THE INDIAN EDIBLE OYSTER

TECHNOLOGY OF SEED PRODUCTION AND FARMING

भाकृअनुप
ICAR

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
Indian Council of Agricultural Research
Post Box No. 2704, Cochin 682 031, India

This Brochure was issued on the occasion of "The Indian Edible Oyster Harvest Mela," held at the Research Centre of the Central Marine Fisheries Research Institute, on 27th and 28th September 1992 at Tuticorin, Tamil Nadu.

Published by : **Dr. P. S. B. R. James,**
Director,
Central Marine Fisheries Research Institute,
Cochin.

Editing and Layout : **Dr. K. Rengarajan,**
Senior Scientist,
Central Marine Fisheries Research Institute,
Cochin.

Front Cover : **An opened Edible oyster *Crassostrea madrasensis* with meat.**
Back Cover (outside) : **The Edible oysters grown in Oyster Farm ready for the harvest.**
Back cover (inside) : **A natural oyster habitat during low tide at Tuticorin.**

PRINTED IN INDIA
AT THE ST. FRANCIS PRESS, ERNAKULAM, COCHIN - 682 018

The Indian Edible Oyster *Crassostrea madrasensis* : opened and valves separated.

PREFACE

The oysters are highly esteemed sea food and considered as a delicacy in U.S.A., Europe, Japan, etc. The world production of oysters by culture in 1988 was estimated at 10.01 lakh tonnes, mostly coming from the temperate countries. In recent times, keen interest is evinced in Oyster culture in several tropical countries where it has vast untapped potential for augmenting production several fold and in providing rural employment.

In India there is a growing demand for oyster meat in some parts of the country. The oyster resources are limited, scattered at several places and known to show wide fluctuations in abundance. Since early 70's the ***Central Marine Fisheries Research Institute*** has been conducting researches on various aspects of oyster biology and culture. As a result, viable technology for oyster culture, including hatchery production of seed, is now available. Recently the Institute has set up an Oyster farm, partly funded by the National Bank for Agriculture and Rural Development at its Tuticorin Research Centre for scaling up the Oyster culture operations.

A major lacuna for the development of Oyster culture in the country on commercial lines is the lack of awareness among the concerned. This Brochure "***The Indian Edible Oyster***" contains information on oyster resources, morphology, anatomy and biology of oysters, technology for seed production and various types of farming methods, post-harvest technology and economics of Oyster culture. It is hoped that this publication fills this gap and stimulates interest in Oyster culture, leading to the establishment of commercial farms.

Cochin 682 031,
2nd September 1992.

P. S. B. R. James
Director

THE INDIAN EDIBLE OYSTER

INTRODUCTION

It is said that the 'oyster' is scientifically the best known marine animal. It is one of the most widely cultivated species. It was among the first of the marine species to be cultured and hence comparatively speaking Oyster culture has the longest history. As early as the first century B.C. the Romans were the first to develop simple methods of collecting oyster seed and growing them for food. The Japanese developed 'Habitate' culture technique *i.e.* culture in nets fixed to bamboo poles, during the seventeenth century and at the turn of the 20th century they evolved off bottom culture, especially hanging methods. These methods yielded good results and were adopted by majority of oyster farmers of Japan, as the environmental conditions of the coastal area were highly favourable for practising these methods. Japan produces about 2.6 lakhs tonnes of oysters annually and also several millions of seed oysters in shell strings are exported to North America to be cultured along the Pacific Coast of U.S.A. The Republic of Korea, France and Australia are other leading oyster producing countries.

Until recently oyster farming has been considered as a traditional practice followed only in temperate countries. The awareness about the vast potentialities for the development of oyster farming in tropics is recent and serious efforts are directed in developing suitable techniques under tropical conditions. Further, the growing demand for animal protein in the developing countries and the faster growth of the oysters have given impetus for farming oysters. Philippines, Thailand, Malaysia, India, Sierra Leone and Brazil are some of the developing countries of the tropical zone, carrying out investigations to organise oyster farming operations on commercial scale.

