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RESEARCH ARTICLE

Odonata diversity of the middle and lower reaches of the Red River basin, Yunnan, China

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Abstract: Eighty six species of Odonata are recorded from the middle and lower reaches of the Red River basin. *Archineura hetaerinoides* is recorded from China for the first time. Five genera and five species are new to Yunnan Province. Among the six types of odonate habitats, forest streams have the highest species diversity whereas ponds have the most species shared with other habitats. Both of these two habitats are important in biodiversity conservation and need urgent protection.

Key words: Odonata, new records, biodiversity, habitats, Red River, protection.

Introduction

The middle and lower reaches of the Red River basin is located in one of the biodiversity hotspots of the world, the Indo-Burma Hotspot, and is significant in biodiversity conservation (the IUCN Indo-Burma Freshwater Biodiversity Workshop in 2011). With plenty of river branches, complex terrain, diverse vegetation types, and distinct vertical differentiation, this area houses a huge number of dragonflies. Odonates occupy both aquatic and terrestrial habitats and sensitive to different environment factors, therefore, they are commonly treated as good bioindicators (Springate-Baginski *et al.* 2009). Recently, large-scale environment assessments, using relatively complete odonate biodiversity data, have been carried out (Clausnitzer *et al.* 2009; Riservato *et al.* 2009). Thus detailed biodiversity information is indispensable not only to conservation but also to environment assessment. However, up to now, no odonate diversity survey has been done for the Red River basin. According to data getting from field works between years 2006 to 2010, the present study

provides detailed Odonata biodiversity information of the middle and lower reaches of the Red River basin.

Material and methods

About the Red River basin

The Red River originates in Maocaoshao, Weishan, Yunnan, running from northwest to southeast, passing through Weishan, Nanjian, Shuangbai, Xinping, Yuanjiang, Honghe, Shiping, Jianshui, Yuanyang, Gejiu, Jinping, Pingbian, and Hekou, before flowing into Vietnam. The total length within China is 690 km with a fall of 2510 m (Xie 2002). The middle and lower reaches of the Red River basin (102°25'-103°57'E, 22°26'-23°22'N), 210 km from east to west and 70 km from south to north, lies in the low altitude plateau of western Yunnan, and connects to the Hengduan and Ailao Mountains. Xilong Mountain, the peak of this area, has an altitude about 3074 m, whereas the lowest point where the Nanxi River joins the Red River has an altitude of only 76 m. Below 500 m the vegetation is moist rain forest, from 500-900 m is montane rain forest, 1400–1800 m is tropical monsoon evergreen broad-leaved forest, 1800–2600 m is montane mossy evergreen broad-leaf forest, and above 2600 m is summit mossy dwarf forest (Jiang 1980).

Survey

During year 2006 to 2010, from March to August, 2–3 days of field survey was conducted each month. Sampled places include: low altitude riparian areas Honghe (Daheigong), Jianshui (Atu), Yuanyang (Nansha, Wubang, Lanyamen), Gejiu (Abang, Lushuihe), and middle to high altitude areas Gejiu (Yangjiatian Reservoir, Wugushao, Tabai), Jinping (Adebo, Maandi). Specimens were collected with a sweep net. Field photos were taken by a Nikon D90 camera. Specimens were first dipped in acetone for 4-8 hours then dried and stored into hyaline plastic bags. All studied specimens are deposited in the Institute of Entomology, College of Life Sciences, Nankai University.

Habitat classification

Odonate habitats were divided into six types according to water style (lotic or lentic), altitude, and other features.

Type **I** (ponds): Small area habitats (no more than 10×10 m^2) at low altitudes, rich in emergent aquatic plants, common to most sample locations.

Type **II** (paddy fields): The largest number of habitats as well as the most serious affected by human activities, dried and plowed several times each year.

Type **III** (reservoir): Large areas of lentic water in mountains, all higher than 1300 m, water level fluctuating a little in a year.

