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NOTE

FRESHWATER MUSSELS IN THE BYCATCH OF A SNAIL FISHERY IN THE POYANG LAKE REGION, CHINA: A POTENTIAL CONSERVATION OPPORTUNITY

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ABSTRACT

Poyang Lake, China's largest freshwater lake, has high ecological and economic value. The area is a global hotspot of freshwater mussel diversity, and it supports an important dredge fishery for snails, which results in substantial mussel bycatch. The mussel fauna changed dramatically in the last two decades, and many large species disappeared from the lake. We hypothesize that snail dredging may be a factor threatening mussel populations in the area. We describe the snail fishery and its associated mussel bycatch in Qinglan Lake, a satellite of Poyang Lake. We evaluate the potential impact of unselective harvest on the mussel fauna, and we estimate the value of mussels as a commodity for local fishers. Fishers harvested an average of 859 mussels per trip, with 17 mussel species present in the bycatch. We estimated that annual mortality from bycatch represented about 5% of the total mussel standing stock in the lake. The market price for mussels was low compared to target snails. This low value provides a potential conservation opportunity of providing financial incentives to fishers for returning mussels to the lake.

KEY WORDS: Unionoida, Asia, bycatch mitigation, fisheries management, mussel conservation

INTRODUCTION

Freshwater mussels (Mollusca: Bivalvia: Unionoida) are highly imperiled worldwide, and they provide important ecosystem and cultural services (Vaughn 2018). Mussels have a long history of harvest by humans for pearls, for nacre and craft industries, as a protein source, as calcium for livestock, and as fertilizer in agriculture. Overexploitation for pearls and nacre products decimated mussel populations in Europe and the Americas, but harvest declined after the Second World War, when nacre products were mainly replaced by synthetic materials (Anthony and Downing 2001; Haag 2012; Clavijo 2017). Freshwater mollusk harvest remains of great importance in China (ca. 20,000 tons harvested in 2000; FAO 2023), but many species are facing extinction from overexploitation (Do et al. 2018; Liu et al. 2020b). Most research on mussel diversity and distribution has focused on Europe and North America (Lopes-Lima et al. 2018), but recent research has begun to examine these aspects of the Asian mussel fauna (e.g., Bolotov et al. 2017; Zieritz et al. 2016, 2018). However, the factors important in mussel declines and conservation in Asia remain poorly studied.

Poyang Lake (Jiangxi Province) is China's largest freshwater lake and, along with a series of satellite lakes, is connected to the Yangtze River. Poyang Lake and its satellite lakes are well known for their ecological and economic importance (Leeuw et al. 2010; Xia et al. 2010; Zhong and Lu 2011; Huang et al. 2013). The area is home to more than 35 mussel species (Xiong et al. 2010, 2012; Zieritz et al. 2018), making it a global hotspot for mussel diversity. Two gastropod species, *Rivularia auriculata* and *Bellamya aeruginosa*, dominate the benthos and support a fishery based on traditional fishing craft and gear and labor-intensive methods (Cai et al. 2014). Fishers collect snails using small boats equipped with hydraulic dredges that pump sediments

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(including mollusks) from the lake bottom onto a conveyor. Sediments are screened to remove mud and sand, and mollusks are deposited in sacks for transport to market.

Snails harvested by this fishery are an important source of food for human consumption and an important commodity for the local community (Ma et al. 2010; N. Ferreira-Rodríguez, unpublished observations). Dredging is unselective and results in substantial mussel bycatch, which is sorted from target snail species at lakeside villages and sold as a secondary commodity for human consumption. We describe the snail fishery, and its associated mussel bycatch, in Qinglan Lake, a satellite lake of Poyang Lake. We evaluate the potential impact of unselective harvest on the mussel fauna, and we estimate the value of mussels as a commodity for local fishers. We discuss how mussel bycatch from the snail fishery could be considered in mussel conservation plans in the region.