In India pioneering attempts were made by James Hornell in 1910 in developing Oyster culture in the erstwhile Madras State. Scientific investigations were undertaken during early 70's by the Central Marine Fisheries Research Institute, at Tuticorin. The Institute has conducted R & D programmes on all aspects of Oyster farming during the last two decades, culminating in a wealth of informations on the technology of Oyster farming. The Brochure outlines various aspects of the technology of farming of the Indian Edible Oyster or the Indian Backwater Oyster ***Crassostrea madrasensis*** (Preston) including information on biology, ecology and economics of Oyster farming.

RESOURCES AND DISTRIBUTION

The living species of oyster are grouped into two families ***Ostreidae*** and ***Gryphaeidae***. Under the family ***Ostreidae*** six genera are recognised and under ***Gryphaeidae*** there are two genera. The various genera and species are identified on the basis of shape, size, colour and other characteristics of the shell, anatomical features of promyal chamber, gill ostia, heart and gut and breeding habits are the basis for classification of oysters. Based on these aspects a chart for the identification of species of Indian oysters is shown in Fig. 1.

THE INDIAN EDIBLE OYSTER

INTRODUCTION

It is said that the 'oyster' is scientifically the best known marine animal. It is one of the most widely cultivated species. It was among the first of the marine species to be cultured and hence comparatively speaking Oyster culture has the longest history. As early as the first century B.C. the Romans were the first to develop simple methods of collecting oyster seed and growing them for food. The Japanese developed 'Habitate' culture technique *i.e.* culture in nets fixed to bamboo poles, during the seventeenth century and at the turn of the 20th century they evolved off bottom culture, especially hanging methods. These methods yielded good results and were adopted by majority of oyster farmers of Japan, as the environmental conditions of the coastal area were highly favourable for practising these methods. Japan produces about 2.6 lakhs tonnes of oysters annually and also several millions of seed oysters in shell strings are exported to North America to be cultured along the Pacific Coast of U.S.A. The Republic of Korea, France and Australia are other leading oyster producing countries.

Until recently oyster farming has been considered as a traditional practice followed only in temperate countries. The awareness about the vast potentialities for the development of oyster farming in tropics is recent and serious efforts are directed in developing suitable techniques under tropical conditions. Further, the growing demand for animal protein in the developing countries and the faster growth of the oysters have given impetus for farming oysters. Philippines, Thailand, Malaysia, India, Sierra Leone and Brazil are some of the developing countries of the tropical zone, carrying out investigations to organise oyster farming operations on commercial scale.

In India pioneering attempts were made by James Hornell in 1910 in developing Oyster culture in the erstwhile Madras State. Scientific investigations were undertaken during early 70's by the Central Marine Fisheries Research Institute, at Tuticorin. The Institute has conducted R & D programmes on all aspects of Oyster farming during the last two decades, culminating in a wealth of informations on the technology of Oyster farming. The Brochure outlines various aspects of the technology of farming of the Indian Edible Oyster or the Indian Backwater Oyster ***Crassostrea madrasensis*** (Preston) including information on biology, ecology and economics of Oyster farming.

RESOURCES AND DISTRIBUTION

The living species of oyster are grouped into two families ***Ostreidae*** and ***Gryphaeidae***. Under the family ***Ostreidae*** six genera are recognised and under ***Gryphaeidae*** there are two genera. The various genera and species are identified on the basis of shape, size, colour and other characteristics of the shell, anatomical features of promyal chamber, gill ostia, heart and gut and breeding habits are the basis for classification of oysters. Based on these aspects a chart for the identification of species of Indian oysters is shown in Fig. 1.

Of the six species of oysters found in Indian waters the first four mentioned below are known to be of commercial value.

