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The impacts of invasive Nile tilapia (*Oreochromis niloticus*) on the fisheries in the main rivers of Guangdong Province, China

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ABSTRACT

Nile tilapia (*Oreochromis niloticus*) is one of the most widespread invasive fish species, and this species has successfully established populations in the major rivers of Guangdong Province, China. Field surveys and manipulative experiments were conducted to assess the impacts of Nile tilapia on fisheries. We determined that the increase of Nile tilapia in these rivers not only affects the CPUE (catch-per-unit-per-effort) of the fish community and native fish species but also reduces the income of fishermen. In the manipulative experiments, we observed that the growth of native mud carp decreased in the presence of Nile tilapia. Our results suggest that the invasion of Nile tilapia negatively affected the fishery economy and native fish species, and suitable control measurements should be taken.

1. Introduction

Although the introduction of alien fish species has significantly contributed to global aquaculture and the production of capture fisheries, this introduction is also regarded as one of the most important causes of species endangerment and extinction (De Silva et al., 2004; Attayde et al., 2011; Giannetto et al., 2012; Lowe et al., 2012). After habitat modification, the invasion of non-native species is one of the major threats to freshwater fish biodiversity (Arthur et al., 2009). The impact of non-native fish populations on native species may arise from competition for resources and habitats, nutrient cycling, water quality changes, predation, hybridization, and the importation of parasites and diseases (Canonico et al., 2005; Carey and Wahl, 2010; Arthur et al., 2009). However, the impacts of introduced species may vary according to species (Arthur et al., 2009).

Nile tilapia (*Oreochromis niloticus*) is native to Africa and is one of the most popular fishes used in aquaculture due to its ability to tolerate a wide range of environmental conditions, flexible habitat requirements, reproductive strategies, fast growth, and aggressive and omnivorous feeding habits (Canonico et al., 2005; Martin et al., 2010). These traits allow this fish to be a successful invasive species that has become one of the two most widely introduced fish species (De Silva et al., 2004;

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Peterson et al., 2005; Attayde et al., 2011). Published studies have indicated that Nile tilapia have successfully colonized most areas of the world (Costa-Pierce, 2003; Zambrano et al., 2006; Martin et al., 2010; Attayde et al., 2011; Gu et al., 2012a,b; Grammer et al., 2012). The invasion of Nile tilapia can cause ecological problems in several ways: 1) Nile tilapia generally can outcompete native species for food and habitats, which reduces the native fish populations due to competitive displacement (Canonico et al., 2005; Martin et al., 2010; Vicente and Fonseca-Alves, 2013), 2) Nile tilapia cause the extinction of native fish species by preying on eggs, fry and small fish of other species (Russell et al., 2012; Vicente and Fonseca-Alves, 2013). 3) Nile tilapia change photosynthesis and the production of the aquatic ecosystem to result in eutrophication; the bio-turbidity usually results from the feeding and excretion habits of tilapia (Peterson et al., 2005). However, the impacts of Nile tilapia on native species vary by region and native species (Canonico et al., 2005; Arthur et al., 2009).

Tilapia culture in Mainland China started in the early 1960s. China has been producing the majority of the world's tilapia since 1997 (Zhu et al., 2008). The production of tilapia in Guangdong Province exceeded 45% of the total production in China (Chu et al., 2012). Natural populations of tilapia have established in the main rivers of Guangdong Province due to their ability to overwinter and reproduce in natural waters (Gu et al., 2012a,b, 2014a,b). Of the tilapia species introduced to China, *O. niloticus* was the most common in the main rivers in Guangdong Province (Gu et al., 2012a, 2014a,b). Guangdong Province is recognized as a global biodiversity hotspot that contains many endemic and indigenous fish species (Radhakrishnan et al., 2011). Considering the potential impact of Nile tilapia on native biodiversity, the impacts of Nile tilapia in the rivers of Guangdong Province need to be assessed and managed accordingly.

We investigated the abundance of fish communities and alien Nile tilapia in the main rivers of Guangdong Province and conducted control experiments to assess the impacts of Nile tilapia. In this study, we asked the following questions: 1) does the abundance of Nile tilapia affect the catch-per-unit-per-effort (CPUE) of native fishes in different surveys and sites, 2) does the increase of Nile tilapia affect the income of fishermen 3) does Nile tilapia invasion affect the growth of the native mud carp?

2. Methods

2.1. Impact on fisheries

To investigate the relationship between fish species biomass and the abundance of alien Nile tilapia, a field survey was carried out at five sites along the Pearl River (which consists of the Xijiang River, Beijiang River, and Dongjiang River) and Jianjiang River, which are located in Guangdong Province, South China. Among the five sites, three (Zhaoqing, Shaoguan and Huizhou) are located at the Pearl River (one each in the Xijiang, Dongjiang and Beijiang Rivers), while the other two sites (Meihua and Huazhou) belong to the Jianjiang River basin and are located along the Meihuajiang and Jianjiang Rivers, respectively (the sites were same to Gu et al., 2014b).

The fish were sampled a total of 18 times between August 2011 and March 2014; each sampling took place over two days, and all fishing boats at each site were investigated. All samples were collected from the fish industry, and no protected species were sampled. In this study, fish were primarily caught with gillnets and shrimp pots, and all surveys were conducted using the same fishing gear. All catches were weighed with the help of the fishermen in the surveys. The fish were then identified, and the number of species was quantified. All Nile tilapia were collected and weighed. In the wild tilapia populations, many individuals are the hybrid offspring of Nile tilapia. In this study, such hybrids were considered Nile tilapia. The following data were also collected at each site: 1) the average catch-per-boat-per-day for each survey, 2) the weight ratio and total weight of Nile tilapia for each survey, and 3) the price of main the fish species in the surveys.

All boats in our surveys were identical, with a total length of 5–5.2 m, and all fishermen in our surveys were 30–45 years old. Two fishermen (usually a couple) worked on each boat, and all fishermen were specialized and only worked in fishing. Thus, we believe that the fishing effort was the same. Therefore, we used the average catch-per-boat-per-day collected as the CPUE.

The market price of different fish species related to the per capita income of fishermen. It also related to the selectivity of fishing gear and the trend of the fish populations. Alien fish prices that are lower than those of other species will increase the fishing pressure on native species. Moreover, the price also indicated that a species is unwelcome, such as the common carp in the USA and *Hypostomus* spp. in China (Gu et al., 2012a): lower-priced alien fish are discarded after being caught, which will lead them to multiply. Thus, we recorded the price of the main fish species in the surveys to evaluate the impact on the income of fishermen caused by Nile tilapia, which also indicate the trend of Nile tilapia abundance.

Linear and logistic regressions were used in all the surveys and at all sites to determine whether the weight ratio and total weight of Nile tilapia impacts the average CPUE. Statistical analyses were performed using SPSS16.0, and the results were considered significant at $P \leq 0.05$.

2.2. Impact on native mud carp

To assess the effect of the invasion of Nile tilapia on the growth of native fish species, we examined the impact of the invasive Nile tilapia on the most popular native fish (mud carp *Cirrhina molitorella*) in the natural waters of Guangdong Province, China. Field and control experiments were carried. We used juvenile native mud carp and invasive Nile tilapia caught in the lakes of the Pearl River Fisheries Research Institute at the same time on 9 June; the juvenile mud carp (0.2 ± 0.02 g) and Nile tilapia (1.8 ± 0.3 g) were screened separately before experiments.