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PEARL CULTURE

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
P.B. No. 2704, Cochin 682 031, India

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BIOLOGY OF PEARL OYSTER *PINCTADA FUCATA* (GOULD)

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INTRODUCTION

Comprehensive account on the biology of the Indian pearl oyster, *Pinctada fucata* (Gould) has been wanting. Age and growth of pearl oysters of the Gulf of Mannar was studied by Herdman (1903), Hornell (1922), Devanesen and Chidambaram (1956), Chacko (1970) and Chellam (1978). The age and growth of the pearl oysters of the Gulf of Kutch was studied by Gokhale *et al.* (1954), Narayanan and Michael (1968) and Pandya (1975). Chellam (MS) has traced the growth of the pearl oyster from the settlement of the spat in the hatchery, whose day of spawning is known, to the age of three years, reared in the farm at Tuticorin Harbour.

Study on the food and feeding habits of the pearl oysters in Indian waters is scanty excepting the work of Herdman (1903) and Chellam (1983). Ota (1959 a b, c, d) has studied in detail the feeding habits of *Pinctada martensii* from Japan with particular reference to seasonal changes, nuclear insertion and different conditions of culture grounds. Kuwatani (1965 a, b) has traced the anatomy and function of the stomach of the Japanese pearl oyster and the feeding mechanisms with reference to passage of charocal particles in the digestive systems.

Not much is known about the reproductive biology of the pearl oysters in the Indian waters excepting the work of Herdman (1906), Hornell (1922 a) and Chacko (1970). Cahn (1949) and Uemoto (1958) have found a relationship to exist between temperature and spawning in oysters of the Japanese waters. Tranter (1958 c, d) observed biannual spawning in the Australian pearl oysters.

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MATERIALS AND METHODS

The study on the growth of pearl oyster was based on periodic measurement of pearl oysters under culture (Chellam, 1978). Chellam (MS) has used spat produced in the hatchery to trace growth over a period of three years. The dorsoventral measurement indicated the length, taken monthly, on the averages of 30-50 oysters. The weight was the averages of 30-50 oysters belonging to different batches grown in the Harbour farm, whose day of spawning was known.

Chellam (1983) had preserved the pearl oysters immediately after collecting them from the natural beds and farms, in 5% formalin and the stomach and intestine were examined qualitatively for their contents. He had fed experimentally with the laboratory reared pearl oyster larvae to find out the fate of the larvae ingested.

To study the reproduction of pearl oysters in the farm at the Tuticorin Harbour (Gulf of Mannar), monthly samples of at least 30 animals were collected and analysed during the period January 1980 to December 1981. The length (DVM), thickness and weight were recorded. The left valve of the oyster was removed by cutting the adductor muscle of the side along the shell. After nothing the colour and fullness of the gonad visually, the stages of maturity were confirmed through smear. The gonad follicles were anastomising in nature, covering most of the dorsal and ventral surfaces, penetrating into the visceral mass extending upto the labial region when fully mature. The viscera was removed from the right shell and preserved in Bouin's solution for 48 hours. The gonad was trimmed from all other tissues and transferred to 70%

(V/V) ethanol for storage. It was then dehydrated, embedded in paraffin, sectioned at 7 microns and stained with Delafield's haematoxilin and counter stained with eosin.

Age and Growth

At the farm at the Krusadai Island, Devanesen and Chidambaram (1956) have found the rate of growth of spat of five months and above to be 5%. As the age increases, the rate of growth decreases. The growth was 45 mm at the end of one year, 55 mm at the end of two years, 60 mm at the end of three years, 65 mm at the end of four years and 70 mm at the end of five years. The weight of the oyster was 10 g, 30 g, 45 g, 60 g and 70 g at the end of first, second, third, fourth and fifth years. Chacko (1970) came to similar conclusions by observations on natural populations in the pearl banks of Tuticorin during 1954-57. Chellam (1978) has found the growth of the pearl oysters to be moderate in the shallow water farm at Veppalodai. The growth increments were greater from September to January when the quarterly mean temperature was 28.47°C and salinity 31.48‰.