The Indian backwater oyster *Crassostrea madrasensis* (Preston)

The Chinese oyster *Crassostrea rivularis* (Gould)

The West coast oyster *Crassostrea gryphoides* (Schlotheim)

The Indian rock oyster *Saccostrea cucullata* (Born)

The Bombay oyster *Saxostrea cucullata* (Awati and Rai)

The Giant oyster *Hyastissa hyotis* (Linnaeus)

The oyster resources of the country are restricted, but the oyster beds are distributed in several centres along the Indian Coast. The production from these beds is mostly utilised for local consumption and is not monitored on regular basis. However, few surveys conducted by the CMFR Institute indicate the production at less than 2000 t whole weight/year.

Crassostrea madrasensis

This is a euryhaline species found in dense population along the east coast of India. It inhabits backwaters, creeks, banks of the estuaries, coastal bays and lagoons. Along the east coast of India there is no information on oyster resources of West Bengal. In Orissa, oyster beds are located in Bahuda Estuary near Sonapur and at the mouth of the Chilka Lake. In Andhra Pradesh oyster beds are distributed in Sarada Estuary near Waltair, Bhimunipatnam Backwater, the banks of Upputer Canal, Kakinada, Krishnapatnam and Gokulapalli Backwater. In Gokulapalli area oysters are regularly exploited.

Of all the maritime States , Tamil Nadu has rich oyster resources. Near Madras, in Pulicat Backwater oyster bed covers about 10 ha and the standing stock of oysters has been estimated at 1320 t. Ennore Backwater has 45 ha oyster beds with a standing stock of 18,600 t and oysters are regularly exploited by fisherfolk throughout the year. There are oyster beds with an area of 1.6 ha in Vaigai Estuary near Athankarai and the biomass was estimated at 390 t. At Tuticorin 3 oyster beds extending in an area of 3.25 ha have been recorded. In Killai Backwater, Pazhayar Estuary, Muthupet Swamps and Tambraparani Estuary oyster beds exist (Fig. 2).

Crassostrea madrasensis occurs in Andaman Islands at Port Blair, Havelock Island, Mayahender and Dighipur.

Although oysters were found in many estuaries and backwaters of Kerala, the populations appear to be small. In Ashtamudi and Vembanad Lakes and Cochin Backwater, the growth and conditions of the oysters were poor. In North Kerala, in the estuary of Mahe, the creeks of Darmadam, Valapatinam, Nileshwar and Chandaragiri sizable oyster populations were recorded. There is regular exploitation in these areas.

In Karnataka, the oyster resourcses are distributed in Nethravathi, Mulki, Udyavara, Venkatapur, Coondapoor and Kali Estuaries and oysters are regularly exploited.

Crassostera gryphoides

This is also a euryhaline species occurring along the west coast of India, particularly in north Karnataka, Goa and Maharashtra. In Maharashtra this species is found in all creeks and backwaters and is regularly exploited.

