Shellfish Fishery in the North Western Part of the Red Sea

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Abstract: The Red Sea and Gulf of Suez are characterized by their unique diversity of fish and invertebrate species. This study aimed to investigate the status of one of the most economically important bivalve species in the Gulf of Suez, the pearl oyster *Pinctada radiata* stock for the proper management of its populations. Abundance and distribution patterns of the species were studied by conducting a survey, using an underwater visual census technique, at which SCUBA diving were used to investigate the deep areas, while snorkeling were used at the shallower areas. The results showed a scattered distribution pattern of the species with very high population in El Gimsha Bay (northwestern Red Sea). The bay is characterized by a robust oyster population with very high densities (average 164 shell/m² at the sea grass habitat), abundance (9.84 million shells) and biomass (4.29 kg/m²). Most of the population was recorded at depths from 4 to 6 m. Spatial distribution of the oyster was correlated to the substrate type and it was found that the sea grass habitat is the favorite for *P. radiata*. During the survey a sample of 650 specimens were collected for further population structure studies. Size frequency distribution analysis indicated that the life span of the oyster is about 5 years and the von Bertalanffy growth function (VBGF) estimates were: \( L = 10.31 \) cm shell length (DVM) and \( K = 0.34 \) year\(^{-1}\). The instantaneous total, natural and fishing mortality coefficients were 0.565, 0.31 and 0.255 respectively and the exploitation rate was 0.452. In conclusion, pearl oyster stock in Gimsha Bay is healthy and keeping the fishing activity at safe rate will not affect the natural population.

Key words: Pearl oyster %Pinctada radiata %Abundance %Biomass %Population structure %Red Sea

INTRODUCTION

North-western part of the Red Sea particularly Gimsha Bay is the most important sea bed for pearl oyster in the Egyptian sector of the Red Sea. This area has been heavily exploited before banning of the shellfish fishery in 2002. The pearl oyster *Pinctada radiata* is one of the most economically important bivalve species in this area. Pearl oysters have been prone to exploitation due to the considerable value of the pearls and the nacre, or “mother of pearl”, of the shell which is used in the button and jewelry manufacture, their edible flesh and because of the animal’s sessile nature and tendency to occur in sufficient densities at shallow depths for relatively easy collection which in turn increase the severity of the population destruction. Oyster beds have important direct and indirect effects through their tremendous processing capacity as filter feeders, removing sediments and other particulate matter from the overlying water column. Natural oyster populations are the principal source of the seed collection for pearl culture and oyster hatcheries, despite of the advanced hatchery and culture technology that takes place nowadays.

Many studies on pearl oyster occurrence, distribution, standing stock and population structure have been conducted in Cook Islands [1, 2], Hawaii [3], French Polynesia [4–6], the Indian Ocean [7, 8], coastal Kenya [9], the Mediterranean [10] and the Arabian Gulf [11–14]. However, few studies were conducted in the Red Sea [15, 16]. In Northern Red Sea (Gimsha Bay), limited studies deal with population structure and biology of Pearl oyster *P. radiata* was carried out [17, 18].

The aim of this study was to assess the current status of the oyster population in Gimsha Bay depending upon three attributes; 1- Quantity based on the overall density and biomass of the oyster bed; 2- Quality based on overall shell appearance and percent of live to dead oysters and 3- Size composition to determine growth and mortality rates.

MATERIAL AND METHODS

Study Area: Gimsha Bay is one of the most productive fishing grounds for the pearl oyster *P. radiata* in the Egyptian sector of the Red Sea. It is a semi-closed bay, about 12 Km long and 5 Km width at the south western
side of the Gulf of Suez (Fig 1). The bay is subjected to strong wave action and moderate south west current. It is characterized by sandy substrate interrupted with few loose small rocks with high cover of sea grass and algae (*Sargossum dentifolium* and *S. latifolium*). The oyster beds in this bay consist of vertical clusters built upon a fragile matrix of shells (both live and dead oysters), mussels and gastropods, surrounded by sea grass.

