# Activities of the Sudan — IDRC oyster culture research project

# by Dr Osman M. Farah, Red Sea Fisheries Research Centre, Port Sudan, Sudan

# Introduction

The mother-of-pearl oyster *Pinctada margaritifera* var. *erythraensis* (Jamenson) has been cultivated in Dongonab Bay since 1904. Dongonab Bay, which lies about 160 km north of Port Sudan (Figure 1), is the major natural breeding ground for mother-of-pearl oysters. This is mainly because the bay is large (area of about 305 km<sup>2</sup>), shallow (average depth=16 m), protected and with many areas of rocky and sandy bottom offering good chances of survival after settlement. The circulation regime during breeding seasons favors retention of larvae inside the bay.

The oysters are valued only for their shells, which are mainly used in the manufacturing of large buttons for women's fashion, knife handles, jewellery, inlay work and poultry feed. The shells used to be exported, mainly to Italy and Germany. Recently there has been a good market for shells in Egypt.

The shell industry is getting very profitable because there is a good market for the shells. Shell price has increased dramatically during recent years. The selling price of a kilogram was 6 SDP in 1986, 30 SDP in 1989, 40 SDP in May 1990 and 60 SDP in



Figure 1. Location of Dongonab Bay

October 1990 (12.1 SDP = US\$1.00). The high price has attracted many fishermen and encouraged them to switch from catching fish to diving and collecting wild oysters. The private sector is also getting involved in the oyster business.

#### Activities of Phase I (1978-1985)

The general objective of Phase I was to develop a culture technology that can be handled by artisanal oyster farmers.

The following activities were conducted during Phase I:

# 1. Seasonal changes in the condition factor of Pinctada

The objective of this study was to make general observations on the seasonal changes of condition factor (fatness) of the oyster and determine the breeding season. Results showed that there was a drop in condition factor in May to July due to the spawning season.

#### 2. Identification drinctada larvae

Using the method of comparing and matching advanced umbonal stages of larvae with the prodisconch of recently settled spat, three types of larvae were suspected to be *Pinctada margaritifera*.

# 3. Efficiency of different substrates in spat collection

Several materials were tested to determined their efficiency in spat collection. Bamboo, half shells, plastic mesh and asbestos sheets were used. Half shells were the most efficient, followed, by bamboo, plastic mesh and asbestos in descending order.

#### 4. Distribution definctada spat

The objective was to discover the horizontal and vertical distribution of spat. Collectors were erected at several sites in Dongonab Bay, in addition to the traditional site at Um Elshiek, near the surface and down to the sea bottom at intervals of one metre.

Results showed that several sites inside Dongonab Bay were good for spat collection (e.g. Abu-faham, Abu Salama, Saatalla, Sarara). It was also shown that spat can be collected from sea surface down to 4 m with maximum density at 3 m.

# 5. Seasonal variation in spat setting at the Dongonab village site

The main objective was to have an insight into the seasonal variability of spat setting, with the aim of defining the breeding season of *Pinctada margaritifera*. Fourteen shells were suspended from a long line just below the sea surface at Dongonab village site. Cultch were removed every two weeks and replaced by new shells of approximately similar dimensions. The shells removed were examined for number, height and length of attached spat. Results showed a high density of spat between July and August, indicating that the breeding season was from June to September.

## 6. Culture difinctada in various materials

This was to test the efficiency of several materials of different designs in the cultivation of oysters. Folded plastic mesh sheets, nylon tubes and Japanese baskets were used. Results showed that nylon tubes are the best, followed by Japanese baskets, large mesh size plastic mesh and finally by small mesh size plastic mesh. But the nylon tubes were not practical and with Japanese baskets, the oysters are subject to predation. Therefore large mesh size plastic mesh was determined to be the best.

# 7. Influence of depth on the growth of oysters

To check the suitability of the whole water column for oyster cultivation, oysters were cultivated at various depths from near the surface down to the bottom. Results showed that the whole water column could be used for oyster cultivation.

### 8. Growth rates in different localities

The objective of this experiment was to explore the possibility of expanding oyster cultivation outside Dongonab Bay. Mohamed Qol and Shanab Bay were the sites selected in addition to Dongonab Bay. Results showed that the growth rates were satisfactory at all sites, with maximum rates in Shanab Bay.