Type **IV** (river): Altitude between 100-500 m, high speed running water, usually muddy, yellowish or reddish color in rainy season. No emergent aquatic plants except some low bushes along the sides, including reaches of the Red River in Honghe, Yuanyang, and Hekou, and some branches.

Type **V** (forest stream): Clean water with trees and bushes along both sides, altitude between 200-1000 m (Fig. 1), including Jianshui (Atu), Yuanyang (Nansha and Lanyamen), Gejiu (Abang, Manhao and Lushuihe)

Type **VI** (montane stream): Very clean water, covered by trees and bushes, altitude between 1300-1700 m, usually at headwater area (Fig. 2).

Abbreviations: C- Common; DD-Data Deficient; O- Occasional; R- Rare; NC- New record for China; NY- New record for Yunnan.

Figures 1-2. Investigated habitats. **2,** Jinping, Maandi; **1,** Gejiu, Manhao.

Results

Species list

A total of 86 odonate species, belonging to two suborders, 16 families, and 57 genera are recorded (Table 1). *Archineura hetaerinoides* (Fraser, 1933) is new record for China. The genera *Rhipidolestes* Ris, *Coeliccia* Kirby, *Periaeschna* Martin, *Hemicordulia* Selys and *Devadatta* Lieftinck are new to Yunnan Province. Thirty species are common and 39 species occasional. *Devadatta ducatrix* Lieftinck, 1969, *Anisopleura yunnanensis* Zhu & Zhou, 1999, *Euphaea opaca* Selys, 1853, *Indocypha katharina* (Needham, 1930), *Anax guttatus* (Burmeister, 1839), *Sympetrum speciosum* Oguma, 1915 and *Trithemis pallidinervis* (Kirby, 1889) are rare species.

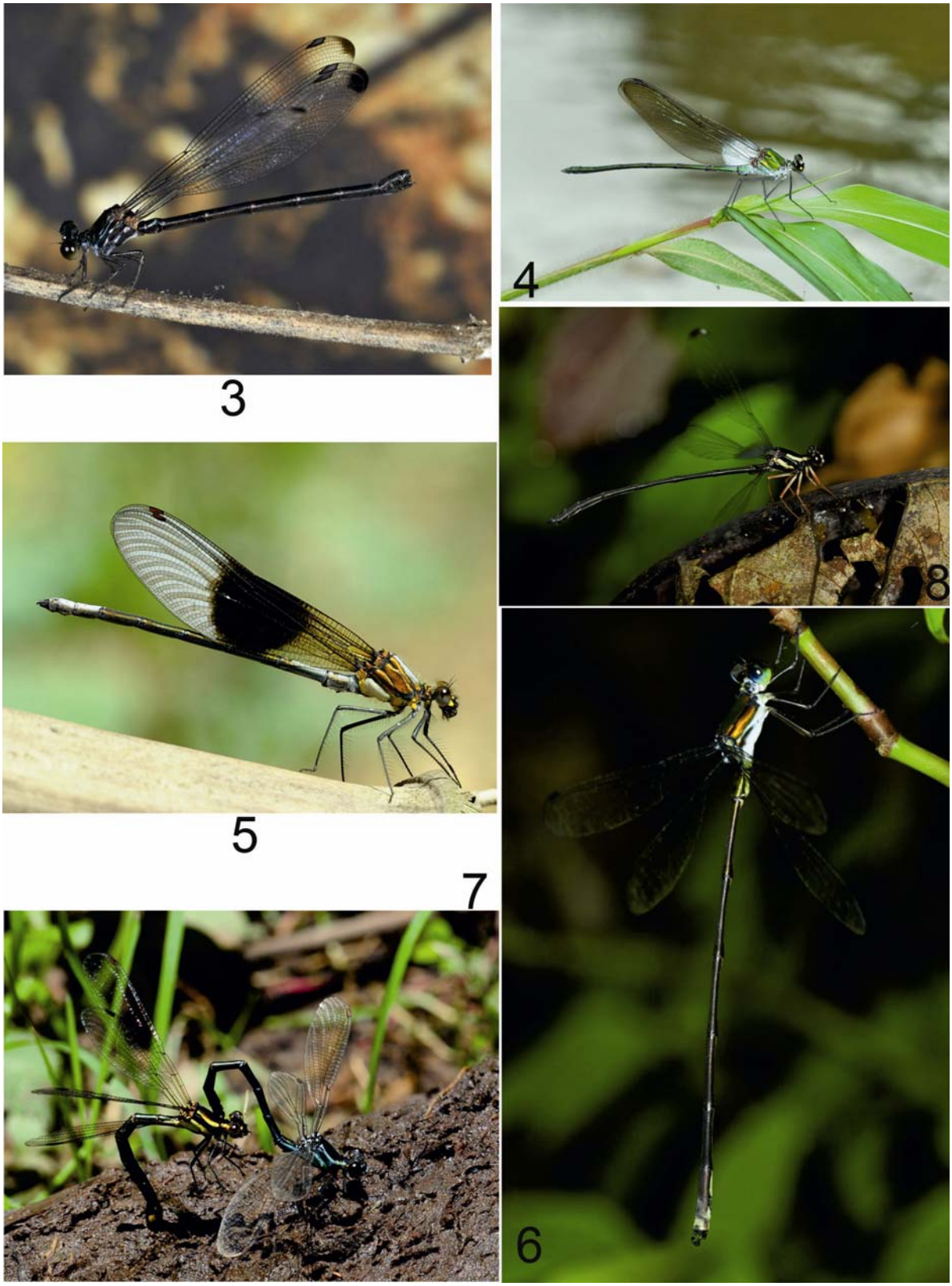
Table 1. Species diversity Odonata of the Red River basin, Yunnan, China.