The age and growth of pearl oysters of the Gulf of Kutch, based on the number of growth rings on the shells, was studied by Gokhale *et al.* (1954), Narayanan and Michael (1968) and Pandya (1975). In the Gulf of Kutch, the pearl oysters, *Pinctada vulgaris* (Schumacher) (= *P. fucata*) grew vigorously in winter months when the temperature varied from 23°C to 27°C and growth ceased in summer (Gokhale *et al.*, (1954). The relative increase between age and linear measurements was studied by Narayanan and Michael (1968) and the growth in length (height) was found to be 44.05 mm, 61.68 mm, 76.20 mm, 81.62 mm, 85.15 mm and 86.65 mm at the end of first through sixth year.

Chellam (MS), while tracing the growth of *Pinctada fucata* produced in the hatchery and grown in the farm at Tuticorin Harbour, found the spat to attain a mode of 47.0 mm at the end of first year, 64.5 mm at the end of second year and 75.0 mm at the end of third year. The estimated von Bertalanffy growth parameters were $L\infty = 79.31$ mm, $K = 0.07557$, $to = 0.44$ months. The corresponding weights at ages 1 to 3 years were 8.3 g, 31.6 g and 45.4 g respectively. The length-weight relationship was found to be a curvilinear one and was different for the first, second and third year groups of oysters. The equations derived were :

$$\text{Log } Y = -2.5430 + 1.9477 \text{ Log } X \text{ — I Year}$$
$$\text{Log } Y = -7.0902 + 4.7532 \text{ Log } X \text{ — II Year}$$
$$\text{Log } Y = -2.5827 + 2.2629 \text{ Log } X \text{ — III Year}$$

where X = dorsoventral measurement (length) in mm and Y = weight in g.

The observations on the increase in length (dorsoventral axis) is in conformity with the growth observed in oysters of the Gulf of Kutch (Narayanan and Michael, 1968). The increase in weight is in agreement with that observed at the farm at Krusadai Island, Gulf of Mannar by Devanesen and Chidambaram (1956) and the observations at Tuticorin (Chacko, 1970).

Food and Feeding

Herdman (1903) noted unicellular organisms including infusorians, foraminifers and radiolarians to form largely the food of pearl oysters. Inclusion of minute embryos, larvae of various animals, algal filaments, spicules of alcyonarians and sponges was also seen in the stomach of pearl oysters. Ota (1959 d) has seen bivalve larvae in the stomach content of the Japanese pearl oysters which were similar in size to that of the swimming bivalves in summer months. Chellam (1983) has reported the presence of diatoms, flagellates, larvae of lamellibranchs, gastropods, heteropods, crustacean nauplii, appendages and frustules of copepods, spicules of sponges and unidentified spores, algal filaments, detritus and sand particles in the stomach and intestine of *P. fucata* collected from the farm. The oysters collected from the natural beds were also found to contain the same organisms in their stomach and intestine. The size of the straight-hinge larvae found in the stomach measured 57.5 to 115 μ in length and that of the umbo larvae ranged in size from 162.5 to 232.5 μ in length. The sizes of the planktonic lamellibranch larvae present in the farm area were close to those of the larvae found in the stomach of the pearl oysters.

By experimental feeding of starving pearl oysters with straight-hinge larvae, Chellam (1983) found that within 45 minutes all the larvae in the water had been filtered and ingested. The larvae, ejected as pseudofaeces, were found entangled in mucus. The faecal matter extruded within 2 hours contained larvae alive. The trochophore larvae of 5 hours old, when fed, passed through the pseudofaeces and faeces and, if separated from the mucus and reared, developed further. The larvae retained in the stomach for more than two hours were either dead or feeble and inactive.

Korringa (1952) after studying the feeding methods of lamellibranchs, concluded that they are a wasteful feeder. Only part of the material ingested can be digested. No evidence of selection of food is found