# 9. Oyster growth in relation to fouling

The purpose was to see the effect of fouling organisms on oyster growth rate. Results showed that fouling has little effect on growth especially at low densities (density used was 50 oysters/ $0.2m^2$ ).

#### 10. Training

Three graduates supported by IDRC obtained M.Sc. degrees. Two graduates supported by the Sudan Government obtained Ph.D. degrees.

It can be seen from above that the research done in Phase I was mostly biological and established the capacity of the Red Sea Fisheries Research Section to do research on the culture of the oyster. This led to Phase II where specific objectives were more concentrated on culture methods.

#### Activities of Phase II (1985-1990)

The general objective of Phase II was to re-establish commercial mother-of-pearl oyster culture along the Red Sea coast. The specific objectives were:

- 1. To assess suitability of embayments, besides the traditional site at Dongonab Bay, for *Pinctada* spat collection and cultivation;
- 2.To evaluate, on a commercial and pilot scale, alternative culture techniques to maximise economic returns;
- 3. To develop the capacity for oyster pathology research and investigate the causes of the mass mortalities;
- 4. To help establish commercial farms by demonstrating culture techniques to farmers and extension workers;
- 5. To further strengthen oyster research capability within the Red Sea Fisheries Research Section.

To achieve the above objectives the following research was conducted.

Objective 1: To assess suitability of embayments, besides the traditional site at Dongonab Bay, for *Pinctada* spat collection and cultivation

This strategy is based on spreading cultivation over most of the Sudanese coast instead of at one site so that commercial production will not be jeopardised by occasional mass mortalities occurring at one or a few sites. In April 1986, only four sites were selected: Halaib, Arakyai, Halou and Swakin (Figure 2). In February 1987, another site (Dalaout) was added. The criteria for site selection are that the site should be protected and have wide areas of relatively shallow (<10 m) waters. The site should be near inhabited areas and easy to reach by truck.

At each site, 6 Japanese baskets covered with 1/2in rabbit wire were attached to a long line. Each basket contained 50 oysters randomly taken from spat. Initial oyster height was recorded and growth rates and oyster survival were monitored.



Figure 2. Index map showing site locations

The results show that growth and survival rates were good at all sites tested and were comparable to those at the Dongonab site. This finding indicates that most of the coastal area is suitable for oyster cultivation. Transport and other problems made expansion of the site evaluation difficult. It was decided that effort should be concentrated on three sites: Dongonab, Mohamed Qol and Arakyai. The first two have been used for many years and Arakyai seemed to have the most potential of the five sites, but was not successful.

Objective 2:To evaluate on a commercial and pilot scale, alternative culture techniques to maximise economic returns

#### A. Spat collection

The traditional spat collectors (wood frame + bamboo sheets) developed by Crossland and Reed were too large and massive ( $1m \times 1m \times 4m$ ) to be constructed, transported and handled by farmers who only have canoes or small boats. Therefore, collectors that are not expensive, small, efficient, and easy to install by a single farmer have been considered. In 1986, bamboo collectors (both frame and sheets) of varying sizes (frame dimensions 100cm x 100 cm x 100 cm, 100 cm x 75 cm, 75 cm, 100 cm x 50 cm x 50 cm) were constructed and used for spat collection. Sheets of Doum palm rope with bamboo frames (60 cm x 30 cm) were also used for collecting spat. To determine spat loss during the spat collection period (July–Nov.), some bamboo and some doum palm rope sheets were covered with 1/2in rabbit wire.

It was observed that small bamboo collectors are more efficient and less expensive than the medium and large bamboo collectors. Although the doum palm rope sheets are the most efficient and the least expensive, they are not recommended because they deteriorate so rapidly that if they are left in the water until November, the spat will be totally lost. If they are removed from the water before November, the spat attached to them will be too small and will pass through the 1/2in rabbit wire used in the trays and fall on the bottom. It was also seen that covering collectors increased spat production (26 per cent for bamboo collectors and 11 per cent for doum palm rope sheets) but the production cost/spat was increased by 69 per cent and 75 per cent for bamboo collectors and doum palm rope sheets respectively. Therefore it is not recommended to cover collectors.