**Sampling:** A survey of *Pinctada radiata* populations was carried out in Gimsha Bay during July 2006. During the survey, 10 sites were investigated. At each site replicate transects were made parallel to the shore and covering different zones and habitats. The length of each transect was about 150 m, 2-5 replicates were made in each zone. Along each transect 10 quadrates were made each 10 m x 10 m (100 m²). In each site the following information were recorded:

- Population density of *P. radiata* was determined as number of individuals / m².
- Abundance was estimated for the study site as all the individuals occurring at the site [19].
- At each quadrat different biotopes and type of substrate were described in terms of percentage of sand, rubble, seagrasses, algae and rocks.
- At representative quadrats all the animals were collected for studying the population structure.
Data Analysis: A representative sample of 650 individuals of *P. radiata* from 5 m deep was collected. Each living specimen of the pearl oyster was cleaned from the extraneous bio-fouling organisms by scraping its ventral and dorsal shell valves. Each individual was weighed to the nearest 0.5 g (total wet weight) after blotting excess water. Then the dorso-ventral measurement (DVM), which is the maximum length from the hinge to the ventral edge of the shell, was measured by a vernier caliper to the nearest 0.5 cm. Parameters of the relationship between length and mass were estimated by regression analysis:

$$M = a \times L^b$$

Where $M$ is ash-free dry mass, AFDM (g), obtained by ignition of soft tissue at 100°C for 24 hours, $L$ is the shell length (DVM) (mm) and $a$ and $b$ are constants.

Length-frequency histogram was constructed with 0.5 cm intervals. The Modal Class Progression Analysis Method [20] was applied to assess the age groups. Growth in shellfish is commonly described by the von Bertalanffy growth function (VBGF); this model describes maximum growth and does not assume rotational symmetry about an inflection point [21]. It has been used extensively to describe the growth of other species of shellfish e.g. *Spisula solidissima* [22]; *Mercenaria mercenaria* [23, 24] and *Ostrea edulis* [25]. The model equation is:

$$DVM_t = DVM_{\infty}(1-e^{-K(t-t_0)})$$

Where $DVM_t$ is the dorso-ventral measurement at age $t$, $DVM_{\infty}$ is the asymptotic size, $K$ is a growth coefficient and $t_0$ is the curve origin. The reliability of these growth parameters was tested using the Munro’s phi prime index ($M$) computed from the equation derived by Pauly and Munro [26]:

$$M = \log_{10} K + 2 \log_{10} L_4$$

The total mortality coefficient ($Z$) was estimated from the mean length in the population; using the method of Beverton and Holt [27]

$$Z = K (L_{\infty} - L') / (L_{4} - L')$$

Where $K$ and $L_4$ are the growth parameters of the von Bertalanffy equation, $L'$ is the mean length in the population above $L'$ where $L'$ is the cut-off length. The natural mortality coefficient ($M$) was estimated by the method of Taylor [28] for bivalves.

$$M = 2.996/A_{0.95}$$

Where $A_{0.95}$ is the 95% of the asymptotic length.

The total production was calculated for *P. radiata* by the mass-specific growth rate method [29, 30] from the size-mass relation, the size frequency distribution and VBGF:

$$P = E Ni \times Mi \times Gi (g \mathrm{AFDM} \ m^2)$$

Where $Ni$ is the average number of animals (N m$^{-2}$), $Mi$ is the mean individual AFDM in length class I and $Gi$ is the mass-specific growth rate:

$$Gi = b \times K \times (L / Li)^{-1}$$

Where $b$ is the exponent of the size-mass relation, $K$, $L_4$ are VBGF parameters and $Li$ is the mean size in class $i$.

The P/B ratio of the *P. radiata* population was calculated from total production $P$ and mean biomass $B$.

RESULTS

Shellfish Species Composition: Five shellfish species of economic commercial importance were recorded in Gimsha Bay. The pearl oyster *P.radiata* was the most abundant species comprising about 92.8% of the shellfish fishery followed by *Bursa granularis* (4.0%) and *tectus dentatus* (1.28%), *Gafrarium sp.* (1.47%) and *Strombus tricornis* (0.42%) as shown in Fig 2.

Density and Abundance of *P. Radiata*: As most of the oyster beds were occurred in Gimsha Bay, an intensive survey was conducted in the area. The population density of *P. radiata* recorded at the bay differed according to different substrates (Fig 3). Sea grass and algae substrates were the most suitable habitat for *P. radiata*. In contrast, sandy areas were unfavorable for populations of *P. radiata*. The sea grass substrates recorded the highest density ranged between 315.4 and 15.4 ind/m$^2$, followed by algae areas (310.7-16.5 ind/m$^2$). While, these densities were greatly reduced at sandy areas (95.6-7.6 ind/m$^2$).

Generally, the bay is characterized by a robust oyster population with very high abundance of 9.84 million shells.

