

Rapid Communication**The first wild record of invasive redhead cichlid, *Vieja melanura* (Günther, 1862), in Hainan Island, China**Ren Zhu¹, Kang Chen^{1,2,3}, Xingwei Cai⁴, Gaojun Li⁴, Yifeng Chen^{1,2,*} and Zhixin Shen^{4,*}¹Laboratory of Biological Invasion and Adaptive Evolution, Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan 430072, China²University of Chinese Academy of Sciences, Beijing 100049, China³Yangtze River Fisheries Research Institute of Chinese Academy of Fishery Sciences, Wuhan, 430223, China⁴Hainan Academy of Ocean and Fisheries Sciences, Haikou 571126, ChinaAuthor e-mails: zhuren@ihb.ac.cn (RZ), chenkang992@163.com (KC), Caixw618@163.com (XC), 150599790@163.com (GL), chenyf@ihb.ac.cn (YC), shen_266@msn.com (ZS)

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The redhead cichlid, *Vieja melanura* (Günther, 1862), is a freshwater and brackish water fish native to southern Mexico and Costa Rica. It was introduced into China as an ornamental fish species in the 1990s. During a comprehensive fish survey in Hainan Island conducted in April and August 2019, twenty redhead cichlid individuals, including two mature males, four mature females and fourteen juveniles, were captured at four sites in the Nandu River. This finding reveals that this species has successfully established feral populations in Hainan Island. This is the first report of the invasion success of redhead cichlid in Hainan Island, even in China. The redhead cichlid is very likely to compete with native species (e.g., *Culter recurviceps*) by occupying similar niches, thereby threatening the survival of native species and changing food webs, ecosystem structures and functions. Local governments and environmental protection organizations should carry out surveys to monitor the redhead cichlid invasion and implement interventions to prevent further spread. The escape of ornamental fishes to natural water bodies is an important contributor to elevated invasion risks, which should be paid attention to globally.

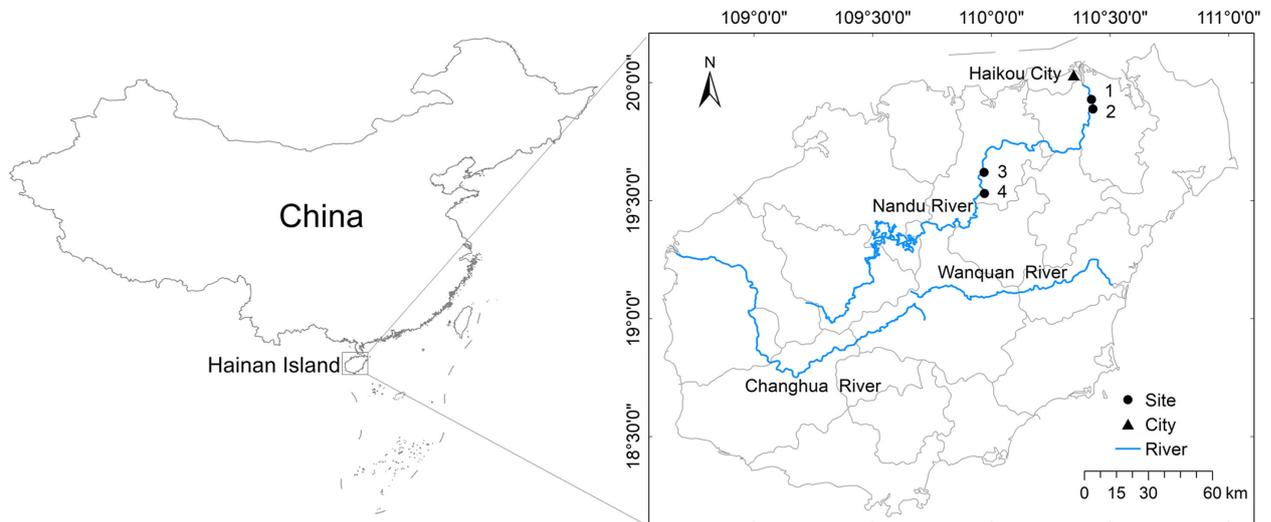
Key words: biological invasion, ornamental fish, *Vieja melanura***Introduction**

