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OYSTER CULTURE—STATUS AND PROSPECTS

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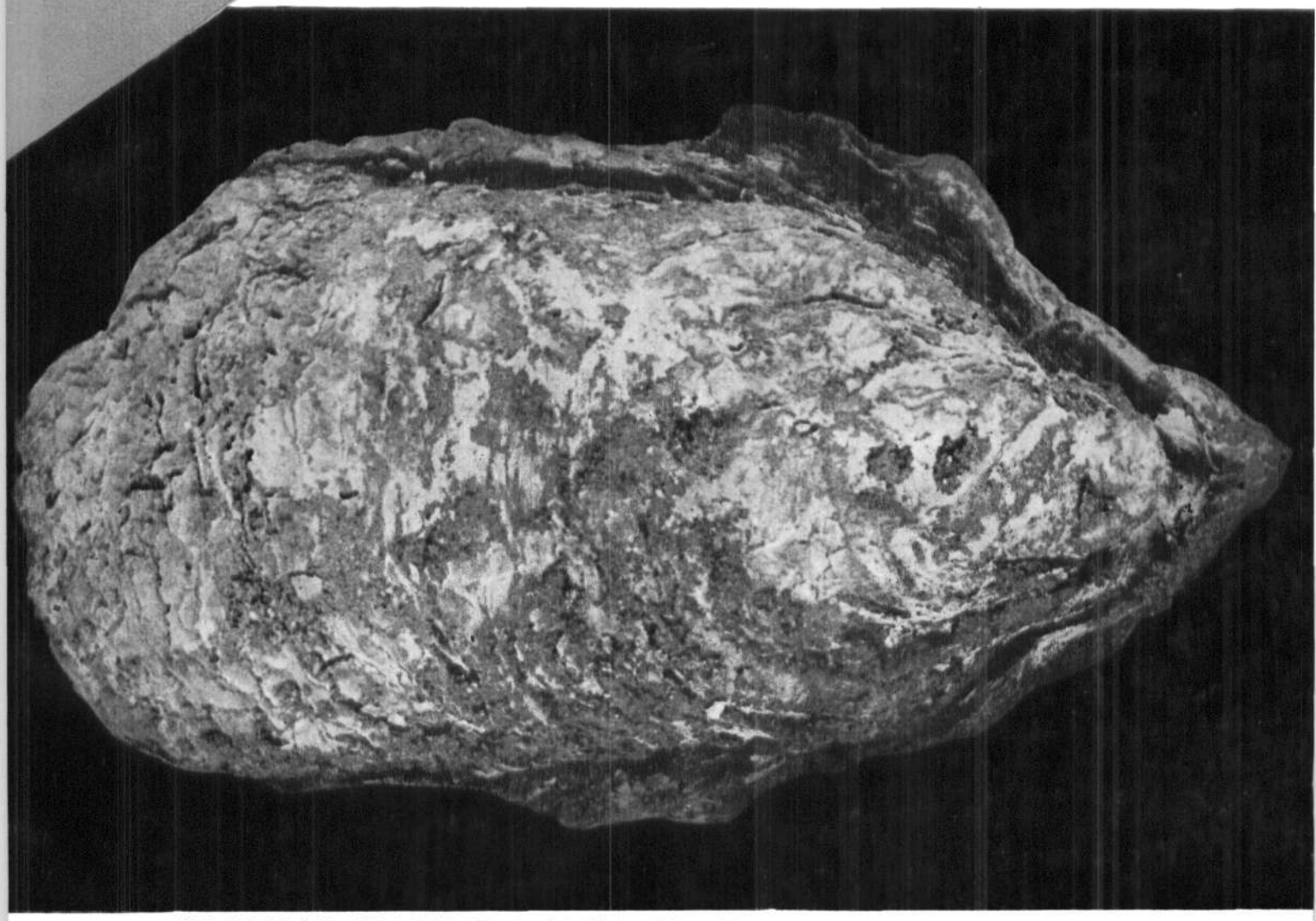

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BIOLOGICAL ASPECTS OF OYSTERS

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INTRODUCTION

Purchon (1968) has stated that about thousand articles are being published annually on molluscs and out of these 300 to 400 articles deal with oysters. This is mainly because oysters enjoy a wide range of distribution and are ubiquitously present in different habitats. Among marine organisms the oysters are one of the most widely cultured organisms. These facts account for the voluminous literature on oyster biology that have come out during the past fifty years.

