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SALINITY TOLERANCE AND RATE OF FILTRATION OF THE PEARL OYSTER *PINCTADA FUCATA*

K. ALAGARSWAMI AND A. C. C. VICTOR

Scheme on Pearl Culture
Central Marine Fisheries Research Institute, Tuticorin-628 001

ABSTRACT

Salinity tolerance and rate of filtration of the pearl oyster *Pinctada fucata* were studied during 1975-77. The oysters were experimented in salinities ranging from 14 to 58‰. Although a truly marine form, the pearl oyster has been found to tolerate a wide range of salinity from 24 to 50‰ for short durations of 2-3 days. Salinities below and beyond the a' ove range caused mortality of oysters. The rate of mortality in the dilutions of 16, 15 and 14‰ were 10, 50 and 100% respectively and mortality in higher concentrations of 52, 55 and 58‰ were 67, 100 and 100% respectively.

In the normal sea water (salinity 34‰) the removal of neutral red in solution was 52.1% in 2 hours and 92.6% in 8 hours. The rate of filtration was low in dilutions and the total filtration was bel ,w 25% in the salinities of 14 and 20‰. In the higher concentrations, filtration was 49.5, 53.7 and 41.8% in the salinities of 44, 50 and 57‰ respectively at the end of 4 hours.

In the Gulf of Mannar, where a pearl culture farm is located, the normal salinity range during 1974-76 was 32.15-35.58‰. An unusual incidence of dilution of sea water down to 15.69‰ occurred in the farm at Veppalodai in November 1977 due to heavy rainfall and floods in the rivers caused by an active north-east monsoon. However, this did not affect the oysters as the low saline condition did not last for more than a day.

INTRODUCTION

PEARL OYSTERS of the genus *Pinctada* are truly marine throughout their range of distribution. They occur from the intertidal reef flats to a depth of 54 m (Hynd, 1955). However, pearl oyster farms in Japan are sometimes located in areas which are subject to the influence of fresh water discharge by rivers (Alagarswami, 1970). Investigations on the effect of diluted sea water on the pearl oysters have been conducted by Katada (1958, 1959) and Ota and Fukushima (1961). Lamellibranchs in general, and the edible oysters and mussels in particular, have been extensively studied for their rate of water transport under different conditions (Loosanoff, 1953; Rao, 1953 ; Jørgensen, 1955, 1960, 1966 ; Durve, 1963). The rate of water filtration of pearl oyster was studied by Tsujii and Ohnishi (1957) and Katada (1958). Castagna and Chanley (1973) experimentally determined the salinity tolerance limits of 29 species of bivalves in Virginia waters. The estuaries and the adjoining marine realms along the Indian Coast are influenced by the enormous discharge of river water during the monsoons. The salinity fluctuations are large from 0‰ to 35‰ in the estuaries. Since there was no information on the salinity tolerance and rate of filtration of pearl oysters of the tropical waters, experiments on these aspects were conducted on *Pinctada fucata.*

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Material and Methods

Pearl oysters used in the experiments were obtained from the natural beds in the Gulf of Mannar (depth 20m) where the salinity range of the bottom water is from 32.54‰ to 35.26‰. The experiments were conducted in two parts, the first series on salinity tolerance during 1975-76 and the second series on rate of filtration in different salinities in August 1977.

Salinity tolerance experiments were carried out in glass troughs of 30 cm diameter holding 1.5 ltr. sea water of different salinities. Sea water of experimental salinities was prepared by adding fresh water to normal sea water for dilution and adding fresh common salt collected from the salt pans for increasing the concentration. In all, 16 experiments were carried out in the salinity range of 14.01‰ to 57.99‰ with larger intervals of about 4‰-5‰ nearer the normal salinity and smaller intervals of about 1‰ to 2‰ nearer the extremes. Ten oysters were used in each experiment, placing two in each glass trough. The average size of the oysters of this series was 49.7 mm (dorso-ventral axis) and the average weight was 21.3 g.

