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Comparison of the culture performance and profitability of wild-caught and captive pond-reared Chinese mitten crab (*Eriocheir sinensis*) juveniles reared in grow-out ponds: Implications for seed selection and genetic selection programs

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ABSTRACT

The Chinese mitten crab, *Eriocheir sinensis*, is a commercially important freshwater crab with a high market value in East Asian countries. The farming of *E. sinensis* has undergone rapid development in China. Generally, ponds are stocked from two seedstock sources, captive pond-reared juveniles (coin-sized seed, PR) or wild-caught seedstock of *E. sinensis* (WC). Anecdotally, WC stocks are preferred as they are thought to perform better in culture compared with PR stocks. However, the availability and low cost of PR seedstock have resulted in this becoming the dominant seedstock for production, despite a lack of selective breeding programs. We compared the growth, gonadal development, survival, crab yield, feed conversion rate (FCR), size distribution, and profit between WC and PR populations of *E. sinensis* seedstock from the Yangtze basin that were cultured in commercial-sized production ponds. The PR had a higher body weight, weight gain rate (WGR), and specific growth rate (SGR) than the WC during the mid-period of the study (July to August) whereas WC had a higher WGR and SGR than PR during the latter part of the study (September to October). Regardless of sex, PR commenced their puberty molt and gonadal development earlier than WC, which resulted in PR having a significantly higher gonadosomatic index (GSI) than WC during the periods between September and November. WC had the higher survival and crab yield, and a lower FCR at the end of the study, though the differences were not significant. However, the proportion of larger sized male or female adults was higher in WC (male ≥ 225 g/crab; female ≥ 125 g/crab) than in PR. The cost of purchasing and feeding WC seedstock was greater than that of the PR seedstock, however the return-on-investment (ROI) for WC seedstock was higher because of higher yield and the higher price for larger crabs. Despite having better culture performance and greater ROI from stocking WC crabs, this source of seedstock is not sustainable for the *E. sinensis* farming industry because of the variable quantity, high seed cost, and very limited natural seedstock resources in the Yangtze River. Thus, there is a need for genetic-improvement breeding programs focused on the establishment of captive stocks to obtain desirable traits, such as larger harvest size, low FCR, and delayed onset of maturity in *E. sinensis*.

1. Introduction

The Chinese mitten crab *Eriocheir sinensis* is a native freshwater crab that is widely distributed throughout the eastern region of China (Sui et al., 2009). During the past few decades there has been a significant increase in the artificial culture of this species in China (Wang, 2013a,b). Because of high market demand due to its taste, and advances in hatchery and growout techniques, *E. sinensis* culture has spread to ponds, reservoirs, and lakes throughout China since the 1990s (Sui et al., 2011). Consequently, aquaculture yields have steadily increased, from 8000 tonnes in 1991 to approximately 714,400 tonnes in 2012 (Wang, 2013a,b). The native range of *E. sinensis* includes three main drainage basins: the rivers of Liaohe, Yangtze, and Oujiang (Sui et al., 2009). In general, the Yangtze population of *E. sinensis* has the largest adult body size, as well as the best growth performance and taste among the three populations (Li et al., 2000, 2002; Zhang et al., 2000). Therefore, most pond-reared populations of *E. sinensis* in middle and eastern China originate from the wild Yangtze population (Wang and Wang, 2013).

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Based on the life cycle of *E. sinensis* in the Yangtze River basin, the culture of this crab is divided into three discreet stages: larval or hatchery stage (2–4 months, to produce megalopae), coin-sized juvenile culture or nursery stage (8–10 months, to produce coin-sized crablets for the following growout) and market-sized or adult growout culture (7–10 months, to produce market-sized adult crabs) (Cheng et al., 2008). Between 1990 and 1995, pond-reared broodstock was successfully used for the seed production of *E. sinensis* in commercial hatcheries, closing the life-cycle of this species in captivity (Wang, 2013a,b). However, to reduce broodstock costs, most commercial hatcheries in China tended to select small, pond-reared adult *E. sinensis* (females: 60–100 g/ind.; males: 80–150 g/ind.) broodstock that had not undergone genetic improvement (Zhang and Li, 2002; Sui et al., 2011). This resulted in selection for small sized crabs and often led to inbreeding and the degeneration of pond-reared *E. sinensis* stock that originated from the Yangtze basin (Dixon et al., 2008; Wang and Wang, 2013). In addition, during the 1990s and early 2000s, megalopae and juveniles from the Yangtze population of *E. sinensis* were more expensive than those from other populations (Zhang and Li, 2002), which stimulated significant demand for megalopae and juvenile *E. sinensis* from this region. Wild or artificial seedstocks from other *E. sinensis* populations were subsequently introduced to the Yangtze basin for aquaculture purposes (Wang, 2013a,b). Such introductions and the subsequent culture of different *E. sinensis* populations within the Yangtze basin undoubtedly lead to germplasm hybrids among pond-reared Yangtze populations (Li et al., 2009). As a result, there was a consistent decline in performance in culture, characterized by slow growth rates and a high percentage of small sized adult crabs (Sui et al., 2009; Wang, 2013a,b).

