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Prospects for aquaculture of bay lobsters (*Thenus* spp.)

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Abstract The Australian Fresh Research and Development Corporation Pty Ltd (AFR & DC) in association with the Department of Primary Industries and Fisheries, Bribie Island Aquaculture Research Centre (DPIF, BIARC) has been researching and developing the aquaculture potential of the Bay Lobster, *Thenus* spp. since 1995. The project was undertaken with the view of developing an economically sustainable supply of consistently high quality seafood products in controlled environments unaffected by the unpredictable forces of nature.

The AFR & DC achieved a world first by successfully rearing larvae of this species through to the juvenile stage and then to maturity. The attributes of this species, including rapid growth to commercially acceptable sizes within 13 months from hatching, ability to tolerate crowding and high market prices make it a highly attractive commercial aquaculture proposition. The AFR & DC has been conducting research to confirm these attributes in the laboratory initially and subsequently in pilot scale production. The successful pilot scale production is based on a better understanding of animal biology, including the digestive system, nutritional requirements and physical requirements.

Key words: *Thenus*, aquaculture, digestive system, commercialization

Introduction

Bay lobsters (*Thenus* spp.), locally known as the Morton Bay bugs, are members of the scyllarid lobster family and are found along the entire northern coast of Australia from Shark Bay in Western Australia to Coffs Harbour in northern New South Wales (Kailola *et al*., 1993). There are two *Thenus* species: *Thenus indicus* (the Mud bug) and *Thenus orientalis* (The Sand bug) (Fig. 1). Mud bugs are brown overall and have brown stripes on their walking legs, while Sand bugs are speckled overall and have spots on their walking legs. Mud bugs prefer a bottom of fine mud, and are typically trawled from inshore coastal waters of 10 to 30 meters depth. Sand bugs tend to prefer sediments with a larger, coarser particle size, and are usually trawled from a depth of 30 to 60 meters in the coastal shelf and offshore areas (Courtney *et al*., 2001). The Queensland catch of Bay Lobster is currently 400-650 tonnes as a by-product of prawn and scallop trawling with a wharfside value of at least $5.2-8.2 millions (Courtney *et al*., 2001). The current minimum legal size for all *Thenus* species in Queensland is 75mm carapace width, and the capture of egg-berried females is prohibited (Courtney, 2002).

Currently, commercial aquaculture of any palinurid and scyllarid lobster species is not being carried out anywhere in the world. The major unsolved problem for developing aquaculture techniques of lobster species lies in the successful maintenance of the planktonic larval (phyllosoma) stages, where the phyllosoma stages are longer-lived (generally 150 to 300 days) and pelagic in natural habitat. Although significant efforts for advancing rearing methods of rock lobster phyllosomas have been made in recent years, mass-culture of rock lobster phyllosomas is still not feasible at this stage. However successful results have been reported from a recent study of