Considering the current interest in our country in developing oyster culture as an industry this chapter aims to place all available information on oyster biology to make it useful to scientists involved in oyster studies.

HABITAT AND DISTRIBUTION

Along the Indian coasts the occurrence of oysters of only two genera *viz.*, *Crassostrea* and *Saccostrea* has been reported. Of these *Crassostrea* spp. are widely distributed along both coasts, while *Saccostrea* represented by *S. cucullata* is comparatively not so abundant. Of the eight species listed by Awati and Rai (1931) the three species *C. madrasensis*, *C. gryphoides* and *C. rivularis* are important as resources. The other species are of little or of no consequence. These species thrive well in coastal and estuarine conditions. But *Crassostrea madrasensis* is widely distributed along both coasts, whereas *C. gryphoides* and *C. rivularis* are restricted to only North western coastal zones. Naturally even the very little information we have on the Indian oyster species is more on *C. madrasensis* as reflected in the work of Hornell (1910, 1916), Paul (1942), Rao (1951, 1956, 1983), Rao and Nayar (1956), Durve and Bal (1962), Rao (1974, 1983), Nayar and Mahadevan (1983) Mahadevan (1983), Purushan *et al.* (1983), Reuben *et al.* (1983), Joseph and Joseph (1983), Thangavelu and Sundaram (1983), Thangavelu and Muthiah (1983), Rajapandian and Rajan (1983) and Samuel (1983).

Descriptions of the external morphology of the oyster shells and the internal anatomy of the oysters are well documented by Galtsoff (1964), Awati and Rai (1931) and Purchon (1968). Korringa (1952) has also made an exhaustive review of the description and functional differentiation of different body systems of the oysters. Hence further description of these in respect of *C. madrasensis* will be redundant in this chapter as there are very few differences in the above aspects described.

The biology of oysters is greatly influenced by the environmental factors in the habitat. Feeding, growth maturation, spawning, development and setting of oyster spat are greatly influenced by the varying environmental factors such as temperature, salinity, pH, dissolved oxygen, sediments and food. By far temperature and salinity of the water greatly influence the growth, survival, reproduction and larval growth and metamorphosis.

Increased industrial activity has led to increased release of toxic substances including hevy metals into the environment. This material may be discharged directly into estuarine and marine environments or may accumulate there through water run off. Many of these substances such as arsenic, cadmium, chromium, copper, lead, mercury etc. can be concentrated by oysters and thus become a potential hazard to human beings who consume them. Further these materials may exert a lethal or sublethal effect on different stages

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of the life-cycle of oysters, with consequent influence on population abundance. Hence monitoring of heavy metals has to be carried out in order to find out any unusual increase in heavy metal content before it becomes a health hazard.

Food and Feeding

Food

The food of oysters mainly consists of organic detritus and phytoplanktonic organisms such as diatoms and nannoplankters. The widely accepted view on food of oysters is that phytoplankton constitutes the principal source of shellfish food. Spores and particulate matter of seaweeds are also found in the stomach. Nelson (1947) found that the abundance of the diatom *Skeletonema* has been responsible for the healthy growth and good condition of oysters of Delaware Bay. Jorgensen (1975) observed correlation between rapid growth of oysters and the presence of the diatoms, *Skeletonema* sp. *Chaetoceros* sp. and *Thalassiosira* sp. Epifano (1979) comparing nutritional effects of different algal species, found a combination algal diet with *Isochrysis galbana* and *Thalassiosira pseudonana* promotes better growth than the diet consisting of only a single species.

These microorganisms and other particulate matter are filtered from water by ciliary action of gills and transported to the mouth and from there passed to the stomach and digestive diverticula for digestion and absorption. The mechanism of feeding in adult oysters has been well documented (Nelson 1938, 1960, Korringa 1952, Menzel 1955, Jorgenson 1966, 1975, 1976, Owen 1974). Galtsoff (1964) provides an excellent account of the anatomy and physiology of gills.