In the second series on rate of water filtration, seven experiments were conducted in the salinity range of 13.98‰-56.96‰. In each experiment 5 oysters were used, each individually placed in beakers containing 1 litre of experimental solution. The neutral red technique developed by Cole and Hepper (1954) and subsequently used by other workers (Nagabhushanam, 1956; Durve, 1963) was employed. The strength of the solution of neutral red in sea water was 0.001%. The optical density of the solutions was read out in a photo colorimeter at intervals of 30 min by pipetting out 10 ml of the solution from each beaker which was poured back in the respective beakers after noting the reading. According to Cole and Hepper (1954), the amount of neutral red removed from the water seemed to depend directly upon the volume of water pumped through the gills. Jørgensen (1960) found that the rates at which suspension of colloidal graphite were cleared by the animal equalled the rates at which water was transported through the gills. Hence, the rate of removal of neutral red from the solution is assumed to be equal to the rate of filtration of the pearl oyster. The average size of the oysters used in the experiments was 45.9 mm and the average weight was 16.9 g.

Salinity Tolerance

The experiments on salinity tolerance lasted from November 1975 to May 1976 and the temperature of water in the experimental troughs ranged from 24.0°C in February to 30.8°C in May during the period of study. However, in each experiment the temperature showed a narrower variation ranging from 0.2°C to 1.4°C. The total range of the values of the dissolved oxygen was 3.4-8.0 ml/l and the oxygen level in each experiment was maintained by aeration. The pH remained more or less steady between 8.12 and 8.30. Experiments were conducted in the following salinities (‰): dilutions—14.01, 15.03, 15.95, 16.99, 19.02, 24.03, 26.05 and 29.03; normal sea water—34.05; higher concentrations—38.05, 42.97, 45.00, 50.07, 52.08, 55.09 and 57.99. Water was changed every six hours to avoid any perceptible increase in salinity due to evaporation. Observations made during the experiments

include (1) lapse of time from immersion to the opening of the valves denoted here as the conditioning time, (2) total duration the oyster remained open, (3) shell activity relating to the number of times the valves closed and opened during the experiment and (4) mortality of oysters. Although some individual variations were noticed in each experiment, a common behaviour could be seen in a majority of oysters. The mean values of the batch of 10 oysters in each experiment have been considered to reflect the common behaviour of oysters in each salinity.

Conditioning time

In normal sea water of salinity 34.05‰, all the oysters opened immediately on immersion. In dilutions, the average conditioning time showed variations from 16 min in 26.05‰ to 22 hr 10 min in 14.01‰. The oysters opened within the first hour in the salinities of 29.03, 26.05 and 24.03‰, during the sixth hour in 19.02‰, nineteenth hour in 15.03 and 16.99‰, twentieth hour in 15.95‰ and during the twenty-third hour in 14.01‰. On the other hand, in higher concentrations, the conditioning time showed a narrow variation from 12 min in 50.07‰ to 4 hr 45 min in 57.99‰. The oysters opened within the first hour in the five higher concentrations, except in 38.05‰ in which they opened during the second hour and in 57.99‰ during the fifth hour.

Duration the oysters remained open

In the normal sea water the oysters remained open throughout the duration of the experiment except for the closure and immediate opening of the valves. The data presented in Table 1 show that in the lowest salinity of 14.01‰ the oysters did not open during the first day but remained open for a considerable period during the second day. In dilutions of salinity from 15.03 to 16.99‰ the oysters remained open only for a short time during the first day, but for a longer duration (69% to 88% of the time of observation) on the second day. Between salinities of 19.02 and 29.03‰ the oysters remained open for 47 to 93% of the duration on the first day itself. This would show that in the salinity range 14.01-16.99‰ the oysters remain tightly shut for a long duration until they have to perforce open for the purpose of feeding or for oxygen metabolism. But after the animal gets exposed to the lower salinities, they enter into a passive phase, remaining open for a long duration as observed on the second day.

In the immediate higher salinity concentration of 38.05 to 45.00‰ the oysters remained open for 58 to 99% of the time on the first day itself. From the salinity of 50.07 to 57.99‰, the oysters showed a decrease to 27-33% of the time during the first day (except in 52.08‰ in which the duration was 72%). In this higher range of salinity, the oysters remained open for 78 to 100% of the time during the second day, which indicated that the oysters had entered the passive phase of remaining open.