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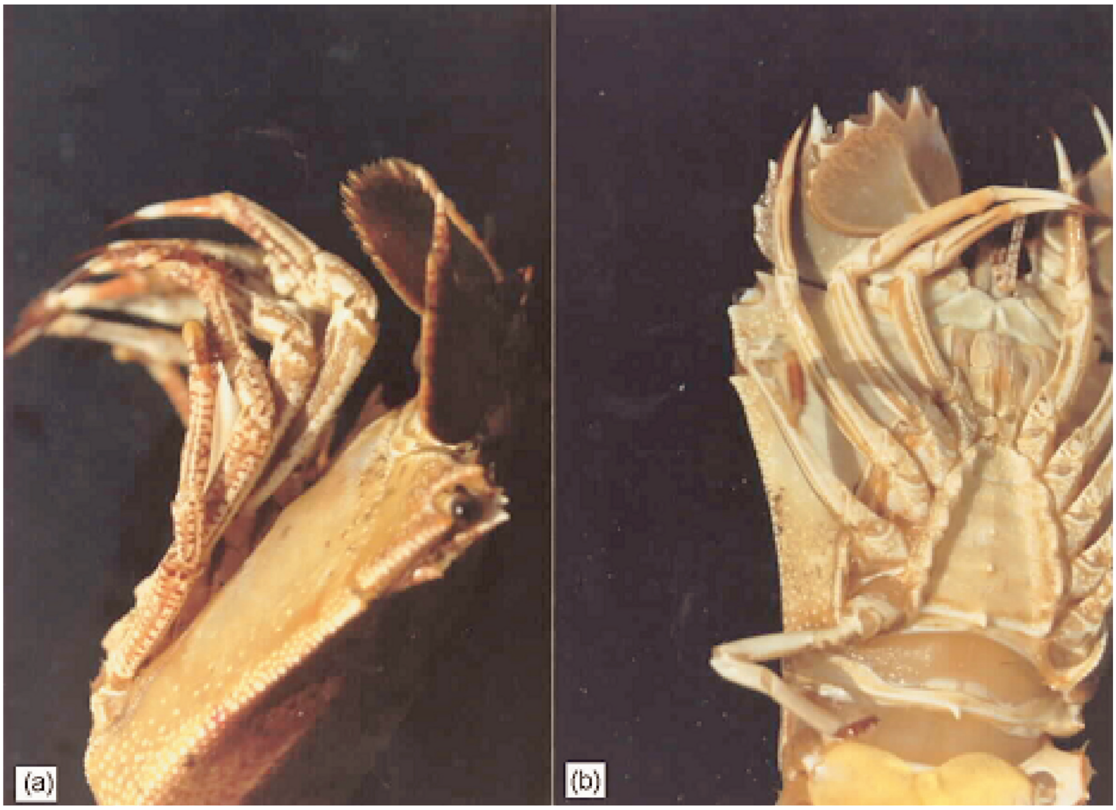

Fig. 1. (a) Sand bug *Thenus orientalis*, indicating spots on their walking legs and (b) Mud bug *Thenus indicus* indicating stripes on walking legs.

Thenus species, where phyllosomas of *Thenus* pass through only 25 to 30 days with high survival rate (>80 %), and juveniles can grow to market size (250 g) within 400 days in the growout phase (Mikami, 1995). This paper examines the potential to apply information and techniques obtained from rearing of *Thenus* from the experimental scale, and describes the proposed recirculation commercial scale facility for *Thenus*.

Biology of Thenus

Thenus spp. live on the sandy or muddy sea floor in tropical-subtropical coastal waters. Within the genus *Thenus*, *T. orientalis* is the larger of the two species and generally caught in greater depths, ranging from 30-60 m. The smaller species, *T. indicus* is generally taken in depths to about 30 m (Courtney, 2002). Females spawn as many as 60,000 eggs per individual during the summer. Two spawnings per one female during one season is common, showing two spawning peaks in early summer (August-September) and late summer (January-Feburary) (Kailora *et al.*, 1993). Phyllosomas hatched from eggs go through 4 moult stages, then metamorphose to the benthic nisto stage. The average total body length of newly hatched phyllosomas is 3.86 mm for *T. orientalis* and 3.67 mm for *T. indicus*, and that of final (4th) instar phyllosomas is 18.22 mm for *T. orientalis* and 16.44 mm for *T. indicus*, respectively (Mikami and Greenwood, 1997). The average duration of hatchery reared phyllosomas of *Thenus* at the temperature of 26-27℃ is 25-30 days (21 days minimum), believed to be the shortest duration of the phyllosoma stage within any palinurid or scyllarid species (Mikami, 1995). After 19 moults, most juveniles can reach a typical market size of about 250 g. The time taken from eggs to market size depends on temperature and food supply, but generally ranges for 400 to 450 days. Some females can spawn eggs 1 year from hatching, but most females spawn 2-3 years after hatching (Kailora *et al.*, 1993).

Functional morphology of the lobster digestive system

There is no doubt that diet is an important factor affecting survival of phyllosomas and juveniles/adults of lobster species, and one of the key issues for successful development of lobster aquaculture. Observation of the functional morphology of the digestive system can indicate the suitability of particular food types and contribute to better understanding of the requirements for larval and growout diet developments. Knowledge derived from the study of the digestive system can also be used as an indication of whether developed diets are properly utilized by phyllosomas and juveniles/adults. There are many publications on the functional aspects of digestive system of lobster species, with review of Mikami and Takashima (2000).

