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A comparative study of fish species composition in two spatially isolated nature reserves, Jiangxi, China

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The ichthyofauna of mountain streams in the Danzhangshan Nature Reserve (DNR) and the Raoheyuan Nature Reserve (RNR) was investigated during 2008. A total of 385 samples were collected and classified into seven families and 14 species from the two nature reserves. There were 12 species belonging to seven families in the RNR, while eight species from four families were collected in the DNR. Overall, six species were found to be endemic to China, representing five families. The relative abundance of endemic species to China was higher in the RNR than in the DNR. Current threats to conservation of fishes in both nature reserves were reviewed and management solutions are suggested.

Key words: Fish, species, diversity, conservation, nature reserve, China.

INTRODUCTION

Jiangxi Province (between 113°34¢36²-118°28¢36²E and 24°29¢14²-30°04¢41²N) is located in south China, and to south of the middle and lower reaches of 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 River, Xinjiang River, Fuhe River, Raohe River and Xiuhe River) 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 mountain 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 highly threatened (Duncan and Lockwood, 2001). Most mountain streams in the Danzhangshan Nature Reserve (DNR) and the Raoheyuan Nature Reserve (RNR), both located in Jiangxi Province, are shallow and the hydrology of most headwater streams has been modified

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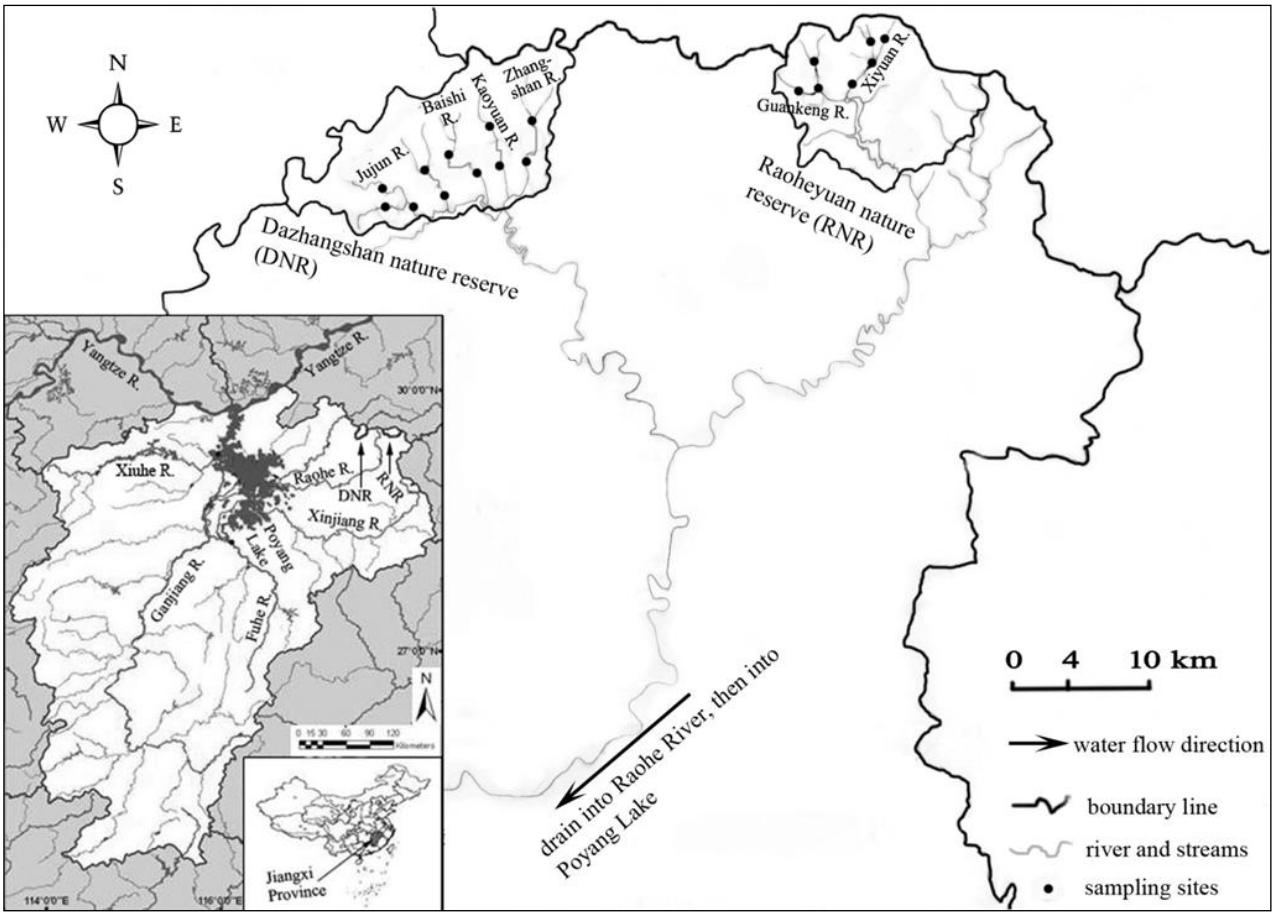

Figure 1. Map showing location of the two nature reserves and sampling sites.

