
Factors controlling mortality of Red Sea Brachyuran crab larvae in rearing systems

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Abstract: Larviculture of brachyurans is essential for the purpose of systematics, conservation and other considerations. In this review, design of crab larval rearing apparatus and information on larval nutrition are reviewed and discussed. Studies have shown that crab larvae survived better in relatively smaller vessels than in bigger ones. The “planktokreisel”-based system allows larvae to develop with minimal mechanical stress, while providing adequate water renewal and circulation. Aeration is also another vital factor in rearing systems. Crab larvae cannot metamorphose to the subsequent stages on diets consisting solely of algae, protists and non-living particles. Considering the mouth size of first-formed zoea of Leucosiidae and Xanthidae, unconventional starter live feeds like nauplii of copepods are worth culturing for ensuring high feeding success. Detritus, bacterial diversity and dissolved amino acids are other unexplored areas demanding further study. The contents of this brief review would be helpful in designing a crab larval culture system and in reducing rearing associated mortality through better nutrition and controlling other associated factors.

Key Words: Brachyuran crabs, Red Sea, larval rearing, larval systematics, zoea

Introduction

Gathering information on species composition is the basis for understanding the processes affecting the equilibrium of communities or ecosystems. In this sense, the extinction of local populations or the introduction of exotic species is known to influence the dynamics of a given community. Prior identification and record-

ing of species assemblages are often crucial for adequate interpretation of disturbances, either anthropogenic or natural.

Exhaustive biomonitoring of the Red Sea is scanty and comparative zoeal descriptions from the wild to ascertain taxa are lacking. Considering the importance of brachyuran larvae

in systematics, a study was carried out to gather information on the species diversity in the Jeddah coastline of Red Sea by rearing the zoea of ovigerous females of Grapsidae and Leucosiidae is far from complete, Cuesta *et al.* (1997, 2006) and Cuesta and Schubart (1999) suggested that zoeal and megalopal stages of all grapsid genera (except Leptograpsodes with no larval data known) present a combination of consistent morphological characteristics that allows their distinction from other grapsoid families.

Zoeal and megalopal stages of leucosiid species are important components of meroplankton. Three subfamilies including 34 species and 13 genera were recorded in the Red Sea (Vine, 1986), but little is known of their larval development in Red Sea (Al-Aidarooos, 1993). A more detailed knowledge of the brachyuran diversity and the habitat in which they live may facilitate future research into their biology, ecology and also on the development of many species whose larvae are still unexplored.

Larval rearing of Red Sea brachyurans is not without its disappointments and failures. Collecting fertile ovigerous females of certain species still depends on sampling effort and success is never guaranteed. The specimens need an environment with constant temperature and rearing is time-consuming, requiring meticulous attention to detail. Even then, for no apparent reason, larval cultures occasionally

crash (Clark, 2009). The majority of brachyurans have a metamorphic life cycle with planktonic larval stages and benthic adult stage. Larvae taken from the natural environment have traditionally been difficult to identify (Clark and Paula, 2003), while hatching and rearing of crabs in the laboratory have allowed larvae to be identified unequivocally since the adults are known species (Clark *et al.*, 2005). The morphology of brachyuran larvae is crucial for the study of life histories of decapod crustaceans as well as their systematic relationships (Lee and Koo, 2008).

Culture rearing unit design considerations

Hamasaki *et al.* (2007) reported mass larval mortality in bigger tanks but found that larvae survived better in relatively smaller vessels. The survival rate of snow crab larvae in 500-litre tanks rapidly decreased and few larvae moulted to the second zoeal stage (Kogane and Hamasaki, Unpubl. data). However, in 1-litre beakers, mean survival to the first crab stage reached ca. 30% (Kogane *et al.*, 2005). Differences between survival rates in large tanks and small vessels were also observed for other brachyuran species (Hamasaki, 2003; Hamasaki *et al.*, 2002a).

