Giant Clam (*Tridacna spp.*), A Potential Candidate for Green Aquaculture of High Revenue in Jordan's Gulf of Aqaba

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ABSTRACT

The present work introduce an aquaculture attempts of the two existing species of giant clams, *Tridacna squamosa* and *T. maxima* in the Gulf of Aqaba. Recognized clam culture methods were adapted and modified to suite the prevailing environmental conditions of Red Sea. *In situ* gonad biopsy for both species showed that the gonad state was inversely correlated with the frequency of spent gonads (r=0.31), spawned (r=-0.25) and regressive (r=-0.29) eggs, and positively related to the frequencies of mature eggs (r=0.59, p<0.05). In laboratory, attempts were performed on the artificial induction of wild broodstock of the two species, larval to post-metamorphic rearing and *in situ* nursery culture. A marked seasonality was observed in the reproductive success in both species. Combined heat and serotonin induced spawning during winter showed protracted larval development and total mortality during pre and post metamorphosis. Summer spawning, however, was partially successful yielding clam juveniles of *T. maxima* and *T. squamosa.* Yet, the present culture trials yielded the pioneer stocks of clam juveniles of 2-20 and up to120 mm shell lengths (SL) at ages of 3-6 months and two years old of both *T. squamosa* and *T. maxima*, respectively. Future efforts will be on the integrated farming or polyculture of giant clams with other marine ornamental species in closed systems to demonstrate the production of high-valued commodities without harming the environment.

Keywords: *Tridacna spp*., giant clams, aquaculture, Gulf of Aqaba, Red Sea, Jordan.

INTRODUCTION

Culture techniques on giant clams in the tropics were developed over the past two decades (Mies et al. 2012; Heslinga et al. 1990; Usher and Munro, 1988; Braley, 1992; Calumpong, 1992; Bell et al. 1997). The most widely-used technique to date involves giant clams spending up to their first year in land-based facilities and then being transferred to the ocean for grow out (Tisdell and Menz, 1992; Gomez et al. 1994; Mies et al. 2012). In spite of their high fecundity, the natural recruitment success in giant clams is low (Lucas, 1994; Friedman and Teitelbaum, 2008). The fertilized eggs develop into swimming larval veligers (after 2 days), become settled pedi-veligers (7-9 days) and then undergo metamorphosis (2-3 weeks) to adapt to a phototropic mode of existence by taking up photosynthesizing algal symbionts, the zooxanthellae (Lucas, 1994; Sudek et al. 2012).

Simple village-based farming methods were developed in the Indo-Pacific region (Braley, 1992; Ellis 1998) to supply giant clams to a diverse and growing market (Bell et al. 1996). Specimens of 50-100 mm SL are popular in the million-dollar tropical marine aquarium industry (Heslinga, 1996). Villagers for the aquarium trade reared several species of giant clams for 8-10 months grow out were earning good profits (Bell et al. 1996). In addition, larger clams of 120-150

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mm SL have proved particularly suitable as sashimi (live seafood), and can be grown to market size in 18-24 months with a survival of 85% (Foyle et al. 1997). The establishment of village farms has also paved the way for cost-effective restoration of giant clams in the wild, which were suffered heavy depletion in many developing countries, mainly to supply the market for adductor muscle. Marketability studies show that clam farming is generally profitable, particularly if a suite of clam products, e.g. shell, mantle and adductor muscle, are sold (Leung et al. 1994). The costs of providing giant clam seed, both in relation to labor and capital costs are non-linear and highly scale-dependent (Tisdell and Menz, 1992). One centralized hatchery can therefore provide the basis for community-based grow-out of spat, sustaining and expanding existing stores of natural capital in the region.

Almost nothing is known about either giant clam recruitment in the Gulf of Aqaba or the factors governing the reproductive activity of the natural Red Sea broodstock. In addition, farming of giant clams was not attempted in the Red Sea, in spite of the occurrence of indigenous broodstocks of *T. maxima* and *T. squamosa* which are proper for aquaculture (Kilada 1994; Mies et al. 2012; Mies and Sumida, 2012). Therefore, the present study aimed at establishing a pilot plant for giant clam aquaculture in Jordan's Gulf of Aqaba, Red Sea, in order to demonstrate the feasibility of marine production practices in the oligotrophic waters of Aqaba Gulf which are both, environmentally sound and profitable.