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 (SFIPI, 2005a, b).

At present, there have been several notable surveys of the flora and fauna within the two nature reserves. These studies include surveys of the bird, amphibia, reptile, and insect faunas and flora (SFIPI, 2005a, b). However, until this work there have been no studies on the distribution and abundance of fish species in both nature reserves. The aims of the present study were: (1) to characterize the species composition of the fish fauna and their distribution in both nature reserves; (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 DNR (total area: 153.70 km^2, altitude: 1629.8 m) and RNR (total area: 115.96 km^2, altitude: 1468.5 m) are located in the northeastern Jiangxi Province (Figure 1). Both reserve areas present humid subtropical climate and belong to the forest ecological nature reserve for the conservation of evergreen broad-leaved forest ecological system and biodiversity (SFIPI, 2005a, b). Most mountain streams flow into the Le'an River which drains into the Raohe River (Figure 1).

Study site

Three-monthly samples were made at 11 sites in the DNR and seven sites in the RNR during 2008 (Figure 1). At each sampling site, the GPS position and altitude were recorded using a Garmin GPS map 76Cx. Physico-chemical parameters (water temperature, dissolved oxygen, pH, stream width and water depth) were measured. Water temperature, pH and dissolved oxygen levels were measured with a hand-held YSI multi-meter before entering the water to minimize disturbance. In addition, the habitat types were recorded for all sites.

Fish survey

All the stations were characterized by shallow water depths, narrow channel widths, and relatively fast water currents flowing over boulder substrate. At each site, samples were collected using an electrofishing device consisting of two copper electrodes on

Table 1. Key catchment characteristics within the sampled areas across the two nature reserves, including altitude and number of sampling sites, stream width and water depth, and habitat types.

Catchment	Nature reserve	Altitude (m)	Depth (m)	Width (m)	Number of sites surveyed	Habitat description
Xiyuan River (XR)	RNR	290-320	0.7-2.5	3.0-10.0	4	Slow flowing and slightly turbid water with gravel and sandy substrate, river shaded by riparian vegetation.
Guankeng River (GR)	RNR	295-356	0.6-2.0	4.0-11.0	3	Slow flowing and slightly turbid water, gravel and sandy bottom, shaded by riparian vegetation.
Baishi River (BR)	DNR	254-299	0.4-0.8	1.5-4.0	2	Fast flowing and clear water with rocky and pebbles sediment, shaded by forest canopy
Jujun River (JR)	DNR	245-312	0.3-0.9	1.5-5.0	5	Fast flowing and clear water with gravel, sandy and pebbles sediment, shaded by forest canopy.
Zhangshan River (ZR)	DNR	881-928	0.2-1.0	1.0-3.5	2	Fast flowing and clear water with gravel and rocky substrate, shaded by forest canopy.
Kaoyuan River (KR)	DNR	258-306	0.3-1.2	2.0-4.0	2	Fast flowing and clear water with rocky and sandy substrate, shaded by forest canopy.

wooden handles, powered by a 500-watt portable AC generator. Stunned fish were 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 in shallow pools of the stream system. Approximately, 100 m of stream segment, typically comprising pool, run and riffle habitats, was sampled at each site. Collected specimens were preserved in 10% formalin solution until counting, after which they were stored in 5% formalin solution. All specimens were identified according to Zhu (1995), Chen (1998), Chu et al. (1999) and Yue (2000).

Data analyses

The relative abundance of each species at each sampling site was estimated by: $P_{jk} = N_{jk} / N_k$, where N_{jk} = the number of species j collected in site k; N_k = the total number of all fish collected in site k. To assess specific differences in the two nature reserves, we calculated richness, evenness, diversity indices and Bray-Curtis dissimilarities index based on species and abundance data from each site using PRIMER 5 software.

RESULTS AND DISCUSSION

Physical and chemical parameters

Physico-chemical characteristics were similar among all studied sites in the two nature reserve (Table 1). Most of the 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, the rivers were speedy flowing. The water was clear, and shore vegetation was forest canopy. This appearance is typical of undisturbed forest stream at higher altitudes.

