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Review Article

Fisheries Assessment, Gametogenesis and Culture Practice of Local Bivalve: A Review

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ABSTRACT

Hard clams are found to overwhelm the benthic territory from the remote oceans in the marsh region, especially the tropical region. It is a filtered feeder that feeds upon microorganisms, debris and dissolved primal matter as the metabolic vitality hotspot for development. The abundance of food source caused mariculture of hard clam a possible practice in the open sea. Although harvested hard clams through mariculture progressively increase each year, they are still found to be less than oyster and cockle production. Knowledge of gametogenesis is essential for shellfish culture with a specific end goal to resolve the appropriate conditions for breeding. The gametogenesis is ordered into six phases, i.e. resting, early advancement, late advancement, ripe, spawning and spent. Fertilisation between sperm and egg occurs after hard clam spawning by chemical and physical incitement in the environment. Inseminated eggs experience several phases, i.e.; trochopores, D shape hatchlings, umbonal hatchlings and juvenile phase before ending up as mature shellfish. This review is chiefly intended to cover the biology and culture capability of hard clams, especially in Malaysia.

Keywords: Biology, gonad development, hard clams, mariculture, veliger

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INTRODUCTION

Western Coast of Peninsular Malaysia is known for shellfish culture, which consists of *Perna viridis, Paphia undulata, Anadara granosa,* and *Crassostrea* spp. (Poutiers,

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1998; Vakily, 1989). In Sarawak, most of the bivalves (*Modolus* spp., *Pinna* spp., *Placuna* spp., *Polymesoda* spp., *Meretrix* spp.) are gathered from natural environment, with a high demand from the local market (Hamli et al., 2012; Idris et al., 2008; Lovatelli, 1988a).

Among shellfish that are found in natural habitats, *Polymesdoa* spp. (Corbiculidae) and *Meretrix* spp. (Veneridae) are mostly exploited by local communities in the coastal areas of Sarawak as a protein substitute. According to Hamli et al. (2012), these hard clams were traded at seven divisions in Sarawak. Despite a high demand from the market, there is no documentation on hard clam culturing practice from Sarawak. Most fishermen collected it from the mudflat area during the low tides. The coastal area, together with flora and fauna, sustains each other to form a tangible ecosystem. Sarawak itself sustains a large area of lowland of approximately 1.24 million ha or 13% of the total land area (Page, 2011). This area consists of wide areas of mudflats, which provide a proper habitat for hard clams and other bivalve species. Therefore, this area is able to support a large number of fauna consisting of adequate supply of nutrients to help prolong clam heredity.

However, lowland area is vulnerable to the destruction and pollution from rapid urbanisation activities in Sarawak. Pollution from the urban area and factories will damage the natural habitat of clam species. Pollutants commonly derived from sawmills, wood chip and sago factories may destroy the natural habitat of molluscs and other biodiversity (Davy & Graham, 1982). Disturbance of the habitat will alter the nutrient and biotic composition, which eventually affects the survival of hard clams. Moreover, the depleting number of hard clams also may result in overexploitation to meet the market demand, which increases every year.

Morphology

Bivalve is also identified as two symmetrical shells or two valves associated with tendon at the pivot (Spencer, 2002; Webb et al., 1978). Poutiers (1998) described that Veneroida orders had three diverging cardinal teeth belonging to Veneridae and Corbiculidae families. Cardinal teeth are significant in valve movement mechanism as a hinge which is regulated by anterior and posterior adductor muscles (Spencer, 2002). The resting position of adductor muscle will cause the ligament to spring apart the valves and the valves are closed when the adductor muscle turns to a constricted position.

The dorsal area of clams comprises of a ligament which functions as a fixing and is necessitated for valve opening and closing mechanisms. Adjacent to the hinge is a conspicuous bulge known as umbone, which is frequently seen on the dorsal surface and located more in the anterior region (prosogyrate). Most of bivalve umbone is well-developed within a week after fertilisation (Helm et al., 2004). Growths lines can be seen in the outer shell and typically run parallel to the shell margins. Hard clams only have a short siphon, which is located in the posterior area of the valve since it is not a deep burrow type as compared to the Solenidae family.

These fundamental shell attributes are noteworthy for hard clams distinguishing proof. Different investigations were implemented based on shell features to quantify the development of bivalve and furthermore as an apparatus to contrast between comparative or distinctive species. Several studies have used morphology and morphometric analysis to differentiate the two species of bivalve, such as Pinnidae (Idris et al., 2009; Scheltema 1983). Babaei et al. (2010) also reported on the relationship between shell measurement with the visceral mass and shell weight of *Amiantis umbonella*. Application of morphometric dimension through anatomical character is also important to clarify taxonomic identification of *Corbicula* and its distribution (Araujo et al., 1993).

Growth performance, shell shapes and sizes of hard clam are influenced by environmental factors. Variable physical factors of the environment are known to influence shell morphology and relative proportions of many bivalve species such as latitude (Beukema & Meehan, 1985), depth (Claxton et al., 1998), shore level (Franz, 1993), currents (Fuiman et al., 1999), water turbulence (Hinch & Bailey, 1988), wave exposure (Akester & Martel, 2000), type of bottom (Claxton et al., 1998) and sediment type (Newell & Hidu, 1982). Morphological variation in shells depicts the growth performance of bivalve. Claudi and Mackie (1994) reported the importance of environmental factors for the survival and growth of zebra mussel (*Dresissena polymorpha*). Food availability and population density are also important to determine the shell morphology, shell length and body mass ratio of bivalve (Alunno-Bruscia et al., 2001).