Process of ingestion

The food particles carried by streams of water pass through the gills and become entrapped, bound in mucus and are transferred towards food collecting furrows. Masses of collected food are converged in strings of mucus to the labial palps where particulate matter is sorted either to be passed on to the mouth or rejected as pseudofaeces. The labial palps on either side of the mouth play an important role in sorting the food. The outer palps join together above the mouth, where they form the upper lip and the inner palps fuse together below the mouth as lower lip. A narrow cavity found between the inner palps is known as median gutter and the spaces between the external and internal palps are termed lateral gutters. These are the principal paths by which the food is converged to the mouth. Bernard (1974) suggests that the ciliated ridges of these grooves (gutters) are mucus-reducers with ability to reject the entire mucus-particle load on their surface if the size of the particles is large. Smaller particles with lesser amount of mucus follow a deeper sinuous path of ciliary tracts towards the mouth. The final acceptance or rejection of particles is determined mainly by the amount of mucus secreted by the gills and palps.

Process of digestion

The digestion and absorption of food in oysters is effected extracellularly in the stomach and intracellularly in the digestive diverticula. Yonge (1926), George (1952) Levine (1946) and Newell (1953) by their investigations found with conclusive evidence the presence of amylase, glycongonase, oxidase and lipase in the stomach. Yonge (1926) viewed that protein and fat digestion occurred only intracellularly within the wandering phagocytes and starch is digested only extracellularly by the action of thyliamylase. In general the phagocytosis i.e. intracellular digestion and absorption mainly occur in the ducts and tubules of digestive diverticula. These cells are the only absorptive areas in the gut (Purchon, 1968). Further phagocytes play an important role in the removal of waste materials from digestive diverticula. They discharge waste materials in the intestinal lumen by bursting off.

Extracellular digestion in the stomach is effected by the mechanical turning of the stomach and chemical dissolution of the crystalline style. The movement of the food in the alimentary tract is mainly accomplished by the strong ciliary motion of the epithelial lining of the system.

In the stomach, the crystalline style performs a number of functions that are relevant to the digestive process (Purchon, 1968). The style rotates (Yonge, 1969) at a rate of 90 revolutions/minute. By the rotatory movement the food material is drawn to the stomach more rapidly than it could enter under the impetus of the oesophagal cilia. Further the movement of the style stirs the general contents of the stomach and brushes these against the corrugated ciliary sorting areas which may segregate nourishable particles and eject them into the midgut. As the head of the style gently rubs the contents of the stomach against the gastric shield, the food particles may undergo certain amount of trituration and partial reduction of the particle size. The style slowly dissolves liberating the amylolytic enzymes which initiate a preliminary phase of extracellular digestion in the stomach.

The digested and undigested particles flow in the digestive tubules of the digestive diverticula. Purchon (1955, 1968) suggests that the cavities of the stomach, the ducts and the tubules of the digestive diverticula are in communication and that the fluid may pass to and out of the duct as a result of changes in pressure on the system. This could be effected by local changes in the tonus of the muscle fibres which are present in the wall of the stomach and around the individual ducts and tubules of the diverticula (Purchon, 1955). In the larva of oyster, rudimentary diverticula having two simple sacs exhibit rhythmic alternate contraction to bring about the movement of the particles in alimentary tract. The contraction of diverticula is effected by a slender shield of muscle fibres that pass over the top of the diverticula (Awati and Rai 1931, Purchon 1968).

From the midgut the rejected materials by the typhlosole channel reach the hindgut wherefrom these materials are further thrust by epithelial cilia to the rectum and anus.

