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Productivity and Economic Values of the Pearl Oyster (Pinctada margaritifera var erythraensis) Cultured in Dongonab Bay, Red Sea

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Abstract:

This study was conducted at Dongonab Bay, Red Sea, Sudan during January - December 2010 to estimate the economic value of the pearl oyster *Pinctada margaritifera var erythraensis* cultured in two systems (hanging and bottom,).

The productivity and the economic values of oysters cultivated in the hanging and the bottom systems were estimated in case of shell production only and in case of pearl and shell production. Pearl production is more lucrative. The hanging system demonstrated the highest productivity (645035SDG) and profitability (642289.28 SDG) despite its initial cost, while the bottom system demonstrated low productivity (425290SDG) and profitability (423432.58 SDG).

Key words: *Pinctada*, Oyster, Productivity, Economic, Dongonab Bay, Red Sea

Introduction:

The Red Sea houses wonderful and diverse living and non-living resources, the living resources including Fishes, Crustaceans, Echinoderms and Bivalves. One of these bivalves, the mother of pearl oyster, *Pinctada margaritifera* var *erythraensis* which is found along most of the Sudanese Red Sea coast. The maximum length of these oysters is up to 25 cm (Ali *et al.*, 1992). Many studies have been conducted on *Pinctada margaritifera* var *erythraensis* such as Mortality (Nasr, 1982), feeding and growth (Nasr, 1984), hatchery and nursery (Southgate and Beer, 1997), allometric growth (El-Sayed *et al*., 2011) and biometric relationships (Elamin and Elamin, 2014).

Live oysters are used for artificial pearl culture in Dongonab Bay. There are two methods for obtaining pearl oysters in Sudan:-

1- Collection from the shallow coastal waters by skin diving native fishermen, especially from Dongonab Bay, Shubuk Swakin and Halaieb area.

2- Culturing oysters within and outside Dongonab Bay.

Pearl production on commercial level started in Sudan by the Gulf Pearl Company (1996-upto now) but production has not yet reached high levels. The major factor that limits pearl production worldwide is the availability of oysters needed to be seeded for the pearl culture. This limitation does not apply to Sudan as any number of desired oysters can be produced through culture. Thus it is anticipated that in the future Sudan will be a major producer of artificial pearls.

According to Ali (1984 and 1988) the global market for shells is estimated in the range of few hundred millions US $ while the pearl market worth billions of US $. It is anticipated that in the future Sudan will be a major producer of artificial pearls.

This paper intended to complete gaps in the economical knowledge that match with growing importance of pearl farming realized in the world, to update the previous studies and to establish cost benefit analysis of two culture systems.

Materials and Methods

Study area:

The field part of the present study was conducted at Dongonab Bay. The laboratory part was carried out at the Gulf Pearl Company laboratories.

Dongonab Bay lies about 176 km north of Port Sudan. It extends from NNW to SSE between latitudes 20° 56′ N and 21° 13′ N, and longitudes 37° 05′ E and 37° 15′ E. It is the largest bay within the Red Sea. The total area is 305 km^2, and the length from north to south is about 32 km. The maximum width is 14.5 km at Dokhana Bay and the minimum width is 3.2 km at Ras Adliai (Farah, 1982). Dongonab Bay and Mokawar Island have been announced Marine Protected Areas since 2004 (Kemp and Klaus, 2006).

Cost benefits analysis of the culture systems:

Prices of the culture materials are in Sudanese pounds (1US $ equivalent 2.5 SDG at the time of the study). The estimations are based on current prices at Port Sudan market during May 2011. The shell price is based on the current price at Dongonab village during the same year.

Calculations of the cost based only on culture materials and spat collection

Results:

The cost benefits analysis of the hanging system:

The 1st culture year:

In the first year the oysters spent 6 months on the spat collectors as spat and six months on the nursing long line as young oysters. During this year the 200 m long line used housed 150 panels each having 24 pockets. Each pocket housed one 6 month old oyster (fresh spat) i.e. each line supported 3600 oyster (150 panels x 24 pockets). Six months later the oysters were taken out and put in panels having larger pockets. The same long line now supported 150 panels each with 15 pockets. Oysters spent six months on this line. The cost of the spat collector line and the nursing long line is given in Table 1and 2.

The 2nd culture year:

The 200 m long line used in year 1 was also used in year 2 (now we can call it growing long line). This growing long line housed 150 panels each having 15 pockets. Each pocket housed one 1 year old oyster. The whole long line housed 2250 oysters i.e. (150 panels x 15 pockets). For culturing the entire 3600 oyster an additional 120 m length of growing long line was needed. At the end of the second year the oysters were taken out and put in larger panels having 8 pockets each.

