

Development of a Sustainable Mangrove Crab Industry through Science-Based Research

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Farming of mangrove crab (or mud crab) species, e.g. *Scylla serrata*, *S. tranquebarica* and *S. olivacea* has long been established in the Philippines although the preferred species for growing is *S. serrata*. The Philippines' total production of mangrove crab from aquaculture in 2013 was estimated at 16,160 metric tons valued at PhP 5.2 billion, making the country the second top producer of mangrove crab in the world (FAO, 2015). The sources of crab seeds for farming are from the wild and in recent years, a small percentage from hatcheries. Degradation of the natural habitat and uncontrolled collection of all sizes of crabs have resulted in the depletion of the natural population of mangrove crab. As a stopgap measure, the Bureau of Fisheries and Aquatic Resources (BFAR) together with the provincial and municipal government issued ordinances that prohibit the gathering and selling of crablets (≤ 3 cm) outside the municipality of origin to reduce not only the volume of harvest from the natural habitat but also the collection and trading of ovigerous (berried) females. This has resulted to increased acceptability of hatchery-reared crab juveniles by crab growers. Through the R&D efforts of the Philippine-based SEAFDEC Aquaculture Department, dissemination of sustainable management of mangrove crab culture to the region has been intensified for a sustainable mangrove crab industry in Southeast Asia.

Intensifying Research on Sustainable Mangrove Crab Production

The SEAFDEC Aquaculture Department (AQD) has been conducting studies on mangrove crab seed production since 1977 but was discontinued due to focus of studies on other priority crustaceans such as *Penaeus monodon*. Studies were later reactivated in 1997 when the Australian Centre for International Agricultural Research (ACIAR) provided funds to AQD for the conduct of studies that mainly focused on the development of seed production and improved farming techniques. Later in 2002, the European Union also provided funds for AQD to implement a four-year collaborative project on the culture and management of *Scylla* species. With involvement of the University of Wales in Bangor, United Kingdom; University of Ghent, Belgium; and Can Tho University, Viet Nam, the AQD collaborative project was aimed at improving the reliability and economic viability of mangrove crab hatchery and nursery production for mangrove-pond aquasilviculture systems and stock enhancement. Moreover, the Government of Japan through its Japanese Trust Fund also partially funded a four-year study on the domestication of mangrove crab starting 2007.

With such outpouring support, AQD was able to carry out refinements on the grow-out phase of mangrove crab culture starting in 1981, including the establishment of various stocking densities and feeding schemes, and development of culture management schemes in succeeding years. In 1995, AQD initiated studies on crab culture in mangrove pens in Panay Island in the Philippines, which were followed by trials on crab monoculture in tidal flats and estuaries with existing mangroves which were verified in various places in the country together with efforts that aim to enhance the adoption of crab culture technologies in coastal communities.

The approach used was based on the framework under the Institutional Capacity Development on Sustainable Aquaculture of AQD where science-based technologies are disseminated to coastal communities, Local Government Units (LGUs) and other stakeholders. As a result of such development, AQD attained advancements in mangrove crab culture (**Box 1**) that had been disseminated to the Southeast Asian region through capacity building and massive information dissemination.

Series of activities in the production of soft-shell mangrove crabs using hatchery-produced seeds is shown in **Box 2**. This scheme is being promoted by AQD not only in the Philippines but also in the whole Southeast Asian region.

