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Ichthyofaunal diversity of mountain streams in the Tongboshan Nature Reserve, China

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Tongboshan Nature Reserve (between 28°03′30″ - 28°10′33″N and 118°12′00″ - 118°21′36″E) is located in the northeast of the Wuyi Mountain Range in the eastern Jiangxi Province. The fish fauna of mountain streams in the nature reserve was investigated seasonally during 2012. A total of 442 samples were collected and classified into four orders, eight families and 22 species. None of them collected in the nature reserve was exotic species. Among them, *Zacco platypus* was the most abundant fish species collected, followed by *Onychostoma barbatulu* and *Acrossocheilus parallens*. A total of 10 species were found to be endemic to China. Current threats to conservation of fishes in the nature reserve were identified and management solutions are suggested.

Key words: Tongboshan Nature Reserve, Mountain streams, ichthyofauna, diversity, conservation.

INTRODUCTION

Jiangxi Province (between 24°29′14″ - 30°04′41″N and 113°34′36″ - 118°28′36″E) is located in southern China, to the south of the middle and lower reaches of the Yangtze River. Poyang Lake, the largest freshwater body in China, is located in the north of Jiangxi Province. The area immediately surrounding Poyang Lake consists of low-lying alluvial plains prone to flooding. Mountains close to the boundaries of Jiangxi Province surround this region and all the five major rivers in the province (Ganjiang, Xinjiang, Fuhe, Raohe and Xiuhe Rivers) flow into the Poyang Lake. The drainage to Poyang Lake is a narrow outlet named Hukou, which flows into the Yangtze River and marks the northern border of the province. The sources of the rivers in Jiangxi Province are located in the surrounding mountains. Of a total of 220 recorded freshwater fish species throughout Jiangxi Province, about 131 species (59.5%) are believed to be endemic, many present in the mountainous regions (Huang et al., 2011). Protected areas such as nature reserves could play an important role in conservation of freshwater fishes within Jiangxi Province, but there is a need to better identify the conservation value of these areas in relation to biogeographical diversity of fishes and the factors impacting on fish communities.

Worldwide, freshwater fishes are the most diverse of all vertebrate groups, but are also the most threatened group of vertebrates after amphibians (Moyle and Leidy, 1992; Bruton, 1995; Duncan and Lockwood, 2001). Most

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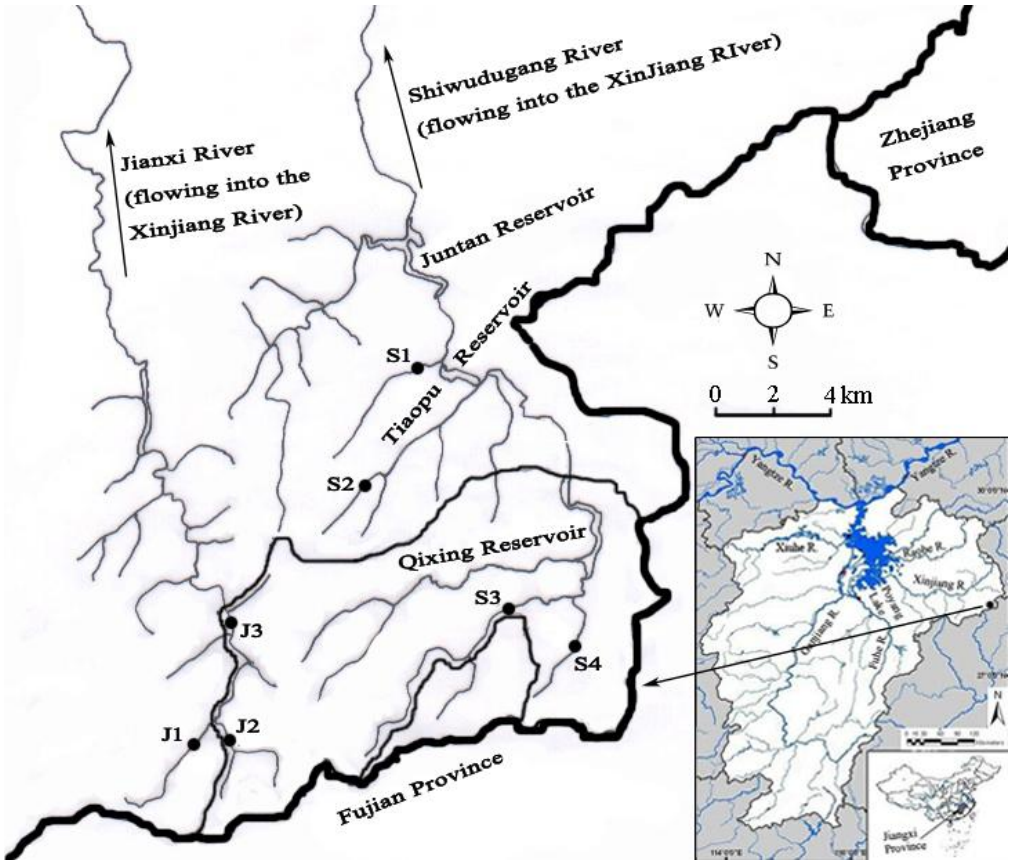