Shell activity

Shell activity, as can be seen from Table 1, was maximum in the normal sea water with an average of 16.25 closures per oyster during the first day. In dilutions, the shell activity decreased gradually (except in 24.03‰ which showed a spurt of activity). In the salinity range 14.01-16.99‰ an increase in shell activity was observed during the second day as compared to the first day. In the higher salinities there was a decrease of shell activity from 34.05 to 45.00‰ beyond which

there was a gradual increase upto 55.09‰, falling again at 57.99‰, during the first day. During the second day the shell activity considerably decreased in all the higher salinities, in contrast to the increase of shell activity noticed on the second day in the lower salinity range.

TABLE 1. *Behaviour of pearl oyster in different salinities (‰) on first and second day*

(Values are averages of ten oysters)

Salinity	First Day			Second Day		
	Observation period (hr-min)	Duration oyster remains open (hr-min)	Shell activity	Observation period (hr-min)	Duration oyster remains open (hr-min)	Shell activity
14.01	7-10	0-00	0.0	9-45	6-24	3.6
15.03	7-10	0-58	1.2	7-45	6-30	1.9
15.95	7-10	0-40	2.3	7-30	6-37	3.5
16.99	6-40	0-56	2.8	7-30	5-12	5.4
19.02	9-40	4-34	2.7	2-15	2-15	4.0
24.03	6-30	6-00	13.5	N.O.		
26.05	8-00	7-27	8.2	N.O.		
29.03	7-10	6-30	9.35	N.O.		
34.05	6-40	6-40	16.25	N.O.		
38.05	5-25	3-40	6.2	N.O.		
42.97	5-55	3-27	5.8	N.O.		
45.00	8-15	5-42	5.5	7-55	7-07	10.0
50.07	7-05	2-22	7.75	7-30	5-49	7.25
52.08	8-00	5-47	9.4	8-00	7-49	1.8
55.09	7-20	1-59	11.1	7-30	7-30	0.0
57.99	11-40	3-20	4.7	9-34	9-26	0.5

N.O. — Not Observed.

Mortality

The oysters were kept in the water of respective experimental salinities for a day after the termination of the detailed observations. The rate of mortality was 100% among the oysters kept in the salinity of 57.99, 55.09 and 14.01‰, 67% in the salinity of 52.08‰, 50% in the salinity of 15.03‰ and 10% in the salinity of 15.95‰.

The relationship among the above four factors has been shown in Fig. 1. Only the data relating to the observations made on the first day have been plotted. The conditioning time is considerably longer in the lower salinities than in the higher salinities. The duration oyster remains actively open is maximum in the normal

salinity of 34.05‰ and it decreases on either side. Similarly the shell activity drops on both sides of the normal but is relatively more in higher salinities. Mortality sets in at the salinity of 15.95‰ in the lower range and at 52.08‰ in the higher range, leading to total mortality at 14.01 and 55.09‰.