Addressing Issues and Concerns in the Mangrove Crab Industry

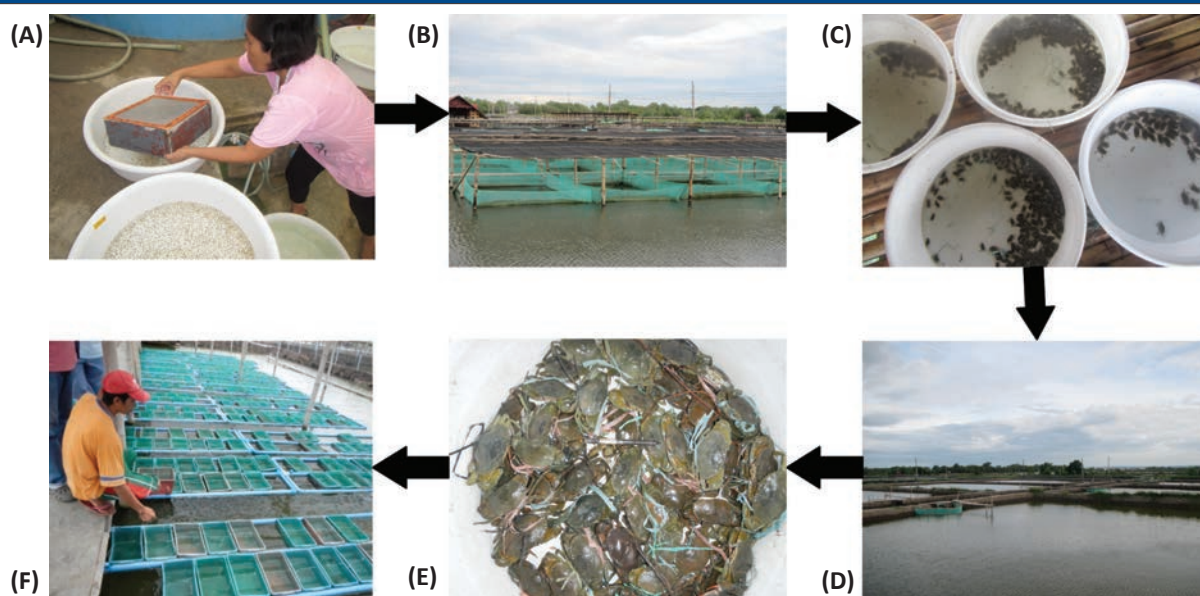
Although basic technologies had been developed for all phases of culture, e.g. hatchery, nursery, grow-out, fattening and soft shell crab production, studies have been conducted by AQD to continuously refine the techniques in order to improve the economic viability of producing crablets and adult crabs. Moreover, major issues that impede the sustainable development of mangrove crab industry are also being addressed. These include lack of seedstock, cannibalism particularly at the nursery phase, use of fish as aquafeed, difficulty of zoea V to molt to megalopa stage (Molt Death Syndrome or MDS), and diseases (bacterial and fungal infection, protozoan infestation in eggs and larvae, and White Spot Syndrome Virus or WSSV in sub-adult and adult crabs in ponds).

In an effort to address concerns as well as the various issues facing the industry, the Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development (PCAARRD) of the Philippine Department of Science and

Box 1. Advances attained by AQD's R&D on mangrove crab

- Completion of life cycle of mangrove crab species
- Genetic structure and domestication of *S. serrata*
- Comparison of lipids in wild and pond-reared broodstock
- Assessment of reproductive performance in broodstock fed formulated feeds and/or natural food
- Identification of ovarian and embryonic development of *Scylla* spp.
- Development of hatchery technology and pilot testing of hatchery operation
- Determination of digestive enzyme dynamics during early larval stages
- Determination of feeding apparatus and foregut of larval stages
- Determination of feeding levels using natural food during larval stages
- Determination of use of formalin as prophylaxis
- Determination of acute toxicity of nitrite to crab larvae
- Salinity requirements for larvae and crab instars
- Development of nursery technology (Phases 1 and 2)
- Reduction of cannibalism using various strategies such as trimming of claws during intermolt and postmolt, manipulating density, and using various shelters in the hatchery
- Agonistic behavior of crabs
- Dietary tryptophan to reduce aggressiveness of juvenile crabs
- Apparent digestibility of feedstuff by mangrove crab
- Identification of dietary protein and lipid levels and protein to energy ratios
- Development of formulated diets (FD) for the various life stages (broodstock, larvae, juveniles, and subadults) and various feeding schemes using FD and natural food
- Identification of diseases in the hatchery and grow-out culture
- Monosex vs. mixed sex culture of mangrove crabs in pond grow-out
- Development of aquasilviculture using formulated diets
- Stock assessment of mangrove crab species in selected sites
- Behavioral studies prior to release in the estuaries
- Release and retrieval methods in stock enhancement

Box 2. Production of 60-100 g *Scylla* spp. juveniles: hatchery-produced crab instar (A) are cultured in nursery net cages for 3-4 weeks (B) then transferred to nursery ponds and grown for 4 weeks to crablet size (C). The crablets are cultured in bigger pond compartments (D) for 1.5-2.0 months to obtain 60-100 g (E) for stocking in soft-shell crab facility (F)



Deformed abdominal flap in juvenile crabs, one of the common abnormalities, when exposed to high levels of antibiotics during the larval phase

Technology (DOST) launched the National Mud Crab Science and Technology Program (NMCSTP) in 2012 that initially included 14 projects aimed at improving the production, profitability and sustainability of mangrove crab culture. Specifically, the NMCSTP aims to reduce the dependence on the supply of wild caught crabs by accelerating the transfer of improved technologies on hatchery, nursery and grow-out culture to stakeholders; and increase production and maintain or improve the country's status as the second largest producer of mangrove crab in the world.

