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Research Article

Hydrocleys nymphoides (Humb. & Bonpl. ex Willd.) Buchenau (Alismataceae): a naturalized aquatic plant in China

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Abstract

Non-native aquatic plants have caused significant negative ecological and economic impacts in freshwater ecosystems. Waterpoppy (*Hydrocleys nymphoides*) is a rooted floating-leaf vascular plant native to South America that has been introduced to Europe, Oceania, and Africa through the aquarium trade. Recently, this species was brought to China where it has established widespread feral and naturalized populations in the south, southwest and lower reach of Yangtze River. Information about this species in China is very limited. We provide a preliminary overview of its introduction pathway, current distribution, and the ecological and economic impacts caused by waterpoppy in China.

Key words: aquarium trade, macrophyte, water gardens, wetlands

Introduction

Non-native species are among the most serious threats to biodiversity and ecosystem function in aquatic habitats (Vilà et al. 2010). Non-native plants are noteworthy because they alter the community structure and function of aquatic ecosystems, as well as diminishing the ecological services wetlands provide (Hussner 2012). Non-native aquatic plants, such as waterhyacinth (*Eichhornia crassipes*), should be more closely monitored by environmental managers and environmental protection organizations (Wang et al. 2016).

In the past forty years, China has imported a very large number of non-native aquatic plants, significantly greater than introductions in Europe and North America (Wang et al. 2016). As a result, the establishment of non-native aquatic plants in a diversity of China's wetlands has occurred rapidly (Xiong et al. 2018; Wang et al. 2020). Some of these exotics have caused serious environmental problems, including a reduction in biodiversity, deterioration of water quality, and flooding (Wang et al. 2021; Xiong et al. 2021). However, information about some of these non-natives is sparse and has limited the effectiveness of management and control efforts.

Waterpoppy, *Hydrocleys nymphoides* (Humb. & Bonpl. ex Willd.) Buchenau (Alismataceae), is a floating-leaf vascular plant species native to

South America that occurs in still water habitats (Nxumalo et al. 2016). Because of its rapid growth rate and clonal reproduction that prefers still water habitats and clonal reproduction through stem fragments, this species forms dense monospecific stands quickly. Large stands of waterpoppy outcompete native plants by simply crowding them out, preventing the penetration of sunlight in the water column, depleting dissolved oxygen in the water, and impeding water flow (Nxumalo et al. 2016). This species is recognized and listed as a serious problematic invasive plant in Europe, Oceania, and Africa (Williams 2008; Nxumalo et al. 2016; Kodela and Jobson 2018).

The purpose of this study is to provide a preliminary review of its introduction pathway, current distribution, and the potential impacts of waterpoppy in China. This study provides useful information and recommendations to better manage this invasive species.

Materials and methods

Field surveys

Although aquatic plants are easily confused when without flowers or fruits with some native plants, such as watershield (*Brasenia schreberi*) and yellow floating heart (*Nymphoides peltatum*) that have floating leaves like water poppy, they are obviously different as they lack spongy midrib on the abaxial leaf surface (Kodela and Jobson 2018).

Between 2003 and 2020 we conducted over 50 field investigations elucidating the taxonomy and distribution of aquatic plants in China. From June to August each year of field investigation, from three to five groups of investigators (three to seven people in each group) carried out extensive geobotanical surveys in total nearly 280 sites. At each site, the plant community was recorded by standardized methodology and protocols described by Fang et al. (2009). In each of the surveys, some basic biological traits (plant taxonomy), biogeographic information (longitude, latitude) and habitat characteristics (habitat type) were recorded. We revisited all sites where waterpoppy was occurring the subsequent year. For this reason we are reasonably sure that this species has established and has been successfully invading the surveyed wetlands.

Results

Based on our surveys, waterpoppy has successfully become naturalized in 11 sites of south and southwest China and the lower reach of the Yangtze River (Figure 1). Marsh (5 sites), Lakes (4 sites) and streams (sites) are three important suitable habitats for waterpoppy. In sites 5, 7, and 8, waterpoppy has formed monospecific stands (Figures 1, 2), some native species (such as *Potamogeton pectinatus*, *Myriophyllum spicatum* etc.) and another invasive species (*Alternanthera philoxeroides*) occurred in the other sites (Table 1).