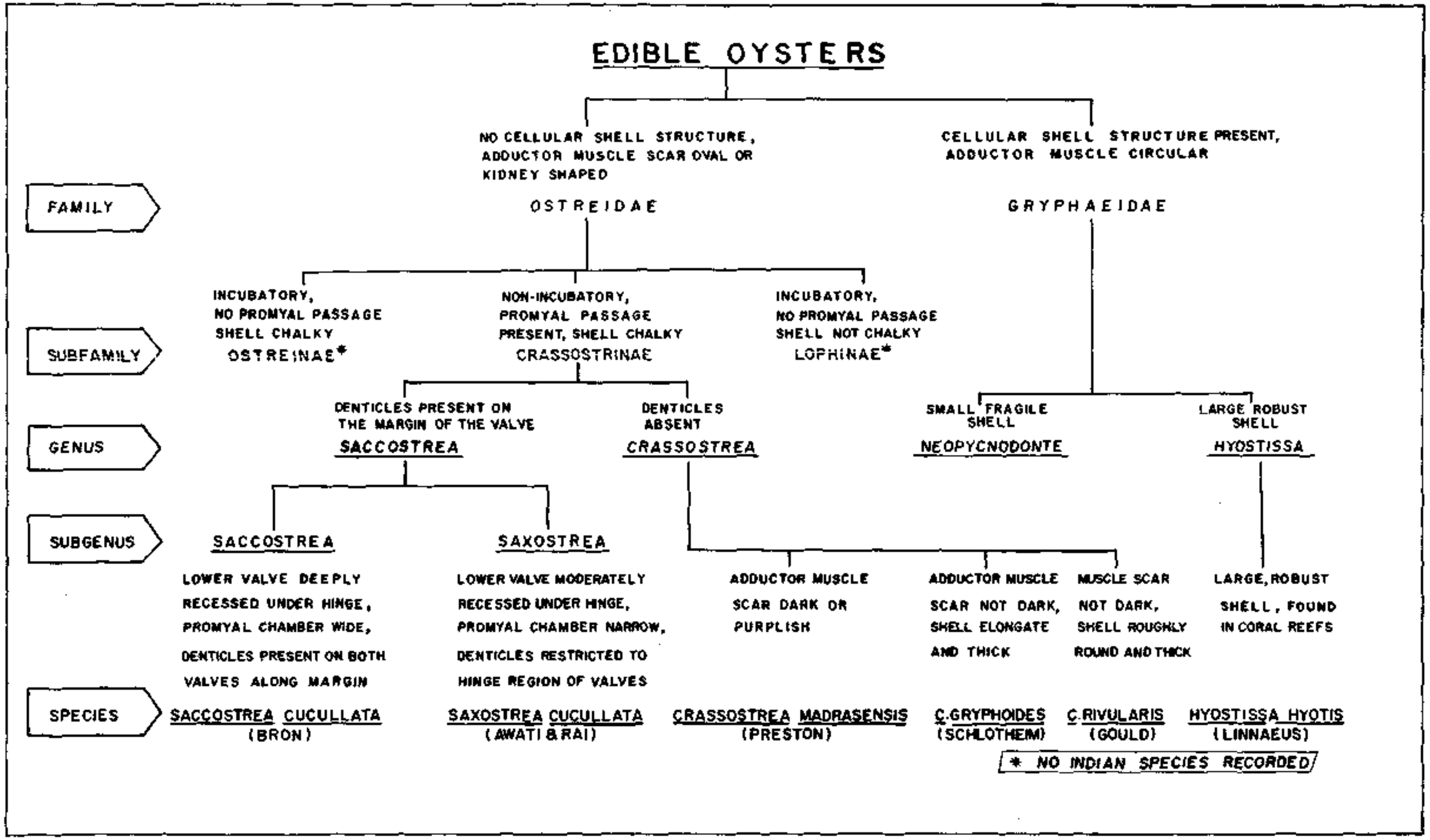


Fig. 1. Chart to identify the Edible oysters.