The introduction of non-native species is one of the major threats to biodiversity conservation (Pyšek and Richardson 2010). For aquatic ecosystems, fish are the most frequently introduced animal group around the world (Gozlan et al. 2010), and non-native fishes have been recognized as one of the main causes of the worldwide decline of aquatic biodiversity (Clavero and Garcia-Berthou 2005; Vitule et al. 2009). Aquarium and aquaculture fishes are considered as the primary sources of non-native fish introduction in China, in particular for the introduction of ornamental fish (Xiong et al. 2015; 2017).

In China, many non-native fishes have been introduced via aquarium trade and aquaculture (Xiong et al. 2015; Wang et al. 2016). However, there

Table 1. Latitude, longitude, altitude and environmental parameters of the sites investigated on the Hainan Island in China.

Site	Latitude (°)	Longitude (°)	Altitude (m)	Environmental parameters				
				Turbidity (NTU)	Water temperature (°C)	Dissolved oxygen (mg/L)	Conductivity (us/cm)	pH
1	19.928561	110.421925	1	25.4	30.7	4.48	95.7	6.98
2	19.888081	110.427881	7	44.4	31.1	4.31	146.2	6.83
3	19.619969	109.969631	45	8.5	29.2	5.57	129.8	7.52
4	19.530069	109.971069	54	12.5	30.1	5.30	121.9	7.59


Figure 1. Map showing sampling sites on the Hainan Island in China.

are few regulations on the management of ornamental fish in China (Wang et al. 2016). As the result, many non-native ornamental species have escaped and established feral populations in the wild, consequently becoming naturalized species (Xiong et al. 2017).

Hainan Island is a tropical island in southern China, and is the second-largest island of the country, with the area around 33 900 km². The island harbors many riverine systems, including Nandu River, Changhua River and Wanquan River, that have a catchment area of over 3 000 km² and drain directly into the ocean. It is also a biodiversity hotspot area (Myers et al. 2000; Sodhi et al. 2001), and more than 10% of the freshwater fish species in Hainan Island are non-native species (Xiong et al. 2018). Therefore, the monitoring and management of non-native fish in Hainan Island is a priority for local governments and environmental protection organizations.

The redhead cichlid, *Vieja melanura* (Günther, 1862), is a freshwater and brackish water fish native to southern Mexico and Costa Rica. It was introduced into China as an ornamental fish species in the 1990s (IFF 2018). In this communication, we report a wild population of the redhead cichlid for the first time in Hainan Island, China.

Materials and methods

A comprehensive fish survey was done in three rivers, including the Nandu, Changhua, Wanquan River, in Hainan Island in April and August 2019. The details and locations of sampling sites are shown in Table 1 and Figure 1.



Figure 2. The picture of redhead cichlid (specimen number: 1904171; Sex: Male; Standard length: 153mm; Total weight: 216.15 g, photograph by Ren Zhu).

Specimens were captured by dip nets (0.5 m in diameter, mesh-size 1 mm) and gill nets (length 20 m × height 1 m, mesh-size 5 mm). Fish were measured to total and standard length (to the nearest mm), and weighed (to the nearest 0.1 grams). The voucher individuals were euthanized by an overdose of anesthesia. A small piece of fin tissue was clipped and stored in 75% alcohol, and the specimens were soaked in 5% formaldehyde for six hours and stored in 70% ethanol for long-term preservation. Morphological measurements (based on Conkel 1993), molecular sequencing (COI, Valdez-Moreno et al. 2009) and specimen anatomies were conducted in the laboratory (Laboratory of Biological Invasion and Adaptive Evolution, Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan). Males, females and juveniles were determined by observing gonads. The water environmental parameters of habitats were measured with HACH 2100Q (USA, ©Hach Company) and YSI Pro20 (USA, ©YSI Incorporated).