Distribution According to Depth: Distribution of *P. radiate* in Gimsha Bay was correlated to different depth strata (Table 1). The highest density was recorded at depths ranging between 4 and 6 m where the substrate
Fig. 2: Species composition of shellfishes in Gimsha Bay

Fig. 3: Average population density (indi/m$^2$) of the pearl *Pinctada radiata* at different substrates in Gimsha Bay

Fig. 4: Size (DVM) mass relationship of the pearl oyster *P. radiata* in Gimsha Bay
Fig. 5: Length frequency distribution of the pearl oyster *Pinctada radiata* from Gimsha Bay

Table 1: Density (ind./m²) of *P. radiata* in different substrates and depth strata

<table>
<thead>
<tr>
<th>Depth m</th>
<th>Seagrass</th>
<th>Algae</th>
<th>Sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 2</td>
<td>15.4-90.4 (39.3±24.0)</td>
<td>16.5-65.9 (33.1±17.4)</td>
<td>7.6-31.6 (17.1±7.7)</td>
</tr>
<tr>
<td>2 - 4</td>
<td>125.8-186.5 (177.3±38.9)</td>
<td>117.6-195.4 (180.1±46.1)</td>
<td>75.4-101.8 (97.4±16.5)</td>
</tr>
<tr>
<td>4 - 6</td>
<td>263.7-301.9 (292.6±19.1)</td>
<td>271.2-310.7 (291.5±14.0)</td>
<td>95.6-111.3 (97.7±8.6)</td>
</tr>
<tr>
<td>6 - 8</td>
<td>272.1-290.0 (281.1±16.0)</td>
<td>201.9-231.2 (215.6±12.0)</td>
<td>90.1-103.3 (92.5±5.1)</td>
</tr>
</tbody>
</table>

Table 2: Estimated growth parameters of pearl oysters in different localities

<table>
<thead>
<tr>
<th>Species</th>
<th>L</th>
<th>K</th>
<th>M</th>
<th>Area</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. radiata</em></td>
<td>10.7</td>
<td>0.25</td>
<td>1.456</td>
<td>Qatar</td>
<td>Mohammed, 1994</td>
</tr>
<tr>
<td><em>P. radiata</em></td>
<td>10.23</td>
<td>0.41</td>
<td>1.637</td>
<td>Northern Red Sea</td>
<td>Yassien, 1998</td>
</tr>
<tr>
<td><em>P. radiata</em></td>
<td>6.92</td>
<td>0.56</td>
<td>1.428</td>
<td>Mediterranean</td>
<td>Yassien et al 2000</td>
</tr>
<tr>
<td><em>P. radiata</em></td>
<td>13.2</td>
<td>0.34</td>
<td>1.77</td>
<td>Arabian Gulf</td>
<td>Mohammed &amp; Yassien 2003</td>
</tr>
<tr>
<td><em>P. margaritifera</em></td>
<td>18.3</td>
<td>0.26</td>
<td>1.940</td>
<td>Cook Islands</td>
<td>Sims, 1992</td>
</tr>
<tr>
<td><em>P. radiata</em></td>
<td>10.31</td>
<td>0.39</td>
<td>1.618</td>
<td>Northern Red Sea</td>
<td>Present Study</td>
</tr>
</tbody>
</table>

was covered by seagrass and algae. About 37.5% of the population was recorded at that depth range. The oyster showed its minimum density (5%) at shallow water of 0-2 m depth. Also a relatively high percentage of individuals (35.6%) were recorded at depth range from 6 to 8 m.

**Biomass and Production:** The estimated total biomass of *P. radiata* in Gimsha Bay was 4292 g/m² and 872.92 g AFDM /m³. The observed relation between length and AFDM $M = 0.0044 \times L^{3.0099}$ ($r^2 = 0.8881$, $n = 592$) (Fig 4) was used for production estimates. Total production was 3798.46 g AFDM /m² and P/B ratio was 4.35.

**Population Structure:** The modal progression analysis (MPA) output indicated 5 distinct modes or length/age groups with mean lengths (DVM) of 2.16, 5.5, 7.0, 8.10 and 8.7 cm, respectively (Fig. 5). The rate of growth was higher for small sizes than for large animals. Growth rate declined with age class from a mean of 3.34 cm/yr to 0.60 cm/yr. The von Bertalanffy growth parameters of *P. radiata* was calculated as $L_a = 10.31$ and $K = 0.39$/y. The longevity ($t_{max} = 3/K$) was found to be 7.69 years and the growth performance index ($M$) was estimated as 1.618.

