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Research Article

Intra-and inter-specific competition effects on survival and growth of juvenile *Procambarus acutus acutus* and *Procambarus clarkii*

Yavuz Mazlum*[1]

*Corresponding author: yavuz.mazlum@iste.edu.tr

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Affiliations

[1]Iskenderun Technical University, Faculty of Marine Sciences and Technology, Department of Aquaculture, Iskenderun-Hatay, TURKEY

Keywords

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ABSTRACT

Four similar sizes eastern white river crayfish *(Procambarus acutus acutus)* and red swamp crayfish *(Procambarus clarkii)* were stocked separately to determine intra and inter-specific-competition. Three treatment levels were used three treatment levels, with six replicates tanks each with stand green rice (representing a stocking density of approximately 21 individuals per m^2). This study was carried out during 90 days to determine growth and survival rate. Results showed that the growth of *P. acutus acutus* in the interspecific-treatment tank was found higher than those grown in the intraspecific-treatment tanks. For *P. clarkii*, no significant differences in growth (estimated from the mean Total length, TL) were detected between treatments. The survival of the two species was the same up to the first 60 days of the experiment, while the difference in survival was only noticeable at 90 days. The survival rate of *P. clarkii* in the intraspecific-treatment tanks (55.0%) was higher than in the interspecific tanks (26.7%) treatment, while the survival of *P. acutus acutus* was found similar in two treatments. It was achieved higher survival, faster growth and larger size in *P. a. acutus* than *P. clarkii* when grown in the tank study. Size of body was important in determining competitive interactions between the two species.

Introduction

Crayfish culture has developed rapidly in recent years and has become one of the most important contributors to the nutritional supply of human demands (Yazıcı and Mazlum, 2019; Mazlum et al., 2019; Mazlum et al., 2020). Its annual production, which was 63.750 million kg in the U.S.A (Lutz, 2019). Presently there are more than 95% of the production comes from Louisiana (Huner, 1995; Eversole and McClain, 2000; Lutz, 2019). Red swamp crayfish and white river crayfish production are the most important commercial crayfish species in North America and are successful in commercial crayfish ponds. In addition both of them may thrive in the low-energy-input, extensive aquaculture systems used in Louisiana and other southern states.

P. clarkii can be easily distinguished from the *P. acutus acutus*. The color of red swamp varies from light olive green to reddish black depending on maturity stage. *P. a. acutus* are sandy white or dark brown color depending on molting stage. *P. a. acutus* chelae are narrower and longer than those *P. clarkii* crayfish. Crayfish are classified according to their feeding habits as herbivores, detritivores, omnivores and sometimes obligate carnivores (Correia, 2005; Nystrom, 2002; Mazlum and Şirin, 2020). They are capable of living in many different habitats in terms of physiological, morphological and behavioral characteristics. Crayfish are found abundant and predominantly among all invertebrates. This organism play an important role in the freshwater food chain by

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feeding on the residues and detritus of thousands of animals, from living and rotten plants, cereals, algae and vertebrates to smaller vertebrates such as small fish species (Lodge et al., 2012; Twardochleb et al., 2013).

P. clarkii and *P. acutus acutus* are cultivated simultaneously in various proportions in Louisiana culture ponds, with the *P. clarkii* dominated catch (Huner and Barr, 1991). However, many ponds were stocked with *P. clarkii* in South Carolina eventually became dominated by *P. acutus acutus* (Mazlum and Eversole, 2000; Mazlum, 2003). Moreover, approximately two years of supplementation, stocking 59-114kg/ha of *P. clarkii* in 1996 and 1997, increased the average proportion of *P. clarkii* in the harvest to only 2% (Eversole et al., 1999). *P. clarkii* was not found in the harvest from these ponds in 2000, 2001 and 2002. *P. clarkii* and *P. acutus acutus* are frequently found in the same habitat and biological requirements are similar between two species (Huner and Barr, 1991; Mazlum and Eversole, 2004, 2005). The red swamp crayfish appears to tolerate warmer water temperatures and poor water quality than white river crayfish. *P. clarkii* is the preferred species in culture because it has a higher fecundity and tolerance to low dissolved oxygen (DO) and great market appeal. *P. acutus acutus* seem to prefer cooler water temperatures and flowing water where oxygen levels are higher (Mazlum and Eversole, 2004, 2005; Mazlum et al., 2021).