MATERIALS AND METHODS:

Gulf of Aqaba being the only sea outlet and the Jordanian coast not exceeding 27 Km. It is strongly oligotrophic and hosts mainly coral reef habitats. This in terms of living resources has two main consequences, low biological productivity interpreted by low catch and considerable sensitivity towards establishing aquaculture. Consequently, and under the pressure of the need for fish resources Jordan has to consider efficient and innovative techniques to introduce aquaculture in the coral reef environment in such a way that secures sustainability for both the ecosystem and proves viability from the economic perspective. Therefore, experiments were performed on giant clam aquaculture that can be economically rewarding and harmless in coral reef ecosystem of the Gulf of Aqaba (Fig. 1)

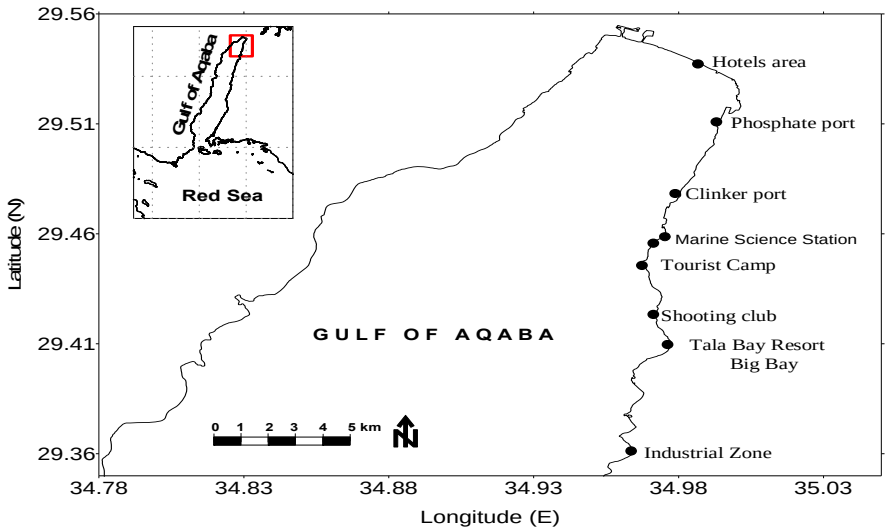

Fig.1: Map of the Jordanian coast showing the sites of clam brood stock collection in Gulf of Aqaba-Red Sea

Gonad Biopsy

Due to the mortality risk involved with the gonad biopsy technique (Braley, 1988) and the overall scarcity of giant clams in Gulf of Aqaba, a limited number of wild giant clam broodstock was used for biopsy test. *In situ* biopsy of the gonad was carried out using SCUBA on a total of six *T. maxima* (13.8 – 25.6 cm SL and seven *T. squamosa* (23.1 – 30.5 cm SL) in their natural fore-reef locations between 2 and 16 m depth in front of Marine Science Station (MSS) over one year. Samples of gonad tissue were collected by injecting around 1-inch from the exhalant opening of the mantle with an aspiration biopsy needle of 10 ml plastic syringe, taking particular care not to injure the liver (Braley, 1988; Mies et al., 2011; Mies et al. 2012). Gonad samples were kept in 2% buffered formalin for further examination under the microscope. The egg stage, egg size and gonad state were determined for each broodstock in each month.

The egg developmental stages used were based on (Braley, 1988; Crawford et al. 1988). The state of the gonad was estimated semi-quantitatively by assessing the total volume of the eggs extracted and by measuring the intensity of resistance of the syringe needle during biopsy (Table 1). Grouping were used to describe the gonad state, namely, vacant, little, not condensed, condensed and very condensed gonad extracts and were given a nominal scale between 1 to 5 (Dix and Ferguson, 1984).

Table 1. The *in situ* gonad state index based on the analysis of gonad biopsy extract.

Nominal scale	Biopsy extract group	Characteristics of gonad extract
1	Vacant	Clear, no visible eggs
2	Little	Few visible suspended eggs
3	Not condensed	Concentrated loosely suspended egg
4	Condensed	Many suspended with settled eggs
5	Very condensed	White tissue mass of concentrated eggs

Culture of giant clams

A total of 25 *T. squamosa* broodstock were collected during one year from different locations along the Jordanian coast of Aqaba Gulf (Fig.1). They were kept for conditioning in the nursery at the seaside of the MSS. The *T. maxima* were placed on the shallow reef flat and *T. squamosa* on a coral ledge at 10-12m depth in order to simulate clam's natural distribution. At onset of reproduction based on data derived from the *in situ* biopsy of gonad. All the specimens of both species were transferred from the seaside nursery into the flow thru land-based ponds constructed at the aquaculture facility at the Marine Science Station of Aqaba. Specimens were recorded in the broodstock list in order to keep track of each individual clam. The list demonstrates information on the location, shell length measurements, induced spawning attempts, gametes release, etc. (Table 2).