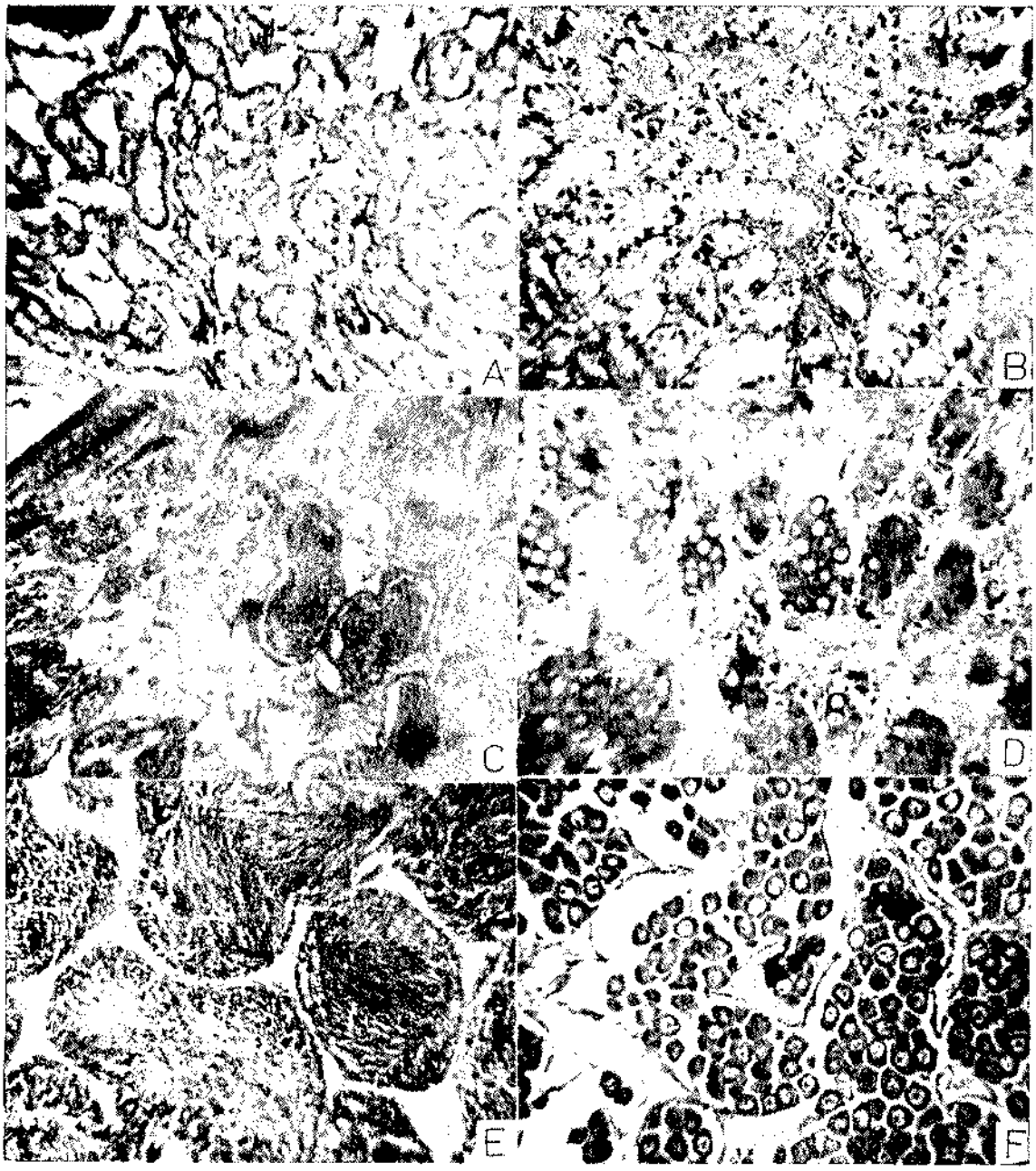

Plate I. A. Inactive gonad ; B. Undetectable minimal gonad development ; C. and D. Developing male and female gonads ; E and F. Mature male and female gonads.

and the actively feeding oyster appears to ingest anything that it can take in. Some micro-organisms found in the stomach are not digested and emerge from the oyster unchanged, often alive. These larvae very rarely succeed in freeing themselves from the mucus and organic detritus they are wrapped in and therefore are doomed to perish.

Reproductive Biology

In *P. albina*, Tranter (1958 c) has divided the gonadial stages into stages of development and stages of regression. The stages in development is subdivided into five stages and the stages in regression into three. This was felt to be too elaborate and overlapping for the oysters of the Gulf of Mannar and hence the modified version of Alagarswami (1966), Walter (1982) and Brousseau (1982) is followed in the classification of gonad stages in *P. fucata*, in this paper. Based on the external appearance and also microscopic examination of smear and gonad sections, gonad development in pearl oyster, *P. fucata* is divided into five stages. The stages are described below based on the gonad development in the female.