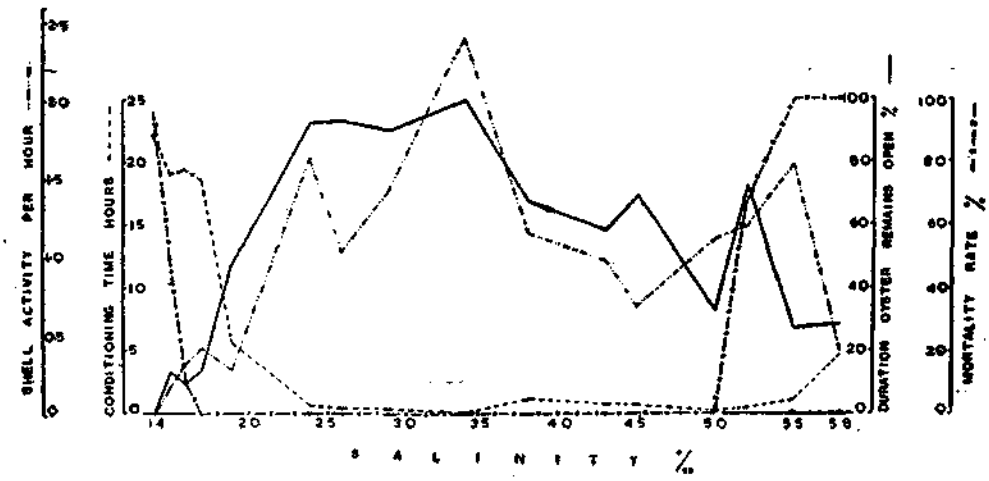

Fig. 1. Behaviour of pearl oyster *Pinctada fucata* in different salinities. (Normal sea water is S. 34‰).

Rate of Water Filtration

The experiments on rate of filtration were carried out in August, 1977. The range of water temperature during the series was 28.5°-31.6°C, but in each experiment the temperature difference was less than 1°C. The initial level of dissolved oxygen ranged between 4.0 and 5.1 ml/l and it was maintained by carefully aerating the water by pumping the experimental solution by a syringe. The pH showed a slight decrease from the initial values of 7.80-8.00 to 7.30-7.50. The experimental salinities (‰) were : dilutions—13.98, 19.90 and 24.10 ; normal sea water—34.23 ; higher concentrations—43.97, 49.90 and 56.96. The duration of experiments ranged from 4 hr to 8 hr depending upon the activity of the oysters. Five oysters were used in each experiment and the average values of neutral red removed have been used in the analysis. When the oysters remained closed continuously for some time there was no removal of neutral red and such periods have not been considered in reckoning the half-hour filtration intervals. Observations were made on conditioning time, rate of filtration and mortality of oysters.

Conditioning time

The average conditioning time in salinity of 34.23‰ (normal) was 36 min. In dilutions, the time taken for the opening of valves was 48 min, 7 hr 05 min and 12 hr 47 min in salinities of 24.10, 19.90 and 13.98‰ respectively. In higher concentrations the time was 40 min, 37 min and 3 hr 25 min in salinities of 43.97, 49.90 and 56.96‰ respectively. The oysters opened more quickly in the higher concentrations than in the dilutions.

Rate of filtration

The percentage of removal of neutral red in solutions of sea water of different salinities by pearl oysters at half-hour intervals are shown in Fig. 2. In all salinities the oysters were active during the first few hours after opening and thereafter the rate of filtration became considerably reduced ; finally there was no filtration with the values remaining practically constant. The rate of filtration was maximum in normal sea water being 33.7% at the end of 1 hr, 52.1% at the end of 2 hr, 76. 1% at the end of 4 hr and 92.6% at the end of 8 hr. In the two lower salinities of 13.98 and 19.90‰, the rate of filtration was very poor, being 13.7% and 22.9% respectively at the end of 4 hr. In the salinity of 24.10‰, filtration was 51.3% at the end of 4 hr.