The 3rd culture year:

The same 200 m long line now supported 150 panels each with 8 pockets. Each pocket housed one 2 year old oyster. The whole long line housed 1200 oysters i.e. (150 panels x 8 pockets). For culturing all of the 3600 oysters about three 200 m long lines are needed. At the end of this year the oysters were cropped for sale as empty shells.

The cost of spat collection long line:

One spat collector line housed about 80 vexar collectors. Each collector produced about 250 spat i.e. the whole line produced 20000 spat (80 collectors x 250 spat).

The annual cost of the spat collector line is 449 SDG as detailed in Table 1.

Table 1. Estimated cost of culture materials per year in SDG for the spat collector line.

System	Description	Quantity	Price SDG	Longevity in years	Cost / year SDG
Long line	16mm nylon rope	200 m	950	20	47.5
	Floats	22	220	20	11
	Chain	6 m	120	20	6
	D shackles	6	120	20	6
	10mm nylon rope	240 m	420	20	21
	8 mm nylon rope	200 m	250	20	12.5
	Cemented anchors	6	120	20	6
	Vexar 3/4 inch mesh size	80 pieces	1440	5	288
	Clips	80	720	20	36
Labor cost	Assemble line		300	20	15
	Total cost of spat collector line		4660		**449**

One spat collector line had an annual cost of 449 SDG per season. It produced 20000 spat, out of which only 3600 spat were used in the hanging system. The rest of the spat, 16400, can be sold for 0.25 SDG each. 20000 spat x 0.25 SDG = 5000 SDG.

Cost of the nursing long line:

Table 2. Estimated cost of culture materials per year in SDG for the hanging culture system.

System	Description	Quantity	Price SDG	Longevity in years	Cost / year SDG
Long line	16 mm nylon rope	200 m	950	20	47.5
	Floats	22	220	20	11
	Chains	6 m	120	20	6
	D shackles	6	120	20	6
	8 mm nylon rope	200 m	250	20	12.5
	Cemented anchors	6	120	20	6
panels	Panels (all types)	150	4500	20	225

Labor cost	Assemble line		300	20	15
	Total cost of long line		6580		**329**

That means culturing 3600 oysters for one production cycle need:

<u>If oysters were cropped after 3 years of culture</u>

Cost of year 1: 1 long line having an annual cost of =329 SDG

The cost of the spat collector long line that produced 3600 spat = 449/20000 x 3600 = 80.82 SDG

One nursing long line plus panels used for six months in year 1had an annual cost of = 329 / 2 = 164.5 SDG

Cost of year 1: = 80.82 + 164.5 = 245.32 SDG

Cost of year 2: 1 complete growing long line and an additional 120 m
had an annual cost of = 329 / 200 x 120 =197.4 + 329 = 526.4 SDG

Cost of year 3: 3 complete growing long lines with an annual cost of = 329 x **3 =** 987 SDG

Year 1 = 245.32 SDG
Year 2 = 526.4 SDG
Year 3 = 987 SDG

Cost of the culture cycle (three years) = 245.32 + 526.4 + 987
= 1758.72 SDG

These calculations assume that the farmer does all the labor work by himself and uses his own boat. Therefore the cost of labor and transport is zero. In these calculations the annual mortality was ignored because it is insignificant.

Benefits from one hanging culture cycle (three years):

Survival in the hanging system was 99%. At the end of the culture cycle oysters grew to an average shell weight of 304.9 gm.

Survived oysters = 3600 x 99% = 3564 oysters,
with total shell weight of 3564 x 304.9 =1086663.6 gm
= 1087 kg
Shell price (Dongonab 2011) = 5 SDG / kg
Total income = 1087 kg x 5 SDG = 5435 SDG

<u>Net profit</u> = 5435 - 1758.72 = **<u>3676.28 SDG</u>**

<u>If oysters were cropped after 4 years of culture</u>

Cost of one hanging culture cycle (four years):

Year 1 = 245.32 SDG
Year 2 = 526.4 SDG
Year 3 = 987 SDG
Year 4 = 987 SDG
= 245.32 + 526.4 + 987 + 987 **= 2745.72 SDG**

Benefits from one hanging culture cycle (four years):

It is assumed that at the end of the fourth year oysters will grow to an average shell weight of 338.7 gm (average of 40 four years old Company oysters).

Survived oysters = 3600 X 99% = 3564 oysters,
with total shell weight of 3564 x 338.7 = 1207126.8 gm
= 1207 kg
Shell price (Dongonab 2011) = 5 SDG / kg
Total income = 1207 kg x 5 SDG = 6035 SDG
Net profit = 6035 - 2745.72 = 3289.28 SDG

The cost benefits analysis of the bottom system:-

The first culture year:

In the first year the oysters spent 6 months on the spat collectors as spat and then six months on the nursing trays as young oysters. During this year one bottom tray housed about 400 six month old oysters. Therefore 9 trays were needed. After six months (beginning of year two) the density was reduced. The cost of the spat collector line and the nursing trays is given in Table 1 and 3.