METHODS

Study Area and Description of the Snail Fishery

Qinglan Lake has an area of 15 km^2 and is a satellite of Poyang Lake. Its mean depth is 3.5 m ± 1.2 (SD; Qiu et al. 2022). The water sources of Qinglan Lake are its main tributary (Fuhe River) and local precipitation, which fluctuates between 20 and 35 cm/month (Zeng et al. 2017). The snail fishery in Qinglan Lake included 80–100 boats more than 10 years ago, but the fishery now includes only 20–30 boats. Existing management measures are restricted to closing the fishery from March to June each year. Currently, it is estimated that 500–1,000 kg of snails are collected per boat per trip, with one trip per day (N. Ferreira-Rodríguez, interview with local fishers), and the annual catch reported by the local community is 240–480 metric tons (based on an estimated 480 trips per year by the entire community). The price for snails is $0.18–0.30/kg (2018 $US; all dollar amounts will be in $US), which represents $90–300 per trip and annual receipts for the local community (10 to 15 families with two dredging boats each) of $43,200–144,000/year (i.e., wholesale price paid to the local community).

Bycatch Assessment

We obtained bycatch data (where bycatch is defined as non-target mussel species) from two opportunistic encounters with local fishers, one each at two locations: Qinglan Lake (28°33′32.85″N, 116°11′7.26″E) on July 11, 2018, and Tachengxiang village (28°32′19.33″N, 116°7′47.27″E) on July 15, 2018 (Fig. 1). On Qinglan Lake, we intercepted a fisher after conclusion of a fishing trip and purchased mussels before they landed. At Tachengxiang village, we purchased mussels from a different fisher after they docked at the village. We purchased all mussels in possession of each fisher and considered these numbers to represent total mussel bycatch per trip. We summed the number of each mussel species in the bycatch from both encounters to obtain the relative abundance of each species in the bycatch. We transported mussels purchased from fishers to the Conchology Laboratory at Nanchang University, where we preserved them in 70% ethanol and later identified and counted them.

Market Price

We estimated the market price of mussels separately for Qinglan Lake and Tachengxiang village. Although mussels can be bought directly from fishers, there is not an established market for them. Therefore, we used fair valuation to estimate the market price. Fair value is the estimated price at which an asset (here, freshwater mussels) is bought when both the buyer (here, researchers) and the seller (here, the fisher) freely agree on a price. We made no distinction among sizes or species, and we estimated market price in $US/100 mussels after negotiations with fishers.

RESULTS

The mean number of mussels harvested/trip was 859 (701 at Qinglan Lake and 1,017 at Tachengxiang village). We were unable to measure the size of the mesh used by fishers to screen mollusks from dredged sediments. However, all mussels in our samples were >44 mm long (maximum anterior-posterior dimension), suggesting that the mesh allowed mussels smaller than that size to escape. A total of 17 mussel species were represented in both bycatch samples (Table 1). The most common species were *Acuticosta chinensis* followed by *A. ovata* and *Nodularia douglasiae*. Other frequent species were *Schistodesmus lampreyanus*, *Lamprotula caveata*, and *S. spinosus*, while the remaining species each represented <5% of the bycatch. All species were present in both bycatch samples, except *Sinohyriopsis cumingii*, which was present only in the sample from Qinglan Lake.

The mean market price was $0.66/100 mussels ($0.42 at Qinglan Lake and $0.90 at Tachengxiang village). Based on these market prices, the mean estimated income per trip provided by mussel bycatch was $6.05 ($2.94 at Qinglan Lake and $9.15 at Tachengxiang village), and estimated mean annual receipts to the communities are $2,904 ($1,411–4,392).

Mean mussel density reported in Qinglan Lake was 0.59/m^2 ± 0.21 SE (Xiong et al. 2010), resulting in an estimated lake-wide standing stock of 8,850,000 mussels (based on 15 km^2 lake area). Based on the mean number of mussels harvested per trip (859) and the estimated number of trips per year (480), annual mussel mortality from harvest is 412,320, representing about 5% of the standing stock each year.

DISCUSSION

Bycatch from the snail fishery may represent a substantial source of mortality for mussel populations in Qinglan Lake and elsewhere in the Poyang Lake region. Our mortality estimate is based on only two observations of bycatch from

