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Review

Molting, reproductive biology, and hatchery management of redclaw crayfish *Cherax quadricarinatus* (von Martens 1868)

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ABSTRACT

Commercial crustacean fisheries are dwindling while demand is growing. Aquaculture is expected to meet supply requirements, thus better egg production and hatchery management are required if the industry is to keep growing. In addition to hatchery management, methods that improve crustacean juvenile production by manipulating their endocrine system are being assessed. Redclaw *Cherax quadricarinatus* aquaculture technology is mature enough to grow into an important industry. However, further growth requires research on nutrition, disease and reproduction. The present manuscript reviews existing literature about redclaw reproduction, hatchery, and nursery technology. Further research is bound to improve monosex larval production or at least develop methods to improve growth in both sexes. The market for redclaw is growing, aquaculture in warm countries is increasing and research is improving aquaculture methodologies of the species. The future is bright.

Contents

1. Introduction

The Australian redclaw crayfish (*Cherax quadricarinatus*, von Martens 1868) is a decapod crustacean (Decapoda: Parastacidae) endemic to

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freshwater habitats of northeastern Queensland, northern and eastern parts of the Northern Territory of Australia and southeastern Papua New Guinea (Curtis and Jones, 1995; Holthuis, 1986; Lawrence and Jones, 2002; Riek, 1969). Growing interest in the species, both for aquaculture and aquarium trades, has resulted in wide translocations within Australia (see Coughran and Leckie, 2007; Doupé et al., 2004) and transcontinentally (see Alimon et al., 2003; Chang, 2001; D'Agaro et al., 1999; Edgerton, 2005; Gozlan, 2010; Holdich et al., 2009; Karplus et al., 1995; Koutrakis et al., 2007; Medley et al., 1994; Ponce-Palafox et al., 1999; Romero, 1997; Rubino et al., 1990; Vazquez, 2008; Vazquez and López Greco, 2007; Volonterio, 2009; Wickins and Lee, 2002; Xiaoxuan and Edgerton, 2001; Yuniarti et al., 2011). Feral populations of redclaw are now established in South Africa (de Moor, 2002), Mexico (Bortolini et al., 2007), Puerto Rico (Williams et al., 2001), Singapore, and Jamaica (Ahyong and Yeo, 2007; Belle and Yeo, 2010; Todd and D'Andrea, 2003).

Redclaw display a number of physical, biological and commercial attributes that make them suitable aquaculture candidates (Edgerton, 2005; Holdich, 1993; Jones, 1990; Masser and Rouse, 1997; Webster et al., 2002). They grow rapidly, reaching commercial size (40–200 g) in 6–9 months at optimal conditions (Rouse et al., 1991; Wickins and Lee, 2002). Other positive characteristics include gregariousness, non-aggressiveness, and non-burrowing behavior, straightforward production technology, and tolerance to relatively high stocking densities (Masser and Rouse, 1997). The species is physiologically robust and can tolerate wide ranges of water quality conditions including low oxygen concentrations (>1 ppm), wide ranges of hardness and alkalinity (20 to 300 ppm), and pH (6.5 to 9) (Masser and Rouse, 1997). Redclaw is classified as a eurythermal, mesohaline species (Meade et al., 2002) as it can also survive wide ranges of temperatures and salinities, respectively (see also Austin, 1995; Karplus et al., 1998; Meade et al., 2002; Nyström, 2002). Moreover, *C. quadricarinatus* is a gonochoristic species exhibiting sexually dimorphic growth patterns where males grow faster and to a larger final size than females. Sexual maturity of males and females is reached in 7 to 9 months (under optimal conditions) after which three to five spawnings per female per year have been observed (Jones, 1995a; Masser and Rouse, 1997). Fecundity is moderate ranging from 100 to 1000 eggs per spawn (depending on female size). Developing redclaw larvae does not go through a planktonic stage and that facilitates hatchery protocols eliminating requirements for expensive and sophisticated setups for larval rearing (Curtis and Jones, 1995; Jones, 1995a; Jones and Ruscoe, 2000; Jones, et al., 2000; Masser and Rouse, 1997; Rodgers et al., 2006). The species can also efficiently utilize a wide range of feed resources from first feeding stages through growout (Jones, 1995b; Jones and Ruscoe, 1996a, 1996b, 1996c; Masser and Rouse, 1997).