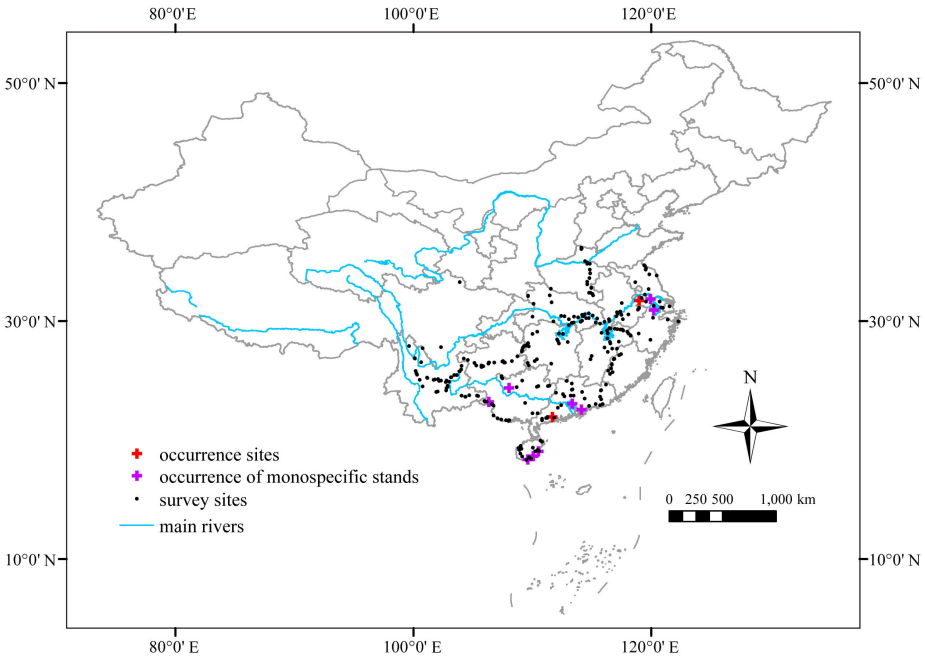

Figure 1. Distribution of waterpoppy (*Hydrocleys nymphoides*) in China. For details see Table 1.

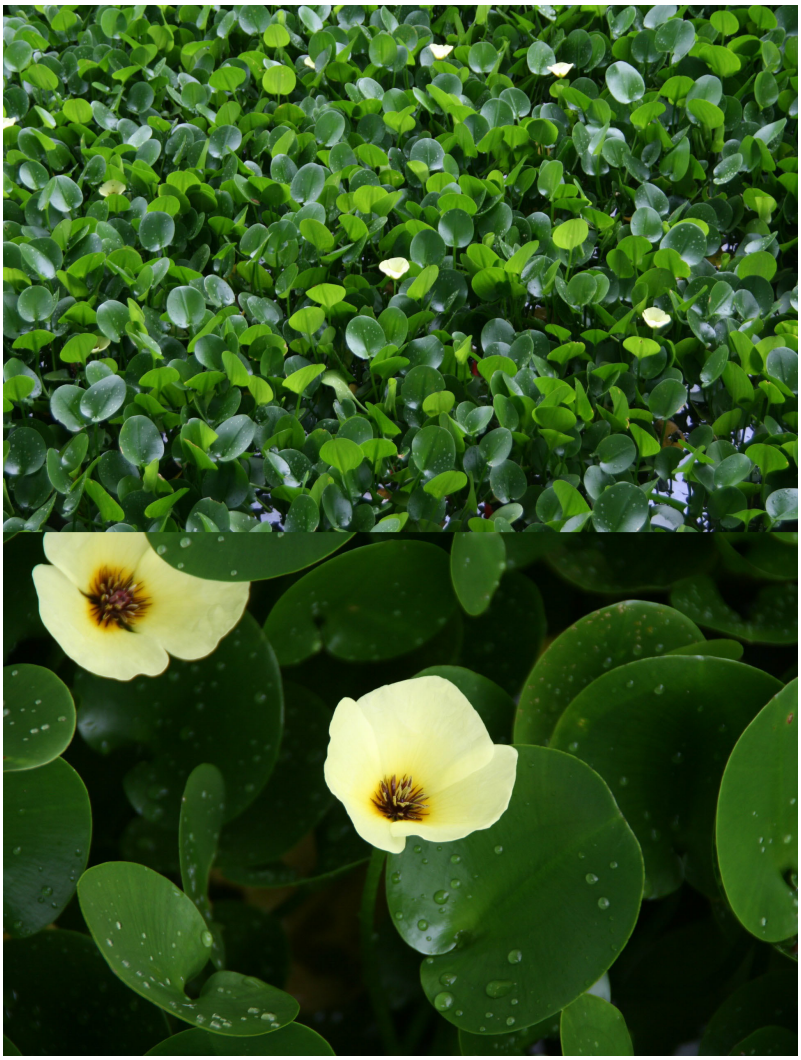

Figure 2. Photographs of waterpoppy (*Hydrocleys nymphoides*) population at Du'an, Guangxi. Photo by Chao Peng.