Results

A total of twenty redhead cichlid individuals were captured from four sites in the Nandu River. The specimens were morphologically diagnosed according to the following features: possesses large black spots at the base of the caudal fin and on the posterior part of the body, dark horizontal to slightly angled band or stripe that typically extends from the caudal-fin base to near the mid-point of the body, the forehead is slightly raised, the front part of the body is red and the back part is purplish black (Figure 2). The molecular sequences of specimens were also checked and matched (100%) on the NCBI database (<https://www.ncbi.nlm.nih.gov/>, GenBank accession number: EU752026.1). The morphometric characteristics of specimens are shown in Table 2. The ranges of total length, standard length and total weight for the specimens were 76–198 mm, 57–153 mm and 8.23–216.15 g, respectively. The water environmental parameters of habitats were shown in Table 1 and Figure 3, with the turbidity ranging from 8.5 to

Table 2. Biological data of redhead cichlid on the Hainan Island in China.

Sex	Number	Total length (mm)		Standard length (mm)		Total weight (g)	
		Range	Mean	Range	Mean	Range	Mean
Male	2	84–198	141.00	65–153	109.00	10.65–216.15	113.40
Female	4	110–179	151.75	86–135	116.50	30.73–171.14	98.96
Juvenile	14	76–110	94.21	57–87	73.00	8.23–33.60	19.85


Figure 3. Habitats of sampling redhead cichlid. Photographs by Kang Chen.

44.4 NTU, water temperature from 29.2 to 31.1 °C, dissolved oxygen from 4.31 to 5.57 mg/L, conductivity from 95.7 to 146.2 us/cm, and pH from 6.83 to 7.59.

Discussion

Specimens of mature males and females, and small-size juveniles captured in our fish surveys strongly indicate that the redhead cichlid have successfully colonized wild water bodies in Hainan Island. The redhead cichlid is an omnivore and oviparity species with a high fecundity. It reaches sexual maturity at 10 cm, can produce 300–500 fry per spawning and up to 1 000 eggs per year (Baensch and Riehl 1985; Conkel 1993). In addition, this species has a strong territorial behavior to protect eggs and larvae. The optimal water temperature for this species is between 25 and 29 °C. The climate of Hainan Island is tropical maritime, with the annual average

temperature varying between 22.8 and 25.8 °C (4–16 °C in January and 9–28 °C in August) (Xiong et al. 2018). These ecological characteristics and the matched climatic conditions allow this species to establish feral populations in Hainan Island.

A recent study has shown that there are 439 non-native freshwater fish species introduced in China, and some of non-native freshwater fish species have successfully established feral populations (Xiong et al. 2015). Aquatic non-native species have been a main threat to Chinese freshwater biodiversity (Xiong et al. 2018; 2019). For example, invasive freshwater fish could lead to declines of native endemic species through hybridization with closely related species, competition for food and habitat, predation, and habitat and ecosystem alterations (Xiong et al. 2015). Despite redhead cichlid occurring in the ornamental trade in China for a long time, there has been no record of it having established populations in the wild (Xiong et al. 2015; 2018). This study is the record of a naturalized population of this species in Hainan Island and also the whole China.

Non-native freshwater fish invasions have caused severe declines of native biodiversity in China (Xie and Chen 1999). Hainan Island, located within the Indo-Burma global biodiversity hotspot area, is a biodiversity hotspot of freshwater fishes in China (He et al. 2020). The freshwater fish fauna of this area includes 138 native species and 16 non-native species (Xiong et al. 2018). In this study area, we found that the redhead cichlid co-occurs with many endemic fishes, such as *Hainania serrata*, *Culter recurviceps*, *Pseudohemiculter hainanensis*, *Toxabramis houdemeri*, *Cranoglanis boudierius multiradiatus* and *Mastacembelus armatus*, in the same catchment. Some of these endemic species (e.g., *C. recurviceps*) occupy the similar trophic level and habitat as redhead cichlid. Thus, these native species are very likely to be threatened by the redhead cichlid through interspecies competition. To prevent the spread and potential impacts of redhead cichlid, local governments and environmental protection organizations should carry out surveys to monitor the redhead cichlid invasion and assess the feasibility of appropriate interventions (e.g., eradication or containment). In addition, the escape of ornamental fishes to natural water bodies is an important contributor to elevated invasion risks, which should be paid attention to globally.

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