Rearing systems based on Greve's (1968) "planktokreisel" proved to be very appropriate for the culture of the frail spiny lobster larvae (Illingworth *et al.*, 1997; Kittaka, 1997). Main characteristic of these systems is the maintena-

nce of larvae and food in suspension by adequate water circulation. Aeration may induce damage to the larvae and sometimes does not provide adequate water circulation, which will cause late-stage larvae to sink in the rearing tanks. The subsequent larval aggregation in the bottom of tanks will lead to "tangling", damage larval appendages or may even result in death of larvae. The "planktokreisel"-based system allows larvae to develop with minimal mechanical stress, while providing adequate water renewal and circulation.

Alternative sources of nutrition

Most species of brachyuran crabs have pelagic larvae that are planktotrophic; that is they must obtain nutrition from external sources to survive. Indeed, larvae of many species require feed shortly after hatching to promote optimal development (Anger and Dawirs, 1981; Staton and Sulkin, 1991). Because crab larvae can swim actively immediately upon hatching and have large eyes, a rapacious carnivorous habit has often been assigned, a paradigm reinforced by the success of laboratory diets that consist of small zooplankters such as brine shrimp nauplii and rotifers (Bigford, 1978) and the lack of success using microalgae (Rust and Carlson, 1960; Sulkin, 1975; Bigford, 1978) and protists (Sulkin, 1975; Bigford, 1978). However, while

larvae cannot metamorphose to the subsequent stages on diets consisting solely of algae, protists and non-living particles, they do consume them in a wide range of sizes (Costlow and Bookhout, 1959; Sulkin, 1975; Levine and Sulkin, 1984b). Furthermore, the authors showed that crab larvae will not only consume non-living microparticles, but also can absorb nutritional components from them. These observations, combined with reports of Incze and Paul (1983) and Paul *et al.* (1989) confirms that natural densities of microcrustaceans and other small animal prey are often lower than those required to sustain crab larvae in the laboratory. This suggests the need to re-evaluate possible role of alternative sources of nutrition, such as protists and microbially colonized detrital particles.

Brachyuran larvae appear to be flexible in the types of prey they ingest, which range from micro- and mesozooplankton to microalgae, heterotrophic dinoflagellates and detrital particles (Perez and Sulkin, 2005; Schwamborn *et al.*, 2006; Burnett and Sulkin, 2007). A broad spectrum of prey types may compensate for low prey densities, thus reducing the risk of larval starvation (McConaughy, 2002). According to Johnson and Shanks (1997), phytoplankton may play an important role as "background plankton", being used by invertebrate larvae as an alternative food source. In fact, Harms *et al.* (1994) provided experimental evidence that

phytoplankton is a major component of the natural diet of *Carcinus maenas* (Linnaeus 1758) larvae, including the megalopae.

Brachyuran crabs have complex life history that includes a free-living zoeal larval stage that is usually planktotrophic. This period of zoeal development is punctuated by a moulting process that results in a number of distinct, successive larval stages that varies in number among crab species, but is generally consistent within a species. Zoeal development is characterized typically by increasing size as larvae proceed through successive stages, with an accompanying increase in morphological complexity and changes in physiology (Levine and Sulkin, 1984a) and behaviour (Sulkin, 1984). In most species, feeding on particulate sources of nutrition must occur in each larval stage for development to proceed through moulting to the next stage (Sulkin, 1975; Bigford, 1978; McConaugha 1985). Feeding soon after hatching ensures adequate nutrition to sustain development (Anger and Dawirs, 1981; Anger *et al.*, 1981; McConaugha, 1985; Staton and Sulkin, 1991). A healthy diet must include large micro- and mesozooplankton (Sulkin, 1975; Bigford, 1978; McConaugha, 1985; Harms and Seeger, 1989; Anger, 2001). In nature, such prey is likely to include the larval stages of other invertebrates and small holoplanktonic zooplankton.