Stage 1 : *Inactive/spent resting*

The gonad shrinks completely and becomes translucent. In some case, it is pale orange in colour. Large vacuolated yellow (fat) cells present in the interfollicular space. The sex is mostly indeterminate. Undetectable minimal gonad development may start in this stage (Pl. I A, B).

Stage 2 : *Developing/maturing*

The transparent nature of the resting gonad is lost. The gonad becomes distinguishable from other visceral tissue. Gametogenetic materials begin to appear in the gonad. As the stage advances, the gonad begins to branch a little along the posterior side of the retractor muscle and advances to the anterio-dorsal region. The gametes begin to proliferate along the follicle wall. In advanced stages, the interfollicular space becomes reduced and in females, the lumen of the follicle may contain some free eggs also. Most of the oocytes (78%) are irregular in shape and without germinal vesicle (nucleus). The average size of the oocyte is 60.0 × 47.5 μ and the germinal vesicle, if present, is 20.0 μ (Pl. I D).

Stage 3 : *Mature*

The gonad spreads on to most of the visceral tissues. It is mostly yellowish cream in females. A little prick on the gonad makes the gametes to ooze profusely. In females, the lumen of the follicle is filled with free and enlarged oocytes. Some of them are attached to the follicular wall. Majority (65%) of the oocytes are pyriform in shape. The average size of the oocyte is 68.0 × 50.0 μ with a well defined germinal vesicle. The average size of the nucleus is 25 μ (Pl. I E).

Stage 4 : *Partially spawned*

The gonad becomes loose and the visceral epithelium becomes dull. The follicle shrinks with the reduction of the gametes in the lumen. The oocytes are free and found along the follicular wall. Most of the oocytes (62%) are spherical and nucleated. The average size of the oocyte is 51.7 μ. Externally, this stage has similarity to stage 2 (Pl. II B).

Stage 5 : *Spent*

The gonad shrinks further with a few left over gametes in the lumen of the follicles. Ruptured follicles are seen in some cases and the lumen some times contain ruptured cellular materials. The oocytes, if present, are few and 98% of them are spherical. The average size of the oocyte is 54.5 μ (Pl. II D).

The foregoing description of the spent stages applies to the animals which have recently undergone oogenesis only. Otherwise they will transform to the spent resting stage quickly. In males also the same pattern of reproductive activity takes place. In stages 2 and 3, the colour of the gonad is pale cream (Plate 1, Fig. C, E). In other stages of oogenesis, the gonads of males and females appear similar externally (Pl. II A, C).

Seasonal distribution of Maturity Stages

Table 1 gives the monthwise percentage distribution of the maturity stages of pearl oyster in the Tuticorin Harbour farm for the period from January, 1980 to December, 1981. The development of gonad appears a continuous process and there does not seem to be any time lag in transformation from stage to stage. Analysing the data, it was seen that the seasonal distribution of different maturity stages can be better expressed by combining the five stages into three categories. The developing/maturing and mature stages are combined to represent gonad development, the partially spawned and spent gonads to represent gonad regression and the spent resting/inactive gonad. Fig. 1 depicts the gametogenic activity of the oysters in the Harbour farm based on the above categories of classification.

In the farm, the inactive, maturing and mature gonads were represented almost in all the months of the year. The partially spawned and spent gonads were present throughout, excepting a break in February and May, 1980 and April-May and September 1981. The percentage of resting/inactive gonads was less during March-May and September-October (1980) and April-June and September (1981). For the years 1980 and 1981, peaks of spawning were noted in January, July-September, December-February, June-August and November. During February-May, October-November (1980) and March-May and September-October (1981), most of the oysters were in the active gametogenic stages with more percentages of developing and mature gonads.