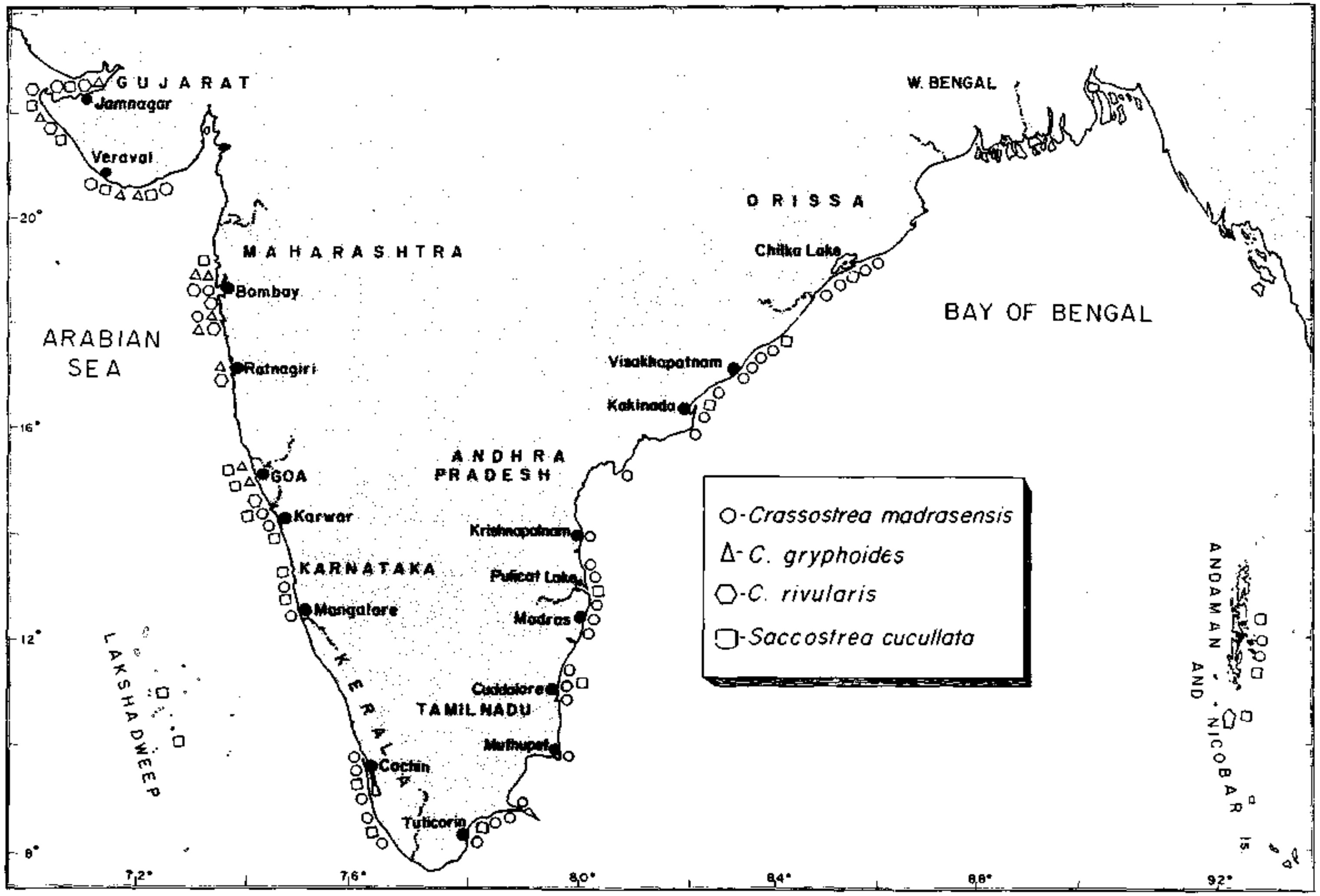


Fig. 2. Distribution of Edible oysters along the Indian Coast.

Crassostrea rivularis

This species is found in the coastal waters and creeks of Gujarat and the oysters are exploited particularly for the shells. This species is known to occur along with *C. gryphoides* in Mahim, Ratnagiri and Jaytapur in Maharashtra.

Saccostrea cucullata

This species is found on rocky substrate in marine environment in shallow coastal and intertidal areas. The oysters are found attached to the rocks and boulders and can withstand surf and wave action. It is found distributed throughout the mainland coast of India and Andaman and Lakshadweep Islands.

MORPHOLOGY, ANATOMY AND BIOLOGY

Morphology

Shell : The edible oyster is a sedentary animal. The soft body of the animal is encased by two shell valves - a lower cupped valve (left valve) and upper flat right valve (Fig. 3). While the lower valve is cemented to the substratum the upper valve acts as a lid to open and close by a hinge mechanism connecting both the valves. The movement of valves is accomplished by the contraction and relaxation of a thick muscle - the adductor muscle. The shell consists of three layers. The outermost layer is known as periostracum. The inner layer is the nacreous layer which is thin, hard and usually shiny. The middle layer is thick and chalky. The shell is primarily composed of calcium carbonate. The periostracum is almost all protein. The texture, size, shape, marking and colour of the shell vary between species and from place to place. The same species grown in different environments exhibits differences in shell characters.