Table 2. The two species broodstock database and spawning trials during 2010-2012

T. maxima	**Shell length**	**Spawning trials**					
Location	Initial (cm)	1rst	2nd	3rd	4th	5th	
Saudi border	26.5	s	e/s	x	e/s		
Mss reserve	25.5	e/s	x	x	s		
Mss reserve	29.2	s	e/s	e/s	x	e/s	
Mss reserve	20.6	x	x	x	x	x	
Mss reserve	27.8	x	e/s	e/s	e/s	e/s	
Mss reserve	28.7	s	x	x			
Mss reserve	19.9	e/s	s				
Fertilizer	14.7	e/s					
T. Squamosa	Shell length	Spawning trials					
Location	Initial (cm)	1rst	2nd	3rd	4th	5th	6th
Mss reserve	36.0	x	x	s	x		
Mss reserve	30.0	x	x	x	e/s	x	x
Mss reserve	29.3	x	x	s	x	s	s
Mss reserve	29.6	x	x	e/s	x	s	
Mss reserve	33.0	s	x	e/s			
Mss reserve	21.8	s	x				
Mss reserve	31.1	s	s	s			
Mss reserve	31.2	s	s				
Tourist camp	25.1	e/s	e/s				
Clinker	25.1	s	s	x			
Clinker	23.4	s	s				
Saudi border	22.3	x	s				
Saudi border	28.5	s	s				
Mss reserve	32.6	s					
Fertilizer	19.8	x	x	x	x	x	
Fertilizer	22.2	e/s	s				
Marine park	25.2	e/s	e/s				
Fertilizer	25.8	e/s	e/s				
Tourist camp	31.5	s	s				
Tourist camp	32.1	x	s				

* S: sperm, e: eggs, x: non

During a period of two years of culture trials, all specimens were subject to artificial and natural spawning. A modification of the reported clam culture methods (Heslinga, 1990; Braley 1992, Lucas 1994, Ellis 1998) was employed to fit the environmental conditions and climate in Gulf of Aqaba. Heat shock and serotonin (Sigma, USA) were applied to induce spawning. Brood stock individuals were exposed to direct sunlight for about 30-60 minutes for spawning stimulation. Clams were then transferred to the spawning tank and were injected with 0.5m ml of serotonin into the clam mantle using a syringe of I ml. The response in spawning and sperm and/or egg release was different in time and amount and that resulted in several clam egg batches (see table 2).

Complete hatching of incubated eggs occurred after about 16 hour and were monitored on the succeeding day. Larval clams were placed in flow thru outdoor tanks equipped with flow thru screen, which is removed at a later stage or on day 14 at maximum when the clams were settled and showed metamorphosis. Larvae (veliger) were fed with the microscopic algae, *Tetraselmis sp* (20 $x10^3$ cell/ml) with daily volume of about 20 L. Prior to pediveliger settlement, isolates of zooxanthellae were collected from the feces of wild clams of the same species and were inculcated to larvae during a period of 5 days. Rearing seawater was filtered to 5 uM until clams became visible after 2-3 months.

Details of the rearing methodology are described in the outline of culture procedure that was developed and modified for Aqaba (Table 3). The rearing trials were resulted in producing small number of juveniles.

RESULTS

T. squamosa showed an extended spawning season with a major spawning in June to August followed by a minor spawning in October to November, as shown by the extremely low gonad state indices during this period (Fig. 2). Gonad state was inversely correlated with the frequency of spent gonads (r=-0.31), spawned (r=-0.25) and regressive (r=-0.29) eggs, and positively correlated to the frequencies of mature eggs (r = 0.59), $P < 0.05$. The gonad state index started to increase in December and a peak in June, where eggs also reached maximum diameter (94±13 µm), compared to an over-all annual mean of 89±10 µm. *T. maxima* also commenced spawning in June showing fractional but sustained spawning over October and appeared to have a major release in September. As stated, gonad state was inversely related to the frequency of spent gonads from June to September. This species showed an early onset of maturity (October) corresponding to the simultaneous increase of both gonad state indices and mature egg frequencies (r=0.53) until it reached maximum values in March to May. Mature eggs of *T. maxima* reached the full size (95±9 µm) also in June, with a mean of 87±9 µm. Both species of giant clam thus showed consistent patterns of significant strong to moderate correlations between the gonad state indices and the frequencies of the egg stages in the Gulf of Aqaba (Fig. 3).

During the warmer months, development was rapid at the usual developmental rate in the tropics, with larvae attaining pediveliger stage after only 7-9 days. In winter, however, development was protracted and chronology was delayed with subsequent total mortality of post-metamorphic clams (Fig.4). Fertilized eggs developed to rotating gastrula in 1- 4 days compared to only 3-6 hours in summer. Likewise, the larval swimming stage persisted for 2-30 days in winter, compared to 5-7 days in summer. Generally, fertilized eggs developed to rotating gastrula in 12 hours post fertilization, followed by trocophores after 1 day and veligers on day 2. Around 7-9 days post fertilization, the swimming veligers develop a foot (pediverligers) and start to settle

on the tank bottom. At the consecutive 2-3 weeks, pediverligers underwent metamorphosis to adapt to its phototropic mode of life with the photosynthesizing algal symbiont (*zooxanthellae*).