Taxon	Location and Collection Data	Habitat Type	Status	Notes
Zygoptera				
Amphipterygidae				
Devadatta ducatrix Lieftinck, 1969	Gejiu, Manhao, Lushuihe tropical rain forest, 5.VI.2010, 500m, 1♂ 1♀.	V	R	NY; (Fig. 3)
Calopterygidae				
Archineura hetaerinoides (Fraser, 1933)	Gejiu, Manhao, Lushuihe tropical rain forest, 1.VI.2010, 550m, 1♂; Hekou, Huayudong Forest Park, 7.VI.2010, 109m, 1♂.	V	O	NC; (Fig.4)
Matrona basilaris Selys, 1853	Yuanyang, Nansha, 9.V.2009, 300m, 2♂1♀.	V	C	
Mnais andersoni McLachlan in Selys, 1873	Yuanyang, Nansha, 29.IV.2009, 200m, 1♂.	V	O	
Mnais gregoryi Fraser, 1924	Gejiu, Wugushao, 26.IV.2009, 1750m, 2♂2♀; ditto., 21.II.2011, 1750m, 1♂.	VI	O	(Fig. 5)
Neurobasis chinensis (Linnaeus, 1758)	Yuanyang, Nansha, 27.IV.2009, 230m, 1♂; Hekou, Huayudong Forest Park, 6.VI.2010, 150m, 1♂.	IV	C	
Vestalis gracilis (Rambur, 1842)	Gejiu, Abang, 3.VIII.2009, 300m, 1♂; Yuanyang, Nansha, 3.VIII.2009, 200m, 2♂2♀.	V	O	
Euphaeidae				
Anisopleura yunnanensis Zhu & Zhou, 1999	Jinping, Adebo, 28.VII.2009, 1600m, 1♂.	VI	R	
Euphaea opaca Selys, 1853	Yuanyang, Nansha, 26.IV.2009, 200m, 1♂.	IV	R	
Euphaea decorata Hagen in Selys, 1853	Hekou, 15.VIII.2009, 150m, 1♂.	V	O	
Euphaea masoni Selys, 1879	Hekou, Huayudong Forest Park, 6.VI.2010, 109m, 1♂1♀.	V	C	
Euphaea ochracea Selys, 1859	Manhao tropical rain forest, 27.VII.2010, 500m, 2♂.	V	O	
Chlorocyphidae				
Aristocypha fenestrella (Rambur, 1842)	Gejiu, Manhao, Lushuihe tropical rain forest, 31.VII.2009, 500m, 2♂; Yuanyang, Nansha, 27.2009, 300m, 1♂.	V	C	
Heliocypha biforata (Selys, 1859)	According to Chao (1994)'s record. Yunnan, Hekou.	V	DD	
Heliocypha perforata (Percheron, 1835)	Hekou, Huayudong Forest Park, 6.VI.2010, 109m, 2♂, 1♀.	V	C	