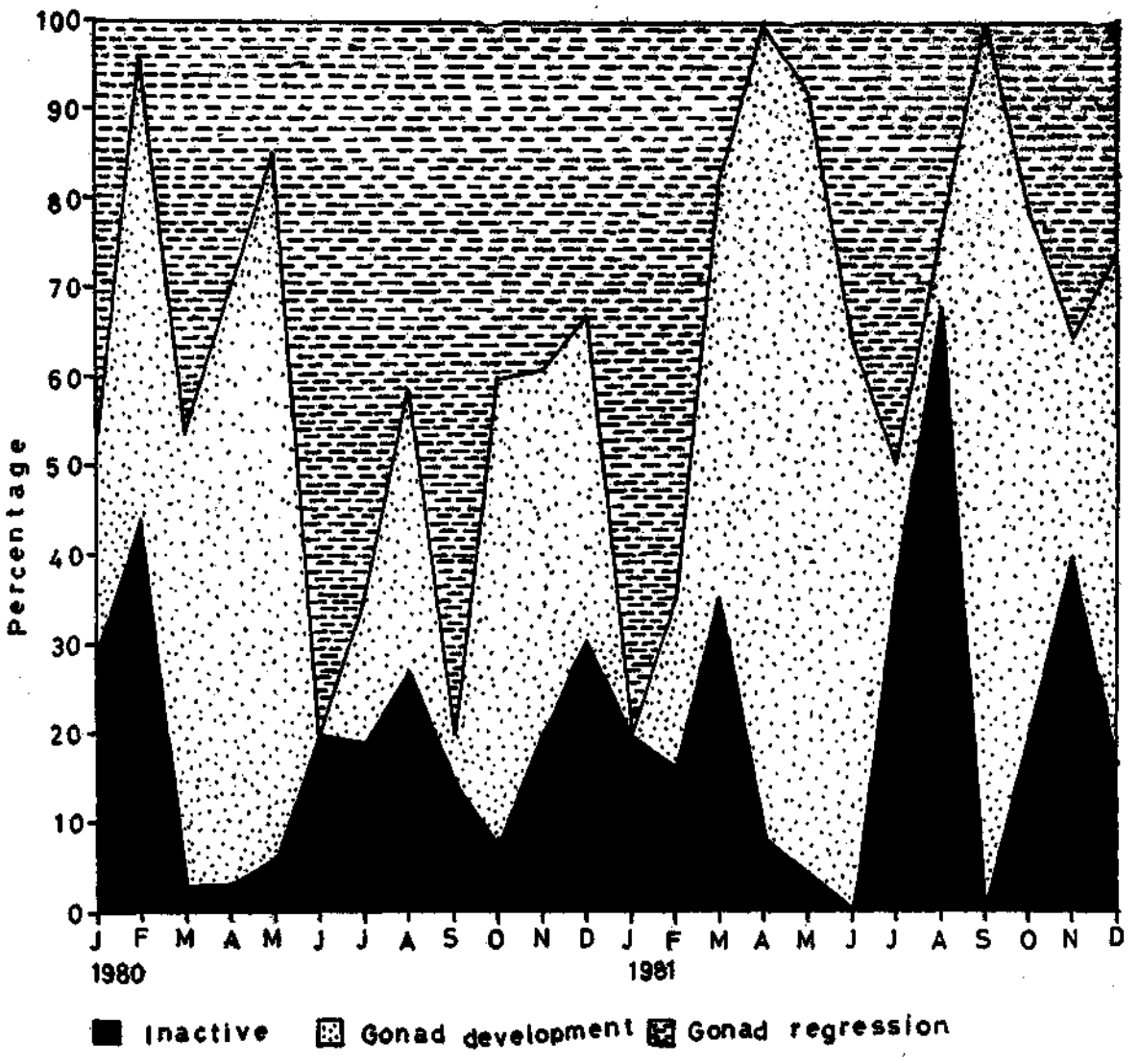

FIG. 1. Gametogenic activity of the pearl oyster *Pinctada fucata* (Gould) at the Tuticorin Harbour farm (1980 and 1981).

SEX RATIO

The distribution of sex among the different size groups of pearl oysters farmed at the Tuticorin Harbour is given in Table 2. In the smallest size group (16-20 mm) with developed gonads, 63.2% were females. But in the group 16-25 mm, the sexes were equally distributed. Only in the large size groups examined (56-65 mm), the females dominated (57.2%). In size groups 26-55 mm the males dominated (62.7%). On the whole, the male-female distribution among the 452 pearl oysters ranging in length from 16-65 mm was 57 : 43.

The gonad differentiation began in the spat (produced

in the hatchery and reared in the farm) of seven months old and in another month the gonad was sexually mature. They spawned when they were nine months old.

TABLE 1. *Percentage frequency of gonad stages in oysters of Tuticorin Harbour farm for the period* 1980 *and* 1981.