The oyster is also capable of absorbing dissolved organic matter in the water through the surfaces of the gills, palps and mantle. Owen (1974) says that the gills of bivalves possess active carrier-mediated transport systems for the absorption of neutral amino acids and hexose monosaccharides. Further Pasteels (1967) observes that amoebocytes within the gill may serve to translocate such materials. Vitamins such as riboflavin, calcium pantothenate, thiamin and pryidoxine when added to the medium have significantly increased the rate of growth of *O. virginica* and *Ostrea lurida* (Davis and Chanley 1956). Pomeroy (1952) and Pomeroy and Haskin (1954) have concluded that significant amounts of phosphate and calcium ions are derived from the water, thus partially fulfilling the requirements of oysters for these ions both for carbohydrate metabolism and shell deposition. According to Jorgensen (1955) 0.05 mg/litre amino acid is available in sea water. Jeffrey (1966) has observed that potentially useful classes of lipids are available in the sea water in the range of 0.5 to 0.6 mg/litre. Lewis and Rakestraw (1955) have reported carbohydrates in coastal lagoons present at 8 mg/litre. In view of the potential absorptive powers, the oysters can assimilate considerable quantity of soluble organic substances from the sea.

Factors affecting the feeding of oysters

Loosanoff and Nomejko (1946) have recorded the pumping rate of oysters as 34.0 l./hour at 25°C. At temperature of 28°C to 32°C a maximum pumping rate of 37 l. to 40 l./hour was observed for 5 to 15 minutes period. According to them the optimum pumping rate occurs at temperature of 25°C to 30°C. Although higher temperature regime increases the pumping rate for a short while after certain time the pumping rate slowly decreases.

Loosanoff and Engle (1947) have reported that the rate of pumping is influenced by the density of microorganisms. In some cases certain inhibiting substances such as metabolites of microorganisms influence the pumping rate. In such instances the rate of pumping is reduced. Under high concentration of microorganisms, the production of pseudofaeces increases. A reverse relation is observed in the production of true faeces.

Theede (1963), Davids (1964) and Thompson and Bayne (1972) have demonstrated that the particle concentration affects filtration rate. In *O. edulis* and *C. angulata* the secretion of mucus increases with higher particle concentration and the ctenidia are blocked.

Growth

The growth of oyster is expressed in terms of increament in length (height of the shell) and weight. The shell growth is correlated with growth of living tissues.

(a) C. madrasensis

Hornell (1910), Paul (1942) Rao and Nayar (1956), Rao (1974), Nagappan Nayar and Mahadevan (1983), Rao *et al.* (1983), Purushan *et al.* (1983), Joseph and Joseph (1983) and Reuben *et al.* (1983) have made investigations on the growth of *C. madrasensis.* It is observed that the growth of spat is rapid during the first 3 months. A size of 38 mm is attained in 90 days registering a growth of 12.6 mm per month and at the the end of first year oysters attain an average size of 84 mm with a total shell and meat weight of 120-130 g per oyster (Nagappan Nayar and Mahadevan, 1983). Rao *et al.* (1983) have observed that an average size of 86.7 mm and maximum of 110 mm were reached at the end of one year at Athankarai. Purushan *et al.* (1983) recorded an average growth of 60-62 mm in a period of 5-5½ months in Cochin backwaters. Joseph and Joseph (1983) found that oysters of Mulki estuary grew to the marketable size of 70 mm in 7 months. Reuben *et al.* (1983) reported a growth of 77-81.8 mm in 12 months in the oysters of Bheemunipatnam backwaters.

(b) C. gryphoides

Durve and Bal (1962) recorded a growth of 37.2 mm and 47.9 mm at the end of six months and one year

respectively in *C. gryphoides* of Kelwa backwaters. The growth of this species is thus distinctly slower than that of *C. madrasensis*.

(*c*) *C. rivularis*

No information is available on the growth of this species.

Growth of oysters is largely influenced by the availability of food and hydrographic conditions. The growth and survival of oyster populations along the east coast of India appear to be relatively better perhaps due to the stable salinity and temperature conditions prevailing along the coast.

In temperate waters growth of oysters is almost restricted to summer months. Loosanoff and Nomejko (1949) observed that in *C. virginica* there is no increase in size, volume or weight during winter months (December-March) while during the eight months, April to November, most rapid growth in length occurred. Quayle (1950) and Cahn (1950) stated that *C. gigas* would require two full summer seasons to attain marketable size of 75-85 mm.