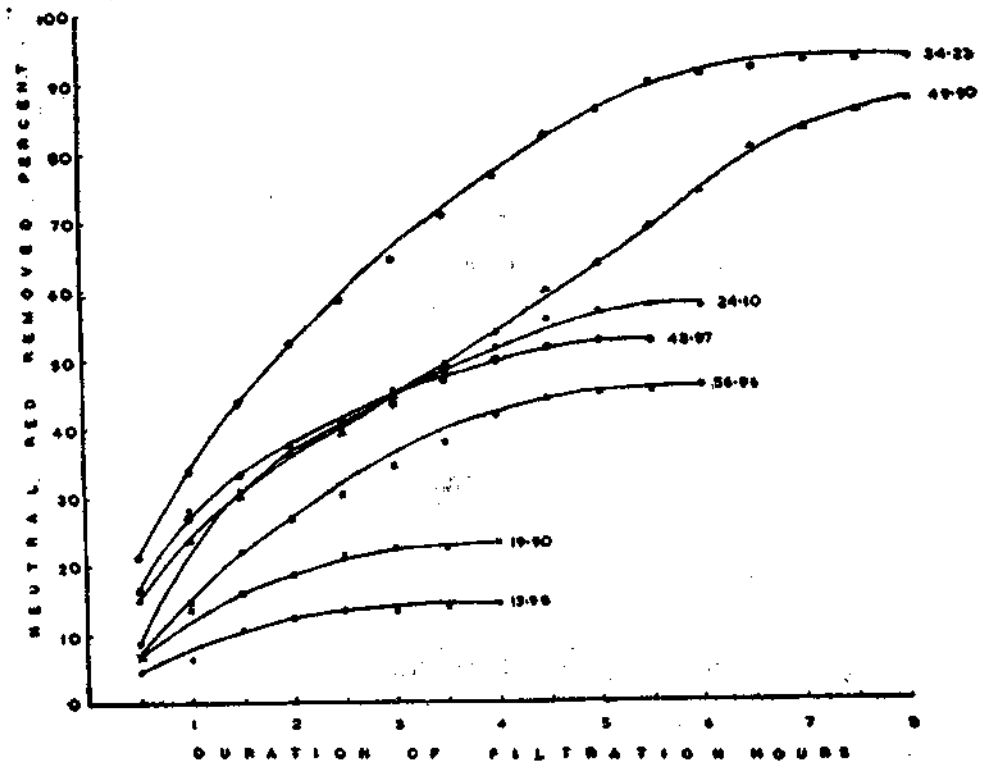

Fig. 2. The effect of salinity on the rate of filtration of pearl oyster *Pinctada fucata*. The values of experimental salinities (‰) are given on the right side of each curve.

In higher concentrations, the rate of filtration was generally higher than in the dilutions. In the highest salinity of 56.96‰, the removal of neutral red was 41.8% at the end of 4 hr and in 43.97‰ the filtration rate was 49.5% for the same duration. The oysters showed an unusual behaviour in the salinity of 49.9‰, with 53.7% removal at the end of 4 hr. A sudden spurt of activity was noticed during the next 3 hr at the end of which the removal of neutral red was 82.6%. This compares well with the 92.1% filtration at the end of 7 hr in normal sea water. In these experiments more than 50% removal was observed in three grades of salinity besides the

normal sea water in 24.10, 43.97 and 49.90‰. The salinities of 13.98, 19.90 and 56.96‰ had a depressing effect on the oysters, more so the two dilutions in which the absorption reached the near 'saturation' point in about 3 hr time and the filtration was below 25%.

Mortality

The mortality rate at the end of 48 hr was 3 out of 5 oysters in the salinity of 19.90‰ and total in the salinities of 13.98 and 56.96‰. In other salinities there was no mortality.

A Low Saline Condition in the Gulf of Mannar

The monthly average values of salinity in the Gulf of Mannar (surface waters) at the site of the pearl culture farm at Veppalodai ranged between 32.15 and 33.58‰ during the three years 1974, '75 and '76. The lower values have been recorded during November-February coinciding with the period of the north-east monsoon. The lowest individual value obtained was 31.26‰ in January 1974. The variations in salinity in an year and among the years have been very small.

An unusual salinity condition was met with in November 1977 when the dilution of sea water reached very low levels in the inshore waters. Under the effect of an active north-east monsoon, there was heavy precipitation in the interior and coastal areas. The numerous creeks and rivers, including the major river Tambraparani, were in spate discharging heavily into the Gulf of Mannar. The rivers Vaippar and Kallar in the immediate vicinity of Veppalodai were also in floods. The total rainfall in November 1977 at Tuticorin (for which data are available) was 399 mm as against 96, 51 and 270 mm in November of 1974, '75 and '76 respectively. A precipitation of 159.4 mm was obtained during the dates November 4-6, 1977 which resulted in the dilution of the sea water. The salinity of surface waters on the pearl oyster bed Devi paar, which is about 15 km off the river mouth of Vaippar, was 28.15‰ and that of bottom waters (depth 12 m) was 29.13‰ on November 7. In the pearl culture farm, which is located about 1.5 km off Veppalodai, the salinity of surface waters was as low as 15.69‰ on November 8 and thereafter increased to 26.53, 28.55 and 31.90‰ on November 9, 14 and 15 respectively, reaching the normal level on the last mentioned day. During the previous three years, the minimum salinities recorded during November in the farm area were 32.78, 32.31 and 33.29‰ in 1974, '75 and '76 respectively. Besides diluting the sea considerably, the floods caused heavy suspension of silt in the inshore waters which could be seen by the change in colour of the sea in the area. In spite of the lowering of salinity to 15.69‰, there was no unusual mortality of pearl oysters in the farm mainly because the low saline conditions prevailed only for a short while.

