for 24 hours, then cooled for 12 hours at room temperature. A total of 10 grams of dried sample were weighed then crushed with the mortar. The fine samples were sieved shaking for 10 minutes. Each fraction was weighed and calculated for cumulative percentage of grain size (Head 1981). The texture was analyzed using hydrometer based on Sulaiman et al (2005).

Fish samples were collected using experimental gillnet with various mesh sized of 0.75, 1.0, 1.25 and 1.5 inches. The net was 50 m length and 4 depths (200 m^2). The nets were equipped with the float at top and sinker at the bottom. The nets were installed perpendicular shoreline in every station (Nasution et al 2007). Fish samples were preserved using 4% formalin solution then after 7 days in formalin the fish samples were stored in 70% alcohol solution for collection. The fish were identified based on Froese & Pauly (2013) and Kottelat et al (1993).

Table 1

The description of sampling locations and GPS coordinate in Lake Towuti, South Sulawesi, Indonesia

No.	*Stations (code)*	*Coordinates*	*Descriptions*
1	Tominanga (A)	02°39'365"E 121°29'935"S	Inlet of Tominanga River and no macrophyte were presence
2	Cape of Manu (B)	02° 40'406"E 121°37'081"S	Open water and no macrophytes were presence
3	Loeha Island (C)	02°46'505"E 121°3'830"S	This is an island in the lake and no macrophytes were presence
4	Hola-hola (D)	02°48'187"E 121°24'94"S	The lake discharge and the water flows into Larona River; macrophytes were presence
5	Kawatang (E)	02°56'377"E 121°23'720"S	The flood plain (swamp area), the connection channel between lake and Kawatang River, presence of macrophytes in some areas
6	Beau (F)	02°48'091"E 121°33'848"S	Inlet of Babasalo River; swamp areas and no macrophytes were presence
7	Cape of Bakara (G)	02°40'893"E 121°25'873"S	There is a high-trunked vegetation (Pandanus)

Table 2

Methods for water quality parameters analysis

No.	*Parameters*	*Methods*
1	Temperature	In situ, Water Quality Checker-Horiba U-10
2	pH	In situ, Water Quality Checker-Horiba U-10
3	Dissolved oxygen (DO)	In situ, Water Quality Checker-Horiba U-10
4	Turbidity	In situ, Water Quality Checker-Horiba U-10
5	Conductivity	In situ, Water Quality Checker-Horiba U-10
6	$N\text{-}NO_2$	Sulfanilamid, spectrophotometry
7	$N\text{-}NO_3$	Brucine, spectrophotometry
8	$N\text{-}NH_4$	Phenate, spectrophotometry
9	Total Nitrogen (TN)	Brucine with $K_2S_2O_8$ as oxydator, spectrophotometry
10	$P\text{-}PO_4$	Ascorbic acid, spectrophotometry
11	Total Phosphorus (TP)	Ascorbic acid, spectrophotometry
12	Chlorofil-a	Extraction with acetone, spectrophotometry
13	Suspended solid (SS)	Gravimetry

Results and Discussion

Habitat charecteristics. The study revealed that the station of Tominanga River (station A), Kawatang (station E), Beau (station F), are inlet of Towuti lake, while Hola-hola (station D) is an outlet of Lake Towuti that flows into Larona River and empties into the Gulf of Bone. A total of 116 species of riparian vegetation were recorded during the study. The high species diversity of riparian vegetation was found at Tominanga, Kawatang, and Loeha Island stations (Table 3). The riparian of *Cyperus* sp.*, Glochidion arborescens*, *Xanthophyllum tennipetalum*, *Kjelbergerdendron celebicum*, *Ottelia mesenterium* and *Ficus*

microcarpa have higher vegetation cover. The riparian vegetation has an important role as a source of organic materials input to water system (allochthonous) and provides food source for aquatic organism such as fish, shrimp, crab and mollusks. For example, *K. celebicum* and *F. microcarpa* are consumed by several fishes in this lake, for example *Anabas testudineus* and *Oreochromis niloticus* (Nasution et al 2009). However, in generally, Lake Towuti is poor in nutrients and therefore it can be classified as oligotrophic lake (Haffner et al 2001). The study revealed that the TP concentration was higher at several locations (Table 4). The water samples were collected at littotal zone of Lake Tuwoti; therefore, the higher TP in zone probably is due to impact of antrophogenic activities from vicinity of the lake, for example settlements and agriculture practices.