Conditions of Oysters

Condition of oyster is recognised as the degree of fatness of an oyster or the extent to which the meat fills the shell cavity. The oyster shell grows to accommodate the soft body. However, the body size of oyster undergoes changes and such changes are associated with the breeding cycle. This is accomplished by development of an increase in size of the reproductive organs followed by a considerable reduction in size after spawning. This process is followed by a slow increase in body size. In temperate waters increased level of glycogen has been associated with this phase. But in tropical waters this phase of glycogen accumulation has not been observed. Changes in the meat content of an oyster are important to the culturist for these greatly affect the meat yield and financial returns. Thus knowledge of the seasonal fatness cycle is most important for successful marketing.

The condition factor is measured as a ratio comparing the dry meat weight (oven dried at 90-100°C) of the oysters to the volume of the shell cavity.

$$\text{Condition factor} = \frac{\text{Weight of dry meat} \times 1000}{\text{Volume of shell cavity}}$$

In *C. madrasensis* the condition may be high if the value is above 140. Values below 70 indicate the poor condition of oysters. It has been observed that along Tuticorin bay the condition factor reaches high values during February-March.

Reproduction

Reproduction of oysters in contrast to many other animals is simple. The gonad of oysters is located under the mantle and consists of branching tubes and follicles on each side of the body encasing the visceral organs. The follicles containing germ cells and follicular tubules with a well developed epithelium to facilitate the passage of gametes. As the gametogenetic activity of oyster increases with accummulation of mature ova and sperms the gonad becomes thick. The ripe eggs and sperms pass along a series of tubes by ciliary action in the tubes which finally merge in a tube along the dorsal side of the body. Two separate systems of genital canals are found one on each side of the oyster which open into the suprabranchial chamber and from there discharged to the exterior.

Maturation of Gonads

Paul (1942) and Rao (1951) have recorded partially spent conditions of the gonad of *C. madrasensis* at Madras all round the year. Among oysters found in Adyar backwaters of Madras and in Tuticorin Bay (Gulf of Mannar) gonads with fully ripe and partially spent conditions have been recorded in high percentages during February-April and July-September. Nayar (1977) and Rajapandian and Rajan (1983) have observed that in the Gulf of Mannar, although the spatfall was observed throughout the year, the peak of gametogenetic activities were recorded during the months February-March (64-78%) and August-September (59-73%). Further they have observed that the diurnal variations in minimum and maximum temperature have well defined relation to the development of gonads and spawning of oysters. The highest value observed during February initiates the maturation of oysters and spawning continues till May. The drop in temperature during the months of June and July showed corresponding decline in the spawning activity of the oysters. In September this value of temperature increased and there was rise in the spawning population.

Cole (1942), Bargeton (1942) and Loosanoff (1942) have described the process of maturation of gonads and the factors influencing them. Among exogenic factors temperature is much more important than any other factors. Rand (1973) in examining the breeding habits of marine animals in time and space concluded

that in Northern climate the animals are characterised by single synchronous spawning in a year, temperate climate by two spawnings and tropical climate by year round spawning. In northern climates gametogenesis sets in European oysters during the middle of May and spawning commences in early June and continues till July or early August.

Obviously, sometimes it is difficult to separate the effects of temperature at different latitudes. Loosanoff and Engle (1942), Korringa (1957) and Galtsoff (1964) have given evidences for the existence of different physiological races of oysters, each with its own threshold spawning temperature. In *C. virginica* there are races that spawn at 17, 20, and 25°C in northern, central and southern latitudes respectively (Stauber, 1950).

Sex ratio

Oysters generally are dioecious but hermaphrodites are not uncommon. It has been well documented that young oysters function primarily as males (60-70%) and later become female. In oysters of the 'O' year class which are up to 78 mm in size 75% are males and in one year old and above, ranging in size from 80-118.5 mm females represent 72% (Nayar *et al.*, MS).