Habitat

Major hard clam species inhabit the estuarine and coastal areas with high nutrient resource and organic matter, which are important to other organisms that inhabit the same ecosystem. Abundance of quality food and nutrient resources are able to support a huge number of organisms that includes hard clam (Bricelj et al., 2017). Moreover, it is also important to influence shell morphology in terms of shell length and body mass ratio of bivalve (Alunno-Bruscia et al., 2001). Furthermore, Kovitvadhi et al. (2006) described that survival rate of freshwater bivalve was affected by diversity of phytoplankton in the habitat.

Formation of bivalve shell can be affected from biotic and abiotic factors in the habitat (Kovitvadhi et al., 2009). Shallow environment can influence the shell characters as detailed by Lajtner et al. (2004), while bivalve population density is connected with sediment form. Most of the coastal areas near the estuarine have sediment characters of sand and mud types which are suitable for *Meretrix* spp. to grow. Other than *Meretrix* spp., *Anadara* spp., which is sometimes found at the same habitat, tends to favour muddy sediments.

They have developed ciliate structures to prevent their branchiae from becoming clogged with fine particles (Broom, 1985; Yoloye, 1975). However, each species may have its own distinct requirements. *Anadara granosa* for example, happens in areas where between 50% to 90% of the substrate is made up of particles under 0.125 mm in measurement (Pathansali, 1966). Some bivalves live on sediment with fine sand over half, mud over 70%, and intermediate granule substance is around 5% to 15% (Baron & Clavier, 1992). Different species recorded can be found on exceptionally coarse coral, non-coral sand, terrigenous sands and medium all around arranged silt with a mean particle size of 0.4 mm (Gibbs, 1978; Narayanan & Sivadas, 1986; Purchon & Purchon, 1981).

Feeding and Nutrient

Bivalves ordinarily utilize the gills optionally inferred part, which are critical in the feeding process. The ciliary tract of gills work on evacuating and arranging the suspended particles from pumping water and this framework is known as suspension filter feeding (Leal, 2002). Food such as phytoplankton that is trapped at the gills will move through the palp, mouth and eventually the digestive system. Generally, feeding on bivalves begins as soon the shell and digestive organ are fully developed. During the larval stage, this organ is still undeveloped, therefore nutrients are fully supplied to bivalve larvae through direct absorption from the surrounding water (Helm et al., 2004). After the shell is fully developed, the food type for bivalve larvae depends on biochemical composition, ingestability and digestibility, which are important for culturing purposes.

Normally, hard clam foods include an assortment of suspended molecules, for example, microorganisms, phytoplankton, waste, dissolved organic matter, amino acid and sugar (Bouillon et al., 2003; Davenport et al., 2000; Nicholas, 1985; Stewart & Bamford, 1975). Information on bivalve nourishment can be resolved through the examination of the bivalve gut content. This sort of examination has been performed by estimating isotopic improvement, consumption inside tissues apart from investigating digestive and absorptive efficiencies (Hawkins & Bayne 1992; Shumway et al., 1987). Generally, bivalves feed on phytoplankton as the primary diet and there is still little data with respect to the detailed food that is consumed by bivalves in nature.

Some bivalves also can be categorized as partially carnivorous since there are a few bivalve species that can ingest zooplankton and benthic organisms (crustacean and bivalve larvae) (Davenport et al., 2000). Seasonal variation on diet type for bivalves occurs especially for algae species. This variation corresponds with the algal bloom periods and it is different for individual algae species. Abundance of phytoplankton in the natural habitat will cause the rapid growth and maximum size of bivalve (Carmichael et al., 2004). However, neither individual nor mixed algal diet produces significant results in *Meretrix meretrix* larvae survival as reported by Tang et al. (2006). Although the phytoplankton is the most important food source, the availability of detritus during the scarcity of phytoplankton at certain periods can help to provide energy for metabolic activity in bivalves. However, only certain detritus can be ingested by bivalves and it depends on the particle size. Venerids and others molluscs comprised appropriate gill filaments (eulamellibranch) to ingest extensive molecules up to 950 µm, and they have great maintenance productivity for molecules measured as little as 1 µm (Jĝrgensen, 1990; Mikulich & Tsikhon-Lukanina, 1981).

Dissolved organic matter in wetlands and oceans is vast, which also serves as the source of nutrient supplement for benthic organisms including hard clams, especially during the scarcity of the essential nutrient (Bouillon et al., 2003). High organic matter is also contributed from fish by-products, which is commonly found near the fish farming areas. Bivalves can transport dissolved organic matter in the form of sugars and free amino acid to the gills and absorb it for metabolic processes (Stewart & Bamford, 1975). The study indicated that *Mytilus edulis* can uptake 94% of natural amino acid and have as low as 10% of it from the ambient seawater (Hawkins & Bayne, 1992; Manahan et al., 1982).