Indocypha katharina (Needham, 1930)	Gejiu, Abang, 21.V.2009, 350m, 1♂.	IV	R	
Synlestidae				
Megalestes sp.	Gejiu, Tabai, 19.VIII.2009, 1200m, 1♂; Gejiu, Wugushao, 16.VIII.2009, 1700m, 1♂.	VI	O	(Fig. 6)
Megalestes micans Needham, 1930	Jinping, Adebo, 29.VII.2009, 1600m, 2♂.	VI	O	
Megapodagrionidae				
Mesopodagrion tibetanum australe Yu & Bu, 2009	Kaiyuan, Mazheshao, 9.VI.2010, 1800m, 1♂, 1♀.	VI	O	(Fig. 7)
Rhipidolestes sp.	Jinping, Maandi, 3.VI.2010, 1100m, 1♂.	VI	R	NY (Fig. 8)
Coenagrionidae				
Agriocnemis femina oryzae Lieftinck, 1962	Mengzi, Lengquan, 15.VIII.2009, 800m, 1♂.	II	C	
Agriocnemis lacteola Selys, 1877	According to Chao (1994)'s record. Yunnan, Hekou.	I	DD	
Agriocnemis pygmaea (Rambur, 1842)	Mengzi, 24.VIII.2009, 1300m, 2♂, 2♀.	I	O	
Ceriagrion fallax Ris, 1914	Gejiu, Wugushao, 8.VIII.2009 1600m, 3♂, 1♀.	II/III	C	
Ischnura aurora Brauer, 1865	Yuanyang, Nansha, 28.IV.2009, 250m, 2♂.	II	O	
Ischnura rufostigma Selys, 1876	Gejiu, Wugushao, 23.VIII.2009, 1700m, 1♂, 1♀.	III	O	
Ischnura senegalensis (Rambur, 1842)	Yuanyang, Nansha, 28.IV.2009, 250m, 1♂, 1♀; Mengzi, 24.VIII.2009, 1300m, 2♂.	I/II	C	
Paracercion melanotum (Selys, 1876)	Gejiu, Wugushao, 23.VIII.2009, 1700m, 2♂.	III	O	
Pseudagrion pruinosum (Burmeister, 1839)	Hekou, Huayudong Forest Park. 6.VI.2010, 150m, 2♂.	V	O	
Pseudagrion rubriceps Selys, 1876	Yuanyang, Nansha, 28.IV.2009, 250m, 2♂.	I	O	
Platycnemididae				
Calicnemia soccifera Yu and Chen, 2013	Jinping, Maandi, 3.VI.2010, 1100m, 2♂, 1♀.	V	O	
Calicnemia eximia (Selys, 1863)	Gejiu, Manhao, Lushuihe tropical rain forest, 26.VII.2009, 550m, 2♂; Yuanyang, Nansha, 21.V.2009, 400m, 1♂.	V	C	
Coeliccia chromothorax (Selys, 1891)	Gejiu, Manhao, Lushuihe tropical rain forest, 26.VII.2009, 500m, 1♂, 1♀; Jinping, Maandi, 2.VI.2010, 1100m, 1♂, 1♀.	V	C	
Coeliccia sp.	Hekou, Huayudong Forest Park., 6.VI.2010, 150m, 1♂, 1♀.	V	O	NY (Fig. 9)
Copera ciliata (Selys, 1863)	According to Chao (1994)'s record. Yunnan, Yuanjiang.	V	DD	
Copera marginipes (Rambur, 1842)	Gejiu, Abang, 3.VIII.2009, 300m, 2♂; Gejiu, Manhao, Lushuihe tropical rain forest. 26.VII.2009, 700m, 1♂, 1♀.	V	C	
Indocnemis orang (Förster in Laidlaw, 1907)	Hekou, Huayudong Forest Park, 7.VI.2010, 150m, Yunnan, 3♂.	V	O	
Protoneuridae				
Prodasineura autumnalis (Fraser, 1922)	Hekou, Huayudong Forest Park, 7.VI.2010, 120m, 1♂, 1♀.	V	O	
Platystictidae				
Protosticta zhengi Yu &	Gejiu, Manhao tropical rain forest, 27.VII.2010,	V	O	