Later, five (5) more projects were undertaken to address the issues on identification of mangrove crab species (especially during the younger juvenile stage), traceability, disease prevention, and muscle emaciation, weight loss, ammoniacal odor, and other factors associated with storage and transport that could lead to lower market value.

Applications of genomics in mangrove crab aquaculture and resource management (stock delineation, molting, etc.) have also been included. The various projects under NMCSTP are being undertaken by AQD, University of the Philippines (Visayas and Diliman) and De La Salle University (Manila).

A summary of results from recent research studies on mangrove crab done by various researchers and scientists in the Philippines is shown in **Box 3**.

Capacity Building

Another very significant activity of AQD is building the capacity of various sectors on the various technologies developed. Under the NMCSTP as in other AQD programs, improved technologies for all aspects of mangrove crab culture have been disseminated to the private sector, Non-government Organizations (NGOs), State Universities and

Box 3. Results of research studies on mangrove crab conducted in the Philippines

Broodstock Management and Seed Production

- Completed life cycle of mangrove annelids (*Marphysa mossambica*) (F_2) resulting to mass production of pathogen-free annelids
- Improved production of good quality larvae using *M. mossambica* as live food and feed ingredient for crab broodstock
- Criteria developed for selection of good quality newly hatched larvae for rearing using formalin stress test
- Natural food reduced by 50% with the use of formulated diets for larval rearing
- Refined feeding and water management reduced MDS resulting to improved survival rate of megalopa/crab instar from 3% to 22%
- Identified application of antibiotics during larval stage as one of the causes of morphological deformities in juveniles

Nursery Phase

- Attained higher survival of 70% in Phase 1 and 70-90% in Phase 2
- Identified net shelters simulating sea grasses as most suitable for nursery, 60-70% SR even at higher density of 50 ind/m²
- Feeding 30 mussel: 70 formulated basal diet sufficient to support good growth, survival and profitability
- Tryptophan in the diet not necessary in nursery rearing in ponds
- Attained better FCR and profitability in the nursery when feeding rations of either 100 initial body weight for the entire 3 weeks, or weekly adjustment of 100-50 -40 % of body weight for weeks 1,2,3, respectively for Phase 1; and weekly adjustment of 40-30-20% for Phase 2
- Established procedure for nursery phase to produce 60-100 g hatchery-reared juveniles for soft-shell crab farming in ponds
- Adopted soft-shell crab technology using hatchery-produced juveniles

Grow-out Phase

- Basal diet and improved formulated diet identified for mangrove crab
- Identified suitable binder that allows feeds to be stable in water in ≥ 5 h
- Assessed feeding behavior of crab: consumption and preference (e.g. semi-moist with different shapes and sizes) of different sizes of crabs
- Improved crab feed developed for commercial production
- Feeding strategies determined (frequency of feeding, amount, etc.)

Diseases

- Developed immunostimulant (polysaccharides from brown and green algae) for improving growth, survival, immunity and disease resistance of crabs
- Identified commercially available immunostimulants for crabs
- Identified two antimicrobial extracts effective against *V. harveyi* *in vitro* and *in vivo* tests
- Determined extracts to be non-toxic at 0.5-4 mg/ml
- Identified non-pathogenic probiont to all crab stages
- Evaluated farming practices and updated list of known diseases and other abnormalities in monoculture, polyculture and aquasiviculture systems
- Identified risk factors during culture