Culture Production

The earliest culturing practice for bivalves was traced back during the Roman civilisation. Oyster was cultured at that time due to the high market demand since it was utilised as food and the ability to produce pearls for jewellery. Bivalves or molluscs from the marine environment received more attention because of their aesthetic and gastronomic appeal (Subba Rao, 1993). There are many types of edible bivalves around the world, but currently only oysters (*Crassostrea*, *Saccostrea*, *Ostrea*), mussels (*Mytilus*, *Perna*), scallops (*Amusium, Pecten*, *Chlamys*, *Aequipecten*), cockle (*Anadara*) and clams (*Ruditapes philipinarum*, *Tapes philippinarum*, *Meretrix lusoria, Mercenaria mercenaria*) are being applied for mariculture practices in the Asian region (Lovatelli, 1988a).

Shellfish Production. Most countries in the tropical area are culturing bivalve intensively to support the local demand. From 1991 until 2005, production of bivalves indicated an increasing pattern with 6.3 million tonnes in 1991, 9 million tonnes in 1995, 13 million tonnes in 2000 and 23.6 million tonnes in 2005 (Figure 1). The increasing pattern is due to the rapid growth of aquaculture and bivalve production in China (Pawiro, 2010). While in the year 2005, 87% of bivalve landing is a result of culture activities (Globefish-FAO, 2007). Therefore, a significant difference between cultured and wild-captured bivalves was observed from 1991 to 2005. The production was indicating wild stocks were incapable of supporting market demand in which the scarcity in production was supported by culturing practices. This pattern certainly will continue to increase for a few years ahead to coincide with the increasing human population around the world. Reliance on the wild stock to meet this rising demand definitely will cause extinction for certain bivalve species in which the only solution is through the culture practice.

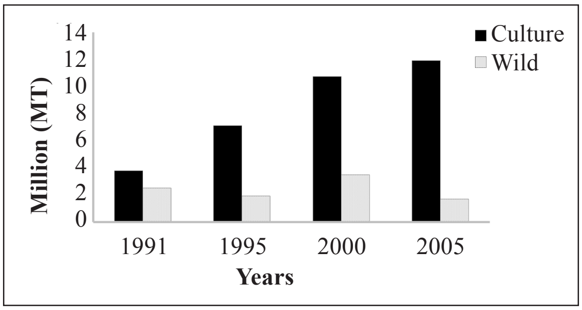

Figure 1. Comparison of cultured and wild captured bivalve for 1991, 1995, 2000 and 2005. Adapted from Globefish-FAO (2007) and Helm et al. (2004)

There are four major marine cultured bivalves currently practised in a few continents (Table 1). Asia has turned into the primary area that adds to the world aquaculture products, including bivalves (Oyster, clam, scallop). Clam is the most elevated bivalve production with 39% yield (Figure 2), which is half of the bivalve world production. Clam production as of late has expanded to 24% of generation because of trade from scallop to clam culture. High mortality in scallop culture in China caused this change due to the high survival rate of clams in contrast with that of scallops (Guo et al., 1999). Meanwhile, different species contributed between 10% to 15% of the world production.

However, Malaysian bivalve generation as opposed to the world bivalve production shows that oyster is the species to contribute the least in bivalve production either from wild or aquaculture sources. Significant

Table 1
Major marine cultured bivalve in the world (Garibaldi, 1996)

Species	Continent
Oyster	Africa, America, Asia, Europe and Oceania
Mussels	Africa, America, Asia, Europe and Oceania
Scallop	America, Asia, Europe and Oceania
Clam	Africa, America, Asia Europe

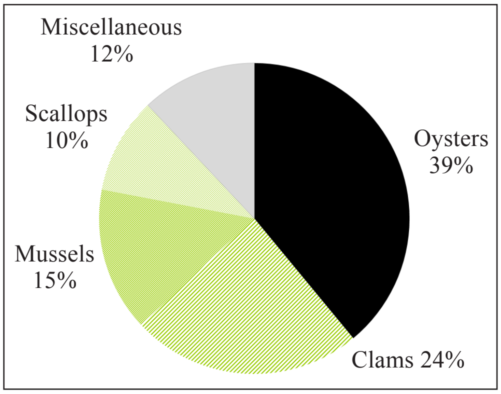

Figure 2. World production of cultured bivalve in year 1999 (Food and Agriculture Organization [FAO], 2001)

mollusc production in Malaysia originates from cockle, which is in conflict to bivalve world creation (Figure 3). Cockle contributed to 67% of Malaysian bivalve production that is followed by clams (28%) and mussels (4%). This examination depends on 12-year allotment which demonstrated Malaysia is still not utilizing its resources at the ideal level to expand the bivalve production through mariculture. However, bivalve production in Malaysia will keep on growing in perspective in the way that Thailand and Singapore are the premier merchants of the bivalve from Malaysia.