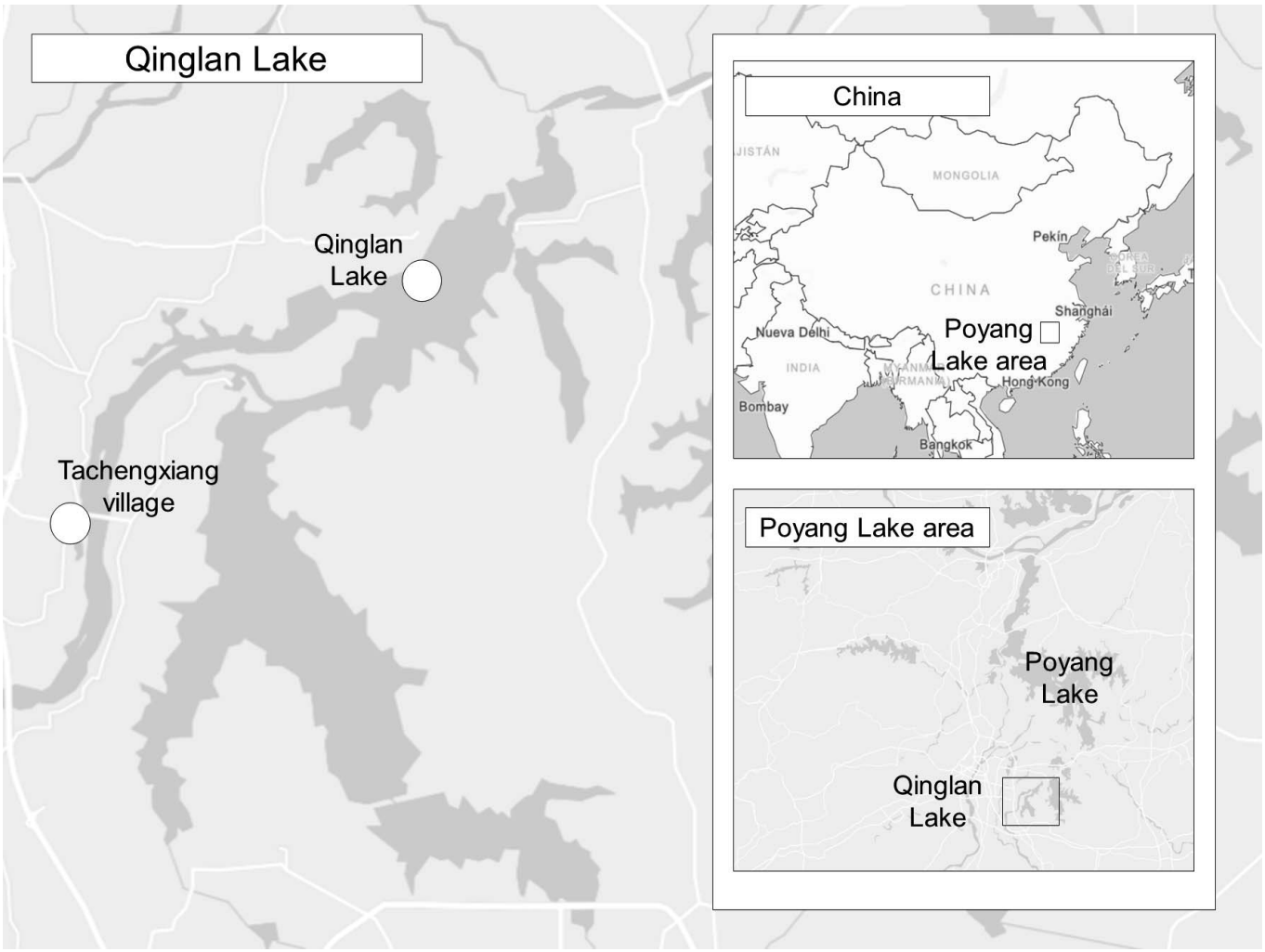

Figure 1. Map showing locations where mussels were purchased from local fishers in the Qinglan Lake (Poyang Lake area, China). Inset maps show the location of the Poyang Lake area in China and the location of Qinglan Lake in relation to Poyang Lake.

two dates, and many factors could influence the extent to which bycatch affects mussel populations. The apparently large mesh size used in the fishery allows escapement of juvenile individuals, which could lessen effects on population growth. However, spatial and temporal variation in harvest, as well as potential underreporting of harvests by fishers, could greatly influence mortality estimates. Nevertheless, our study is the first to quantify mussel mortality from bycatch, and our results suggest that bycatch may exacerbate other potential threats to mussel populations, including water pollution, habitat alteration, and increased drought from climate change (Cai et al. 2014; Zhang et al. 2015; Wang et al. 2019).