The basic structure of the phyllosoma mouthparts in palinurid and scyllarid lobster species is similar; the large labrum and paragnaths form a well-developed semi-enclosed chamber covering the mandibles' top. The symmetrical coronal surface of the mandible is divided into three portions: the canine-like process, the molar process and well-developed incisor process. It is suggested that only soft food masses can enter the semi-enclosed chamber surrounded by the labrum and paragnaths, where only "chewing" of food mass occurs by the well-developed incisor process of mandibles. The stomach of phyllosomas consists of a simple straight tube, different from that of juveniles/adults, which consists of two chambers, the cardio and pyloric chambers. The absence of a two chamber system in the phyllosoma stomach indicates that the function of the stomach is mainly squeezing and filtration of the food particles previously cut and chewed within the mouthparts (Mikami *et al.*, 1994). The midgut gland of the phyllosoma is the most noticeable structure of the digestive system with a single layer of midgut lumens occupying most of the inner carapace. The lumen of the midgut gland consists of the four different cell types (R-cells, B-cells and F-cells); and R-cells and B-cells are thought to be involved intercellular digestion (Mikami *et al.*, 1994). The R-cells are the

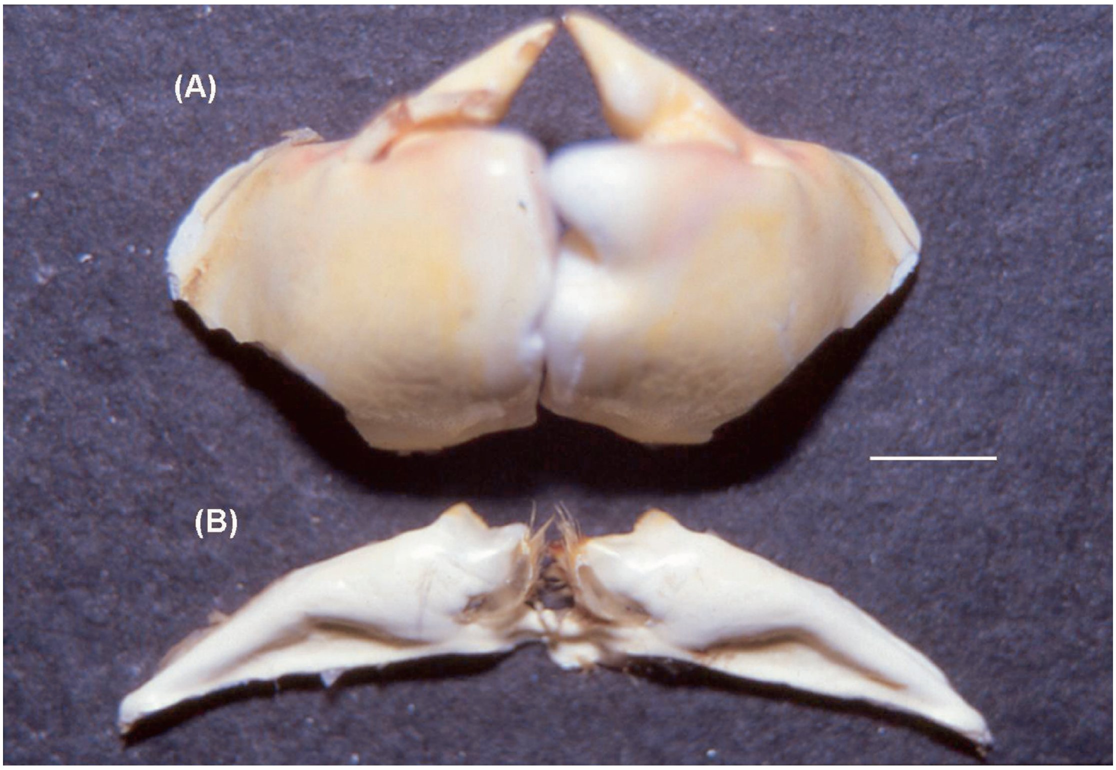

Fig. 2. The mandibles of same size adult of (A) *Panulirus longipes* and (B) *Thenus orientalis*, Scale bar represents 1cm.

most abundant cell type within the midgut gland and characteristically contain a large number of spherical globules after feeding. The R-cells absorb low molecule size digested nutrients including amino acids, carbohydrates and phospholipids by selective transportation through the apical cell membrane. The B-cells pinocytotically absorb nutrients of large molecular size form the lumen of the midgut gland and store these in vacuoles. The theory is that the B-cells store nutrients within the vacuoles, later holocrine to the lumen of the midgut gland and then they are re-digested by the R-cells. The spherical globules of phyllosoma midgut disappear within a short time (0.5-1 hour) after feeding, and also B-cells are not dominant, suggesting continuous feeding of phyllosomas for their maximum growth.