Table 3

The percentage of covered of riparian vegetation in Lake Towuti accoring to sampling stations

No.	Vegetation species	Family	Station						
			A	B	C	D	E	F	G
1	*Acronyhia pedunculata*	Rutaceae	1.0	-	-	-	1.0	-	-
2	*Ageratum conyzoides*	Asteraceae	-	-	-	10.0	-	0.2	-
3	*Aglaia* sp.	Meliaceae	-	2.0	-	-	-	-	1.0
4	*Amphineuron immersum*	Thelypteridaceae	-	-	-	-	-	0.2	-
5	*Anodendron microstachyum*	Araceae	0.5	-	0.1	2.0	-	-	-
6	*Anodendron montanum*	Araceae	-	1.0	-	-	-	0.2	1.0
7	*Arenga* sp.	Arecaceae	-	2.0	-	2.0	-	-	1.0
8	*Aristolochia tagala*	Aristolochiaceae	2.0	-	0.2	-	-	-	-
9	*Arundina graminifolia*	Orchidaceae	-	-	-	-	1.0	-	-
10	*Baccaurea lanceolata*	Euphorbiaceae	-	1.0	2.0	-	-	-	1.0
11	*Bambusa* sp.	Poaceae	-	10.0	2.0	-	-	-	20.0
12	*Blumea balsamifera*	Asteraceae	1.0	-	-	1.0	-	-	-
13	*Borreria alata*	Rubiaceae	-	-	4.0	20.0	-	-	-
14	*Buchanania arborescens*	Anacardiaceae	-	-	-	-	1.0	-	-
15	*Buchanania arborescens*	Anacardiaceae	5.0	-	-	-	-	-	-
16	*Bulbophyllum* sp.	Orchidaceae	-	0.5	-	1.0	-	-	0.5
17	*Bulbostylis capillaris*	Cyperaceae	-	-	-	-	-	1.0	-
18	*Caesalpinia bundoc*	Fabaceae	-	-	2.0	-	2.0	-	-
19	*Calophyllum neo-ehudicum*	Clusiaceae	0.1	-	4.0	-	2.0	-	-
20	*Calophyllum soulattri*	Clusiaceae	2.0	8.0	-	-	-	-	0.5
21	*Calophyllum* sp.	Clusiaceae	6.0	5.0	4.0	-	5.0	-	15.0
22	*Camnosperma auriculatum*	Anacardiaceae	-	-	-	-	1.0	-	-
23	*Capparis micracantha*	Capparidaceae	-	0.2	-	1.0	1.0	-	-
24	*Cassia alata*	Fabaceae	2.0	-	-	-	-	0.1	-
25	*Casuarina equisitifolia*	Cassuarinaceae	4.0	10.0	-	-	-	-	10.0
26	*Chionanthus montanus*	Oleaceae	-	-	-	-	1.0	-	-
27	*Crotalaria striata*	Fabaceae	1.0	-	-	-	-	0.2	-
28	*Ctenopteris obliquata*	Gramitidaceae	-	0.1	-	-	-	-	0.2
29	*Cyperus kyllingia*	Cyperaceae	3.0	-	-	-	1.0	0.2	-
30	*Cyperus* sp.	Cyperaceae	15.0	-	2.0	-	-	5.0	-
31	*Daemonorops* sp.	Arecaceae	0.1	0.2	-	-	1.0	-	-
32	*Dendrobium aloifolium*	Orchidaceae	0.1	-	-	-	1.0	-	-
33	*Dendrobium crumenatum*	Orchidaceae	0.1	0.2	-	-	-	-	0.1