Hermaphroditism

True and functional hermaphrodites probably do not occur but are only transitional phases containing both sperms and developing eggs. Galtsoff (1964) has observed hermaphrodites only among 2, 3 and 4 year old oysters of *C. virginica* and none in 5-8 year old oysters. Rao (1953, 1956) recorded hermaprodites in *C. madrasensis* throughout the year. Further his observations on the changing pattern of sex from male to female and female to male evidently shows that hermaphroditism is a feature found during the transitional phase of sex change. From our observations on the oysters, *C. madrasensis* at Tuticorin hermaphroditism is a feature not frequently found in ripe oysters, but occur in stray instances in spent and recovering stages.

Fecundity

In the larviparous oyster, *Ostrea edulis*, the egg is about 100 μ in diameter and is very large when compared to those of the oviparous oysters *Crassostrea*. The egg of *C. madrasensis* is about 48-60 μ in diameter.

Cole (1941) found the number of eggs spawned by *O. edulis* to be 91,600 by one year old oysters and 218,100, 462,000 and 902,000 eggs were spawned by 2 3 and 4 year old oysters. Cerruti (1941) stated that the number of eggs depends on the size of oyster than the age.

Oysters of the genus *Crassostrea* release more eggs then larviparous oysters. In a season *C. virginica* can release 100 to 200 million eggs (Galtsoff, 1964). In *C. gigas* almost same numbers of eggs per spawning have been recorded (Tomiyama, 1980). During the course of our investigations in *C. madrasensis* a few ripe oysters were selected and forced to spawn by manipulation of temperature. At the onset of spawning the oysters were placed in individual glass trays of 3 l. capacity and allowed to spawn. After completion of spawning the oysters were removed from the tray and the contents were released into a beaker and made up to 10 litres. After proper stirring 100 ml sample was taken and 1 ml of 1% formalin was added to it. After further stirring 1 ml subsample was drawn on a Sedgwick Rafter chamber and the number of eggs present counted. By verifying a few more subsamples it was found that the number of eggs per spawning amounted to 10-15 millions.

Spawning

The two genera of oysters, *Ostrea* and *Crassostrea* have different spawning habits. In *Ostrea* the eggs when released from the gonad are retained in the mantle cavity while the sperms are discharged to the exterior. Eggs are fertilized by sperms from outside and the larval life partly takes place inside the shell before being released into the water. In *Crassostrea*, at spawning both eggs and sperms are discharged directly outside into the open water where fertilization and all subsequent development take place. The process by which the sperms and eggs are discharged is completely different. The sperms are discharged by the contraction of muscles in the walls of the genital ducts. The sperms carried away by the outgoing water current, appear as a dense white stream emerging from between the valves which quickly disperses in water from the exhalent side.

The spawning process is more complex in female oysters unlike the male. The female rhythmically ejects the eggs through the inhalent side. The process is controlled by the edge of mantle folds which can open and close like a zipper. The tentacles of the inner lobe of the mantle act like the components of a zipper, and keep the curtain closed except for a small opening, when spawning takes place. The discharged eggs from the ovary first reach the epibranchial chamber. At this the two edges of the mantle merge and seal the

infra and supra branchial cavities. The adductor muscle is relaxed at this point, resulting in the passage of eggs outside the gill chamber. At this stage the contraction of the adductor muscle forcefully ejects the eggs out through a narrow opening along the inhalent side. This process occurs at regular intervals.

Fertilization

In recent years studies on this aspect of biology have assumed new dimensions since innumerable workers are engaged in perfecting techniques in the artificial propagation of oysters. Investigations on induced spawning, artificial fertilization and laboratory rearing of oyster larvae have provided a fund of information on this aspect of biology.

Eggs lose their fertilizability totally at the end of 24 hours in temperate climate. In tropical conditions it is lost within 4 hours. The fertilizing power of sperms lasts for 3 to 4 hours. Temperature and dilution factors decrease the fertilizing power of sperms (Dupuy *et al.*, 1977). Concentrated suspension of sperm stored at 10-12°C will increase the longevity upto 24 hours. Therefore to ensure optimum fertilization freshly released eggs and sperms should be mixed instantaneously. A suspension of eggs from different females and sperms from several males when mixed would result in optimum fertilization and normal embryonic development. Abnormal fertilization can occur if large proportions of sperms are mixed with small quantities of eggs. This may result in several sperms penetrating the membrane of a single egg and this phenomenon, polyspermy will cause irregular cleavage of egg. Dupuy *et al.* (1977) observed that a delay of one hour or more in adding sperms to newly spawned eggs will increase the incidence of abnormality among the larvae.