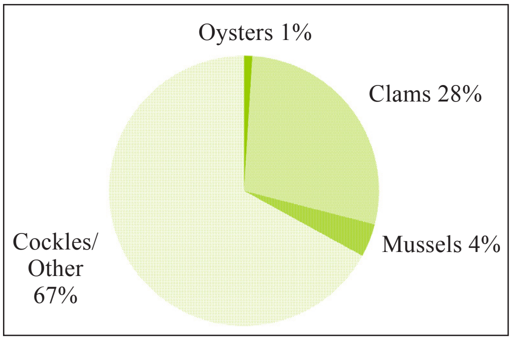

Figure 3. Malaysian bivalve production in year 2011 (Department of Fisheries Malaysia [DOF], 2013)

Hard clam is the suitable animal for mariculture since this animal is akin to herbivores in filtering most of the phytoplankton from the surrounding water and this acquired less concern (Nicholas, 1985). The introduction of hard clam varieties in mariculture is necessary since current commercial production is only dependent on a few bivalve species, while other species are only harvested for normal daily consumption. Fishermen favoured harvesting bivalves from the wild due to some obstacles to cultivate the mollusc. Furthermore, harvesting from wild stock is less expensive as compared to culture which brings with it the need for seed production, nursing, grow out, planting and harvesting (Edwards, 2000; Quayle & Newkirk, 1989). Culture practice for certain hard clams will become non-competitive especially if the species of interest is found abundantly in nature, for instance *Polymesoda* spp. (Hamli et al., 2012).

Semi-culture practice is widely used for hard clam culture since it can promise high clam production during harvesting, resulting from the high density of clam seed planting. However, there are restraints in this kind of culture, especially when related to the seed collection. Seed collection from the wild stock usually depends directly on the amount of seed produced in nature and if seed production is insufficient, it will definitely affect the number of clams harvested (Helm et al., 2004). Breeding season on certain species also affects the seed source for annual production. An alternative way to get enough supply of seeds without depending directly on season changes is by artificial propagation of the clam seed or spat.

Other than seed supply, water quality is an important element to ensure the success of hard clam culture. Semi-culture practice has less intention for water quality maintenance while planting seed involves the natural habitat of the bivalve. The only concern in hatchery culture, especially seed production is water quality. Water quality variables in terms of salinity, temperature and dissolved oxygen are important for broodstock breeding and to ensure the survival of the larvae after fertilization. Water salinity is one of the components for clams that live in marine habitats due to its effect on the osmotic physiology of the organism (MacLachlan & Erasmus, 1974). Low salinity levels will change the spawn activity of bivalve species (Baba et al., 1999). Marine bivalves only tolerate high concentration of salinity, for example *Perna viridis* can tolerate low salinity of 16 ppt whereas other bivalves from estuarine or brackish sources can tolerate a broader level of salinity (Sundram & Syed Shafee, 1989). At the tropical areas, the native bivalves can tolerate high temperatures. For that, water temperature in hatchery cultures should not be too low since it can affect larval growth and survival during culture. When water temperature is high, it will lower the dissolved oxygen in the water by increasing the organism respiration. Prolonged circumstance will cause the bivalve larvae stress and eventually die (Laing & Spencer, 2006). Water quality in hard clam culture is a crucial aspect that should be monitored during the rearing period.

Gonad Development

Hard clam sex can be isolated into male and female (dioecious) and a portion of the animal varieties can form into two genders in a single individual (hermaphrodite). Venerids especially *Meretrix* spp. is dioecious as examined from different studies from the Asia site (Chung, 2007; Durve, 1964; Jayabal & Kalyani, 1987). Notwithstanding, Chu and Kumar (2008) had discovered that only 6% of the *Meretrix lyrata* population comprised a hermaphrodite kind. Hard clams need reasonable states of water saltiness, temperature and satisfactory supplement for gonad development and spawning. Sperm that is secreted into the natural habitat will stimulate female clams to spawn. Common spawns happen at a specific temperature level extending from 4°C to 37°C contingent upon mollusc species and areas (Belda & Del Norte, 1988; Philippart et al., 2003). Tropical region normally consists of mature hard clam species throughout the year. Therefore, spawning activities also occur continuously throughout the year.

Eggs and sperm production (gametogenesis) occur in ciliated ducts known as gonad. The gonad will undergo several stages of development before clams mature and are ready for spawning. The classification of the gonad stages of bivalve is shown in Table 2.

Various methods can be applied to determine the gonadal stages of bivalve and the most commonly used methods are through histology and condition index. Histological method is a technique that needs the sacrifice of the animal in order to determine the gonad stages (Larson et al., 1971; Pronkere et al., 2008). Small amounts of gonad from the bivalve are extracted before undergoing the smearing process. Then, obvious stages of male and female gonads can be determined through microscope observation (Figures 4 and 5).

Table 2
Classification stages of bivalve gonad (Seed, 1975, 1976; Wilson & Seed, 1974)

Stage	Description
Resting	On active stage where there is no sexual activity in process. Gonad indicating genital canals in a collapsed state, lipid and glycogen filled the connective tissue. At this stage, male and female are difficult to identify.
Development (Early)	Gametogenesis begins to occur with little cluster of the germinal cells found spread out to the connective tissue. At the follicles, wall oogonia and spermatogonia are developed. Identification between male and female is still difficult.
Development (Late)	Most of the mantle occupied by male or female follicles respectively. Masses of spermatocytes and spermatids fill the follicles while spermatozoa are scattered among the larger cells in males. While female oocytes have started to accumulate yolk and have grown considerably. Some of the larger oocytes are still attached to the follicular epithelium. Some of the gametes start to ripe and gonad mass is increased by half in the mature condition.
Mature	Gonad fully ripes with follicle filled by spermatozoa with a visible tail. Spermatozoa assemble in lamella, congregating in the centre of the lumen. Only few residual spermatocytes and spermatids may be present. However, in females, the maximum size of oocytes assemble together in the follicles. With the increasing size of follicle, connective tissue is covered. Glycogen and lipid are absent in the connective tissue.
Spawning	Gamete starts to have active secretion. Large numbers of ripe oocytes are still present in the follicles. Residual oocytes tend to be rounded as the reduced number of compact follicles. Sperm number at lamellae is reduced to absent.
Spawned	After final spawning, the follicles begin to collapse and degenerate. Smaller numbers of unspent gametes are rapidly broken down by amoebocytes or undergoing cytolysis and the animal again enters the resting stage.