For many farmed shrimps, selective improvement programs not only result in the domesticated stocks having genetically desirable attributes, such as rapid growth, pathogen resistance, and high survival, but also help reduce the dependence on wild broodstock (Browdy, 1998; Goyard et al., 2002; Kenway et al., 2006; Cock et al., 2009; Gjedrem et al., 2012), such as the Pacific white shrimp *Litopenaeus vannamei* (Argue et al., 2002; Huang et al., 2012) and the black tiger prawn, *Penaeus monodon* (Preston et al., 2004). Although the culture of *E. sinensis* has become a large industry in China, with a value of approximately 5 billion USD, artificial seedstocks are still produced almost exclusively from non-selected, pond-reared broodstock (Wang and Wang, 2013). Because of concerns for the profitability and sustainability of the industry, there is increasing interest in selective breeding programs of *E. sinensis* (Li et al., 2010; Zhu et al., 2012). Because of their superior aquaculture traits (Zhang et al., 2000; Li et al., 2002; Zhou et al., 2003), the wild *E. sinensis* Yangtze population is considered the prime candidate for a founder stock for future selective breeding programs (Li et al., 2009; Zhu et al., 2012).

Since 2005, there has been a closed fishing season and a series of stock enhancement programs for *E. sinensis* in the Yangtze River. These measures have enabled some stock recovery to occur (Chen et al., 2007; Liu et al., 2013). As evidence of this, the annual fishing yields of wild megalopae and coin-sized crab were >3000 kg and 7000 kg, respectively, between 2004 and 2006 in the coastal area of Chongming Island of the Yangtze River (Shi, 2006), which was much higher than the harvest of wild megalopae in 1997 (<500 kg: Cheng et al, 2008). Thus, wild-caught (WC) stocks are available for selective breeding programs and use in pond rearing. However, unlike pond-reared populations, there is little published information describing the growth and gonadal development of wild megalopae and juvenile *E. sinensis* under commercial farming conditions (Zhang and Li, 2001; He, 2005). This lack of information hinders the responsible utilization of wild Yangtze *E. sinensis* resources as well as the development of selective improvement programs based on the wild Yangtze population *E. sinensis* (Chen et al., 2007; Teng et al., 2008). Because wild coin-sized juveniles are thought to perform better in culture than the pond-reared juveniles in the Yangtze basin, some crab farmers prefer to use wild seedstocks (coin-sized juveniles) for the farming of *E. sinensis* (Zhou et al., 2003; Chen et al., 2007). However, it is expensive and time-consuming to collect wild juveniles as fishing boats and commercial trawlers are often required. Therefore, the price of wild juveniles is generally 1.5–2.5 times higher than that of pond-reared juvenile *E. sinensis* in the Yangtze basin (Wu, personal observation). Thus, there is also a need to evaluate the economic profitability of using wild-caught and pond-reared *E. sinensis* juveniles farmed in grow-out ponds.

Our objective was to compare the growth, gonadal development, survival, crab yield, feed conversion rate (FCR), size distribution, and economic benefits of culturing wild-caught and pond-reared *E. sinensis* juveniles in commercially-sized earthen ponds. This information can be used to inform seed selection for culturists and help guide the development of selective improvement programs for the Yangtze population of *E. sinensis*.

2. Materials and methods

2.1. Sources of juvenile crabs

2.1.1. Wild-caught juveniles

Wild-caught *E. sinensis* juveniles were collected from March 15–18, 2012 by fishermen using commercial trawlers in the Yangtze River (32°11′N, 119°27′E) near Zhenjiang City, Jiangsu Province, China. Approximately 200 kg of these juveniles was transported to the Shanghai Yuchi aquaculture farm on Chongming Island, Shanghai, China. Only normal immature, similar-sized, active, and intact juveniles were selected for the experiments. The mean body weights of female and male WC juveniles were 6.58 ± 0.55 g and 6.95 ± 0.74 g, respectively.

2.1.2. Pond-reared juveniles

The pond-reared (PR) juveniles were originally derived from the wild Yangtze population, but were domesticated more than 15 years ago and are a commonly used domesticated population in the Yangtze basin. In May 2011, hatchery produced megalopae were purchased from a commercial mitten crab hatchery in Rudong county, Jiangsu Province, China, where pond-reared broodstocks (female: 75–100 g/ind.; male: 120–150 g/ind.) were used for seed production. Then, hatchery produced megalopae were stocked into three earthen ponds (approximately 0.2 ha/pond) for the growout of ‘coin-sized’ crabs (crablets) at the Chongming research base of Shanghai Ocean University. During the culture period, the juveniles were fed once a day at 17:30 with a commercial formulated diet (Xinxin #1, #2, and #3 diets for juvenile crabs, Zhejiang Xinxin Feed Co., Ltd., Jiaxing, Zhengjiang Province, China). In mid-March 2012, pond-reared juveniles were harvested from earthen ponds. Normal immature, similar-sized, active, and intact juveniles were further selected from pond-reared populations for the experiment. The mean body weights of the female and male pond-reared crablets were 6.31 ± 0.62 g and 6.45 ± 0.67 g, respectively.

2.2. Experimental setup and culture management

The experiment was conducted at commercial ponds at the Shanghai Yuchi aquaculture farm, Shanghai, China between March and December, 2012. The experimental ponds consisted of six large outdoor earthen ponds (length × width × depth = 85 m × 55 m × 1.5 m). Plastic boards (thickness: 0.5 mm) were set up surrounding each pond to prevent crabs from escaping, while the water inlet and outlet of each pond had plastic nets (mesh size: 0.17 mm) to exclude indigenous fishes and other predators from the water source and drainage channel. In mid-February, all experimental ponds were treated with 1200 kg/ha chlorinated lime. One week later, Canadian pondweed, *Elodea canadensis*, was transplanted at 0.6 m × 1.5 m intervals on the bottom of each pond to act as crab shelters and help maintain pond water quality. A compound fertilizer (400 kg/ha in three equal applications, N: 15%, P: 15%, K: 15%, Cat. XK-13-001-01027, Shanghai Xinghua Fertilizer Co., Ltd., Shanghai,