Bu, 2009	600m, 2♂; ditto 5.VI.2010, 550m, 1♂.			
Anisoptera				
Cordulegasteridae				
Anotogaster chaoi Zhou, 1998	Gejiu, Wugushao, 8.VIII.2009, 1700m, 1♀.	VI	O	
Aeshnidae				
Anax guttatus (Burmeister, 1839)	Gejiu, Shadian, Baipo Reservoir, 1♂, 20.VII.2005, 1000m.	III	R	
Anax nigrofasciatus Oguma, 1915	Jinping, Adebo, 30.VI.2009, 1400m, 1♂.	III	C	
Anax parthenope julius Brauer, 1865	Mengzi, 12.VIII.2009, 1300m, 1♂.	I/III	C	
Periaeschna sp.	Gejiu, Tabai, 9.VIII.2009, 1200m, 1♂.	V	R	NY
Gynacantha subinterrupta Rambur, 1842	Gejiu, Manhao, 2.VI.2010, 300m, 1♀.	I	O	
Gomphidae				
Burmagomphus arboreus Lieftinck, 1940	Hekou, Huayudong Forest Park. 7.VI.2010, 109m, 2♂.	V	O	
Davidius sp.	Gejiu, Wugushao, 8.VIII.2009, 1700m, 1♀; ditto, 23.VIII.2009, 1700m, 1♂.	VI	R	(Fig. 10)
Gomphidia interruptstria Zha, Zhang & Zheng, 2005	Hekou, Huayudong Forest Park, 7.VI.2010, 109m, 1♂.	V	O	
Ictinogomphus pertinax (Hagen in Selys, 1854)	Yuanyang, Nansha, 10.V.2010, 200m, 1♂; ditto, 18.V.2009, 220m, 1♂; Gejiu, Abang, 21.VIII.2009, 250m, 1♂.	I/II	C	
Nepogomphus sp.	Gejiu, Manhao, Lushuihe tropical rain forest. 26.VII.2009, 500m, 1♂.	V	R	(Fig. 11)
Nychogomphus lui Zhou, Zhou & Lu, 2005	Gejiu, Manhao, Lushuihe tropical rain forest. 27.VII.2009, 550m, 1♂.	IV	O	
Nychogomphus striatus (Fraser, 1924)	Yuanyang, Nansha, 7.VIII.2009, 200m, 1♀; Gejiu, Abang, 21.VIII.2009, 250m, 1♂.	IV	O	
Paragomphus capricornis (Förster, 1914)	Gejiu, Abang, 3.VIII.2009, 250m, 2♂.	IV	C	
Phaenandrogomphus tonkinicus (Fraser, 1926)	Gejiu, Tabai, 9.VIII.2009, 1200m, 1♂.	V	O	
Scalmogomphus wenshanensis Zhou, Zhou & Lu, 2005	Yuanyang, Nansha, 27.IV.2009, 200m, 1♂, 1♀.	IV	O	(Fig. 12)
Macromiidae				
Epophthalmia elegans (Brauer, 1865)	Mengzi, 12.VIII.2009, 1300m, 1♂.	I/III	C	
Macromia moorei Selys, 1874	Gejiu, Tabai, 17.V.2009, 1200m, 2♂. Only have larvae.	V	O	
Corduliidae				
Hemicordulia sp.	Gejiu, Wugushao, 23.VIII.2009, 1700m, 1♂.	VI	R	NY (Fig. 13)
Libellulidae				
Acisoma panorpoides Rambur, 1842	Hekou, 8.VI.2010, 200m, 1♂.	I	O	
Brachydiplax chalybea Brauer, 1868	Hekou, Huayudong Forest Park, 27.VII.2009, 300m, 1♂.	I	O	
Brachythemis contaminata (Fabricius, 1793)	Hekou, 8.VI.2010, 200m, 1♂.	I	C	
Crocothemis servilia	Hekou, Huayudong Forest Park, 27.VII.2009,	I	C	