Discussion

The experiments on the salinity tolerance and rate of water filtration in *Pinctada fucata* have given comparable results as to the behaviour of the pearl oyster in different salinities in limited time. Based on the results of both the series of experiments and also the low saline conditions observed in the farm it is possible to consider the range of salinity which the pearl oysters could survive. In the low salinities, the conditioning time is considerably high, being more than 5 hr in 19.02‰ and

more than 18 hr around 16.99‰. The duration the oyster remains open is below 50% of the time at the salinity of 19.02‰ and decreases rapidly in still lower dilutions. The shell activity is also poor at 19.02‰ and below. The rate of water filtration is below 25% in salinities of 19.90‰ and below. In the salinities of 24.03-24.10‰, the conditioning time is only 25 min, oysters remain open for 92% of the time, shell activity is high at 1.65 closures per hour, filtration is more than 50% in 4 hr and there is no mortality. In the higher concentrations of 52.08‰ and above, although the conditioning time is less, the oysters shortly pass into the passive phase of remaining open and 67-100% mortality has been observed. In the salinities of 49.90-50.07‰ the oyster shows a higher filtration rate of more than 50% in 4 hr and 86.8% in 8 hr and there is no mortality. Thus, the tolerance range appears to be wide between 24 and 50‰ at least for short spells of time as 2-3 days as has been found during the experiments. In this range of salinity, the conditioning time is less than half-hour in most cases, oysters remain open from 58 to 100% of the time, shell activity is moderate to high at 0.67-2.38 closures an hour and the rate of filtration is above 50% at the end of 4 hr.

As stated earlier some of the pearl culture farms of Japan are located in bays which are affected by the discharge of freshwater by rivers. Katada (1958, 1959) conducted experiments on the influence of sea water of low salinity on the pearl oyster *Pinctada martensii*. According to Katada (1958), low saline waters of density (δ15)* 14.35 did not cause any mortality in the spat and two-and three-year old oysters during the experimental duration of 72 hr. In the density range of 2.89 to 14.59 there was no mortality during the first 24 hr of immersion but mortality was recorded at 48 hr in the densities of 8.35, 10.57 and 10.20 in the above three age-groups respectively. Total mortality occurred at 72 hr at the density of 6.47 in the case of the spat, 8.07 in two-year old and 8.27 in three-year old oysters. In another study (Katada, 1959) he has shown that the low saline waters affect the operated oysters (oysters in which nuclei have been implanted for production of cultured pearls) even more. Comparing three-year old oysters, he found that the unoperated oysters remained unaffected in the density ranging from 6.53 to 21.90 during the first 24 hr, whereas the operated oysters could remain so only for the first 12 hr. At the end of 48 hr the mortality was 16.7% among the unoperated oysters and 30.0% among the operated oysters in the density of 10.57 and 11.21 respectively. Based on these studies, Katada (1958) found that the density of 15.00 may be the safe limit in dilutions for the culture of oysters. Ota and Fukushima (1961) found that in areas where the pearl oysters had to frequently face low salinity sea water, the growth of oysters and quality of pearls were affected.

In the present study, for an immersion time of 30 hr 40 min, the oysters suffered a mortality of 10% in the salinity of 15.95‰, 50% at 15.03‰ and 97% at 14.01‰. Those kept in the salinity of 16.99‰ for the same duration did not suffer any mortality. However, the rate of filtration is very low even in a salinity of 19.90‰. Although Katada (1958) found the density (δ15) of 15.00 (nearly equal to a salinity of 20.65‰) to be the safe limit for the pearl oyster, according to the present study, a salinity of about 24‰ appears to be the safe limit in dilutions. It has been stated earlier that the unusual low saline conditions in the farm at Veppalodai in November 1977 did