Table 1. Geographic location of waterpoppy (*Hydrocleys nymphoides*) in China

No	Latitude	Longitude	Investigation date	Location	Province	Habitat	Accompanying species sampled in the water
1	22.57	114.12	August 15 2016	Honghu Park, Shenzhen	Guangdong	lake	*Potamogeton pectinatus, Ceratophyllum demersum*
2	23.07	113.34	August 19 2016	Haizhu National Wetland Park, Guangzhou	Guangdong	marsh	*Myriophyllum spicatum*
3	21.94	111.66	August 25 2017	Hekou, Yangjiang	Guangdong	marsh	*Hydrilla verticillata*
4	18.37	109.61	December 10 2003	Lizhigou, Sanya	Hainan	marsh	*Salvinia natans*
5	18.63	110.07	December 21 2003	Nanqiao, Wanning	Hainan	marsh	monospecific populations
6	19.04	110.50	December 24 2003	Longgun, Wanning	Hainan	stream	*Lemna minor*
7	23.19	106.33	July 11 2005	Xinrong, Jinxi	Guangxi	marsh	monospecific populations
8	24.39	108.03	July 18 2005	Banling, Du'an	Guangxi	stream	monospecific populations
9	31.73	118.96	June 4 2019	Sanshan Lake, Nanjing	Jiangsu	lake	*Alternanthera philoxeroides*, *Typha orientalis*
10	31.83	119.92	June 8 2018	Tanghu, Changzhou	Jiangsu	lake	*Phragmites australis*
11	30.93	120.20	July 19 2017	Jinyan, Huzhou	Zhejiang	lake	*Alternanthera philoxeroides*

Discussion

Introduction pathways and distribution

For the past forty years, China has had an extremely rapidly growing economy. As part of the increase in domestic amenities, aquaria have gained in prominence as an important household asset for many Chinese people (Xiong et al. 2015; 2017; Wang et al. 2016). China's role as an important producer and exporter for aquarium trade has risen. A great number of fishes, crayfishes, aquatic plants and mollusk species are cultured and sold as aquarium products. Consumers like to acquire novel aquarium species, which has encouraged the import of a broad array of taxa new to the aquarium trade in China. Because of its cup-shaped flowers and heart-shaped fleshy leaves, waterpoppy is an attractive and popular taxon in the ornamental plant market of China. In this investigation, we found that waterpoppy has become widely sold in many aquarium stores in almost all large Chinese cities, including Wuhan, Haikou, Nanjing, Shanghai, Guangzhou among many others. In our investigation in the Huadiwan market (the largest aquarium market in the world), we observed that over 1000 individual waterpoppy plants were sold in a day.

In the past twenty years a great number of wetland parks and constructed wetlands have been built in China and the use of waterpoppy as a showy, easily grown, ornamental has been used ubiquitously in them (Zhang et al. 2012). Waterpoppy occurs in nearly all urban wetlands and parks in south and central China and it inevitably escaped in open waterways and readily established feral populations. Because of similar climates in south China and its region of natural origin, waterpoppy thrives as a pre-adapted invader.

Potential impacts

In suitable habitats (still, shallow and nutrient-rich open water), waterpoppy grows quickly and covers the entire water surface with its fleshy leaves.

These dense stands prevent light penetration and deplete oxygen causing significant biodiversity losses of both native flora and fauna (Gorham 2008). Meanwhile, dense waterpoppy colonies significantly affect human activities, such as fishing, swimming, and boating (Sullivan and Hutchison 2010). Thus, it has been listed as a problematic invasive aquatic plant in Europe, Australia, and Africa (Williams 2008; Nxumalo et al. 2016).

South China and the middle and lower reaches of the Yangtze River are important grain and aquaculture production areas (Piao et al. 2010; Wang et al. 2015). We observed that dense waterpoppy populations occur particularly in irrigation ditches, which may influence the production of grain.

In south and southwest China, especially in Hainan, Guangdong, and Guangxi Provinces, waterpoppy replaces native aquatic plants. For example, we observed that some native species (*Myriophyllum spicatum*, *Potamogeton pectinatus*, *Ottelia acuminata*) were previously more abundant in some streams in the Du'an County, Guangxi in 2005. However, these native species were completely replaced by waterpoppy by 2018. The south and southwest China and the middle and lower reaches of the Yangtze River are biodiversity hotspots with a significant number of endemic species (Myers et al. 2000). Waterpoppy thrives in these regions and is a threat to native biodiversity and ecosystem function.

China's wetlands are increasingly experiencing the most severe threats by exotics of any wetland worldwide (Xiong et al. 2015; 2017; Wang et al. 2016). Some non-native aquatic plants provide suitable habitats and facilitate the invasion and establishment of other non-native species (Xiong et al. 2019). In some of our surveys, we observed that native fishes are completely displaced by non-native mosquitofishes (*Gambusia affinis*). This may be because only mosquitofish can endure the low oxygen in dense monotypic stands of waterpoppy.

Waterpoppy has successfully become naturalized in south and southwest China and lower reach of the Yangtze River where it has become serious threat to agricultural production and native biodiversity. This species has spread quickly in China because of aquarium trade, constructed urban parks and constructed wetlands. Many of the biological traits (growth rate, speed of reproduction) of waterpoppy in China are unknown. More research, monitoring and more restrictive legal provisions are needed to better manage this problematic invasive species.

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Authors' contribution

PL conceived the project, CP carried out the experiments, PL and CP performed data analyses and wrote the manuscript.

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