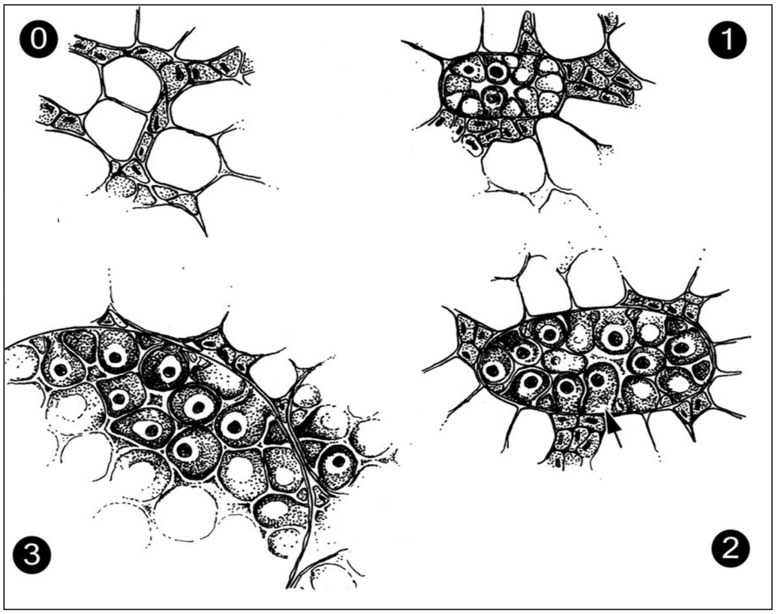

Figure 4. Development stage of ovary. Stage 0: rest, Stage 1: early development, Stage 2: late development, Stage 3: Mature (Duinker et al., 2008)

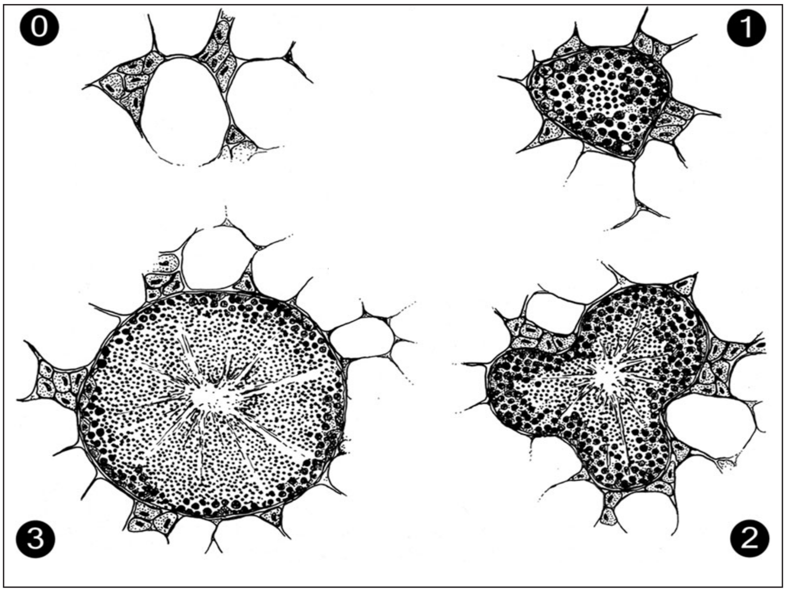

Figure 5. Development stage of testis. Stage 0: rest, Stage 1: early development, Stage 2: late development, Stage 3: Mature (Duinker et al., 2008)

The technique is accurate to identify the gonad stage and sex. However, condition index manipulates the quantitative value on weight of dried soft tissues that is divided with shell weight and multiplied by 100 percent (Davenport & Chen, 1987). It is the cheapest and fastest way to determine bivalve's gonad development compared to histology technique (Austin et al., 1993; Schumacker et al., 1998; Scott & Lawrence, 1982).

Embryonic and Larval Development

During matured phase, hard clam tissue has developed to be more muscular since increasing in mass and size of gametes in both female and male gonads. Increasing of meat weight in bivalves usually is the best time for harvesting because meat productivity is ideal for consumption (Lucas & Beninger, 1985). Physico-chemical changes in the seawater embark the releasing of hard clam sperm into the environment and inducing the female to spawn as well. Secretion of sperm and egg can be identified through the development of a pale cream (Sreenivasan & Rao, 1991) or yellow (Dharmaraj et al., 2004) colour in the water column.