34	*Dendrobium quadrilobium*	Orchidaceae	2.0	-	-	-	-	-	-
35	*Dendrobium* sp.	Orchidaceae	0.1	-	-	-	1.0	-	-
36	*Dicranopteris linearis*	Gleicheniaceae	1.0	-	5.0	-	1.0	-	0.1
37	*Dinochloa* sp.	Poaceae	2.0	-	10.0	-	-	-	-
38	*Dioscorea alata*	Dioscoreaceae	1.0	-	-	-	-	-	-
39	*Dischidia benghalenses*	Asclepiadaceae	0.1	-	-	-	1.0	-	-
40	*Dischidia nummularia*	Asclepiadaceae	2.0	-	-	-	-	-	-
41	*Dischidia rafflesiana*	Asclepiadaceae	0.1	-	-	-	-	-	-
42	*Drymophlocus* sp.	Arecaceae	0.2	-	-	-	2.0	-	-
43	*Drynaria* sp.	Polypodiaceae	2.0	-	2.0	-	-	-	-
44	*Drynaria* sparsisora	Polypodiaceae	0.1	-	2.0	-	2.0	-	-
45	*Eclipta alba*	Asteraceae	0.1	0.1	-	-	-	0.2	0.5
46	*Elaeocarpus littoralis*	Elaeocarpaceae	0.1	-	2.0	-	-	-	-
47	*Eleocharis* sp.	Cyperaceae	-	-	0.2	-	0.1	-	-
48	*Eria* sp.	Orchidaceae	0.1	-	-	-	-	-	-
49	*Evodia aromatica*	Rutaceae	0.1	-	0.2	-	-	-	-
50	*Fagraea ceilanica*	Loganiaceae	0.1	-	0.2	-	-	-	-
51	*Ficus annulata*	Moraceae	10.0	-	-	-	-	5.0	-
52	*Ficus calophylla*	Moraceae	-	-	15.0	-	-	-	-
53	*Ficus glandulifera*	Moraceae	-	1.0	-	-	2.0	-	-
54	*Ficus microcarpa*	Moraceae	-	-	-	-	-	15.0	-
55	*Ficus minahasae*	Moraceae	-	-	-	-	0.5	-	-
56	*Freycinetia* sp.	Pandanaceae	-	-	-	0.5	-	-	-
57	*Fuirena umbellata*	Cyperaceae	-	-	-	-	0.2	-	-
58	*Garcinia celebica*	Clusiaceae	-	-	-	-	0.5	-	-
59	*Gardenia mutabilis*	Rubiaceae	-	-	-	-	-	-	-
60	*Gardenia tubifera*	Rubiaceae	-	-	-	-	30.0	-	-
61	*Gigantochloa* sp.	Poaceae	-	12.0	-	-	-	-	5.0
62	*Glochidion arborescens*	Euphorbiaceae	15.0	-	-	-	-	-	-
63	*Glochidion rubrum*	Euphorbiaceae	-	-	-	5.0	-	-	-
64	*Imperata cylindrica*	Poaceae	-	-	1.0	-	-	-	-
65	*Ipomoea aquatica*	Convolvulaceae	-	1.0	-	-	-	0.2	-
66	*Kjelbergerdendron celebicum*	Orchidaceae	-	-	-	-	-	-	-
67	*Kjelbergiodendron celebicum*	Myrtaceae	5.0	-	25.0	-	10.0	-	-
68	*Knema cinerea*	Myristicaceae	-	-	-	-	-	0.5	-
69	*Leersii hixandra*	Poaceae	-	-	-	-	-	0.5	-
70	*Lindsaea* sp.	Lindsaeaceae	-	-	5.0	-	-	-	-
71	*Lophopetalum javanicum*	Celastraceae	-	-	-	-	-	-	-
72	*Lycopodiella cernua*	Lycopodiaceae	-	-	-	1.0	-	-	-
73	*Mangifera laurina*	Anacardiaceae	-	2.0	-	-	-	-	1.0
74	*Melastoma malabatrichum*	Melastomataceae	-	-	-	20.0	-	-	-
75	*Memecylon costatum*	Melastomataceae	-	-	-	-	0.2	-	-
76	*Mischocarpus sundaicus*	Sapindaceae	-	-	-	-	0.2	-	-
77	*Nauclea purpurascens*	Rubiaceae	-	-	-	-	-	15.0	-
78	*Nepenthes maxima*	Nepenthaceae	-	-	-	0.5	-	-	-
79	*Nepenthes mirabilis*	Nepenthaceae	-	2.0	-	-	-	-	0.5