Competitive interactions between two (or more) co-occurring crayfish species when they highly overlap ecological niches and use similar resources can have long-term adverse effects on species (Söderback, 1991; Gherardi, 2002). Our results clearly demonstrate the competitive advantage of *P. acutus acutus* over *P. clarkii*. Gherardi (2004) reported that larger chelae crayfish species provide more fight-winning advantages over similar length and shorter chelae species. Our previous results indicated that *P. acutus acutus* had longer chelae and longer hatchlings than P. clarkii, but this difference was not significant (Eversole and Mazlum, 2002; Eversole et al., 2006) for proving that size confers advantages in conspecific interactions. Several studies have been designed to better understanding *P. clarkii* and *P. acutus acutus* interactions. The aim of this was to determine the effects of competitive interactions on the growth and survival of *P. clarkii* and *P. acutus acutus*.

Material and Methods

The experiment was conducted in 18 rectangular plastic 57 L tanks located at the Aquaculture Research Facility, Clemson University, Clemson, South Carolina. Prior to experiment, the eighteen tanks were planted with rice (Figure 1). Four *P. clarkii and P. acutus acutus* of the same size were stocked separately for intraspecies treatments or in combination in interspecific-treatment with two individuals of each species. Three treatment levels were used in the experiment, with six replicates tanks each (representing a stocking density of approximately 21 individuals per m^2) with stand green rice. Juvenile crayfish were randomly placed to each of eighteen trial tanks (n=4).

Figure 1. View of experimental tanks from top indicating the position of the standpipe. Rice stand was not fully grown at the time of the photograph.

Flowing pond water with a flow rate of approximately 10 L/h was used in the present study. Dissolved oxygen and temperature were determined daily in the early morning with a 55 YSI oxygen meter. Crayfish were held at 12L:12D cycle. Crayfish were fed daily ad libitum in a 5 cm glass petri dish placed at the bottom of the tank. Uneaten feed was removed from the tank before the next feeding. We measured total length (length from the tip of rostrum to telson, TL) to the nearest millimeter using a digital caliper at the beginning of the experiment and then crayfish were measured monthly interval to determine growth over the 3 month study.

At the end of the experiment, crayfish were counted and measured individually. Growth was evaluated by change in total length (TL) over 90 days and survival (%) calculated according the following equations:

Survival (%) = (final number of crayfish/ initial number of crayfish) x 100.

All data were analyzed by using SPSS software (Version 16.0; SPSS; Chicago, IL, USA). One-way analysis of variance (ANOVA) was used to compare mean differences growth and survival between treatments. A post hoc Duncan's multiple range test was used to test for differences between the treatments. Differences were considered significant at the 95% confidence level. All means were presented with ± standard deviation (SD).

Results

Water temperatures and dissolved oxygen (DO) during the experiment were within acceptable ranges for cambarid crayfish growth (Huner, 1990; Mazlum and Eversole, 2005). There were no differences between the treatments for the mean water temperature of 18.2°C and the mean DO of 5.8 mg/L during the study. The rice feed was decayed and consumed for crayfish throughout the experiment so that very little vegetation and the noxious matter remained in the tanks at the end of the study.

The mean starting of sizes of the two species was similar in both competition treatments. At the end of the experiment, the growth of *P. a. acutus* was found to be significant between treatments (Table 1). *P. a. acutus* which grew significantly faster in the interspecific-treatment tanks than in the intraspecific-treatment tanks. It was observed that no difference was detected in the growth between the treatments for *P. clarkii* (Table 1). After 90 days, the growth rate in the inter specific-treatment tanks was 76. 2±10.3 mm TL in compared to 54.6±8.6 mm TL in the intraspecific-treatment tanks.

Table 1. Mean and standard deviation of the total length (TL) of *P. a. acutus* and *P. clarkii* in the intraspecific- and interspeeific-treatment tanks.

Sample Days	*P. a. acutus* TL (mm)		*P. clarkii* TL (mm)	
	Intraspecific	Interspecific	Intraspecific	Interspecific
30 days	24.9±0.4^{a}	25.2±0.4^{a}	24.3±0.5^{a}	24.0±0.5^{a}
60 days	50.6±7.2^{a}	54.0±5.8^{a}	53.0±7.8^{a}	55.6±5.5^{a}
90 days	54.6±8.6^{a}	76.2±10.3^{b}	63.1±9.5^{a}	62.6±4.3^{a}

Different superscript letters in each line represent significant differences (P<0.05).