Normal reproducing happens to correspond to the ambient conditions of temperature and salinity in the seawater. This causes some bivalve species of only spawning several times a year, while other species from tropical regions are able to spawn throughout the year. Artificial breeding is the best way for seed production without depending on the seasonal changes. Prior to that, cultured spat can be transplanted to the natural habitat for grow out anytime. In the ongoing years, a few studies led to the trigger of clam breeding for a hatchery reason (Table 3). There are two different ways to induce bivalve breeding, for example, chemical incitement by means of a serotonin infusion (Neo et al., 2011) and physical inducement by means of thermal stun, salinity shock and air-drying (Chu & Kumar, 2008).

Table 3
Clams species that have been propagated through artificial breeding

Species	Spawning stimulus	Larval duration	Sources
Tridacna squamosa	Serotinin	2–18 days	(Neo et al., 2011)
Ruditapes philippinarium	Air dried and Thermal shock	20 hours–13 days	(Hur et al., 2005)
Mactra veneriformis	Air dried and Thermal shock	18 hours–14 days	(Hur et al., 2005)
Cyclina sinensis	Air dried and Thermal shock	2 days–17 days	(Hur et al., 2005)
Meretrix lusoria	Air dried and Thermal shock	18 hours–7 days	(Hur et al., 2005)
Potamocorbula amurensis	Thermal shock	2–27 days	(Nicolini & Penry, 2000)
Meretrix casta	Thermal shock	2–9 days	(Sreenivasan & Rao, 1991)

The fertilised egg will form into planktonic larvae, which comprised a few phases (Figure 6). First phase is named as trochophores, trailed by veliger larva phase (D larva phase or prodissoconch I phase, prodissoconch II phase), postlarvae phase, which experience transformation known as juvenile or spat (Reverol et al., 2004; Schejter et al., 2010; Suquet et al., 2013).

Trochophores stage is cell division that occurs within an hour after fertilisation success (Suquet et al., 2013). Veliger larvae stage occurs within 48 hours, in which the shells start to develop and eventually wrap the body. During this period, the essential organ system that includes the swimming organ is formed (Garrison & Morgan, 1999). A bivalve larvae swimming organ known as velum is ciliated and also functions in food collecting. Morphology of the larvae will change with straight at the hinge area to form a 'D' shape which is called as the D larvae stage (prodissoconch I stage). This stage prolongs until a week before larvae enter the prodissoconch II stage. Umbone starts to develop in prodissoconch II stage and becomes prominent as the larvae grow larger (Chanley & Andrews, 1971). Hur et al. (2005) divided the prodissoconch II stage into two groups, which are early umbonal veliger and late umbonal veliger. Larvae reach the mature stage after the foot and gill are prominent. Larvae that begin the sedentary benthic are now in spat stage or juvenile. This stage is appropriate for seed collection and transplant into selected natural habitat for culture practice.

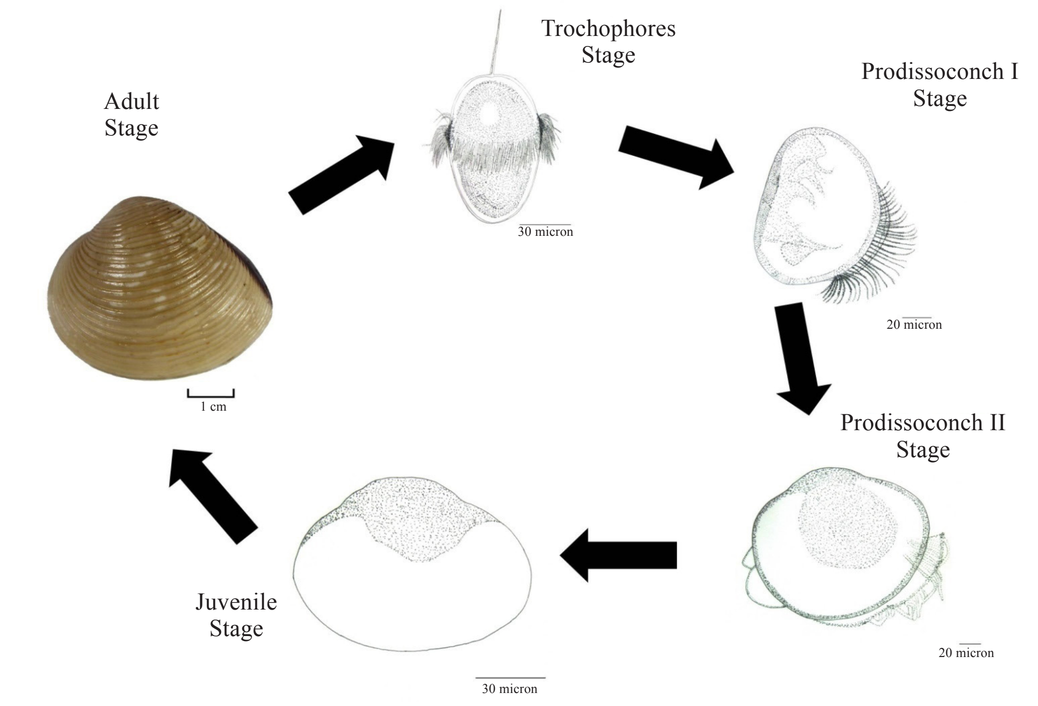

Figure 6. Bivalve larval development stages after Reverol et al. (2004) and da Costa et al. (2008)