In 1987, the above experiments were repeated. Bamboo collectors were made of 10, 9, 8, 7, 6, 5, 4 and 3 bamboo sheets to see the effect of sheet number/collector on the efficiency of the collector. Bamboo and doum palm rope collectors were erected at previously tested sites (Halaib, Dalaout, Arakyai, Haloud and Swakin) to investigate the possibility of collecting spat from these sites. The following results were obtained:

- Density of spat is independent of sheet number/ collector. For bamboo collectors spat density/ m<sup>2</sup> ranged between 60 and 956 oysters while oyster height ranged between 3.20 to 3.83 cm with an average of 3.5 cm;
- —Doum palm rope collectors were about 3 times as efficient as bamboo collectors (spat/m<sup>2</sup> ranged between 480 and 2,000 with an average of 1,045 and oyster height ranged between 2.98 and 3.76cm with an average of 3.3 cm). However, most of these collectors were lost before November 1987;
- -Size of spat increased with decreasing densities;
- —No spat was recorded from collectors in the areas outside Dongonab Bay.

In 1988, 33 collectors with 4 sheets each were erected for spat collection. Results showed that the average

spat height was 2.4 cm and average spat density was  $1,305/m^2$  which is greater than 3 times that of 1987 and double that of 1986.

In 1989, several experiments dealing with spat collection were conducted. Usually spat collectors are put out at the end of June or early July. In 1989, some bamboo collectors were put out in early June. Others were put out in early July to see if the spat collection period would be missed by putting collectors only at this time. To see the effect of protecting collectors, some of them were covered with rabbit wire while others were left uncovered. Collectors made of nylon ropes as netting material were also used, to test their efficiency.

It was seen that 1989 collection was poor with an average of 218 spat/m<sup>2</sup> for both covered and uncovered June and July bamboo collectors ( $\approx 1/6$ of that of 1988). It is also strange that collectors put out in June (whether covered or uncovered) collected less spat than those put out in early July. In all cases, covered collectors produced substantially more spat than uncovered ones but despite this increase in production, the production cost was not reduced. Therefore it is not recommended to cover collectors.

Nylon rope collectors produced three times more than July uncovered bamboo collectors. Cost/spat for the nylon rope collectors was about quarter that of the uncovered collector. Therefore, nylon ropes are recommended but should be tested again.

It is concluded from spat collection studies that:

- to year. Therefore, using a large number of collectors does not guarantee a large crop. Therefore, a spat-fall forecasting system should be developed;
- -Cost of spat collection is increasing so rapidly that within 3 years (1986 to 1989), the cost increased almost 14 times. Despite this increase, the shell industry is getting more profitable because there is also a rapid increase in the selling price of oyster shells.

#### B. Larval identification

In Dongonab Bay, the annual breeding season could vary but in general oyster spawning occurs in summer. To establish a system of spat-fall forecasting, different larval stages must be known. It is necessary to follow larval growth as a method of spat-fall prediction. The accurate method of determining larval species is by culturing. It has not been possible to do the larval culture work necessary

to establish larval identity. However some work was done on identifying the very early juvenile oysters.

In 1986, a study was undertaken for the identification of the advanced larval stages by matching the shape of the advanced larval stages (late umbo) with the disoconch of the smallest spat that was obtained. Results showed that the advanced umbonal stages observed were of 10 different shapes. Only two of these match with the margaritifera spat. More work is needed to culture larvae in the lab.

#### С. **Culture methods**

To improve production of mother-of-pearl shell in the Red Sea, grow-out culture methods such as ground, bottom and off-bottom were tested and evaluated in terms of shell growth, survival rate and cost of culture material. The experiment started in January 1986 and terminated in September 1987 with initial stocking density of 170 oysters/m<sup>2</sup>.

The results show that the off-bottom culture method is the best of all three methods tested because the fast growth rate and high survival rate give high shell yield. The above experiment also showed that both growth rate and cost decrease going from offbottom to ground culture. With proper management of the stocking density it seems that early offbottom culture can be economical, with the second and third year in bottom trays.

A pilot scale experiment started in Dongonab Bay in February 1989 to evaluate the timing of holding Spat density and height vary greatly from yearthe oysters in off-bottom trays, on the bottom in trays and directly on the sea bottom. In this experiment 1.8m x 1.8m trays were used. Each tray was stocked with 648 oysters (stocking density  $= 200 \text{ oyster}/\text{m}^2$ ).