Figure 1. Map showing location of the TNR and sampling sites in the TNR.

mountain streams in the Tongboshan Nature Reserve (TNR) are shallow and the hydrology of most headwater streams has been modified by farming and irrigation of surrounding land. Recently, numerous anthropogenic disturbances, such as clear-cuts, small dams, road construction, fires and mining, have triggered physico-chemical alterations in the mountain streams (Tu et al., 2009; 2012).

At present, there have been several notable surveys of the flora and fauna within the nature reserve (Tu et al., 2009; 2012). However, until this work there have been no studies on the distribution and abundance of fish species in the nature reserve. The aims of the present study are:
(1) To characterize the species composition of the fish fauna and their distribution in the nature reserve;
(2) To review the main threats over fish biodiversity, and
(3) To establish some recommendations to the conservation of the fish fauna.

MATERIALS AND METHODS

Study area

The TNR (total area: 108 km^2, altitude: 1535 m, between 28°03′30″ - 28°10′33″N and 118°12′00″ - 118°21′36″E) is located in the northeast of the Wuyi Mountain Range in the eastern Jiangxi Province (Figure 1). The nature reserve presents humid subtropical climate and belongs to the forest ecological nature reserve for the conservation of evergreen broad-leaved forest ecological system and biodiversity. The annual precipitation is 1626.9 mm, annual temperature is 17.9°C, and forest coverage rate is up to 98% (Tu et al., 2009; 2012). Most mountain streams in the TNR flow into the Jianxi and Shiwudugang River which drain into the Xinjiang River (Figure 1).

Study site

Seven sampling sites were established on Jianxi and Shiwudugang River within the TNR (Figure 1). Sampling site selections were based on the representative habitat types present and accessibility during the study period. At each sampling site, the GPS position and altitude were recorded using a Garmin GPS map 76Cx. And water temperature, dissolved oxygen were measured with a hand-held YSI multi-meter. In addition, stream width and water depth were measured at each site.

Fish survey

Seasonally, samples were made at seven sites in the TNR during 2012. At each site, samples were collected using an electrofishing device consisting of two copper electrodes on wooden handles, powered by a 500-watt portable AC generator. Stunned fish were

Table 1. Characteristics of sampling sites within Jianxi River and Shiwudugang River, TNR, China.

Sampling sites		Altitude (m)	Depth (m)	Width (m)	Water temperature (°C)	Dissolved oxygen (mg/L)	Habitat description
Jianxi River	J1	715	0.2-1.5	1-4	9.6-17.2	9.6-10.8	Fast flowing and clear water, gravel and pebble substrate, shaded by forest canopy
	J2	796	0.1-1.2	1-3	9.0-16.8	9.8-11.2	Fast flowing and clear water, rocky and boulder substrate, shaded by forest canopy
	J3	670	0.2-2.0	2-5	10.2-17.6	9.5-10.6	Fast flowing and clear water, rocky and gravel substrate, river shaded by forest canopy
Shiwudugang River	S1	267	0.3-2.0	3-10	12.9-18.8	7.9-9.9	Slow flowing and slightly turbid water, gravel and sandy substrate, shaded by riparian vegetation
	S2	375	0.2-1.5	3-8	11.9-18.3	8.2-10.5	Slow flowing and clear water, gravel and sandy substrate, shaded by riparian vegetation
	S3	460	0.1-1.0	2-6	12.2-19.0	7.8-10.2	Slow flowing and clear water, gravel and boulder substrate, shaded by riparian vegetation
	S4	330	0.5-3.5	3-15	12.6-19.8	8.9-10.3	Slow flowing and slightly turbid water, gravel and sandy substrate, shaded by riparian vegetation

collected using dip nets or caught by hand. A cast net (mesh 5×5 mm; $\pi \times 0.6^2$ m = 1.13 m^2) was also used within shallow pools of the stream system to collect fish. Approximately 100 m of stream segment, typically comprising pool, run and riffle habitats, was sampled at each site. Collected specimens that could not be identified in the field were fixed in 10% formalin solution for accurate taxonomic verification. All specimens were identified according to Zhu (1995), Chen (1998), Chu et al. (1999) and Yue (2000).