The structure of mouthparts in juvenile/adult lobsters is very different depending on species in relation to their habitat. For example, the mandibles of *Panulirus* are well developed with strong molar and canine processes, suitable for crunching hard material, like the gastropod shell. On the other hand, mandibles of *Thenus* are poorly developed, indicating they are able to chew only soft-bodied material (Fig. 2). The structure of the digestive system of juveniles/adults lobsters suggests juveniles/adults can store nutrition better than the larval stage. The stomach of juveniles/adults consists of 2 chambers (cardiac and pyloric chambers) with series of calcified ossicles, which are capable of grinding stored food into small particles. The lumens of the midgut gland extend three dimensionally, some nutrients such as glycogens and lipids can be stored among the gaps between lumens. These adult digestive system structures suggest they are adequate to starvation and less frequent feeding for their optimal growth.

Development of larval rearing system

Three key issues have now been identified for the successful rearing of oceanic phyllosomas; 1) nutrition, 2) hygiene (bacteria/virus control) and 3) hydrodynamics (tank design). Although *Artemia* and mussel gonad have been used a food source, poor survival and growth rate records indicate that they may not be ideal in terms of quantity and quality, particularly for late stage phyllosomas. Zooplankton (*e.g.*, *Sagittas*, Copepod), hydromedusa and fish larvae have also been tested previously, but have not been successful due to difficulties in maintaining a continuous supply. The development of artificial diets is one solution for overcoming the nutritional problem.

Bacterial/viral control is another key issue for the rearing of long-lived oceanic phyllosomas under controlled environments. Traditionally, a number of antibiotics (*e.g.*, OTC, Streptomycin, Chloramphenicol) and chemicals (*e.g.*, formalin) have been used for controlling bacterial colonies in the rearing water of phyllsomas. Though antibiotics and chemicals are strong agents for minimising

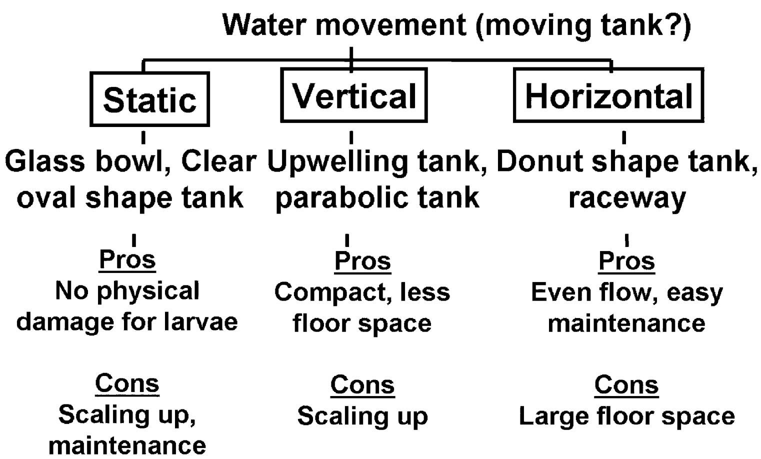

Fig. 3. The summary of larval rearing systems.

bacterial growth in the laboratory, they are not considered a long-term solution for the large scale rearing of lobster larvae. Alternative disinfection methods, such as UV and Ozone (O_3), should be considered.

Tank design with consideration of hydrodynamics is crucial for the maintenance of fragile phyllosomas. Because of the phyllosomas' unique morphology (flat body and long appendages), strong aeration can damage body segments. No water movement, or only gentle water movement, can be used in the tank. Movement of rearing water also needs to take into consideration the phyllosomas' behaviours (swimming, feeding and phototactic), food distribution and maintenance of tank system (Fig. 3).