There were three cultured batches successfully reared to visible juveniles but all in small quantities. Batches of both species were incubated in special nurseries in front of MSS and were monitored for their growth profile on monthly intervals. The conditions in natural environment showed positive effect on growth in specimens of both species. As shown in Fig.5, *T. maxima* exhibit a growth rate of 3.83 mm/month (n=13 clams), growing from a mean SL of 4.81±1.17 to 27.02±4.23 mm from 3-8 months old. *T. squamosa* juveniles range from 4.68±0.88 - 19.46±3.51 mm mean SL from 3-8 months old with a growth rate of 2.74 mm/month (n=23). Within a period of 30 months, the increase in SL with time showed high correlation in *T. squamosa* (R^2=0.95) as well as in *T. maxima* (R^2=0.94). Growth profile of both species showed also high correlation (R^2=0.91 and 0.90 of SL with time in the sea side nursery during two succeeding years (Fig.6).

DISCUSSION

Virtually nothing is known about either giant clam recruitment in the Gulf of Aqaba, or the factors governing the reproductive activity of the natural Red Sea broodstock. Considering the temporal fluctuations of various factors affecting giant clams in this subtropical marginal sea, it required a study on the natural reproductive periodicity of giant clams. This is in order to help define the best period for induced spawning and larval-early juvenile rearing for the pilot culture attempts. However, due to the scant number of broodstocks available, sacrificing the clams were not an option, so *in situ* gonad biopsy technique was applied (Braley, 1984, 1988). The reproductive success of giant clams, from both the field and culture data was limited to the summer months which significantly reduce the culture potential relative to year-round spawning in the tropics (Alcazar, 1988; Trinidad-Roa, 1988; Heslinga et al. 1990). To overcome the reproductive impasse and extend induced spawning period over an entire year, conditioning is necessary through increasing temperature and food of the brood-stock in land-based culture. Moreover, induced spawning and larval rearing attempts on natural unconditioned broodstock resulted in unsuccessful development and larval mortalities during the cold months (unpublished data). Culture results are confirmed by biopsy showing regressive ovaries during winter to spring in natural broodstock. Field and laboratory data from *in situ* gonad biopsy and pilot culture of giant clams were combined to compare the reproduction patterns (see Fig. 2) to published reports in the tropics and in relation to the water quality and environmental conditions in Gulf of Aqaba (Reiss and Hottinger, 1984; Hempel and Richter, 2002; Manasrah, et al. 2006).

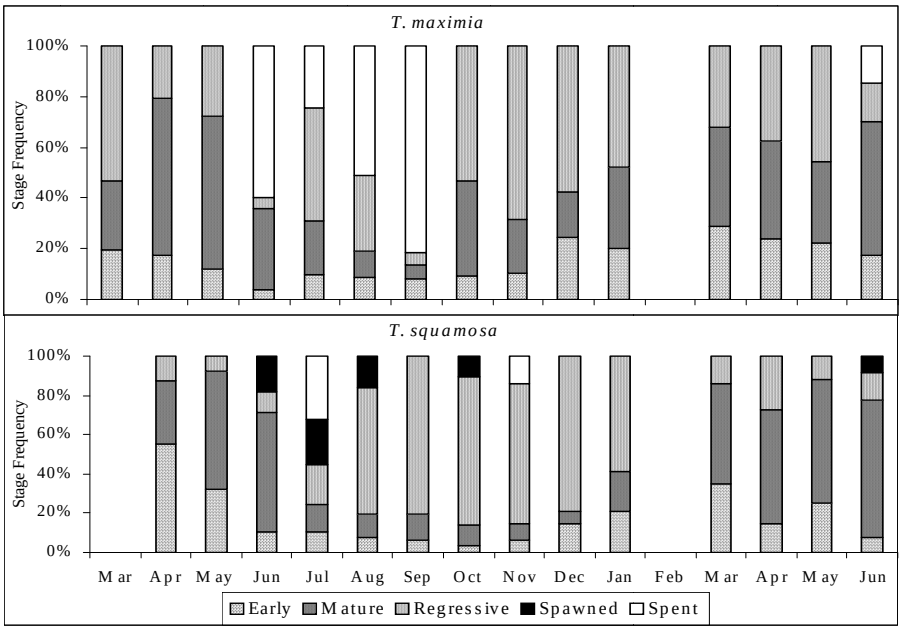

Fig.2: The gonad development index expressed from the gonad biopsy extracts analysis of *T. maxima* (n=6), and *T. squamosa* (n=7) showing the state of gonad during one-year cycle.