80	*Nephrolepis radicans*	Nephrolepidaceae	-	-	-	0.5	-	-	-
81	*Pandanus* sp.	Pandanaceae	-	-	-	0.5	-	-	-
82	*Paspalum conjugatum*	Poaceae	-	-	-	-	-	10.0	-
83	*Paspalum scrobiculatum*	Poaceae	-	-	-	0.5	-	0.5	-
84	*Pennisetum* sp.	Poaceae	0.5	-	-	-	-	-	-
85	*Phanera pulva*	Fabaceae	-	-	0.1	-	-	-	-
86	*Phymatosorus nigrescens*	Polypodiaceae	-	-	0.1	-	-	5.0	-
87	*Piper betle*	Piperaceae	-	0.5	-	-	-	-	0.5
88	*Piper miniatum*	Piperaceae	-	-	0.2	-	-	-	-
89	*Piper* sp.	Piperaceae	-	0.5	-	-	-	-	0.5
90	*Piper unguiculatum*	Piperaceae	-	-	0.2	-	-	-	-
91	*Pleomele angustifolia*	Liliaceae	-	5.0	-	-	-	-	-
92	*Podocarpus neriifolius*	Podocarpaceae	-	-	-	0.5	-	-	-
93	*Ottelia mesenterium*	Hydrocharitaceae	-	-	-	-	-	40.0	-
94	*Pomatocalpa latifolia*	Orchidaceae	-	-	-	2.0	-	-	-
95	*Psychotria sarmentosa*	Rubiaceae	-	4.0	-	-	0.5	-	-
96	*Pteridium aquilinum*	Dennstaedtia Group	-	-	-	-	0.5	-	-
97	*Pyrrosia nummulariafolia*	Polypodiaceae	0.1	-	-	-	-	0.5	-
98	*Rapanea avenis*	Myrsinaceae	15.0	-	-	-	-	-	-
99	*Rapanea hasseltii*	Myrsinaceae	-	-	3.0	-	-	-	-
100	*Rapanea* sp.	Myrsinaceae	-	2.0	-	-	-	-	0.2
101	*Santiria laevigata*	Burseraceae	-	-	2.0	-	-	-	-
102	*Sarcotheca celebica*	Oxalidaceae	-	0.2	6.0	25.0	30.0	-	20.0
103	*Schefflera elliptica*	Araliaceae	-	-	0.1	-	-	-	-
104	*Scleria ciliaris*	Cyperaceae	-	1.0	-	-	-	-	0.2
105	*Scleria purpurascens*	Cyperaceae	0.1	-	-	-	-	-	-
106	*Scoparia dulcis*	Scrophulariaceae	-	-	-	-	-	0.5	-
107	*Stachytarpheta australia*	Verbenaceae	-	4.0	-	1.0	-	-	-
108	*Sterculia insularis*	Sterculiaceae	-	-	0.1	-	0.1	-	-
109	*Syzygium* sp.	Myrtaceae	-	2.0	-	-	-	-	0.2
110	*Syzygium spicata*	Myrtaceae	-	-	-	2.0	-	-	-
111	*Syzygium zeylanicum*	Myrtaceae	0.1	-	-	-	0.2	-	-
112	*Tetracera scandens*	Dilleniaceae	-	-	0.2	2.0	-	-	-
113	*Trichospermum kjelbergii*	Tiliaceae	-	2.0	0.2	-	-	-	-
114	*Trixspermum centipeda*	Orchidaceae	0.2	-	-	-	-	-	-
115	*Vittaria zorteriifolia*	Vittariaceae	-	0.5	-	2.0	-	-	-
116	*Xanthophyllum tennipetalum*	Polygalaceae	-	20.0	-	-	-	-	21.0

A - Tominanga, B - Cape of Manu, C - Loeha Island, D - Hola-hola, E - Kawatang, F - Beau dan, G - Cape of Bakara.