The second culture year:

The trays used in year 1 were also used in year 2 (now we can call them growing trays). This growing tray housed 200 one year old oysters. For culturing the entire 3600 oyster an additional 9 growing trays were needed i.e. all together 18 trays were used. At the end of the second year the density was reduced.

The third culture year:

Same bottom tray now housed about 100 two years old oysters. Therefore an additional 18 growing trays were needed. For culturing all of the 3600 oysters 36 trays were used. At the end of this year the oysters were cropped for sale as empty shells.

The cost of spat collector long line:

One spat collector line housed about 80 vexar collectors. Each collector produced about 250 spat i.e. the whole line produced 20000 spat (80 collectors x 250 spat).

The annual cost of the spat collector line is 449 SDG as detailed in Table 1.

One spat collector line had an annual cost of 449 SDG per season. It produced 20000 spat, out of which only 3600 spat were used in the bottom system. The rest of the spat, 16400, can be sold for 0.25 SDG each.

The cost of the nursing trays:

Table 3. Estimated cost of culture materials per year in SDG for the bottom culture system.

system	**Description**	**Quantity**	**Price SDG**	**Longevity in years**	**Cost / year SDG**
Bottom tray	Coated wire	2 m	20	15	1.33
	Skewer	18 m	90	15	6
	Vexar 3/4 inch mesh size	4 pieces	72	15	4.8
	2 mm nylon rope	30 m	30	15	2
Labor cost	Construction		70	15	4.66

Total cost of tray			282		**18.8**

That means culturing 3600 oysters for one production cycle need:

<u>If oysters were cropped after 3 years of culture</u>

Cost of year 1:

The cost of the spat collector long line that produced 3600 spat = 449/20000 x 3600 = 80.82 SDG

9 trays had an annual cost of = 169.2 SDG

9 nursing trays used for six months in year 1had an annual cost of =
169.2 / 2 = 84.6 SDG

Total cost of year 1 = 80.82 + 84.6 = 165.42 SDG

Cost of year 2: 18 growing trays having an annual cost of =
18 x 18.8 =338.4 SDG

Cost of year 3: 36 trays with an annual cost of =
36x 18.8 = 676.8

Cost of the whole culture cycle (three years) =

Year 1 = 165.42 SDG
Year 2 = 338.4SDG
Year 3 = 676.8 SDG
= 165.42 + 338.4+ 676.8 **= 1180.62SDG**

Benefits from the bottom culture cycle (three years):

In the present study survival in the bottom system was 72%. At the end of the culture cycle oysters grew to an average shell weight of 242.6 gm.

Survived oysters = 3600 x 72 % = 2592 oysters
with total shell weight of 2592 x 242.6 = 628819.2 gm
= 629 kg
Shell price (Dongonab 2011) = 5 SDG / kg
Total income = 629 kg x 5 SDG = 3145 SDG
<u>Net profit</u> = 3145 – 1180.62 = <u>1964.38 SDG</u>

<u>If oysters were cropped after 4 years of culture</u>

Cost of year 1 =165.42 SDG
Cost of year2 = 338.4 SDG
Cost of year 3 = 676.8 SDG
Cost of year 4 = 676.8 SDG
Total cost of the culture cycle = 165.42 + 338.4 + 676.8 + 676.8 **= 1857.42 SDG**

Benefits from one bottom culture cycle (four years):

It is assumed that at the end of the fourth year oysters will grow to an average shell weight of 338.7 gm (average of 40 four years old Company oysters).

Survived oysters = 3600 x 72 % = 2592 oysters,

with total shell weight of 2592 x 338.7 = 877910.4 gm
= 878 kg
Shell price (Dongonab 2011) = 5 SDG / kg
Total income = 878 kg x 5 SDG = **4390 SDG**
Net profit = 4390 – 1857.42 = **2532.58 SDG**

Benefits from pearl culture:
If cultivated oysters were first used for pearl production and after that sold as shells like what the Gulf Pearl Company does then the quality and prices of pearls in the hanging and bottom systems is expected to be as in Table 4 and 5.(Gulf Pearl Company, personal communication).

Table 4. The quality and prices of pearls produced in the hanging system in one culture cycle according to the Gulf Pearl Company records.