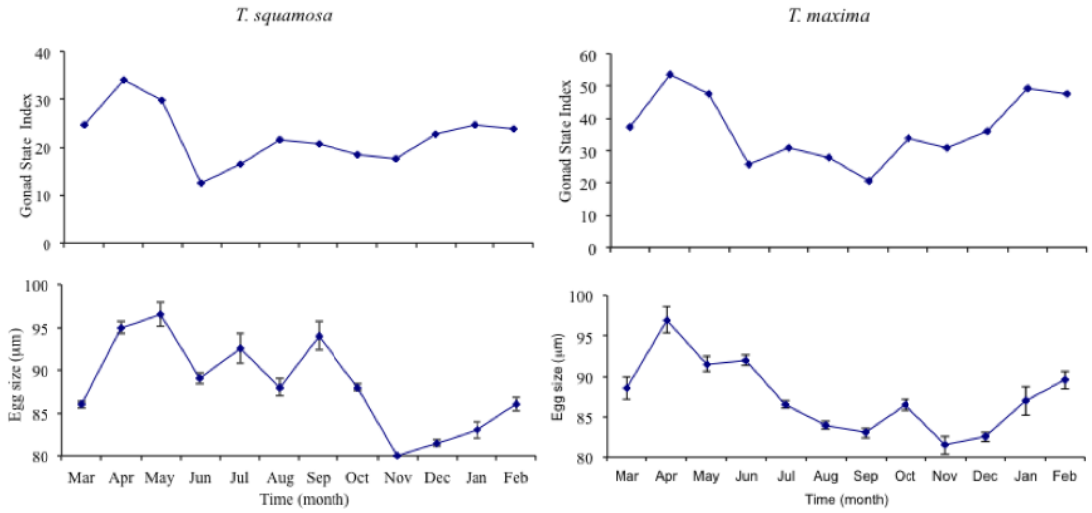

Fig.3: The gonad state index and egg size from the gonad biopsy extracts of *T. squamosa* (n=7) and *T. maxima* (n=6) showing progressive maturity of eggs (Dec-May) culminating in spawning (Jun-Nov).

Artificial stimulation of spawning in wild broodstocks, larval to post-metamorphic rearing, early stage and land-based nursery culture that were carried out for two year cycles showed a reproductive success only in summer. However, the induced spawning in the cold months, although successful, resulted in poor egg quality (late maturity or regressive), extended development always leading to larval mortalities, even if reared indoor with relatively warmer waters (24-25^{o}C). Spawning of both, *T. maxima* and *T. squamosa* in the Red Sea is suggested to take place during the stratified period between June and October (Kilada 1994; Manasrah, et al. 2006). This could be an important implication for conditioning of broodstock to allow for an extended, preferably year-round production of larvae. Methods that were conducted for clam culture in Aqaba did not differ much than what was reported (Braley 1992, Lucas 1994, Ellis 1998). Artificial spawning, larval to post-metamorphic rearing, and land-based nursery culture was attempted over a yearly cycle (see Fig.4).

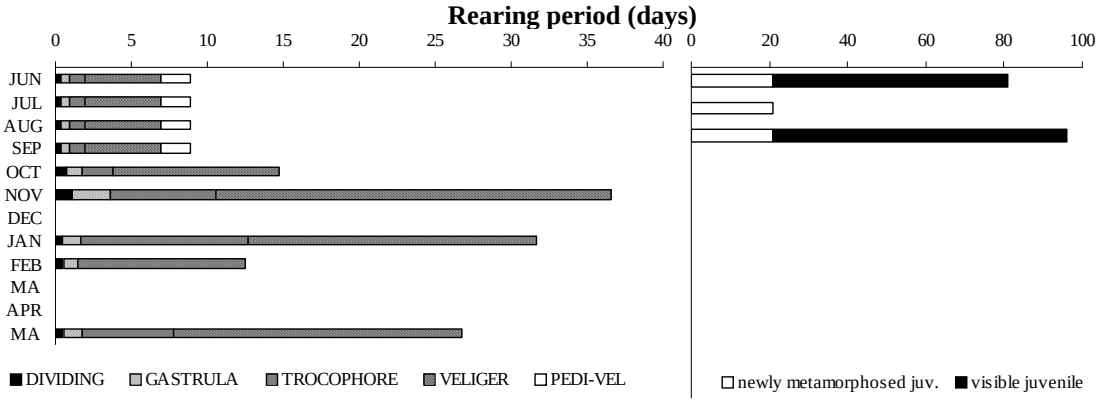

Fig.4: Larval development of giant clams from eggs to pediveligers over a yearly cycle showing protracted larval development and mortality in the winter months (Oct-May).