> The oysters were covered with 1/2in rabbit wire. Nine trays were hung from a long line and nine were placed on cement blocks 40 cm above sea bottom. For ground cultivation, oysters were placed directly on three sandy areas each  $1.8\,\mathrm{m\,x}\,1.8\,\mathrm{m}$  and covered with 1/2in rabbit wire. These trays have been checked regularly. Shell height and survival have been recorded as well as material cost, labour cost, etc for each system.

> In December 1989, three off-bottom trays were moved to the bottom on cement blocks and three bottom trays were moved to ground areas (Figure 3). Also in December 1989, a new set of 21 replicates similar to those of February 89 were set up. In September 1990, 21 more replicates similar to those of December 1989 will be started, three off-bottom



Figure 3. Experimental design of the pilot scale project at Dongonab Bay. Numbers indicate groups of replicates as they are transferred from one culture method to another over the 3 years of the experiment.

trays will be moved to bottom trays and three bottom trays will be moved to ground areas for the February 1989 and December 1989 replicates. Final results for February 1989 replicates will be obtained after February 1992.

### D. Testing new culture materials

Traditionally rabbit wire has been used to cover oysters on nursing and growing trays for protection. In recent years, the quality of the rabbit wire has decreased and the price has increased so rapidly that it might seriously affect the oyster industry in Sudan. Therefore, other materials that can be used instead of rabbit wire should be tested. In December 1987 an experiment was set up to test plastic mesh of various mesh sizes in addition to the rabbit wire. The experiment was terminated in May 1988. Oysters aged two years with shell height of 10.0 cm were cultivated at a stocking density of 200 oysters per tray in bottom culture system. It is concluded from the results that 3/4in plastic should be used to replace rabbit wire.

Because both plastic mesh and rabbit wire are imported, locally available materials (bamboo, wood, nylon ropes) have been examined as netting materials. Other materials (wood, metal pipe) have also been tested as tray frames in addition to the traditional heavy wire mesh. The experiment began in February 1989 and will continue for a complete culture cycle (2.5 years).

Shells of initial height of 3 cm were cultured at an initial stocking density of 350 oysters/tray. The oysters were cultured in 8 trays of different frames with different netting material. All wood frames (3) having bamboo, wood and nylon rope netting materials were damaged and excluded from the experiment, leaving only five frames (4 heavy wire mesh and 1 metal pipe).

It is really too early to draw conclusions from this

experiment because we have to wait for a complete cycle (2.5 years). The general remark that can be made is that the tray that has the highest growth rate has the lowest percentage survival and vice versa.

## E. Size grading

In an M.Sc. thesis (ElNaiem, 1984) it was shown that shell production can be increased up to 27 per cent when animals are graded in their second year of cultivation. The effect of grading throughout the whole culture cycle was not tested. In January 1986, grading was started to determine its effect on shell growth, survival and shell quality for a period of three years. Three experimental groups of oysters were cultivated:

- 1.Graded small oysters with initial height of < 3 cm with an average of 2.2 cm;
- 2.Graded large oysters with initial height of <5 cm with an average of 5.5 cm;
- 3.Ungraded oysters of heights ranging from 1.7 to 7.5 cm with an average of 4.1 cm.

It is reported that the height-specific growth rate (HSR) used to measure the effect of grading on oyster growth indicates that the graded oysters (average of small and large graded shells) have a growth rate that is 30, 47 and 29per cent higher than the ungraded oysters for the first, second and third years respectively. The final shell weight of graded oysters is 35 per cent greater than that of ungraded shells. Oyster survival is slightly higher for graded oysters than ungraded oysters. Although it is recommended that oysters should be graded to have a better yield, grading needs to be tested satisfactorily on a large scale.

#### F. Predation

Spat taken from collectors are covered with rabbit wire for protection until they are more than one year old. The size at which oysters become resistant to predation has not been determined. From January 1986 to May 1988, studies were undertaken to see the effect of predation on oyster growth and survival and to determine the size at which oysters become predation-resistant. Oysters of different ages and different heights were grown in exposed and protected trays. The results indicate that predation has no effect on shell growth. It also indicates that oysters over 11 cm, or about 2 years old, could be cultured without protection and still have reasonable survival. The culture of uncovered older oysters needs to be tested satisfactorily on a large scale.