Data analysis

The relative abundance of each species was estimated by:

$P_j = N_j / N$

where N_j = the number of species j collected in the TNR; N = the total number of all fish collected in the TNR. The Margalef index (D) and Shannon-Wiener index (H) were used to calculate fish species richness for each site (Peet, 1974; Magurran, 1988):

$D = (S - 1) / \ln N$ and $H_k = -\sum P_j \ln P_j$,

Where S = the total number of species collected in the TNR.

RESULTS

Stream characteristics and physicochemical parameters

The physical characteristics of each site are described in Table 1. Physico-chemical characteristics were similar among all studied sites in the TNR. Most of surveyed sampling sites were composed of sandy, gravel and pebbles substrates and the banks were lined by boulders and rocks. Shallow pools and riffles alternated in the segments studied. Generally, most mountain streams had clear water and were shaded by riparian vegetation or forest canopy. This appearance is typical of undisturbed forest stream at higher altitudes. All sampling sites were fully saturated with dissolved oxygen (mean ± SE, 9.6 ± 1.2 $mg \cdot L^{-1}$). And water temperature ranged from 9.0 to 19.8°C. The high dissolved oxygen could be attributed to low water temperature and high water speed.

Fish fauna

A total of 442 specimens were collected and classified into 22 species and eight families in the TNR (Table 2). Cyprinidae (11 species, 50.00% of the total number of fish species collected) was the dominant family followed by Homalopteridae (three species, 13.64%), Bagridae and Gobiidae (two species respectively) while Cobitidae, Siluridae, Amblycipitidae and Synbranchidae were represented by only one specie respectively. The dominancy of fish species in the TNR was *Zacco platypus* (102 specimens, 23.08% of the total specimens collected), followed by *Onychostoma barbatulu* (17.87%) and *Acrossocheilus parallens* (11.99%).

Table 2. Composition and distribution of fish species in the TNR, Jiangxi, China.

Family/species	*Jianxi River*			*Shiwudugang River*			
	J1	**J2**	**J3**	**S1**	**S2**	**S3**	**S4**
Cyprinidae							
Acrossocheilus parallens (Nichols, 1931)*				11	41		1
Onychostoma barbatulum (Pellegrin, 1908)*			1	2	43		33
Opsariichthys bidens Günther, 1873							16
Zacco platypus (Temminck and Schlegel, 1846)	35	31	32			2	2
Gnathopogon imberbis (Sauvage and Dabry de Thiersant, 1874)*							30
Chanodichthys erythropterus (Basilewsky, 1855)							1
Culter alburnus (Basilewsky, 1855)							3
Hemiculter leucisculus (Basilewsky, 1855)							5
Megalobrama amblycephala (Yih, 1955)							2
Sinibrama macrops (Günther, 1868)*							2
Rhynchocypris oxycephalus (Sauvage and Dabry de Thiersant, 1874)	10	11					
Cobitidae							
Misgurnus anguillicaudatus (Cantor, 1842)						2	21
Homalopteridae							
Formosania davidi (Sauvage, 1878)*					3		
Pseudogastromyzon changtingensis tungpeiensis (Chen and Liang, 1949)*		1		17	8		12
Vanmanenia stenosoma (Boulenger, 1901)*	1			1			
Siluridae							
Silurus asotus Linnaeus, 1758							2
Bagridae							
Pseudobagrus taiwanensis (Oshima, 1919)*	15	9	15				
Pseudobagrus medianalis (Regan, 1904)*						1	
Amblycipitidae							
Liobagrus anguillicauda (Nichols, 1926)*	1	1		1			
Gobiidae							
Rhinogobius cliffordpopei (Nichols, 1925)				3			3
Rhinogobius giurinus (Rutter, 1897)			1	6			1
Synbranchidae							
Monopterus albus (Zuiew, 1793)				1		1	1

*Endemic to China (Huang et al., 2011, FishBase: www.fishbase.org).

Overall, 10 species (45.45% of the total number of fish species collected) were found to be endemic to China in the TNR. Endemic fishes were classified into four families. The dominant family of endemic fishes was Cyprinidae (four species) and the subdominant families were Homalopteridae (three species), Bagridae (two species) and Amblycipitidae (one specie). The most common endemic species to China was *Onychostoma barbatulum* (79 specimens, 17.87% of the total specimens collected), followed in order of abundance by *Acrossocheilus parallens* (53 specimens, 11.99%), *Pseudobagrus taiwanensis* (39 specimens, 8.82%), *Pseudogastromyzon changtingensis tungpeiensis* (38 specimens, 8.60%), *Gnathopogon imberbis* (30 specimens, 6.79%), *Formosania davidi* and *Liobagrus anguillicauda* (3 specimens, 0.68% respectively), *Sinibrama macrops* and *Vanmanenia stenosoma* (2 specimens, 0.45% respectively), *Pseudobagrus medianalis* (1 specimen, 0.23%) in the TNR.