The artificial induced spawning were showing consistent pattern with *in situ* gonad biopsy where there is pronounced seasonality in reproductive success in months June to September, but protracted larval development and mortality in winter. This is similar at the high latitude northeastern border of giant clam distribution where winter induced spawning yield regressive eggs with poor survival rate in the low water temperatures (Olivotto, et al. 2011). In both, *T. maxima* and *T. squamosa* spawning in the northern Gulf of Aqaba is restricted to the warmer months, when sea surface temperatures are between 24-27 ^{o}C. During summer months, early stage development of the clams follows the development rate found in giant clams cultured in the tropics, e.g., Philippines, Australia, Palau or Solomon Islands (Heslinga et al, 1984; Juinio et al. 1987; Alcazar, 1988; Usher and Munro, 1988; Braley, 1992; Fitt, 1993; Roa, 1997). A marked seasonality was observed in the reproductive cycle of the two species of giant clams in the subtropical northwestern margin of their distribution. Species-specific reproductive variability (Fitt, 1993; Grice and Bell, 1999) showed an extended spawning season for *T. squamosa* (June-November) with two spawning peaks and a shorter but persistent season for *T. maxima* (June-September).

Table 3. Outline of the culture procedure for the giant clam spawning, larval and juvenile rearing in Aqaba, Jordan

Day	*Stage*	*Activities*
	Broodstocks	Spawning of clam broodstock (heat stress, serotonin)
	Eggs	Separate and count eggs per clam, fertilize and stock in hatching tank (20-25 eggs/ml), Filtered seawater (5uM) with flow-thru screen/drain (55uM)
>3 hr's	Fertilization rate	Fertilization rate determination in sample
Day 1 -2	Trocophores check	Allow settlement, siphon bottom water (unfertilized eggs)
Day 2 - 4	Veligers check	Harvest water column and tank bottom. Stock veligers in larval tank (1-3 vel/ml). Commence algal feeding (10000-15000 cells/ml)
Day 5-7	Veligers	Daily algal feeding (10000-15000 cells/ml)
Day 7-9	Veligers check	For larval stage then harvest to nursery bins (5 clams/ sq m), gentle water flow. Moderate aeration. Algal feeding in outdoor tank (10000-15000 cells/ml)
Day 9+	Pedi-veligers check	Zooxanthellae (20-100 cells/ml) inoculation. Presence of foot check
Day 14	Post-metamorphic clam	More water flow at depth of >50-60cm in tank. Zooxanthellae addition (20 - 100 cells/ml)
Day 30	Microscopic clam check	Samples check (lengths, presence of zooxanthellae, etc.)
Day60-90	Visible juvenile check	Harvest, count and measure. Transfer to nursery.

The chances of spawning gametes is possible all year round, however, the developmental success from fertilized eggs to larval veligers and to post-metamorphic clams was found limited in late spring to summer. However, mortality of larvae still is a major problem during this critical period of early stage. Survival in the hatchery phase may be improved by the use of water filtered to 1 µm, provisions of antibiotics, ozonation or sterilization with UV light (Gwyther & Munro, 1981; Crawford et al. 1988; Heslinga et al. 1996). Filtered seawater was attempted as well as the use of flow thru water supply that might provide to some extent hygienic conditions. The application of flow thru system prevented bacterial contamination without using antibiotics as well as eliminates the need to frequently harvest the larvae which are stressful and labor intensive.

Development rate, however, is delayed in its chronological order during the colder months. As shown in the months of October until May, for example, trocophore stage is reached from few days to more than a week post fertilization, as compared to the summer months. Larval stage is protracted in winter to almost a month and the success of surviving into post-metamorphic clams is nil. Juveniles are able to continue to take up zooxanthellae from the environment throughout the first month of their lives. The maximum average SL exhibited a value of about 120-140 mm which is actually the suitable marketable size with high demand mainly for the growing billion-dollar tropical marine aquarium industry in Europe and North America (Bell et al. 1997; Bruckner, 2001; Knop, 2004; Lindsay et al. 2004). An important market potential also lies in the use of *Tridacna's* derived products for technical and

medical purposes. Mollusk shells are much harder than any comparable synthetic ceramics, featuring a unique architecture which minimizes mechanical damage (Kamat et al. 2000) and the rapid growth and large size of *Tridacna* shells may open up important applications in bone and dental research. Besides, giant clams meat is a traditional food source in the South Pacific and the adductor muscles are highly priced delicacies in Japan, China, Honolulu and Guam (Murakoshi, 1986; Shang et al. 1994). Moreover, their shells are used for souvenirs, jewelries, ornamental objects, tiles and construction materials (Juinio et al. 1987; Hart et al. 1998).

Giant clams could play also an important role in the design of polycultures for indigenous Red Sea species on ecological models that result in zero waste. Through effective recycling of both, nutrients and suspended organic matter, they could be used as biofilters in such integrated systems, with positive feedbacks on both water quality and clam growth. Ecosystem-simulating polycultures might hold the key to the culture of other ornamental species particularly coral reef fish in the Gulf of Aqaba. For example, a doubling in the total capital costs of a hatchery-nursery operation may yield a ten-fold increase in the annual number of seed, lowering the capital cost per unit seed clam by the factor 4-7 (Braley, 1992). This will certainly encourage erecting a new venture for local fishermen societies who presently suffer from sever deficiency in fishery resources in this region (Badran and Al-Zibdah, 2006; Al-Zibdah et al. 2007).