Commercial crustacean fisheries are dwindling while demand is growing. Consequently, better egg production and hatchery management are required if the industry is to keep growing. In addition to hatchery management, attempts are made at sustaining crustacean populations by manipulating the endocrine system to guarantee constant production of juveniles (Nagaraju, 2011). Some methods for stimulating gonadal maturation and spawning in crustaceans include eyestalk ablation, administration of gonad inhibitory hormone antibody, and hormonal level changes by manipulation of environmental factors such as temperature, salinity, and photoperiod (Nagaraju, 2011). Obviously, a proper understanding of the reproductive biology of the species is of crucial importance for the redclaw industry. The present manuscript reviews knowledge about reproductive biology and common hatchery techniques in redclaw aquaculture based on existing literature and author's experience.

2. Molting and reproductive biology of *C. quadricarinatus*

In many crustaceans, molting is necessary for copulation and reproduction to occur. Molting and reproduction are both energy demanding processes in crustaceans (Raviv et al., 2008), and in redclaw, an antagonistic relationship exists between growth and reproduction (Sagi et al., 1997). Frequently, hatchery operators ablate an eyestalk to induce reproduction, coincidentally promoting molting. The X-organ–sinus gland (XO–SG) complex has a regulatory role in this antagonistic balance of molt and reproduction (Shechter et al., 2005), thus before we discuss reproduction, we feel it is important to give a short review of the molt cycle.

2.1. Molt cycle

In crustaceans, growth and development involve periodic shedding and subsequent reconstruction of the hard calcified exoskeleton (cuticle). The cuticle is composed of four layers (epicuticle, exocuticle, endocuticle, and membranous layer) with varying composition and thickness. The epicuticle is the thin outermost layer, which has a dense bi-laminar organization and is composed of protein, lipids, and calcium salts. The exocuticle and the endocuticle, the two inner thicker layers, comprise a calcified matrix composed of chitin–protein fibers stacked in layers of continuously changing orientation (nature's fiberglass) and the innermost membranous layer contains chitin and proteins but lacks mineral deposits (see Yudkovski et al., 2007, 2010 for more information).

The crustacean molt cycle is divided into four stages; premolt, molt (ecdysis), postmolt, and intermolt (Chang, 1995; Lachaise et al., 1993). During premolt the old cuticle separates from the hypodermis via degradation of the cuticle and the concurrent secretion of a new exocuticle and epicuticle. Digestion of the cuticle involves the degradation of circular chitin and proteins. Simultaneously, calcium ions get dissolved out of the mineralized matrix and transferred through the integumentary epithelium to the hemolymph (Ahearn et al., 2004; Shechter et al., 2008a). In crayfish, some of the calcium ions are taken up from the hemolymph to form the gastroliths; a pair of disk-like structures located on the sides of the stomach walls. During ecdysis, water is actively absorbed to increase the body's volume leading to rupture of the partly degraded old cuticle. During postmolt the endocuticle and membraneous layer are formed and the absorbed water is gradually replaced by tissue. At postmolt, the gastroliths collapse into the stomach where they are digested and provide an immediate endogenous source of calcium for the calcification of essential body parts (see Shechter et al., 2008a; Yudkovski et al., 2007, 2010). The remaining calcium needed for shell buildup and mineralization is absorbed from the surrounding water. During intermolt the cuticle is fully developed with very low molt-related activity happening (Yudkovski et al., 2007).

The inverse dynamics of cuticle and gastrolith formation are quite intricate. Calcium is deposited in the gastroliths during premolt and transported back to the cuticle during postmolt (Shechter et al., 2008a). Gastroliths, made of concentric layers of amorphous calcium carbonate (ACC) nanospheres interlaced with α-chitin–protein microfibrils, are formed on both sides of the stomach wall. During premolt, the sources of most calcium are the endocuticle and parts of the exocuticle, whereas the epicuticles do not undergo degradation and remain mineralized throughout the molt cycle. Addadi et al. (2003) postulated that biogenic ACC is likely to be induced and stabilized by specific macromolecules. Bentov et al. (2010) elucidated the possible roles of phosphorylated proteins in the formation of biogenic stable ACC. Results indicated that phosphoprotein (phosphoserine or phosphothreonine) molecules may play a major role in the control of ACC formation and stabilization and that their phosphor-amino acid moieties are key components in this process.

Few transient storage proteins have been identified in crustaceans including orchestin, gastrolith matrix protein (GAMP), GAP 65, and GAP 10 (see Glazer et al., 2010). Shechter et al. (2008b) identified and characterized a negatively charged glycoprotein (65-kDa protein (GAP 65) from the gastrolith matrix of redclaw). This GAP 65 was shown to have two functions; extracellular matrix formation and mineral deposition during biomineralization. It is the most abundant