The mean (± SE) water temperature was 12.6 ± 5.2°C in the DNR and 15.8 ± 2.6°C in the RNR. Water temperature ranged from 9.6 to 15.2°C in the DNR and 11.6 to 19.2°C in the RNR. All sites in the two nature reserves were fully saturated with dissolved oxygen (mean ± SE, 9.2 ± 1.8 $mg \cdot L^{-1}$ in the DNR; 8.6 ± 1.2 $mg \cdot L^{-1}$ in the RNR). The high DO could be attributed to low water temperature and high water speed. Site average pHs were between 5.8 to 7.6 (mean ± SE, 6.8 ± 0.9) in both nature reserves.

Fish fauna in the DNR and the RNR

A total of 385 fish were collected and classified into 14 species and seven families at both nature reserves (Table 2). 118 fish belonging to eight species and four families were collected in the DNR, while a total of 267 fish were collected and classified into 12 species and seven families in the RNR (Table 2).

At both nature reserves, more than half of fish species (eight species, 57.14% of the total number of fish species collected) belonged to the family Cyprinidae (*Acrossocheilus parallens*, *Carassius auratus auratus*, *Opsariichthys bidens*, *Zacco platypus*, *Abbottina rivularis*, *Gnathopogon imberbis*, *Rhodeus ocellatus ocellatus* and *Rhynchocypris oxycephalus*). The following families have been represented by one species per family: Cobitidae (*Misgurnus anguillicaudatus*), Homalopteridae (*Vanmanenia pingchowensis*), Bagridae (*Pseudobagrus ondon*), Odontobutidae (*Odontobutis sinensis*), Gobiidae (*Rhinogobius cliffordpopei*) and Synbranchidae (*Monopterus albus*).

In the DNR, Cyprinidae was represented by five species (62.50% of the total fish species collected in this zone) and the 96 specimens corresponded to 81.36% of the total abundance. In the RNR we collected six species belonging to the family Cyprinidae (50.00% of the total fish species collected in this reserve) and the 205

Table 2. Ichthyofauna recorded in the two nature reserves.

Fish species	RNR		DNR				Total
	XR	GR	BR	JR	ZR	KR	
Cyprinidae							
Acrossocheilus parallens (Nichols, 1931)*	48	35		2		6	91
Carassius auratus auratus (Linnaeus, 1758)	1	5					6
Opsariichthys bidens Günther, 1873	59	21		1			81
Zacco platypus (Temminck & Schlegel, 1846)				1			1
Abbottina rivularis (Basilewsky, 1855)					6		6
Gnathopogon imberbis (Sauvage & Dabry de Thiersant, 1874) *	4	6					10
Rhodeus ocellatus ocellatus (Kner, 1866)		1					1
Rhynchocypris oxycephalus (Sauvage & Dabry de Thiersant, 1874)		25	56		24		105
Cobitidae							
Misgurnus anguillicaudatus (Cantor, 1842)	17	2		3			22
Homalopteridae							
Vanmanenia pingchowensis (Fang, 1935) *	11	1					12
Bagridae							
Pseudobagrus ondon (Shaw, 1930)*	2	3					5
Odontobutidae							
Odontobutis sinensis Wu, (Chen and Chong, 2002)*	2	12			15		29
Gobiidae							
Rhinogobius cliffordpopei (Nichols, 1925) *	10			1		3	14
Synbranchidae							
Monopterus albus (Zuiew, 1793)		2					2
Number of individuals	154	113	56	8	45	9	385

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

individuals obtained represented 76.78% of the total abundance.

The dominancy of the species in the DNR was *Rhynchocypris oxycephalus* [relative abundance (RA), 67.80%], *Odontobutis sinensis* (RA, 12.71%), *Acrossocheilus parallens* (RA, 6.78%), *Abbottina rivularis* (RA, 5.08%) and *Rhinogobius cliffordpopei* (RA, 3.39%). In the RNR, the dominancy was as follow: *Acrossocheilus parallens* (RA, 31.09%), *Opsariichthys bidens* (RA, 29.96%), *Rhynchocypris oxycephalus* (RA, 9.36%), *Misgurnus anguillicaudatus* (RA, 7.12%), *Odontobutis sinensis* (RA, 5.24%), *Vanmanenia pingchowensis* (RA, 4.49%), *Gnathopogon imberbis* and *Rhinogobius cliffordpopei* (RA, 3.75% respectively), *Carassius auratus auratus* (RA, 2.25%) and *Pseudobagrus ondon* (RA, 1.87%).