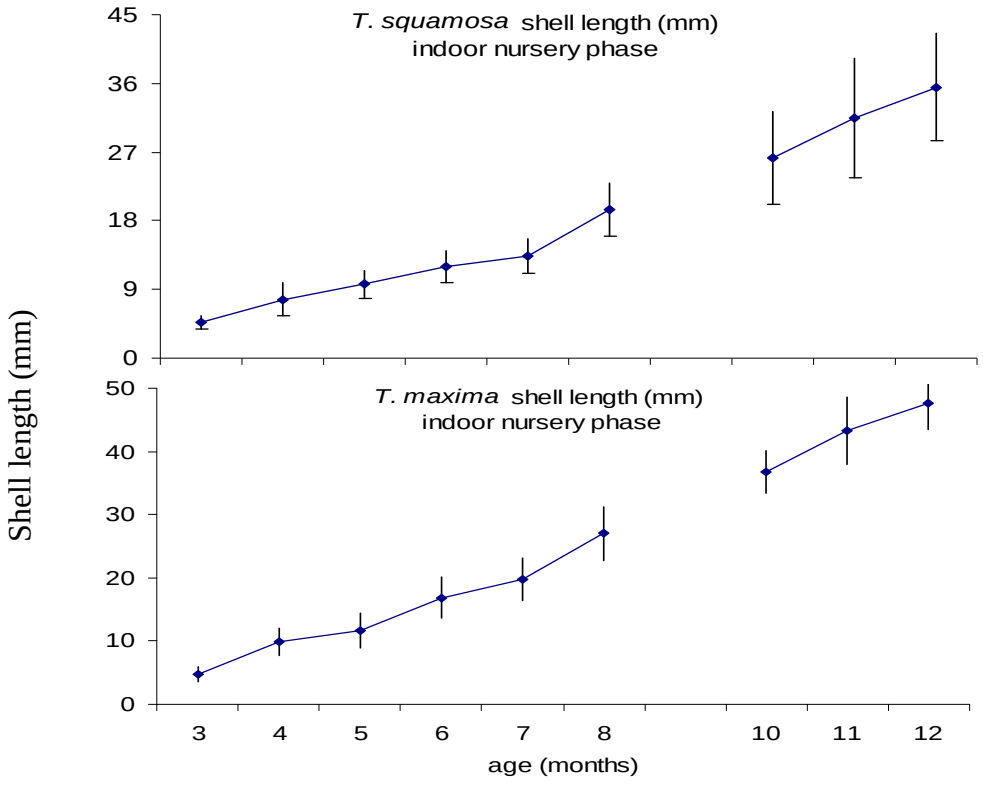

Fig. 5: Growth performance expressed by the increase in shell length (mm) of cultured juveniles of *T. squamosa* and *T. maxima* during the indoor growth phase