Development

In *C. madrasensis* after fertilization the first polar body is observed within 20 to 40 minutes and subsequently the second polar body appears. The first cleavage occurs immediately after the formation of the two polar bodies and the cells in the animal pole divide resulting in the formation of the 8 celled stage. One of the cells (macromeres) formed in the first cleavage retain the identity and remains at the vegetal pole as the macromere. Subsequently after the 6th division, a roughly spherical morula is formed. The gastrula stage is reached between 5 and 6 hours after fertilization. At this stage the larvae start swimming upwards.

The straight hinge stage or 'D' shelled stage, the first veliger stage is reached at the end of 20 hours. The larvae actively swim and collect food with the help of the velum which is formed by an outgrowth of the lateral parts of prototroch area in two semicircular folds or lobes bearing large cilia along their margins. The margin of the velum possesses large cilia which help the larvae to swim and the small cilia present at the base of velum (aboral cilia) direct food particles to the stomodaeum. The larvae at this stage measure 60-70 μ in length (anteroposteriorly).

In larviparous oysters, *Ostrea* early embryonic development and transformation of larvae takes place in the inhalent chamber. These larvae cover densely the surface of the gills and lower mantle lobe which gives the appearance of sprinkled flour. At the time of their release the congregation of larvae are purplish black. After fertilization the larvae are retained in the gill chamber for 7 to 8 days and attain a size of 220 μ before release (Yonge, 1960).

The sequence of events in the development and growth of the larvae of the American oyster *Crassostrea virginica* and the Pacific oyster *C. gigas* are almost similar to that of *C. madrasensis* under laboratory and natural conditions. The larvae attain eyed stage on 13th day in all these oysters and setting takes place on the 14 to 15th day after fertilization. The growth of spat has been observed to be faster in *C. madrasensis* than in *C. virginica* and *C. gigas* which may be probably due to the differences in the prevailing temperature.

Variation in salinity and temperature greatly infuences the growth and settlement of larvae. Growth and setting of the larvae have been observed to be optimum when salinity and temperature regimes are steady. Davis (1958) demonstrated that lowering of salinity from normal level to 15‰ has not resulted in mortality of the larvae. However, at salinities below 12.5‰, 90-95% of the larvae died indicating that they are lethal.

Optimum growth and setting of the larvae of *C. madrasensis* have been observed at salinities 28.0 to 31.5‰ and at temperatures of 25° C to 27.0°C. Dupuy *et al.* (1977) have successfully settled the larvae within 9-11 days at salinity ranges of 15 to 20‰ at a temperature of 27°C and the larvae of *C. gigas* at 20‰ and in 27°C.

Larval food

It is known that some areas are excellent for fattening or growing oysters but not good for spat settlement

and areas where settlement is rich, offer poor conditions for the growth of oysters. Nelson (1950) suggested that the appropriate nannoplankton food for oyster larvae is not found to be useful for adults whereas diatoms and dinoflagellates might fatten adults but are of little use to larvae. Cole (1937), Loosanoff and Davis (1953), Walne (1956) and Ukeles and Sweeney (1969) have demonstrated that the best food for larvae are the phytoflagellates, belonging to the genera *Isochrysis*, *Monochrysis* (*Pavlova*), *Pyramimonas* and *Dunaliella*. The size of these phytoflagellates range from 5 to 8 μ and are highly motile. They are found in the surface and the column waters and are easily filtered by the oyster larvae. Under normal temperature and salinity conditions the straight hinge larvae of *C. madeasensis* need 4,000 to 5,000 cells per larva per day. The intensity of feeding increases with growth. At the time of settlement, 10,000 cells per larva per day is ideal (Nayar *et al.*, 1984).

Diseases and parasites

Large scale mortalities of oysters have occured from time to time for which no rational explanation could be given. Even after exhaustive investigation, the exact cauative factors responsible for such catastrophic outbreaks could not be recognised. Recent studies on histopathological aspects have thrown some light on the possible factors responsible for many instances of large scale mortalities.