The study revealed that the water temperature in Lake Towuti during June to October 2009 was 28.6-31.3^{o}C with an average of 29.6^{o}C (Table 4). The dissolved oxygen ranged between 4.7-7.4 ppm (6.25 ppm in average), it was presumed that the dissolved oxygen in the waters was sufficient to oxidize ammonia and nitrite to nitrate. The study revealed that nitrite ($N\text{-}NO_2$) and ammonium ($N\text{-}NH_4$) concentrations in the lake ranged between 0.001 ppm to 0.007 ppm, and 0 ppm to 0.009 ppm, respectively. In addition, the $N\text{-}NO_3$, $P\text{-}PO_4$. concentrations ranged from 0 ppm to 0.697 ppm (0.076 ppm in average) and 0 ppm to 0.022 ppm (0.008 ppm in average), respectively. According to The Government Regulation of the Republic of Indonesia No. 82 Year 2001 that the maximum limit of

nitrite, ammonium, N-NO_3 and P-PO_4 for fisheries porpuses are 0.06 ppm and 0.02 ppm, 10 ppm and 0.2 ppm, respectively. Therefore, the average values of these parameters still meet the quality standard of regulation for the fishery porpose.

The water temperature and dissolved oxygen play an important role in fish growth and distribution (Peterson & Ross 1991; Whitfield 1999). According to Gido & Matthews (2000) fish utilize habitats within the water body which are physiologically convenient mainly in terms of oxygen concentration and water temperature. In general, there were no significant differences in water temperature and dissolved oxygen in Lake Towuti among sampling sites and it still meets the minimum requirements for the fishes to growth optimum. A similar study was reported by Muchlisin (2013) in Lake Laut Tawar, Indonesia; he has found no differences in water temperature and dissolved oxygen among sampling sites and it was presumed that these factors did not affect the fish distribution in Lake Laut Tawar.

The substrate of Lake Towuti was dominated by sand. The substrate is an important habitat for aquatic benthic organisms, especially benthic fish, shrimp, crabs and mollusks (Wantiez et al 1996; Cushman et al 2004). Organic matter in the substrate plays an important role as food resource for benthic organisms. In general the sandy substrate has low organic matters, however among the sampling stations the Hola-hola and Kawatang stations have high organic matters compared to other sampling locations. The high organic matter in these stations can be associated with nutrient inputs from rivers that enter into this lake.

The turbidity of Lake Tuwoti ranged between 0 to 8 NTU (Table 4). The turbidity describes the optical properties of water which is determined based on the amount of light absorbed and emitted by the materials in water (Greenberg et al 1998). The turbidity is caused by the presence of organic materials and suspended and dissolved inorganic matter (i.e. silt and sand), as well as plankton density and other aquatic micro organisms (Greenberg et al 1998). There was a strong relationhsip between water turbidity and total suspended solid (TSS) and total organic matters (TOM) where the turbidty was higher when TSS and TOM were increased as recorded in Kawatang (station E) (Table 4).

Fish fauna. A total of 11 species were recorded during the study, of these nine species are endemic to Lake Towuti, where yellow pangkilang (*Telmatherina celebensis*) was predominant in Lake Towuti, followed by Anggori (*Glossogobius celebius*). *T. celebensis, Paratherina striata, G. celebius* have high distribution, while *G. matanensis* and *Aplocheilus panchax* have low distribution (Table 5). Wirjoatmodjo et al (2003) recorded five species of introduced fish in Lake Towuti namely: *Oreochromis mosambicus, A. testudineus, Trichopodus pectoralis, T. trichopterus,* and *Channa striata.* Four alien fish species were recorded during this study, however Wirjoatmodjo et al (2003) recorded five species of introduced fish in this lake namely: *Oreochromis mosambicus, A. testudineus, Trichopodus pectoralis, T. trichopterus,* and *Channa striata.* Therefore, *A. panchax* was a new record in Lake Towuti (Table 5). According to Wargasasmita (2005) 19 alien fish species are present in Indonesian waters. In addition, Muchlisin (2012) reported six species of exotic fish in Lake Laut Tawar, Indonesia. Therefore, the total of alien fish species in Lake Towuti was lower compared to Indonesian record in general.

O. mosambicus and *O. niloticus* have been introduced in Lake Tuwoti in 1980 by Local Fisheries Affair (Personal communications with the fishermen in Lake Towuti), and now these species have been dominated the fish population in Lake Towuti. A similar phenomenon has also happened in the Lake Laut Tawar, where the depik (*Rasbora tawerensis*) population, which was the endemic and predominant species in this lake has decreased and now the fishfauna is dominated by *O. niloticus* (Muchlisin et al 2011b).