Year/month	Percentage frequency of gonad stages				
	(1)	(2)	(3)	(4)	(5)
1980					
January ..	29.8	15.3	8.7	6.2	40.0
February ..	43.6	42.8	10.0	..	3.6
March ..	2.3	7.0	44.0	12.0	34.7
April ..	2.5	18.0	49.5	6.0	24.0
May ..	5.3	12.0	69.0	3.7	10.0
June ..	20.0	..	..	60.0	20.0
July ..	18.9	10.0	5.4	30.0	35.7
August ..	26.5	3.0	28.0	7.0	35.5
September ..	14.3	..	5.7	8.0	72.0
October ..	6.8	43.2	9.5	30.3	10.2
November ..	20.3	10.2	30.5	17.0	22.0
December ..	30.5	7.8	28.7	9.0	24.0
1981					
January ..	20.0	..	..	75.0	5.0
February ..	16.0	3.5	16.0	50.0	14.5
March ..	36.0	22.0	24.0	8.0	10.0
April ..	8.0	16.0	76.0	..	..
May ..	4.0	56.0	32.0	8.0	..
June ..	—	4.0	60.0	30.0	6.0
July ..	37.0	13.0	—	—	50.0
August ..	68.0	4.0	4.0	..	24.0
September ..	—	16.7	83.3	—	—
October ..	20.8	33.3	25.0	20.8	—
November ..	40.0	16.0	8.0	6.0	30.0
December ..	16.0	8.0	50.0	—	26.0

TABLE 2. *Sex distribution among different size groups of pearl oysters in the Tuticorin Harbour farm.*

Length range (mm)	No. of oysters	No. of males	%	No. of females	%
16—20 ..	19	7	(36.8)	12	(63.2)
21—25 ..	31	18	(58.3)	13	(42.0)
26—30 ..	23	13	(56.5)	10	(43.5)
31—35 ..	34	22	(64.7)	12	(35.3)
36—40 ..	33	22	(66.7)	11	(33.3)
41—45 ..	44	27	(61.4)	17	(38.6)
46—50 ..	72	46	(63.9)	26	(36.1)
51—55 ..	84	53	(63.1)	31	(36.9)
56—60 ..	62	27	(43.5)	35	(56.5)
61—65 ..	50	21	(42.0)	29	(58.0)

SEX REVERSAL

The mature males and females were separated through smear examination and reared separately for a period of 10 months. The oysters were narcotised to observe the gonads. Periodic examination of the gonads of these oysters showed that there was sex reversal in these oysters (Table 3). The reversion from male to female was noted on three occasions and from female to male on one occasion. One male reverted its sex twice.

TABLE 3. *Sex reversal in pearl oysters.*

Date	No. of males	No. of females	Male—females	Female—male	Dead
28-2-1980 ..	48	26	—	—	—
11- 6-1980 ..	36	26	11	—	1
5- 8-1980 ..	33	23	3	—	14
7-10-1980 ..	27	20	—	2	10
3-12-1980 ..	21	19	5	—	4

INFLUENCE OF ENVIRONMENTAL PARAMETERS ON REPRODUCTIVE CYCLE OF PEARL OYSTERS

Table 4 gives the environmental parameters that prevailed at the Tuticorin Harbour farm during 1980 dnd 1981. In Fig. 2, the temperature, salinity and pH during the years is depicted. From the Figs. 1 and 2, a relationship is found to exist between the temperature and the gametogenic activity (gonad development) and spawning (gonad regression) in oysters of the Harbour farm. During 1980, the percentage frequency of the spawning and spent gonads (gonad regression) was high in January, (46%), June (80%), July (65.7%), August (42.5%) and September (80%). In December, oysters with gonad development and gonad regression were somewhat equal, ie, 33 per cent and 36.5 per cent respectively. During 1981, higher percentages of gonad

TABLE 4. *Environmental data of the Harbour farm* (1980 *and* 1981).