Development of *Thenus* recirculation aquaculture facility in northern New South Wales, Australia

Despite the advantage of a short growout phase, there has been no record of commercial production of *Thenus* anywhere in the world. The major hurdle in the commercialisation of *Thenus* aquaculture has been the difficulty in maintaining the phyllosoma stages. Recently however, the scientific riddle of growing Bay lobsters in a laboratory from eggs to juveniles was solved, with consistent survival of over 80 %. A pilot system for growing Bay lobsters has been operating successfully, and Australian Bay Lobster Producers (ABLP) is currently proposing to develop the aquaculture facility for the production of the *Thenus* spp. in northern New South Wales, Australia. The proposed facility will be based on recirculation aquaculture technology with animals housed in shallow raceways. The project has been designed to produce two products; live hard shell animals of an average 218 g and soft shell animals (frozen or fresh chilled) of an average 45 g. The proposed yearly production of Bay Lobster will be 1076 tonnes in Stage 1 and this will require a standing stock of approximately 400 tonnes of animals (Fig 4).

Australian Fresh Research and Development Corporation (AFR & DC) have been conducting research and pilot scale production of *Thenus* spp. over the past 11 years at the Department of Primary Industries & Fisheries, Bribie Island Aquaculture Research Centre (BIARC). During the early period of research bacterial disease of larvae, associated with poor nutrition was the identified

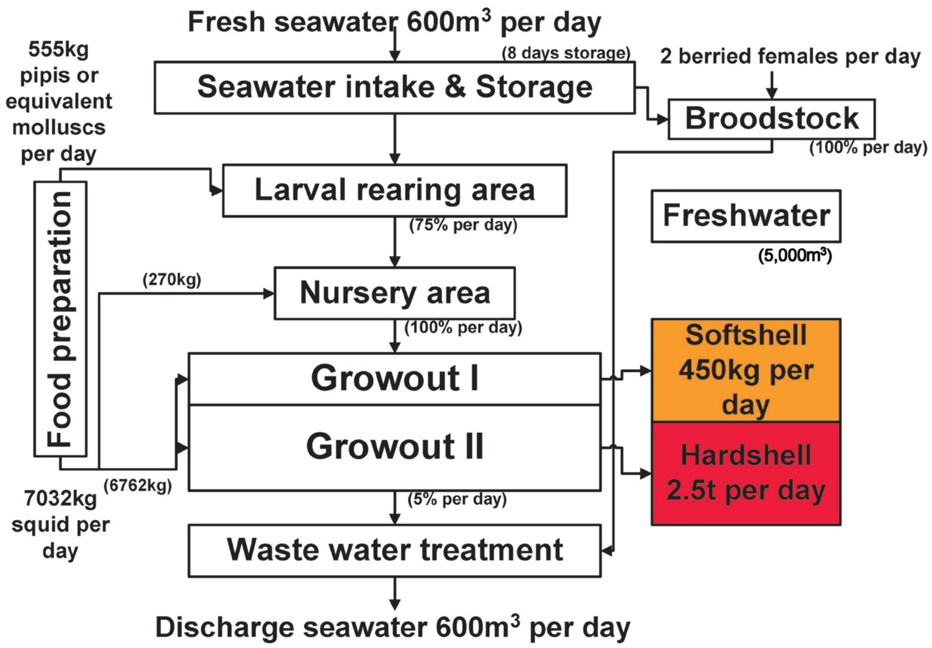

Fig. 4. The summary of proposed *Thenus* aquaculture facility in northern New South Wales, Australia.

cause of mortalities experienced. Modifications to the larval production system and optimization of nutritional requirements have dramatically reduced the incidence of bacteria-related mortality. After the larvae metamorphose to the nisto stage and then become juveniles, they become much more robust and no disease agents have been identified as causing mortality of juveniles/adults during culture trials. The bacteria that have been observed to infect phyllosomas are those always present in any body of seawater. The theory is these bacteria opportunistically attack phyllosomas that are in a poor state of health due to suboptimal environmental and nutritional conditions. Dosing of ozone to ensure sterilisation of the seawater can minimise the level of bacteria-related mortality.

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