General distribution of fish species collected from the seven sampling sites in the TNR was shown in Table 2. Meanwhile, the ecological indices for two rivers in the TNR, Shiwudugang River compared to Jianxi River may be because the fish habitats in the Shiwudugang River have comparatively higher species richness and diversity (Table 3).

DISCUSSION

Factors favoring diversity and endemism

The results of the present field studies on the TNR showed that a total of 22 native species (10.00% of all

Table 3. Comparison of fish species diversity between Jianxi River and Shiwudugang River, TNR, China.

Mountain stream	Total number of species (S)	Total number of individuals (N)	*Margalef diversity index (D)*	*Shannon-Wiener diversity index (H)*
Jianxi River	8	164	1.37	1.57
Shiwudugang River	20	278	3.38	3.17

Jiangxi Province freshwater species) were collected or found to be distributed in mountain streams. For example, *Zacco platypus* (23.08% of the total specimens collected), *Onychostoma barbatulu* (17.87%), *Acrossocheilus parallens* (11.99%), *Pseudobagrus taiwanensis* (8.82%), *Pseudogastromyzon changtingensis tungpeiensis* (8.60%), *Rhinogobius giurinus* (1.81%), *Rhinogobius cliffordpopei* (1.36%) and *Liobagrus anguillicauda* (0.68%) are anatomically well adapted to live in fast flowing current with clear water and relatively higher dissolved oxygen concentration. Generally, they feed on algae growing on the rock as well as detritus and insects. Overall, ten endemic species (250 specimens, 56.56% of the total specimens collected) in the TNR represented 7.63% of total endemic species in Jiangxi Province (131 endemic species; Huang et al., 2011).

This study suggests that mountain streams in the TNR are very important for freshwater fish diversity and conservation in Jiangxi Province, especially for the endemic species. The more abundant or endemic species collected in the TNR may be partially due to habitat stability and lack of disturbances, such as introduction of exotic species. The riparian zones of streams in the TNR are well forested so that stream temperatures rarely reached 20°C even during the summer and dissolved oxygen levels were high at all sites, providing suitable environmental conditions for these fishes. Such as *Rhynchocypris oxycephalus* (21 specimens, 4.75% of the total specimens collected), a representative cold water species of the Holarctic Region in China, tend to be distributed in the north of China. The alternating Quaternary glacial and interglacial periods had the effect of moving *Rhynchocypris oxycephalus* south, where it survived in the small mountain streams where the water is cold (Zhang and Chen, 1997).

It is interesting to note that the fish diversity was comparatively higher in Shiwudugang River than in Jianxi River. The habitats such as water depth and current, shoreline slopes and bottom substrates were relatively different. The substrate in Shiwudugang River was formed mainly of sandy-gravel, whereas in Jianxi River the substrate consisted mainly of rocky-pebbles which are very unstable. According to Zakaria et al. (1999) this condition could be a more suitable habitat for higher species diversity and richness. And most fishes were recorded in a channel stream part of a wide river where the water is deeper and slower. Some species such as *Chanodichthys erythropterus*, *Culter alburnus*, *Hemiculter leucisculus*, *Megalobrama amblycephala*, *Sinibrama macrops* and *Silurus asotus* were only collected at site S4.

Current threats and conservation

During recent decades, streams and rivers in China have been drastically modified because of agricultural activities, drinking water supplies and the construction of multi-purpose dams, artificial reservoirs, levees, and weirs. These physical alterations and other human influences, such as road construction and deforestation have accelerated eutrophication (Fu et al., 2003). For example, Juntan Reservoir (closed on April 1985), Tiaopu Reservoir (completed in the 1980's) and Qixing Reservoir (closed on December, 1991) were built on Shiwudugang River. These factors strongly diminished effective migration for those species moving between different stream habitats. Small and fast-flowing streams have often been changed to large, slow-flowing streams. This change would cause that the organisms become restricted to mountainous areas and to be replaced by other beings adapted to slow-flowing streams (Hu et al., 2009).

In addition, some people go fishing as a source of food in the mountain streams of the TNR using rotenone and other poisons which usually are used to exterminate snails. This kind of fishing not only contributes to reduce fish biodiversity but is also harmful to human health.

Therefore, the primary objective for successful conservation of the freshwater ichthyofaunal diversity in the TNR must be to develop effective controls and management practices that enable life cycle success, dispersal and population maintenance within stream systems. It is necessary to improve effective fish passage facilities in order to enhance the connectivity of streams for fish dispersal and migration. Fishing activities in the TNR, especially using rotenone and other poisons must be strictly prohibited. The present work agrees with the statement that "long-term management and conservation of the fish fauna of nature reserves and other protected areas in Jiangxi Province will require good bench-mark sites and a long-term monitoring protocol" (Jang et al., 2003).

Conflict of Interest

The authors declared that they have no conflict of interest.

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