# Objective 3: To develop the capacity for oyster pathology research and investigate the causes of the mass mortalities

The short-term training of a Sudanese pathologist in bivalve pathology was completed. Following this, a baseline study of Pinctada margaritifera was started by sampling normal oysters and examining them histologically. During this study and from other samples taken from groups held in stressful culture situations, there has been no sign of any pathogen. However, the technicians stationed at Dongonab have been shown how to take and preserve oyster samples if there is any sign of abnormal mortality starting in any group of oysters. So far there has been no mortality of this sort in Dongonab. There was one occurrence of very high mortality at Arakyai which is still completely unexplained. The lack of significant mortality in Dongonab Bay over the five years of Phase II is a big change from earlier times. One reason may be the improved maintenance now provided to the trays.

Experimental induction of stress was planned during Phase II. The biological response of the oysters and the role of stress in favoring pathogens was to be observed. An overcrowding experiment was conducted on 20-month and 10-month-old ovsters. Densities used for the 20-month-old ovsters were 20, 97, 179, 194 oysters/m<sup>2</sup>. No trend relating survival to densities was observed. Densities used for the 10-month-old oysters were 247, 494, 741, 988, 1,235, 1,481 oysters/m<sup>2</sup>. Results showed that survival decreased with increasing densities reaching 54 per cent at 1,235 oysters/m<sup>2</sup> and 30 per cent at 1,481 oysters/m<sup>2</sup>. Apparently, these densities did not reach a stress level. Therefore more work is still needed. An exposure-to-air experiment was also conducted on oysters 5 months (spat), 15 months and 25 months old. Results showed that young oysters (spat) were less resistant to exposure and all spat died in the first day of exposure. Rinsing of oysters with sea water increased their resistance to air exposure.

# Objective 4:To help establish commercial farms by demonstrating culture techniques to farmers and extension workers

Demonstration farms were initially set up at Shanab Bay, just north of Dongonab, and Mohamed Qol, just south of Dongonab. These farms consisted of several large trays to be maintained by a local fisherman. They were to receive 50 per cent of the production. The farm in Shanab failed when the fisherman left. Although it looks like a good site for oyster culture, Shanab has no resident human population, which causes difficulties. The farm at Mohamed Qol has had reasonably good maintenance and yield has been satisfactory. A third farm was set up in Dongonab a year later which has also been going well. Production at the farms was good in 1988, with about 300 to 500 kg per farm, but decreased in 1989, to about 50 to 90 kg per farm. It is thought that the decrease may be due to the 'unreported harvesting' of the stock.

A large farm at Arakyai was set up in collaboration with the Marine Fisheries Department in 1988. Unfortunately, there was complete mortality of the stock early in 1989. The cause has not been explained.

# Other related research

Meteorological and oceanographic studies have been conducted at the Dongonab Bay, Arakyai and Halaib sites. Results showed that conditions were normal at these sites. In May 1989, a sudden rise in air and water temperatures (water temperature reached 27°C) was observed in Dongonab Bay. Oysters in shallow areas were reported dead. The sudden rise in temperature was thought to be the cause of that mortality.

# Objective 5:To further strengthen oyster research capability within the Red Sea Fisheries Research Section

Short-term training has been completed for three of the full-time scientists in Port Sudan and for the pathologist who is stationed in Khartoum. One scientist presented a paper at the World Aquaculture Society Meeting in Guayaquil, Ecuador and subsequently had short term attachments at the IDRC-supported oyster culture project in Jamaica and at Dalhousie University. Another scientist attended the IDRC-supported Economics in Aquaculture short course at University Pertanian Malaysia. The third Port Sudan scientist had a two-month attachment at the University of Delaware to learn coastal oceanography methods. The pathologist spent two months with an oyster pathologist at Rutgers University in New Jersey, USA.

## Reference

ElNaiem, A. G. (1984). Variability in growth of the mother-of-pearl oyster *Pinctada margaritifera* in the Red Sea (Sudan). Master of Science Thesis. <u>Dalhousie</u> University, Canada. 120 pp.

*This article is a reprint of an article from* Out of the Shell: *Mollusc Culture Network Newsletter, Vol. 1 (4), February 1991, pp. 5–12.* 

Editor's note: refer also to the abstracts on p 44 and 45 of this issue of POIB.