At the 90 days, survival of the both species was lower in the interspecific-treatment tanks (50.0%) than in the intraspecific-treatment (26.7%) tanks. P. clarkii survival in the interspecific-treatment tanks (26.7%) was also lower than in the intraspecific tanks (55.0%) (Table 2). *P. acutus acutus* survived at a similar rate in the interspecific-treatment tanks (50.0%) and intraspecific-treatment tanks (63.7%) whereas *P. a. acutus* survival was similar in the two treatments.

Table 2. Mean and standard deviation of the survival (%) of *P. a. acutus* and *P. clarkii* in intraspecific and interspecific-treatment tanks.

Sample Days	*P. acutus acutus* Survival (%)		*P. clarkii* Survival (%)	
	Intraspecific	Interspecific	Intraspecific	Interspecific
30 days	24.9±0.4^{a}	25.2±0.4^{a}	24.3±0.5^{a}	24.0±0.5^{a}
60 days	50.6±7.2^{a}	54.0±5.8^{a}	53.0±7.8^{a}	55.6±5.5^{a}
90 days	54.6±8.6^{a}	76.2±10.3^{b}	63.1±9.5^{a}	62.6±4.3^{a}

Means within a species that share different superscripts are significantly different (P <0.05).

Discussion

Sympatic crayfish species compete for food resources (Bulter and Stein, 1985), and aggression and competition for these food sources play an important role in crayfish interactions (Soderback, 1991). In this study, it was revealed that the competition between the two species is more intense than the competition between the species. For example, the survival of two species in the interspecific treatment tanks was lower than in the intraspecific treatment tanks. The growth (TL) of both species was found to be higher in the interspecies treatment than in the intraspecies treatment, which supports previous studies (Kozak et al., 2007). Compared to interspecific pairs, individuals of *P. acutus acutus* initiated and gained greater numbers of interactions. Because of this, he was able to dominate agonistic interactions against his opponents without getting into more or longer fights and thus getting into more fights. While these values did not change for *P. clarkii,* the unilateral results of the fights reveal the competitive advantage of *P. acutus acutus* as *P. clarkii* individuals did not win the competitions. As in other similar studies, crayfish length, weight and claw length had effects on dominance, and as a result, the dominance of *P. acutus acutus* over *P. clarkii* was determined by (Eversole et al., 2006; Fero et al., 2007; Martin and Moore, 2007; Mazlum and Eversole, 2005). Eversole et al. (2006) reported that the aggressive behavior of *P. acutus acutus* individuals is the most important factor that provides an important advantage and determines the outcome. It is true that where aggressive behavior leads to death, competing crayfish have the potential to grow faster depending on the feed source. Therefore, the highest growth is expected to occur in tanks with the highest mortality (ie, interspecies tanks) (Table 2). This indicates that larger crayfish continue competitively over smaller crayfish (Momot, 1984). In environments with low stocking density, mortality is higher in tanks with high stocking (McClain, 1995). Eversole et al. (2006) indicated that male *P. a. acutus* had significantly longer chelae than male *P. clarkii* while female *P. a. acutus* chelae were longer than female *P. clarkii*. They suggested that the body size of *P. a. acutus* was important in defining the interaction between the two species. This situation has been noted in previous studies (Eversole et al., 2006; Mazlum et al., 2007). This may be one reason why the survival of red swamp crayfish in interspecies tanks is lower than in intraspecies tanks for white river crayfish. Eversole et al. (1999) showed in their previous studies that the percentage of *P. clarkii* in the harvest of these two species decreased gradually from 97% in 1991 to 45%, 33%, 4% and 1% in 1992, 1993, 1994 and 1995, respectively. Considering the previous results, it is thought that body size, fecundity and egg diameter are effective as well as abiotic and biotic factors in the decrease of *P. clarkii* in culture population (Eversole and Mazlum, 2002).

Conclusion

P. a. acutus achieved higher survival, faster growth and larger size than *P. clarkii* when grown in the tank study. The size of the body was significant in describing competitive interactions between two species.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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