Culture Technique

Simple innovation and less labour obtained for hard clam culture is an imperative perspective to urge individuals to include in bivalve cultivating. Advanced technology, improvised methods and effectiveness in hard clam culture are the main keys needed to overcome the rise in market demand for this sort of fisheries product. Technology in aquaculture is also important in dealing with physical and mechanical aspects to deal with water, cultivated organisms and nursery (Ernst et al., 2000; Lee et al., 2000; Papandroulakis et al., 2002; Summerfelt et al., 2000). Moreover, the reliable characteristic for instance, inexpensive seed supply and fast growing species are also important in hard clam culture (Davy & Graham, 1982). Furthermore, hard clam provides a protein source for human consumption and serves as decorative accessories in ornamental industry, which gives a high value to the hard clam (Baylon, 1990).

Selecting an appropriate site for clam cultivation is an important aspect affecting growth and survival for the clam. Area of culturing must be sheltered from any extreme weather of strong waves that can wash out the sown spat. In addition, good quality of physical-chemical condition, especially temperature and salinity are also important. At the tropical regions, high temperatures throughout the year causes the abundance of phytoplankton, which is a food source for filter feeders. Culture areas must not be near the industrial areas to prevent ingestion of industrial waste, sewage and other pollutants (Fujiya, 1970).

Currently, application of semi-culture practices for bivalve farming is worldwide. Semi-culture practices are involved in seed collection from the wild nature and transplanting at one area for proper growth. Low cost and easy harvesting are the crucial parts of this technique that are able to be applied in every country. This culturing method is practised in the United States, Portugal, China, Taiwan, Japan, Korea, Vietnam, Philippines, Sri Lanka, Malaysia, Indonesia and Thailand (Angell, 1986; Baylon, 1990; Chu & Kumar, 2008; Gosling, 2003; Lovatelli, 1988a; Whetstone et al., 2005).

Growing bivalve spat at the culture side has been done for a few species such as clam, oyster, mussel, and scallop (FAO, 2001). Different culture techniques are applied due to the various bivalve species behaviour in the wild habitat. Appropriate techniques applied will ensure the survival of the bivalve through the cultivation period. Moreover, the practice technique enables the non-native or exotic bivalve to be introduced in the particular area. The introduced species are found to be more in areas that do not have native bivalve to be cultured (Davy & Graham, 1982). There are two fundamental procedures presently used in bivalve culture, for example, bottom and off-bottom culture. Many modifications have been made based on these two techniques to lower the cost, adjusted to location condition and authority regulation.

Off-bottom Culture. Developing bivalve spat over the substrate or sand is known as off-bottom culture and this is suitable for oysters and mussels. Cultured bivalve by this technique is generally kept in the crate, sack, net and enclosure (Gervis & Sims, 1992; Walton et al., 2013). This method is practiced either in the intertidal zone or at the ocean. With advanced technology, adapted to the geographical area and local conditions, man had invented culture gear that expands the off-bottom culture into a new level. Presently, there are four strategies in view of off-bottom culture, for instance, raft, rack, long line and trestle frameworks (Figure 7).

Rack and trestle systems are only applicable in the intertidal area as both methods need stakes that are fixed to the seabed. However, raft and longline systems are applicable at the open sea due to the floating feature. Despite topographical adaptation, off-bottom culture gives points of interest to the bivalve culture in terms of development, survival and attention (Walton et al., 2013). Bivalves that are cultured close to the water surface will have fast development because of the wealth of phytoplankton (Mackey et al., 2002; Paerl, 1988). Cultured bivalves are also free from predators and burial due to distance from the seabed, which will increase the survival rate during culture. Furthermore, in terms of nursing, fouling organisms are easily controlled and removed from the shell. Notwithstanding the favourable circumstances, off-bottom has hindrance in terms of cost when considering the labour and gear equipment (Maeda-Martinez et al., 2000).