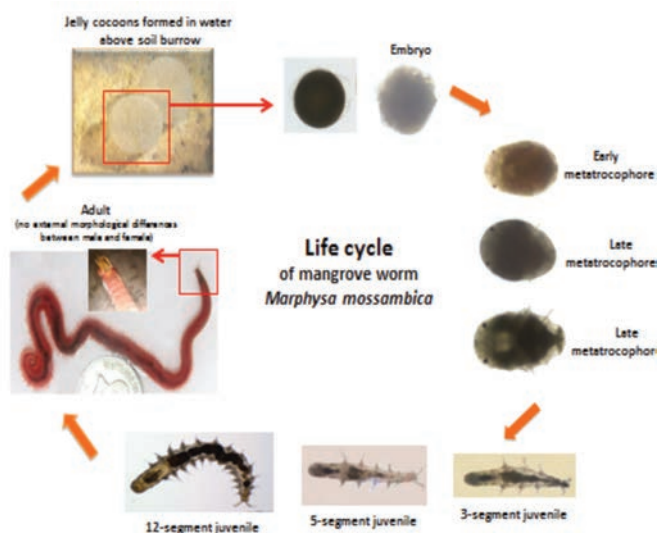
Feeds and Feeding

- Identified spherical or tubular as best form for formulated diet for juveniles
- Identified synthetic binders as more effective than natural feed binders in making pellets stable in the water up to 24 h.
- Developed SEAFDEC/DOST-PCAARRD grow-out diet for commercial production

Others

- Determined/developed applications of genomics on mangrove crab (maps, apps, molting and intermediate phenotype)
- Determined physiological responses of mangrove crab juveniles from coast of Bataan, Philippines to mercury/heavy metal levels

Colleges (SUCs), government agencies and LGUs through collaborations, regular training programs at AQD or on-site, conferences, workshops and publications. A number of private crab hatcheries had been established in the country through the NMCST under the guidance of AQD. A prototype demo-hatchery showcasing improved hatchery protocols was set up in Guindulman, Bohol. This demo hatchery is capable of producing 40,000 crab instars and was turned over to the Bohol LGU in May 2015.



Complete life cycle of mangrove worm *Marphysa mossambica*, used as mangrove crab feed (Adapted from VR Alava, 2007)

Furthermore, the Philippine Government also provides capacity building to various sectors on the different phases of mangrove crab culture. The various collaborations and the continuous activity on crab culture enabled AQD to package crab technologies, conduct local and international training courses and on-site technology demonstrations, and publish extension manuals and scientific publications since the mid 1990s. On-site training courses on mangrove crab culture had been conducted for members of LGUs, People's Organizations and coastal communities in the country, as well as in other countries such as in Brunei Darussalam, Myanmar, Timor Leste, India, and Bangladesh. A number of stakeholders from the private sector are now engaged in crab seed production.

Most of the hatchery operators that are into crab seed production are also engaged in marine fish seed production with an established rotifer production system. Rotifer is the major food item for the early larval stage of mangrove crab. Other hatchery operators have modified their shrimp hatchery facilities for crab seed production. To impart the recent technologies and developments in crab culture, a National Mud Crab Congress was organized by AQD, University of the Philippines-Visayas and PCAARRD-DOST. Funded by PCAARRD-DOST, the Congress brought together scientists, industry practitioners and stakeholders, government, and the academe from various parts of the Philippines. Recent developments related to culture or husbandry, diseases,



Net shelters simulating sea grasses are most suitable for nursery rearing of mud crab

resource enhancement and management, sustainable aquaculture and post-harvest of mangrove crabs were shared with the participants. Relevant issues and problem areas surfaced during the workshop and recommendations to address these were put forward for further research. Thus, the R&D on mangrove crab had been translated into improved production. With the developments and refinements of technologies, it is expected that the Philippines will increase its production by 25-50%. Other Southeast Asian countries could also follow suit in the future.



International trainees at AQD's Mud Crab Training identifying the ovarian maturation of crabs (*top*), and on-site trainees supervised by AQD Scientist in the construction of bamboo cage for fattening of crabs in Timor Leste (*above*)

Philippine National Standard (PNS) for Live Mangrove Crabs

The Bureau of Agriculture and Fisheries Standards (BAFS) of the Philippine Department of Agriculture (DA) in collaboration with government and research agencies, academe and industry practitioners developed the Philippine National Standards (PNS) for live mangrove crabs. PNS determines the food safety and quality requirements for live mangrove crabs to ensure health and safety of consumers and make the product globally competitive. After several deliberations, the PNS for live mangrove crab was finalized and approved by the DA Secretary in 2016. The World Trade Organization has also been notified of the PNS which is also applicable to mangrove crabs coming into the country, if any.

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