Year/month	Temp. (°C)	Salinity (ppt)	Clarity (m)	pH	Rainfall (mm)
1980					
January ..	25.2	31.84	1.00	8.15	—
February ..	26.0	33.30	1.50	8.50	—
March ..	28.8	34.02	1.50	8.20	—
April ..	30.5	34.89	1.75	8.17	74.4
May ..	31.4	35.38	2.00	8.15	—
June ..	29.0	35.48	0.50	7.75	—
July ..	26.7	34.92	1.50	7.82	—
August ..	27.0	34.55	1.00	7.90	1.2
September ..	28.1	34.10	1.00	8.00	17.9
October ..	29.7	34.36	0.40	7.65	88.8
November ..	29.2	34.11	1.25	7.85	240.5
December ..	26.4	32.53	0.75	8.05	203.1
1981					
January ..	26.1	31.93	1.25	8.10	0.3
February ..	27.2	32.10	2.87	8.12	20.2
March ..	29.48	32.93	2.28	7.93	16.3
April ..	31.40	33.35	2.23	8.10	18.5
May ..	30.60	33.94	2.30	8.00	24.6
June ..	27.33	34.17	2.05	7.94	13.8
July ..	27.84	33.89	2.78	8.03	3.4
August ..	26.75	33.85	1.94	8.07	—
September ..	29.05	33.99	2.78	8.04	41.5
October ..	29.10	33.76	3.12	8.07	58.7
November ..	28.13	32.71	3.64	7.79	34.0
December ..	26.47	31.16	4.89	8.01	28.2

regression was noted in January (80%), February (64.5%), July (50%) and November (36%). During the period of gonad regression in the years 1980 and 1981, a corresponding lowering of water temperature (Table 2) was also seen. Majority of the gonads were in the developmental stages during February (51.7%), March (51%), April (67.5%), May (81%), October (51.7%) 1980 and April (92%), May (88%), June (64%), September (100%), October (58.3%) and December (58%) 1981. During the corresponding months,the surface temperature was found to be high (Table 2).