We presumed that the fish population of Lake Towuti has decreased over the last decade. For example, In 2002 Wirjoatmodjo et al (2003) reported 21 species of fish in the Lake Towuti, but it was decreased to 11 species in 2008 (Nasution 2008), which was equal to present study; but some species which have recorded in previous study, there were not caught in this study, namely: sepat rawa (*T. trichopterus*), dui-dui (*Dermogenys megarhamphus*), red pangkilang (*Tominanga* sp.), and rice fish (*Oryzias marmoratus*).

Table 4

The water quality parameters of Lake Towuti, Sulawesi Indonesia recorded during

Parameters	*Unit*	*Station*						
		A	*B*	*C*	*D*	*E*	*F*	*G*
pH		7.69-8.40	7.70-8.10	7.51-8.30	8.00-8.30	7.75-8.30	7.51-7.60	7.46-8.10
Conductivity	mS cm^{-1}	0.140-0.146	0.141-0.156	0.142-0.148	0.139-0.146	0.142-0.149	0.143-0.153	0.143-0.150
Turbidity	NTU	0-2	0-2	1	0-2	0-8	4	0-2
Dissolved oxygen	ppm	6.11-7.30	5.45-7.00	6.07-6.60	5.65-7.00	6.05-7.40	4.70-5.96	5.70-6.53
Temperature	^{o}C	29.3-31.0	28.7-29.3	28.7-30.2	28.7-30.8	29.6-30.6	28.7-29.9	28.6-31.3
Total Suspended Solid	ppm	0	0	0	0	0-8.8	1.6-11.2	0-0.4
Chlorofil-a	mg/m^3	0-0.002	0-0.145	0-0.241	0-0.344	0-2.019	0-1.847	0
$N\text{-}NO_2$	ppm	0.001-0.003	0.001-0.004	0.001-0.004	0.001-0.002	0.001-0.004	0.004-0.007	0.001-0.004
$N\text{-}NO_3$	ppm	0.006-0.068	0.007-0.697	0-0.004	0-0.132	0-0.088	0-0.179	0-0.038
$N\text{-}NH_4$	ppm	0-0.001	0	0	0-0.006	0-0.007	0	0-0.009
TN	ppm	0.110-0.325	0.118-0.793	0.087-0.165	0.099-0.603	0.042-0.299	0.005-0.218	0.012-0.480
$P\text{-}PO_4$	ppm	0-0.012	0-0.014	0-0.012	0-0.016	0.007-0.018	0-0.012	0-0.022
TP	ppm	0-0.143	0-0.169	0-0.111	0-0.114	0.021-0.127	0-0.211	0.020-0.097
Total Organic Matters	ppm	5.240-13.472	8.483-13.722	23.451-27.942	8.483-29.938	8.233-25.198	18.212-28.940	12.225-17.464

A - Tominanga, B - Cape of Manu, C - Loeha Island, D - Hola-hola, E - Kawatang, F - Beau dan, G - Cape of Bakara.

Table 5

Fish species which were caught using experimental gill net

Fish species	Station							TNF	Status	FOI (100%)
	A	B	C	D	E	F	G			
Telmatherina celebensis	289	42	35	65	175	246	29	881	Endemic	100
Paratherina striata	9	3	3	1	2	5	1	24	Endemic	100
Paratherina cyanea	22	0	0	11	6	0	0	39	Endemic	42.86
Glossogobius celebius	22	2	3	32	15	25	4	103	Endemic	100
Glossogobius flavipinnis	3	1	4	45	0	0	0	53	Endemic	57.14
Glossogobius intermedius	2	0	3	4	3	12	7	31	Endemic	85.71
Glossogobius matanensis	0	0	0	0	0	0	1	1	Endemic	14.29
Oreochromis niloticus	3	0	0	0	0	1	0	4	Exotic	28.57
Channa striata	1	0	0	0	0	0	0	1	Exotic	14.29
Anabas testudineus	5	0	0	0	0	2	1	8	Exotic	42.86
Aplocheilus panchax	0	0	0	0	0	5	0	5	Exotic	14.29
Total number of fish	356	48	48	158	201	296	43	1150		

A - Tominanga, B - Cape of Manu, C - Loeha Island, D - Hola-hola, E - Kawatang, F - Beau dan, G - Cape of Bakara; FOI – frequency of incidency; TNF – total number of fish.