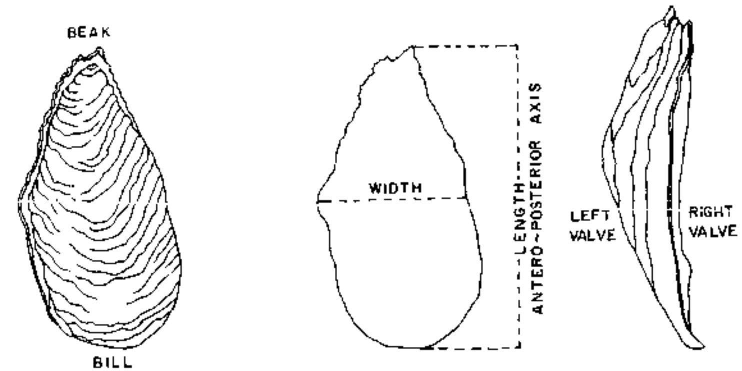


Fig. 3. Shell valves of an Edible oyster.

Anatomy

With the upper valve removed and the oyster lying on the left valve, the body of the oyster lies with the mouth near the hinge or the beak and the posterior side is the rounded end or the bill. The long axis of the oyster is actually the height, but common usage indicates this as the length. The dimension perpendicular to the height in the plane of the shell is the length (dorso-ventral axis), but referred to as width in usage. The mantle covers the soft body, except for the adductor muscle area.

Crassostrea rivularis

This species is found in the coastal waters and creeks of Gujarat and the oysters are exploited particularly for the shells. This species is known to occur along with *C. gryphoides* in Mahim, Ratnagiri and Jaytapur in Maharashtra.

Saccostrea cucullata

This species is found on rocky substrate in marine environment in shallow coastal and intertidal areas. The oysters are found attached to the rocks and boulders and can withstand surf and wave action. It is found distributed throughout the mainland coast of India and Andaman and Lakshadweep Islands.

MORPHOLOGY, ANATOMY AND BIOLOGY

Morphology

Shell : The edible oyster is a sedentary animal. The soft body of the animal is encased by two shell valves - a lower cupped valve (left valve) and upper flat right valve (Fig. 3). While the lower valve is cemented to the substratum the upper valve acts as a lid to open and close by a hinge mechanism connecting both the valves. The movement of valves is accomplished by the contraction and relaxation of a thick muscle - the adductor muscle. The shell consists of three layers. The outermost layer is known as periostracum. The inner layer is the nacreous layer which is thin, hard and usually shiny. The middle layer is thick and chalky. The shell is primarily composed of calcium carbonate. The periostracum is almost all protein. The texture, size, shape, marking and colour of the shell vary between species and from place to place. The same species grown in different environments exhibits differences in shell characters.

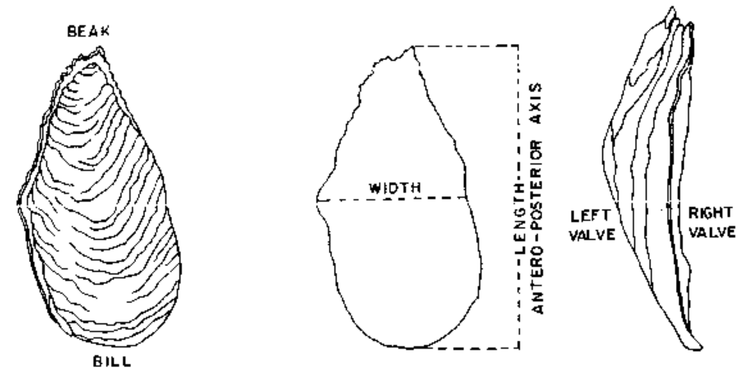


Fig. 3. Shell valves of an Edible oyster.