Overall, six species were found to be endemic to China and endemism of stream fish in both nature reserves combined was 42.86%. Relative abundance of endemic species to China was higher in the RNR (50.00%) than that in the DNR (37.50%). Endemic fishes were classified into three species and three families in the DNR, and six species and five families in the RNR. The dominant family of endemic fishes was Cyprinidae [101 individuals, relative abundance of endemics (RAE) 62.73%, two species] and the subdominant families were Odontobutidae (29 individuals, RAE 18.01%; one species), Gobiidae (14 individuals, RAE 8.70%; one species), Homalopteridae (12 individuals, RAE 7.45%; one species) and Bagridae (5 individuals, RAE 3.11%; one species). The most common endemic species to China was *Acrossocheilus parallens*, followed in order of abundance by *Odontobutis sinensis*, *Vanmanenia pingchowensis*, *Gnathopogon imberbis*, *Rhinogobius cliffordpopei* and *Pseudobagrus ondon* in the RNR. In the DNR, the endemic species were *Odontobutis sinensis*, the most frequent followed by *Acrossocheilus parallens* and *Rhinogobius cliffordpopei*.

The ecological indices for the two nature reserves showed that in the RNR, there were comparatively higher species richness, evenness and diversity. The Bray-Curtis dissimilarities index for the two nature reserves was 54.64% (Table 3).

Factors favoring diversity and endemism

The results of the present field studies on both nature reserves show that a total of 14 native species belonging to seven families were collected or found to be distributed in mountain streams. Overall, six species belonging to five families were found to be endemic to China. The

Table 3. The comparative ecological indices for the two nature reserves.

Parameter	DNR	RNR
Species count (S)	8	12
Number of individuals (n)	118	267
Common species (RA)	*Acrossocheilus parallens* (6.78%)	*Acrossocheilus parallens* (31.09%)
	Opsariichthys bidens (0.85%)	*Opsariichthys bidens* (29.96%)
	Rhynchocypris oxycephalus (67.80%)	*Rhynchocypris oxycephalus* (9.36%)
	Misgurnus anguillicaudatus (2.54%)	*Misgurnus anguillicaudatus* (7.12%)
	Odontobutis sinensis (12.71%)	*Odontobutis sinensis* (5.24%)
	Rhinogobius cliffordpopei (3.39%)	*Rhinogobius cliffordpopei* (3.75%)
Common family (S)	Cyprinidae (5)	Cyprinidae (6)
	Cobitidae (1)	Cobitidae (1)
	Odontobutidae (1)	Odontobutidae (1)
	Gobiidae (1)	Gobiidae (1)
Richness index		
Margalef (D)	1.467	1.969
Evenness indices		
Shannon's (H)	1.149	1.892
Pielou's (E)	0.552	0.761
Simpson's (λ)	0.485	0.209
Diversity indexes		
Hill's number, N_1	3.154	6.630
Hill's number, N_2	2.062	4.791
Bray-Curtis dissimilarities index	54.64%	

more abundant species or endemic species collected from both nature reserves belonged to the family Cyprinidae. Huang et al. (2011) stated that Cyprinidae is the most species-rich or endemic species-rich family recorded throughout Jiangxi Province. The fish diversity was comparatively higher in the RNR than in the DNR. The hydrological characteristics such as water depth and current, shoreline slopes and bottom substrates were relatively different. Mountain stream was wider in the RNR than in the DNR. The substrate in the RNR was formed mainly of sandy-gravel, whereas in the DNR, the substrate consisted mainly of rocky-pebbles which are very unstable. Several dense aquatic vegetations in the RNR have created small unique pool habitats. 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. Therefore, the caught fishes were mostly in the slow water area, particularly amongst the aquatic vegetation.

It is interesting to note that *R. oxycephalus* was dominant in the DNR and subdominant in the RNR. The presence of this representative cold water species of the Holarctic Region in China, which is restricted to mountain streams in Jiangxi Province (except for the Xunwushui River and the south of Jiangxi Province), may be related to the effect of Quaternary glaciations (Zhang and Chen, 1997). Fish of the genus *Rhynchocypris* tend to be distributed in the north of China whilst *R. oxycephalus* is found south as far as the Minjiang River in Fujian Province. It had suggested that the alternating Quaternary glacial and interglacial periods moved *R. oxycephalus* to the south where the species had survived in the small mountain streams where the water is cold (Huang et al., 2011).

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, Duanxin Reservoir was built in the RNR on December 1975 and Qinghua Reservoir was built on the boundary area of the DNR in April 1990. 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 make 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 catch fish for

food in the mountain streams of both nature reserves 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 both nature reserves 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 both nature reserves, especially using rotenone and other poisons must be strictly prohibited. The present work agrees with the statement 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).

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