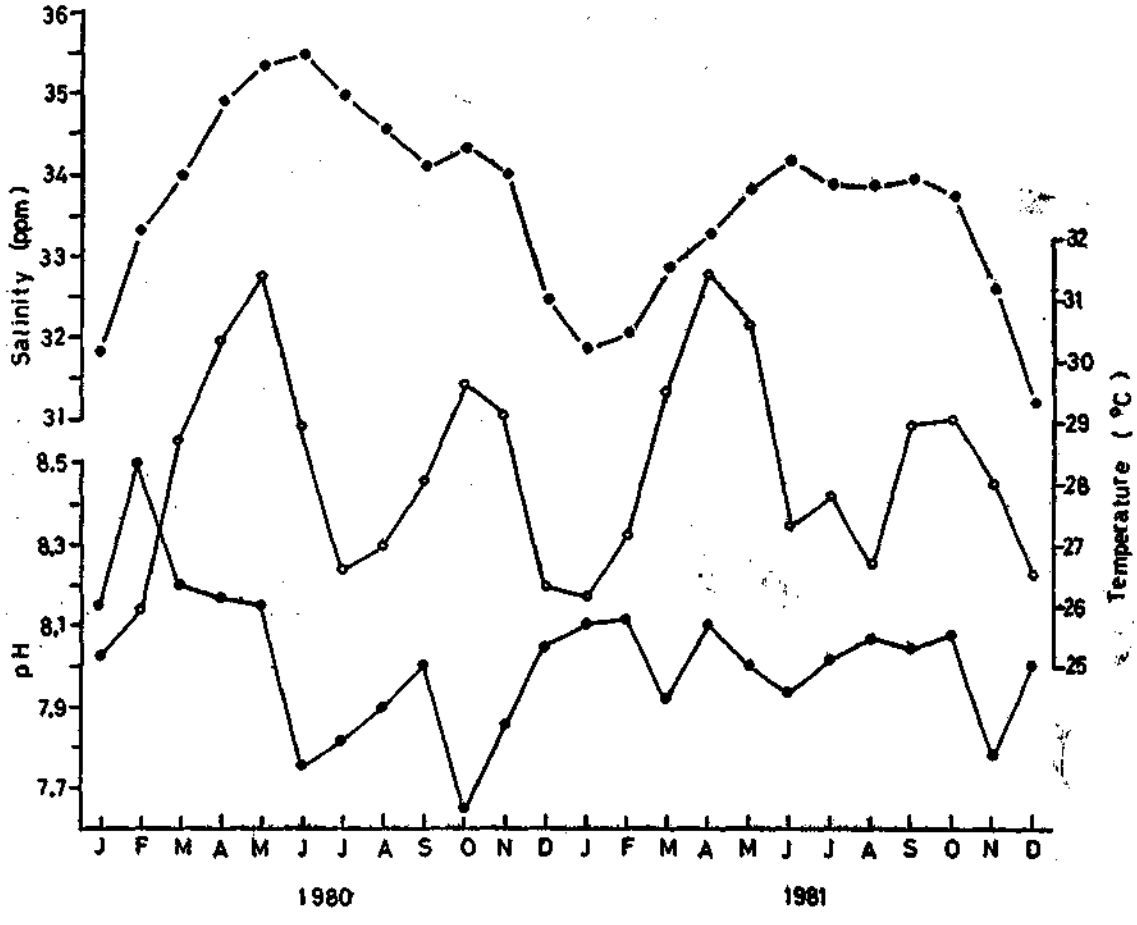

FIG. 2. Monthly averages of salinity, temperature and pH in the Tuticorin farm (1980 and 1981).

The salinity range in the Harbour was not much (Table 2). Like temperature, though not pronounced, biannual peaks were noted (Fig. 2). The major peak was during May-June (1980 and 1981) and the minor one during October-November (1980) and September-October (1981). The salinity may also play a combined role with temperature in the gonad development and spawning. In both the years, the peaks fell more or less close to that of temperature. The pH ranged from 7.65 to 8.50. However, no relationship could be noted for this parameter in pearl oyster reproduction or other environmental conditions. A rainfall of 240.5 mm and 203.1 mm was recorded in November and December, 1980 at the Harbour area with a continuous rain in low intensity till December, 1981 which was responsbile for the comparatively low saline condition in that year.

DISCUSSION

Earlier works on pearl oyster reproduction from different parts of the world confirm Orton's Rule that 'if temperature conditions are constant or nearly so and the biological conditions do not vary much, animals will breed continuously'. Herdman (1906) and Hornell (1922 a) have reported two peaks of spawning in Sri Lankan and Indian pearl oysters; during May-July and November-January in the former and April-May and September-October in the latter. The peaks of spawning coincided with the southwest and northeast monsoon periods. According to Chacko (1970), spawning takes place in all the months of the year. In Japan, the spawning occurs when the water temperature reaches 25°C and pH 7.8 (late June to early

August) (Cahn, 1949). In the Ago-Bay (Japan), it continues from June to middle of July (Uemoto, 1958). In Australian waters also, the *P. albina* breeds continuously throughout the year but most activey in April-May when the sea temperature begins to fall (Tranter, 1958 c). In *P. margaritifera* the major spawning was in early January and late July and the lesser spawning in other months (Tranter, 1958 d).

In the Tuticorin Harbour (Gulf of Mannar), two peaks of spawning, during June-September (1980) and December (1980) February, July-August and November (1981) were observed. A slight reduction in temperature had triggered the spawning in both the years of observations. The increase in water temperature had resulted in gonad development. The range in salinity and pH was not much in the farm area and their influence on the maturity and spawning of the farm oysters, if any, was not known. Tranter (1958 b) has noted highest frequency of ripe gonads in warmer months and highest frequency of spent gonads in cooler months. Most rapid decrease in gonad ripeness (spawning) coincided with the decreasing sea temperature. Lesser spawning occurred during other months of the year. Ripe gonads were present throughout and therefore spawning was possible throughout the year.

The sex ratio of 604 animals of 3 and 4 years old was 56 : 44 in Japanese waters (Uemoto, 1958). In the Harbour farm, among the 452 animals ranging in length from 16-65 mm, males dominated when they were below 55mm. The overall sex ratio was 57 : 43.

Pinctada albina sexually matured within the first 6 months (Tranter, 1958b). In the Tuticorin farm, the *P. fucata* was mature within 8 months and spawned in the ninth month. From the natural bed, the smallest oyster with mature gonad was 15.5 mm in length.

Cahn (1949) reported the maximum sex change in *P. margaritifera* to be 73%. Tranter (1958c) has observed 17 sex changes, 7 protandric and 10 protogynic, within a period of 15 months in *P. albina*. He observed that protandry dominated the sexuality of all oysters and that the succession of phase continued season by season. Uemoto (1958) noted 13 hermaphrodite animals having spermatozoa in the ovaries which were in the process of sex reversal. In the oysters from the Harbour farm, in a period of 10 months, 19 protandric and 2 protogynic reversal of sex was observed. A maximum of 30% of them changed the sex on one occasion.

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