Quality	**Percentage**	**Characteristics**	**Price / pearl SDG**
Grade A	10 %	Round pearls	1250
Grade B	30 %	Different shapes	125
Grade C	30 %	Uncompleted pearl	50
Reject	25 %	Oysters reject	-
Mortality	5 %	Mortality	-

Oysters are usually inoculated for pearl production when they are two years old (beginning of year three). They are cropped for pearls after another two years. That means they must be cultivated for four years.
From the above table the cropped 3600 oysters of the hanging system are expected to produce 360 pearls grade A, 1080 pearls grade B and 1080 pearls grade C. Prices of these pearls will be as follows:

Grade A = 360 x 1250 = 450000 SDG
Grade B = 1080 x 125 = 135000 SDG
Grade C = 1080 x 50 = 54000 SDG

Total income from selling pearls of the hanging system:
= 639000 SDG

Table 5. The quality and prices of pearls produced in the bottom system in one culture cycle according to the Gulf Pearl Company records.

Quality	**Percentage**	**Characteristics**	**Price / pearl SDG**
Grade A	10 %	Round pearls	1250
Grade B	20 %	Different shapes	125
Grade C	25 %	Uncompleted pearls	50
Reject	10 %	Oysters reject	-
Mortality	35 %	Mortality	-

In the bottom system natural mortality was 28% i.e. the 3600 oyster will decrease to 2592 oyster at the beginning of year three (phase of inoculation).

From the above table the cropped 2592 oysters of the bottom system are expected to produce 259 pearls grade A, 518pearls grade B and 648 pearls grade C.
Prices of these pearls will be as follows:

Grade A = 259 x 1250 = 323750 SDG
Grade B = 518 x 125 = 64750 SDG
Grade C = 648 x 50 = 32400 SDG

Total income from selling pearls of the bottom system:
= 420900 SDG

The final benefits of the culture systems in the present study:
The final benefits from the hanging and the bottom systems are shown in Table 6.
The cost of one culture cycle (four years) in hanging system form 0.43% of the productivity, while it forms 0.44% of the productivity in the bottom systems. The final profit from shells and pearls production of the hanging system forms 60.27% of the sum of two systems, while the final profit of the bottom system forms 39.73%.

Table 6. The final benefits (grand net profits) from shell and pearl production from the hanging and bottom systems.

Purpose	**Hanging**	**Bottom**
Cost of one culture cycle (four years)	2745.72SDG	1857.42 SDG
Income from shell production at end of one culture cycle (four years)	6035 SDG	4390 SDG
Income from pearl culture	**639000** SDG	**420900** SDG
Net profit of shell production at end of one culture cycle (four years)	3289.28 SDG	2532.58 SDG
Final profit from shells and pearls	**642289.28 SDG**	**423432.58 SDG**

Cost benefits analysis of the different culture systems:
Using a number of criteria, including cost of equipment which was based only in culture materials, ease of construction, degree of fouling, growth rate and survival, the two systems are ranked in Table 7.

Table 7. The cost benefits analysis of the hanging and bottom systems.

Criteria	**Hanging**	**Bottom**
Initial cost	+	+ + +
Cost of construction and running	+ + + + +	+ + +
Ease of construction	+ + + + +	+ + + +
Fouling	+	+ + +
Growth	+ + + + +	+ + +
Survival	+ + + + +	+ + + +
Benefits	+ + + + +	+ + + +
Total	27	24

+ = least favorable, ++ = moderate favorable, + + + = favorable, + + + + = more favorable , + + + + + = most favorable.

Discussion:
Studying growth of *P. margaritifera* is of interest for pearl farming because growth constitutes a useful indicator of both pearl oyster health and the suitability of the environment, as it represents the integrated response of the entire physiological activity of the organisms, and the shell growth rates can provide essential information on pearl growth since shell increment and deposition of nacreous matter on the implanted nucleus are strongly correlated (Coeroli and Mizuno, 1985).
The present study showed that the hanging system is the best system, followed by the bottom system, because the fast growth rate and high survival of its oysters resulted in higher shell yield. The cost decreased going from hanging, to the bottom system.

Selection of the appropriate culture method must consider factors other than pure biological advantages (growth and survival) and cost / benefit such as the availability of the initial capital. Furthermore, it should be noted that the criteria used to assess the suitability of a given culture unit may vary between distant sites depending on local conditions. Predation is not a major cause of juvenile pearl oyster mortality at Orpheus Island (Southgate and Beer, 1997) however, in areas like the Solomon Islands predation results in significant pearl oyster mortality (Friedman and Bell, 1996). Spat transferred directly from collectors into uncovered trays in Dongonab Bay, incurred mortalities of up to 50% (Reed, 1962). Culture units should be selected with a view to minimizing predation. However in the present study no significant predation was observed in any of the culture systems used. Clearly, in developing countries or remote locations, the choice of culture system will also be influenced by the culture materials locally available.

Conclusions:
Although the hanging system has a higher initial cost the shell production and pearl production from it is more lucrative than from the bottom system. Pearl oysters are more lucrative only when cultivated for pearl culture. Then used oysters are sold as shells.

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