Mortality from bycatch may affect mussel species differently, resulting in shifts in community composition. Before 1998, the most common mollusks in the Poyang Lake area included many large unionid species, such as *Lamprotula leaii*, *L. caveata*, *Aculamprotula tientsinensis*, *N. douglasiae*, *Lancelaria* spp., *Cuneopsis pisciculus*, *Arconaia lancelata*, *Sinanodonta woodiana*, *S. cumingii*, and *Cristaria plicata* (Cai et al. 2014). After 1998, many of these large species disappeared from the area or declined in abundance (Xiong et al. 2010). For example, *L. caveata* previously was a dominant species (>15% of the fauna), but it represented only 6.3% of individuals in our samples, and, apart from *N. douglasiae*, other large species were rare or absent. In contrast, our samples were dominated by the smaller species *A. chinensis* and *A. ovata*.

Among the mussel species we found in the snail fishery bycatch, *Cuneopsis rufescens* is the only species of conservation concern. This species is listed as vulnerable at the national and global levels by the IUCN Red List (IUCN 2022; see Table 1), and its current distribution is limited to only two locations in China: Poyang Lake and Dongting Lake (Hunan Province; see Liu et al. 1979). Proposed threats to this species include water pollution and urbanization, but bycatch mortality may represent an additional threat. *Lanceolaria grayii* is listed as "least concern" at the national level, but its conservation status has not been evaluated by the IUCN due to insufficient data; the potential impact of the snail fishery in the Poyang Lake area and elsewhere in its range should be

Table 1. Representation of mussel species in bycatch of the snail fishery in Qinglan Lake, Jiangxi province, China ($N = 1,718$ individuals, aggregated from two fishing trips). IUCN classifications are from IUCN (2022), and Chinese conservation status is based on Liu et al. (2020a, 2020b).

Species	IUCN Classification	Chinese Conservation Status	Percent
Aculamprotula tortuosa	Not listed	Vulnerable	2.15
Acuticosta chinensis	Least concern	Least concern	32.95
Acuticosta ovata	Least concern	Least concern	19.85
Anemina arcaeformis	Least concern	Least concern	0.87
Arconaia lanceolata	Least concern	Not listed	1.16
Cuneopsis heudei	Least concern	Least concern	0.76
Cuneopsis pisciculus	Least concern	Least concern	0.29
Cuneopsis rufescens	Vulnerable	Vulnerable	0.17
Lamprotula caveata	Least concern	Not threatened	6.34
Lamprotula leaii	Not listed	Least concern	1.86
Lanceolaria eucylindrica	Not listed	Vulnerable	0.17
Lanceolaria grayii	Data deficient	Least concern	0.58
Nodularia douglasiae	Least concern	Least concern	18.51
Schistodesmus lampreyanus	Least concern	Least concern	8.73
Schistodesmus spinosus	Least concern	Near threatened	5.12
Sinanodonta woodiana	Least concern	Least concern	0.41
Sinohyriopsis cumingii	Not listed	Least concern	0.06

considered in future conservation status assessments. Similarly, the impact of the snail fishery on "not listed" species (i.e., *Aculamprotula tortuosa*, *L. leaii*, *Lanceolaria eucylindrica*, *S. cumingii*) should be considered in future IUCN assessments, especially *A. tortuosa* and *L. eucylindrica*, which are listed as "vulnerable" at the national level.

Mussels harvested as bycatch have a low market value ($3–9 per fishing trip) compared to target snail species ($90–300 per fishing trip). The low market value may present a conservation opportunity if proper incentives are applied. Specifically, it may be feasible to provide economic compensation to local fishers in exchange for returning mussels to the lake instead of returning them to the village for sale. In Qinglan Lake, such compensation would total $2,904 per year for the local community. Evaluating costs and benefits of, and building support for, such measures require a better understanding of the threat to mussel populations posed by bycatch mortality and the benefits of reducing this mortality. Additional sampling and development of population models are necessary to quantify the effect of bycatch mortality and how it varies among species based on body size, size at maturity, recruitment rate, and other vital statistics of the fishery. It is also necessary to quantify the value of ecosystem services and other benefits provided by healthy mussel populations in this area. The valuation of mussels in this region and other areas of the world where they are exploited should be a research priority (Strayer 2017).

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