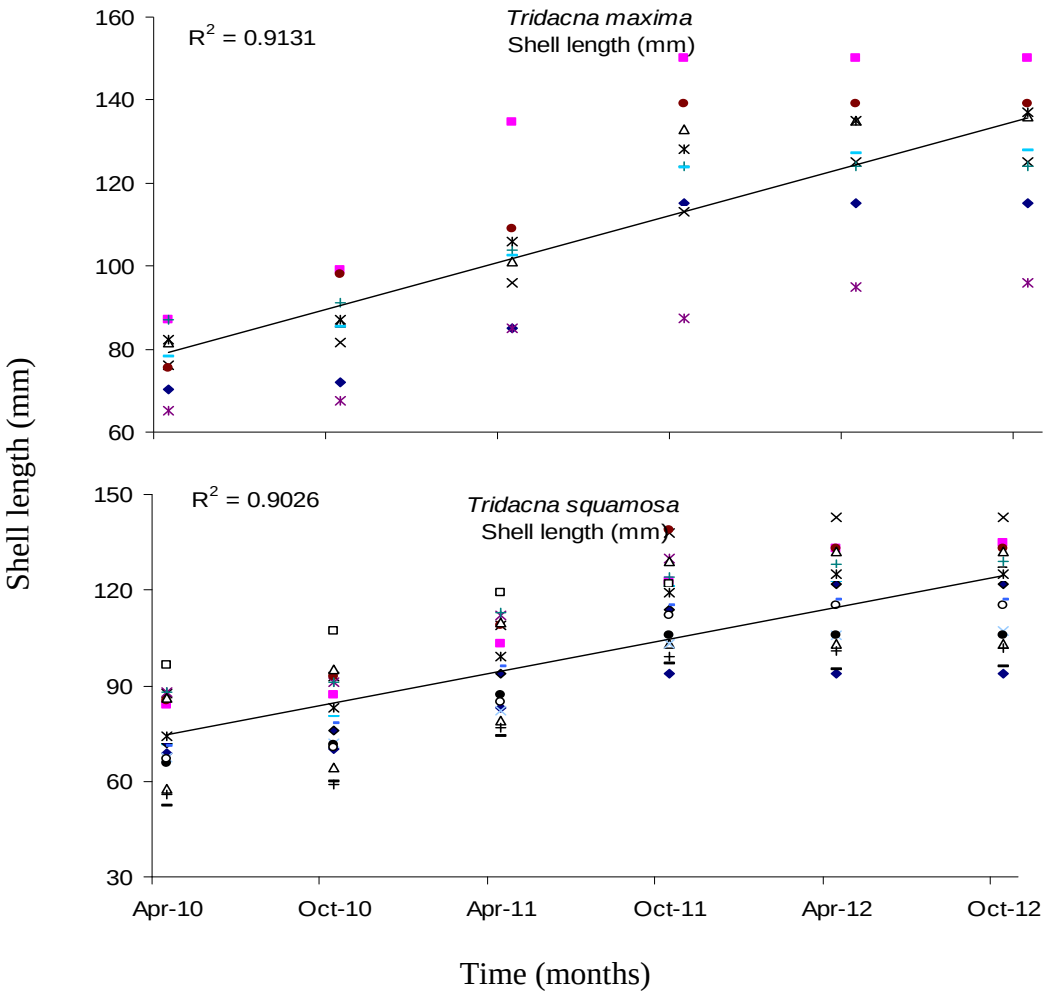

Fig. 6: Growth performance expressed by the increase in shell length (mm) of cultured juveniles of *T. squamosa* and *T. maxima* of the *in situ* growth phase during two years

In conclusion, after numerous rearing attempts, there were three clam batches successfully reared to visible juveniles. The summer spawning was successful in yielding these juveniles. Although only few were harvested (n=14-34), these batches are the pioneering stocks of cultured clams in the Gulf of Aqaba. In addition, it provides an indication for the potential of both species for captive aquaculture in this region (Red Sea), the northwestern limit of their geographical distribution.

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المحار العملاق (*Tridacna spp*) مرشح واعد للاستزراع البحري الرفيق بالبيئة وذو مردود اقتصادي مجد في خليج العقبة

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ملخص

يقدم العمل الحالي محاولة لاستزراع نوعين من المحار العملاق (*Tridacna squamosa* and *T. maxima*) في خليج العقبة، البحر الاحمر. تم اتباع الطرق المعتمدة في عملية الاستزراع مع إجراء تعديلات محددة عليها من أجل موائمة الظروف الطبيعية السائدة في المنطقة. دلت نتائج خزعات البيوض المأخوذة من مبايض هذين النوعين في بيئتهما الطبيعية، إن حالة الانضاج ترتبط بعلاقة عكسية مع عدد مرات تفريخ المبايض ($r = - 0.31$) وكذلك عملية اطلاق البيوض ($r = - 0.25$) بالإضافة الى مجموع البيوض الرديئة ($r = - 0.29$) بينما ارتبطت بعلاقة مضطردة مع عدد تكرارات تواجد البيوض الناضجة ($r = 0.59, P < 0.05$). أما في المختبر فقد تم اجراء تجارب لاستزراع المحار العملاق حيث شملت طرق تحفيز تفريخ الامهات، دراسة المراحل الاولى من تطور اليرقات وكذلك تربية الصغار في حواضن في البيئة الطبيعية البحرية. أظهرت نتائج الاستزراع أن هناك موسمية واضحة في مدى نجاح التكثير لهذين النوعين. حيت اظهر تفريخ البيض باستخدام التحفيز الحراري والكيميائي ثم إلى يرقات أنها ذات تطور مطول خلال الشتاء وتتعرض للنفوق في مرحلة ما قبل وما بعد التحور. إلا أن التفريخ خلال الصيف كان أفضل ولو جزئيا وأنتج بنجاح يرقات من المحار لكلا النوعين. وعليه، فان التجارب الحالية استطاعت ايجاد عدد طليعي من يرقات المحار وبأطوال صدفة تراوحت بين 2–−20–وكذلك إلى 120 ملم عند الأعمار 3–6 اشهر وسنتين لكلا النوعين، على التوالي. النتائج الأولية لتجارب استزراع المحار العملاق كأحد كائنات الشعاب المرجانية في خليج العقبة تدعم تجارب الإكثار المستقبلية لتكون على أساس التكامل في الاستزراع البحري بين أكثر من نوع من كائنات الزينة البحرية ويكون المحار إحداها، وذلك باستخدام الأنظمة المغلقة، وهي جميعها مجدية اقتصاديا ورفيقة بالبيئة.

الكلمات الدالة: ترايداكنا، المحار العملاق، استزراع مائي، خليج العقبة، البحر الأحمر، الأردن.

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