The length frequency distribution of *P. radiata* was used for the estimation of the mean length in the population $L'$ and the cut-off length $L'$. The calculated values were 3.5 cm and 6.28 cm respectively. Using these values with the growth parameters in the equation derived by Beverton and Holt gives total mortality estimate of $Z = 0.565 \text{year}^{-1}$.

The natural mortality coefficient was estimated as $M = 0.31 \text{year}^{-1}$. The average observed death rate was
40.2 ind/m². The percentage of dead shells was 18.1% in seagrass substrate, 16.7% in algae substrate while it was 31.6% in sandy bottom.

The fishing mortality coefficient F was estimated indirectly by subtracting the estimates of the natural mortality coefficient from the estimates of the total mortality coefficient, since Z = F + M. The resultant F was 0.255/y. These results lead to an estimates of the exploitation rate of E = 0.452.

**DISCUSSION**

The Gulf of Suez is known by its great diversity and density of shellfishes. More than 20 shellfish species were recorded in the Gulf of Suez, of which 7 species have economic commercial importance [17]. The pearl oyster P. radiata is the most abundant species comprising about 65% of the shellfish fishery followed by tectus dentatus (15%), then the Bursa granularis comes in the third grade by about 10% followed by the Strombus tricornis and lambis truncate (6%). Both Pinctada margaritifera and Tridacna sp. constitute about 2% [18].

To the best of our knowledge, this study is the first to investigate the state of the pearl oyster Pinctada radiata stock in the Gimsha Bay, Northern Red Sea, after banning of the shell fishery in 2002. The population ecology of the stock showed that the density of the oyster is very high (average density 164.2 shell/m²), when compared with the average densities of P. margaritifera (0.2 and 2 shell/m²) in Andaman and Nicobar Islands in India [7], (5.59 and 4.58 shell per 100 m²) in the Cook Islands [1], (1.0 ± 0.8 shell/m²) in French Polynesia [2] and (105.3 to 06 shell/m²) in Coastal Kenya [9].

Spatial distribution of the oyster was correlated with substrate type and it was found that the sea grass habitat is the favorite for P. radiata. Most of the population was recorded at depths of 4 to 6 m. In this respect it was reported that the larvae of marine bivalves tend to be concentrated near the water surface [31] while Tomaru *et al.* [32] stated that pearl oysters settle are more abundantly in shallow water than 6 m depth.

The estimated high mass-specific production ensures that the pearl oyster is highly producer species in the community. The high abundance and production rate give the species potential economic value should be used for export markets and it is apparently a valuable species for aquaculture.

The growth results of P. radiata in Gimsha Bay showed that the bulk of the stock is consisted of age classes 2 and 3 and that average growth in the initial years is relatively slow, at around 3.3 cm per year. This is higher than the growth rate (1.8 cm/y) reported by Narayanan and Micheal [33] for P. fucata (= P. radiata) in India, (1.2 cm/y) in Japan for P. fucata [34], (2.76 cm/y) recorded for P. radiata in the Red Sea [17], (1.94 cm/y) in the Mediterranean Sea [10] and in the Arabian Gulf [13]. But, this growth rate is very close to the growth rate (30 mm per year) achieved by wild stocks of P. maxima in Western Australia [35] and is slower than the growth rate achieved by P. maxima on farms [36].

Table 2, compares the estimated growth parameters of pearl oyster in different localities. Considerable spatial and individual variation in growth of P. radiata in the different areas was noted, this can be attributed to the different survival strategies and ecological factors present at the different latitudes. Estimates of L₂ and K for P. margaritifera and P. maxima show that these species are larger and faster growing than P. radiata, this was expected because P. margaritifera grow to larger sizes (18 cm DVM) and P. maxima is recognized as the largest of pearl oysters in the world [37]. The average observed mortality rate of 40.2 ind/m² and the percentage of dead shells are relatively high; this may be due to the banning of the fishery which led to a crowded population formed of vertical clusters built upon a fragile matrix of shell (both live and dead oysters). The estimated natural mortality of M = 0.31/y is higher than that estimated by Hart and Joll [34] for P. maxima (0.11 -0.18) and by Sims [1] for P. margaritifera (M = 0.11) who suggested that low rates of M for pearl oysters are to be expected.

It could be concluded that for the maintenance and development of pearl oyster production in Gimsha Bay, some management regulations should be adopted. These include establishment of closing season and preserved areas for maintaining the spats and spawning biomass. Further studies should be undertaken for estimation of maximum sustainable yield and total allowable catch. Beginning of aquaculture for this species in Egypt should be considered.

**REFERENCES**