(Drury, 1773)	600m, 1♂; Jinping, Adebo, 27.VII.2009, 1300m, 1♀.			
Diplacodes trivialis (Rambur, 1842)	Yuanyang, Nansha, 26.IV.2009, 200m, 1♂; Mengzi, 12.VIII.2009, 1300m, 1♀; Hekou, 8.VI.2010, 200m, 1♂, 1♀.	I/II	C	
Neurothemis fulvia (Drury, 1773)	Yuanyang, Nansha 3.V.2009, 200m, 1♂; Hekou, 8.VI.2010, 200m, 1♂.	I	C	
Neurothemis tullia (Drury, 1773)	According to Chao (1994)'s record. Yunnan, Hekou.	I	DD	
Onychothemis testacea Martin, 1904	Hekou, Huayudong Forest Park, 6.VI.2010, 109m, 1♂.	V	O	
Orthetrum albistylum Selys, 1848	Jinping, Adebo, 30.VII.2009, 1300m, 1♀; Gejiu, Wugushao, 23.VIII.2009, 1600m, 1♀.	II/III	C	
Orthetrum glaucum (Brauer, 1865)	Yuanyang, Nansha, 28.V.2009, 200m, 1♂; Gejiu, Manhao, Lushuihe tropical rain forest, 27.VII.2009, 400m, 1♂.	V	C	
Orthetrum luzonicum (Brauer, 1868)	Gejiu, Tabai, 19.VIII.2009, 1200m, 1♀; Jinping, Adebo, 30.VII.2009, 1300m, 1♂.	II	O	
Orthetrum pruinosum neglectum (Rambur, 1842)	Gejiu, Tabai, 19.VIII.2009, 1200m, 1♂; Gejiu, Abang, 21.VIII.2009, 250m, Yunnan, 1♂, 1♀.	I/II	C	
Orthetrum sabina (Drury, 1770)	Yuanyang, Nansha, 18.V.2009, 200m, 1♂; Mengzi, 11.VIII.2009, 1300m, 1♂, 1♀.	I/II	C	
Orthetrum triangulare (Selys, 1878)	Gejiu, Wugushao, 26.V.2009, 1600m, 1♂; Gejiu, Manhao, Lushuihe tropical rain forest, 26.VII.2009, 500m, 1♂; Kaiyuan, Mazheshao, 9.VI.2009, 1300m, 1♂	III	C	
Palpopleura sexmaculata (Fabricius, 1787)	Gejiu, Wugushao, 8.VIII.2009, 1600m, 1♂.	I/II	C	
Pantala flavescens (Fabricius, 1798)	Mengzi, 29.II.2008, 1300m, 1♂.	I/II	C	
Potamarcha congener (Rambur, 1842)	Yuanyang, Nansha, 9.V.2009, 200m, 1♂.	I	O	
Pseudothemis zonata (Burmeister, 1839)	Yuanyang, Nansha, 9.V.2009, 200m, 1♂, Only have photo.	I/III	C	
Sympetrum fonscolombii (Selys, 1840)	Gejiu, Wugushao, 8.VII.2003, 1700m, 1♂.	III	O	
Sympetrum speciosum Oguma, 1915	Gejiu, Wugushao, 26.V.2009, 1700m, 1♂.	III	R	
Tholymis tillarga (Fabricius, 1798)	Yuanyang, Nansha, 19.V.2009, 200m, 1♀; ditto, 30.V.2010, 200m, 1♀.	I	O	
Tramea sp.	Yuanyang, Nansha, 26.IV.2009, 200m, 1♂.	IV	R	
Tramea transmarina euryale (Selys, 1878)	Hekou, 8.VI.2010, 300m, 1♂, 1♀.	I	O	(Fig. 14)
Tramea virginia Rambur, 1842	Gejiu, Abang, 21.VIII.2009, 250m, 1♂.	I	O	
Trithemis aurora (Burmeister, 1839)	Mengzi, 12.VIII.2008, 1300m, 1♂; Hekou, Huayudong Forest Park, 17.VI.2010, 109m, 1♂.	I	C	
Trithemis festiva (Rambur, 1842)	Yuanyang, Nansha, 2.VIII.2009, 200m, 1♂.	V	C	
Trithemis pallidinervis (Kirby, 1889)	Kaiyuan, Sanjiaohai Reservoir, 8.VII.2006, 1000m, 1♂; Gejiu, Wugushao, 11.VII.2003, 1700m, 1♀.	III	R	
Zygonyx iris malayana Laidlaw, 1902	Yuanyang, Nansha, 5.V.2009, 200m, 1♂; Hekou, Huayudong Forest Park, 6.VI.2010, 150m, 1♂.	IV	C	