Some epizootic viruses are suspected to be the agents causing such diseases. The reasons for such mortalities at Malpeque Bay and Prince Edward Island, U.S.A. during 1915 have been ascribed to viral diseases. The oyster population in these affected areas reached its former level of production after several years and it has been surmised that current populations are resistent strains that have been developed from survivors. The evidence that the infectious agent is still present is suggested by the fact that nonindigenous oysters are susceptible to the disease and die within the first or second year after the introduction (Aron Rosenyfield, 1967). Many microbial diseases are reported from all over the world. The same disease which has been observed in oysters of Japanese waters has been noticed in those in the Nasselle river, Willapay Bay, Washington.

'Dermo' a dreaded disease causing heavy mortality among eastern American oysters was first identified as fungal disease caused by the fungus *Perkinsus marinus* (= *Dermocystidium marinum*). Oysters affected by 'dermo' show watery digestive gland, thin mantle and atrophied gonads. Mycelial disease or gill disease is common in *C. gigas*. Shell disease caused by the fungus *Ostracobiabe implexa*, inflicted heavy mortality among Dutch oysters during 1930 (Korringa, 1952). This is characterized by the formation of pustules on the inner shell surface.

Minchinia nelsoni, known as MSX disease has caused heavy mortality among the oyster population in Delaware Bay, U.S.A. during 1955. *M. nelsoni* is a haplosporidian very active during summer months. Similarly the dreaded disease known as SSO caused by *M. coastalis* takes heavy mortality of oysters. *Hexamita* a commensal flagellate of oyster causes the disease known as Pit disease. Korringa (1952) has stated that in Dutch waters the 'pit disease' is caused by the prolific multiplication of *Hexamita* under low temperature conditions.

Several metazoan parasites have been found in many species of oysters. Most of these organisms are the larval stages of helminths having oysters and other bivalve molluscs as intermediate hosts. The larval trematodes of the genus *Bucephalus* have been found in American, European, Japanese and Indian waters. Although these parasites do not cause heavy mortality among oysters, they enter the gonadal tissues and cause damage resulting in the sterility of the oysters (Joseph, 1978). Samuel (1978) has described a digenic nematode parasite which is common in the gonads of *C. madrasensis* and causes sterility of the gonad.

Predators and Competitors

The oyster predators and competitors are crabs' sea stars, molluscs and organisms which grow on the shell and smother them. Korringa (1976) lists several species of crabs, fishes and molluscs as the predators of oysters. Some of these organisms such as crabs and fishes prey upon oysters weighing less than 5 gm.

Predatory gastropods such as *Busycon*, *Urosalpinx*, *Thais* sp. and *Trilonalia* attack young oysters along Atlantic and Pacific coasts. *Repana* sp. forms one of the serious oyster drills in Japanese waters. Among gastropods, *Cymatium cingulatum* has been observed to cause considerable damage to young *Crassostrea madrasensis* of size 35-55 mm in Tuticorin Bay in Gulf of Mannar (Thangavelu and Muthiah, 1983).

Among other major predators, the sea stars cause most difficult problem to the oyster growers in summer months. Fishes such as *Myliobatis* and *Pasgrus* have been observed as predators of oysters in France.

Polydora, a polychaete has been often found to cause noticeable damage to the oysters. The worm first settles on the shell and slowly occupies a position between the mantle and shell edges. It accumulates a mass of mud around itself and the oyster responds by secreting shell to cover the mud-worm complex. The meat of oysters heavily infested by *Polydora* is in poor condition and the shellfish are more susceptible to disease (Korringa, 1952).

Certain organisms such as Bryozoans (*Membranipora*), barnacles (*Balanus*) and mussels compete for space during settlement. Sometimes, the spat collectors are fouled by these organisms. On the fouled spat collectors, the larvae of oysters may not settle. To a large extent, the barnacles feed on oyster larvae. To avoid this, the spat collectors are laid precisely at the time when settlement of oyster larvae is likely to occur. Placing of spat collectors in advance before the spatfall would result in the fouling of collectors and thereby the setting of oyster spat is prevented.

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