* The sigma-t values given by Katada (1958) are densities of the dilutions at 15°C. Salinities corresponding to the densities of 2.89, 6.47, 6.53, 8.07, 8.27, 8.35, 10.20, 10.57, 11.21, 14.35, 14.59, 15.00 and 21.90 which are cited in the present paper would, respectively, be 4.85, 9.51, 9.53, 11.60, 11.87, 11.98, 14.38, 14.87, 15.70, 19.81, 20.11, 20.66 and 29.67‰ (Taken from the Tables of KEALA, B.A. 1965. Table of sigma-t with intervals of 0.1 for temperature and salinity. *U.S. Fish. Wildl. Serv., Spl. Sci. Rep.*—Fish No. 506, 186 pp).

not cause any mortality among the oysters. The low salinity of 15.69‰ was observed on November 8 and the very next day, the value increased to 26.53‰. Although the duration for which the low salinity prevailed in the farm area is not known, based on the amount of rainfall which was the highest at 76.4 mm on November 6 and the salinity in the pearl oyster bed (Devi paar) on November 7 at 28.15‰ it could be presumed that the farm oysters would not have faced the low saline conditions for more than a day. As has been observed in the experimental work, the oysters remain shut for 19 to 22 hr protecting themselves from low saline conditions. Hence, it can be presumed that there was no mortality of oysters in the farm as they had been able to tide over the adverse condition lasting not more than a day by remaining completely closed.

The European mussel *Mytilus edulis* occurs in salinities ranging from 30 to 10‰ and even down to 4‰ in some areas, and the American oyster *Crassostrea virginica* lives for weeks at salinities just above fresh water (Gunter *et al.*, 1973). But as stated by Gunter *et al.* (1973), individuals of *M. edulis* are small in very low and high salinities which may be due to stress conditions under these salinities. The pearl oyster, being truly a marine form throughout its life-cycle, has comparatively narrower tolerance limits.

It is well-known that lower salinities have a depressing effect on the filtration rate of bivalves (Cole and Hepper, 1954; Nagabhushanam, 1956). Loosanoff (1953) observed that a sharp reduction in salinity from 27 to 20, 15, 10 and 5‰ decreased the pumping rate of *Crassostrea virginica* to 24, 89, 91 and 99.6% respectively for approximately 6 hr after transfer. But no serious damage to oysters was observed as a result of the transfer to lower salinities. Decreased filtration rate has been observed in lower salinities in the pearl oyster and is less than 25% at 14‰ and 20‰ even after 4 hr. Durve (1963) found that in *Meretrix casta* the rate of filtration was adversely affected both at low and high salinities. In the clam the filtration rate remained fairly high even at the salinities of 45 and 56‰ and at 64‰ the rate became erratic. In the present study it has been seen that the rate of filtration of the pearl oyster was comparatively high (above 50% removal in 4 hr) in the higher salinity range, including the unusually high filtration rate in 49.9‰, except at 56.96‰. Compared to *M. casta*, the rate of filtration of the pearl oyster appears to be low. In the normal sea water the clam removed about 57% of the neutral red in 15 min time (Durve, 1963), whereas the pearl oyster has taken 2 hr 30 min to remove 58.4% of the neutral red in the same salinity.

Korringa (1951) stated that a satisfactory treatment against the boring polychaete *Polydora* was to expose the oyster (*Ostrea edulis*) to fresh water for 16 hours. Hrs-Brenko and Igit (1968) investigated the effects of fresh water and saturated sea water brine in controlling the fouling organisms on the cultivated mussels and oysters. They found that exposure to saturated brine was more harmful to the mussels and oysters and fresh water was a more suitable medium for treatment to remove the epibionts. In the pearl culture farm, oysters are affected by the fouling and boring organisms, of which the polychaetes *Polydora* spp. and the sponge *Cliona* have been found to cause mortality of pearl oysters. On exposure to fresh water the pearl oysters have been found to resist from opening the valves for about 12 hours and once they open they become dead soon. Experiments on the control of fouling and boring organisms in the pearl oyster farm have been taken up on the basis of results obtained in the present study.

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