Figures 3-8. Odonata species. **3,** *Devadatta ducatrix* Lieftinck; **4,** *Archineura hetaerinoides* Fraser; **5,** *Mnais gregoryi* Fraser; **6,** *Megalestes* sp.; **7,** *Mesopodagrion tibetanum australe* Yu & Bu; **8,** *Rhipidolestes* sp.

Figures 9-14. Odonata species. **9,** *Coeliccia* sp.; **10,** *Davidius* sp.; **11,** *Nychogomphus lui* Zhou, Zhou & Lu; **12,** *Scalmogomphus wenshanensis* Zhou, Zhou & Lu; **13,** *Hemicordulia* sp.; **14,** *Tramea transmarina euryale* (Selys).

Species diversity in habitats

Species diversity in each habitat has been shown in Figs. 15-16. Paddy fields (Type II) are usually near to rivers (Type IV). However species occurring in these two habitats are seldom overlapped to each other. For example, *Ictinogomphus pertinax* is only found patrolling around paddy fields and ponds but never flying into rivers nearby. Meanwhile, 12 paddy fields species as well as 7 reservoirs (Type III) species are also found in ponds (Type I). Rivers, forest streams (Type V), and montane streams (Type VI) have all their species exclusively, i.e. never been found in other habitats.

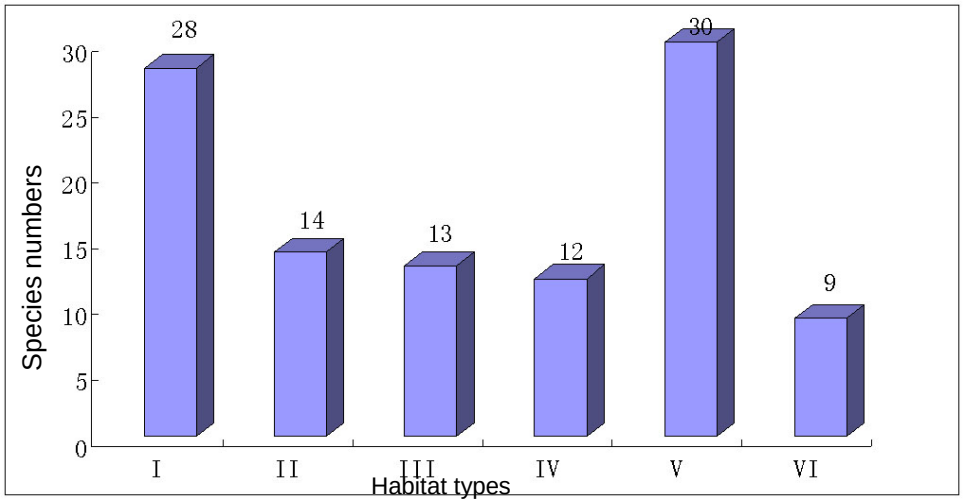


Figure 15. Numbers of species in each type.

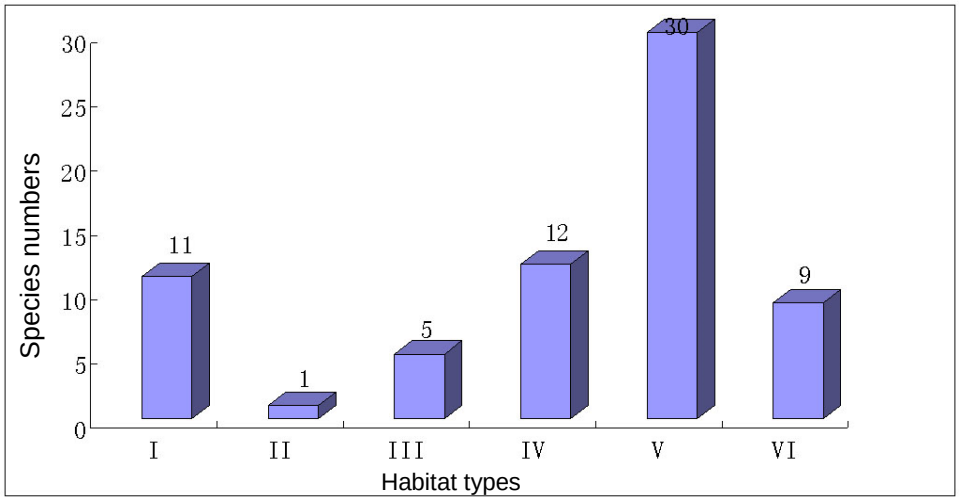


Figure 16. Number of species unique to each type.

Discussion

Archineura hetaerinoides, a charming and cryptic calopterygid damselfly, is formally reported to occur in China for the first time (Fig. 4) which is known limited to Laos and Vietnam before (Karube 2002). Some other uncommon species are also distributed in this area, such as *Devadatta ducatrix* (Fig. 3), *Mnais gregoryi* (Fig. 5), etc. The high species diversity (relative to the area of the basin) and the presence of many rare species indicate that the middle and lower reaches of the Red River basin is a real paradise for dragonflies. Some

species treated as undetermined species ('sp.') presently need further researches when complementary specimens are available.

Generally, low altitude areas have more species than middle and high altitude. Forty-eight species occurs below 500 m with 34 of them are limited to this scope. Thirty three species occurring between 1300–1700 m and 20 of them are restricted to this scope. Lotic waters own more species (51 species) than lentic (34 species) waters. Therefore, forest streams have the largest species diversity and the most exclusive species. Ponds also have distinct high species diversity, sharing a large number of species with other habitat types (paddy fields and reservoirs). To some degree ponds can be the 'refuges' for species in paddy fields and reservoirs which are intensively affected by human activities.

Many little hydropower stations are in building now in the middle and lower reaches of the Red River basin, which may considerably change the local water environment, especially in low altitude areas. Habitats of dragonflies may suffer from severe damage. Emergency measures should be taken to protect these habitats, especially for forest streams and ponds. Little ponds are quite easy to be neglected and destroyed by human activities since they are small in size and usually treated as inessential to both biodiversity conservation and agriculture.

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