Although field studies have indicated that

larval crabs ingest phytoplankton (Incze and Paul, 1983; Paul *et al.*, 1989; Meyer-Harms and Harms, 1993), laboratory studies have shown that diets consisting solely of such prey cannot sustain development (Sulkin, 1975; Bigford, 1978; Anger, 2001). Newly hatched larvae must be provided with prey immediately or survival will be reduced even if subsequent feeding with optimal prey occurs (Anger and Dawirs, 1981; Anger *et al.*, 1981; Staton and Sulkin, 1991). Satisfying such needs may be problematic for newly hatched larvae. Such larvae typically hatch on or near the bottom and must swim up into the water column, an activity that demands expenditure of energy, to encounter large micro- and mesozooplankton in densities sufficient for effective feeding (McConaugha, 1985; Natunewicz and Epifanio, 2001). Larvae may meet this challenge by ingesting phytoplankton, thus accessing a source of nutrition that by itself cannot sustain development, but may nevertheless provide sufficient sustenance until they encounter patches of more favoured prey (Perez and Sulkin, 2005).

Perez and Sulkin (2005) reported that stage 1 larvae of six species of crabs ingested 13 different species and strains of dinoflagellates, including toxic strains. Furthermore, newly hatched larvae have been shown to ingest non-living prey, including detrital particles (Lehto *et al.*, 1998). They thus appear to be opportunistic

encounter feeders, meeting nutritional demands by ingesting a wide variety of prey types. However, this feeding model for newly hatched larval crabs is a complicated one. On the one hand, larvae are not efficient feeders, capturing particles that they do not ingest (Hinz *et al.*, 2001) and ingesting particles of little or no nutritional value (Levine and Sulkin, 1984b; Lehto *et al.*, 1998). On the other hand, larvae can be quite selective among various algal types, ingesting some and rejecting others (Hinz *et al.*, 2001; Perez and Sulkin, 2005). Indeed, in spite of this capacity to select among feed types, larvae will nevertheless ingest potentially toxic dinoflagellates, including at least one strain that kills them (Perez and Sulkin, 2005).

The increased nutritional contribution of microbially enriched particles is consistent with reports that detrital consumers are more dependent upon the microbial layer associated with detritus than on the substrate itself (Fenchel, 1970; MacKay and Kalff, 1973; Barlocher and Kendrick, 1973; Cummins, 1974). Larvae may benefit directly from the organic matter provided by the microbes or indirectly from the detrital substrate that has been physically and/or biochemically modified by the action of the microbes (Lawson *et al.*, 1984). Bacteria as biocontrol agents in larval rearing are most effective in higher survival percentages (Nopni and Maeda, 1992). The

timing of the introduction of a prey organism into a culture system is important for a number of reasons. Firstly, live food organisms are provided as prey, and therefore need to be easily captured, digested and assimilated by the cultured species. Various prey organisms have varying sizes, swimming speed, digestibility and assimilation efficiencies all of which may change with ontogeny of the prey and the larvae.

It is generally through research such as this that appropriate feeding regimes are elucidated. While the provision of various species of prey organisms with differing physical and nutritional characteristics throughout the larval rearing period may ensure the larvae have a suitable prey at all times. The difficulties in terms of culture and hatchery management may make the overall hatchery unprofitable. Secondly, prey organisms compete with the larvae for specifically provided microalgae and dissolved oxygen, which can be in limited supply in intensive hatchery systems (Ruscoe *et al.*, 2004). Some live feeds can produce toxic metabolites, including ammonia that can compromise water quality (Samocha *et al.*, 1989).

To summarize, still there is plenty of grey area on information related to larval rearing technique of Brachyuran larvae and their nutritional requirements. Other than developing more efficient larval rearing systems, the optimal rearing conditions and rearing techniqu-

es needed for better survival demand intense research. Rearing protocol that included combination of a green-water batch system for early stages and a recirculating system with micro-algae supplementation for later stages resulted in the best overall performance of *Scylla paramamosain* larvae (Nghia *et al.*, 2007). In nutritional parlance, unconventional starter live feeds like nauplii of copepods are worth culturing for ensuring high feeding success. Detritus, bacterial diversity and dissolved amino acids are other unexplored areas demanding further study.

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