Linkage between habitat characteristics and endemic fish species. The study revealed that most of the endemic fish species were found in Tominanga (station A) and according to Principle Components Analysis (PCA) showed that phosphorus and aquatic vegetations of *Cyperus* sp. and *Ottelia mesenterium* have important role in the Lake Towuti in general. Based on endemic fish species, for example *T. celebensis* that the suspended solid, total phosphorus and vegetation covers (*Cyperus* sp. and *O. mesenterium*) are important factors for determining the distribution of this endemic fish. While total of organic matters (TOM) is an important factor for distribution of *P. cyanea.* Moreover, pH, TN, and *Borreria* sp. covers play an important role in determining the distribution of *Glossogobius flavipinnnis*; while pH, suspended solid (SS), TOM and sediment are crucial factors for *G. intermedius.* In addition ammonium is the single important factor for determining the distribution of *G. matanensis* in Lake Towuti (Figure 2).

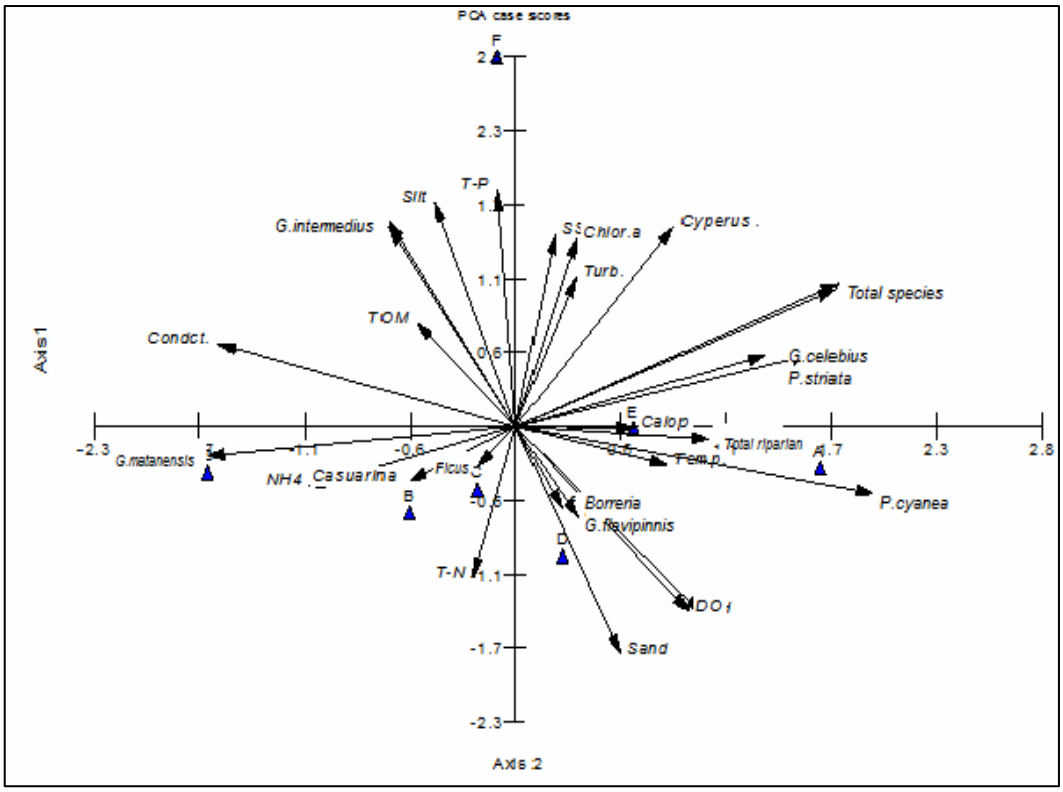

Figure 2. Principle Component Analysis between fish species and environmental factors of Lake Towuti.

Conclusions. The pH, total phosphorus, total organic matter, aquatic vegetations and suspended solid and sediment play an important role for distribution and existence of fishfauna in lake Towuti. The average values of those parameters meet the quality standard of Indonesian regulation for the fishery purpose. A total of 11 species of fish were recorded during the study, from which seven are endemic to Lake Towuti. Tominanga and Hola-hola stations have the highest fish diversity comparing with other locations.

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