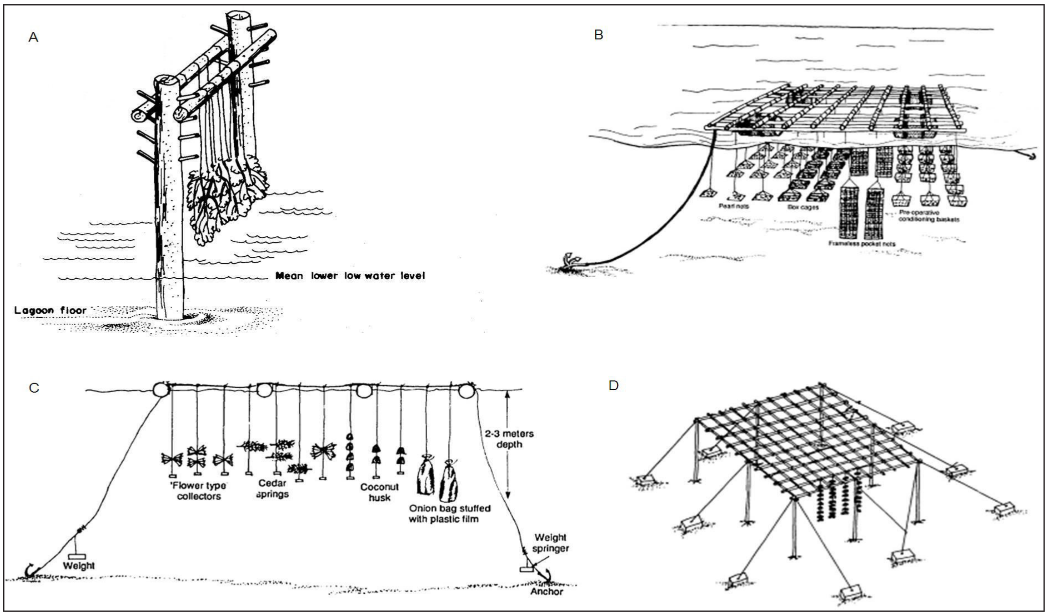

Figure 7. Types of gear used for off-bottom culture. (A) Rack system, (B) Raft system, (C) Longline system, (D) Trestle system (Gervis & Sims, 1992; Lovatelli, 1988b)

Bottom Culture. Bottom culture is alluding to bivalve seed scattered uninhibitedly onto the seabed (Kleinman et al., 1996). Certain bivalve species, for example, oysters will probably join the stone that is present on the seabed. Besides, seabed can serve as the support for a few simple equipment, for example, cage, bottom bag, frame, and rocks for bottom culture (Figure 8). Simple equipment is adjusted to improve the management, nursing and harvesting process.

This culture technique is broadly used in bivalve culture, generally for hard clams which need a substrate for interment behaviour (Table 4). In general, bottom

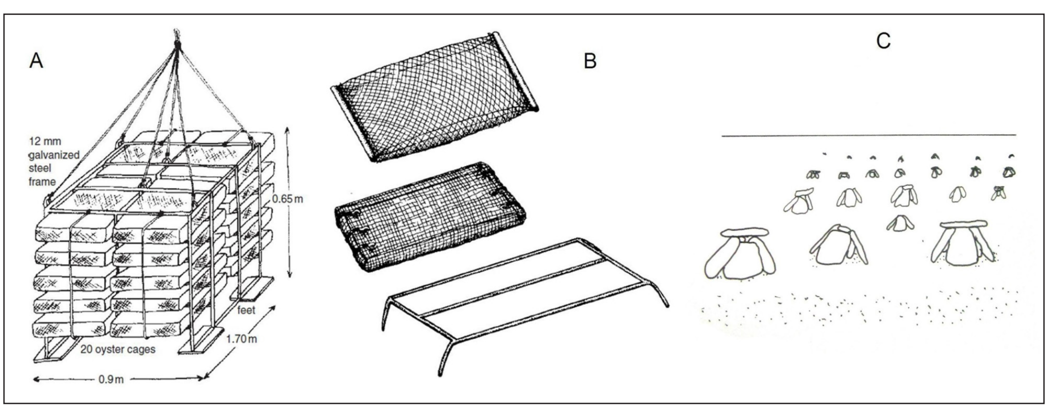

Figure 8. Types of gear used for on-bottom culture. (A) Cage system, (B) bottom bag system, (C) rock system (Cai & Li, 1990; Hardy, 2006; Toba, 2002)

culture is applied in the intertidal area with the intention of easier harvesting process and nursing.

Although bottom culture only uses minor equipment, it benefits the culturist in terms of cost and less work being required for the underlying setup and nursery. Besides that, bottom culture can change the biological system structure by expanding the biodiversity in the natural surroundings (Ysebaert et al., 2009). This demonstrates the execution of bottom culture can enhance the organic accessibility in the sediment. Furthermore, exposed bivalves to the residue will cause bivalves, particularly spat, being powerless against predators like crabs and birds (Toba, 2002). This would therefore result in a low survival rate of the cultured bivalve.

Table 4
Common bivalve species culture by bottom culture system

Common name	Species	Location	References
Mussel	*Mytulis edulis*	Holland, Denmark	(Baylon, 1990; Dolmer et al., 2012)
	Perna viridis	India	(Kripa & Surendranath, 2007)
Cockle	*Anadara granosa*	Malaysia	(Davy & Graham, 1982)
Clam	*Paphia malabarica*	India	(Appukuttan et al., 1993;
Clam	*Mercenaria mercenaria*	United State	Whetstone et al., 2005;
Clam	*Ruditapes philippinarum*	France, Ireland	Gosling, 2003)
Oyster	*Crassostrea edulis*	United State, France	(Robert et al., 1991; Toba, 2002)
Scallop	*Patinopecten yessoensis*	Japan	(Hardy, 2006)

CONCLUSION

Hard clams are shellfish that have a huge part in marine protein creation and because of that, scientists have created numerous strategies to propagate the clams in a small or huge scale. Culture of hard clams, particularly *Meretrix* spp. begins from brood stock conditioning, breeding, larvae rearing, transplanting and lastly harvesting. Prior to the culture application, it is fundamental to comprehend the factors that control the natural limits in the hard clam, for instance, a high measure of meat that is available during the development stage in gametogenesis, which is a reasonable period for harvesting. In this manner, hard clams can be exposed as the substitute protein source of marine that gives profitable value to the country.

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