Anatomy

With the upper valve removed and the oyster lying on the left valve, the body of the oyster lies with the mouth near the hinge or the beak and the posterior side is the rounded end or the bill. The long axis of the oyster is actually the height, but common usage indicates this as the length. The dimension perpendicular to the height in the plane of the shell is the length (dorso-ventral axis), but referred to as width in usage. The mantle covers the soft body, except for the adductor muscle area.

Mantle : The mantle fold spreads as a pair of two thin skirts from the hingeline down towards the bill, covering the viscera. The edges of the mantle have three lobes or folds which are mainly sensory and assist in controlling the flow of water to the body. The mantle edge lies close to the edge of the shell where most of the shell is deposited. By secretion of the mantle edge the shell increases in length and width.

Adductor muscle : This is a thick core of muscle which holds the shell valves together and brings about the movement of valves to perform the vital functions of the animal.

Gills : When both the free portions of the mantle are removed extending along the whole ventral part of the body are four long finely ridged structures - the gills. The gill filaments bear series of cilia which create an incoming water current through the ventral shell gape. The gill filaments perform both respiratory and food collecting functions. The filtered water is then passed out dorsally through the promyal chamber. The various ciliary tracts on the gill filaments carry the filtered particles to the palps and mouth. The mucus secreted by cell present in the the gills entangles particles floating in the water and prevents the clogging of the gills. The veins present in the gill axis branch into network of capillaries, which pass into each filament where blood is oxygenated.

Heart : Removal of the tissues anterior to the adductor muscle exposes the heart. It consists of a ventricle and two auricles, enclosed by the pericardium. The posterior vein reaches the auricle after drawing oxygenated blood from the gills. From the ventricle the colourless blood is pumped into the anterior aorta to supply the blood to the viscera of the body except the adductor muscle. The adductor muscle is supplied with blood separately by the posterior aorta from the ventricle. On the ventral margin of the pericardium a pair of nephridia are present for excretion.

Alimentary canal : The organs concerned with the collection, digestion and absorption of food comprise gills, labial palps, mouth, oesophagus, stomach, gut, digestive diverticula and the crystalline style sac. The greater part of the alimentary canal lies within the visceral mass.

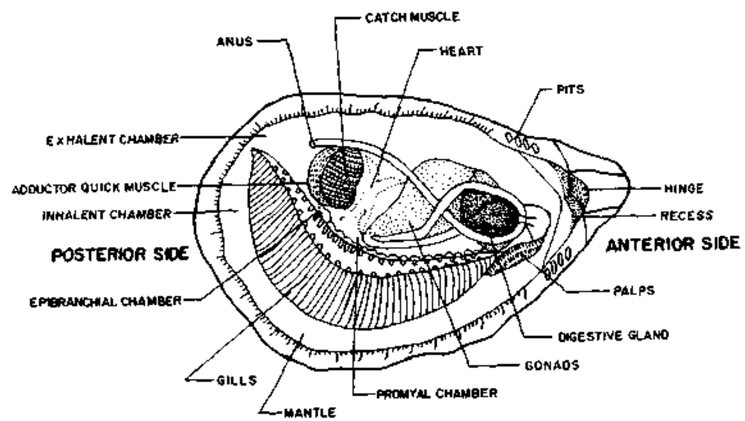


Fig. 4. Anatomy of an Edible oyster.

The food particles carried by streams of water pass through the gills and become entrapped in mucus and passed as mucus strings to the labial palps, where particles are sorted either to be passed on to the mouth or rejected as pseudofaeces. The ingested food is digested and absorbed extracellularly in the stomach and intracellularly in the digestive diverticula. The

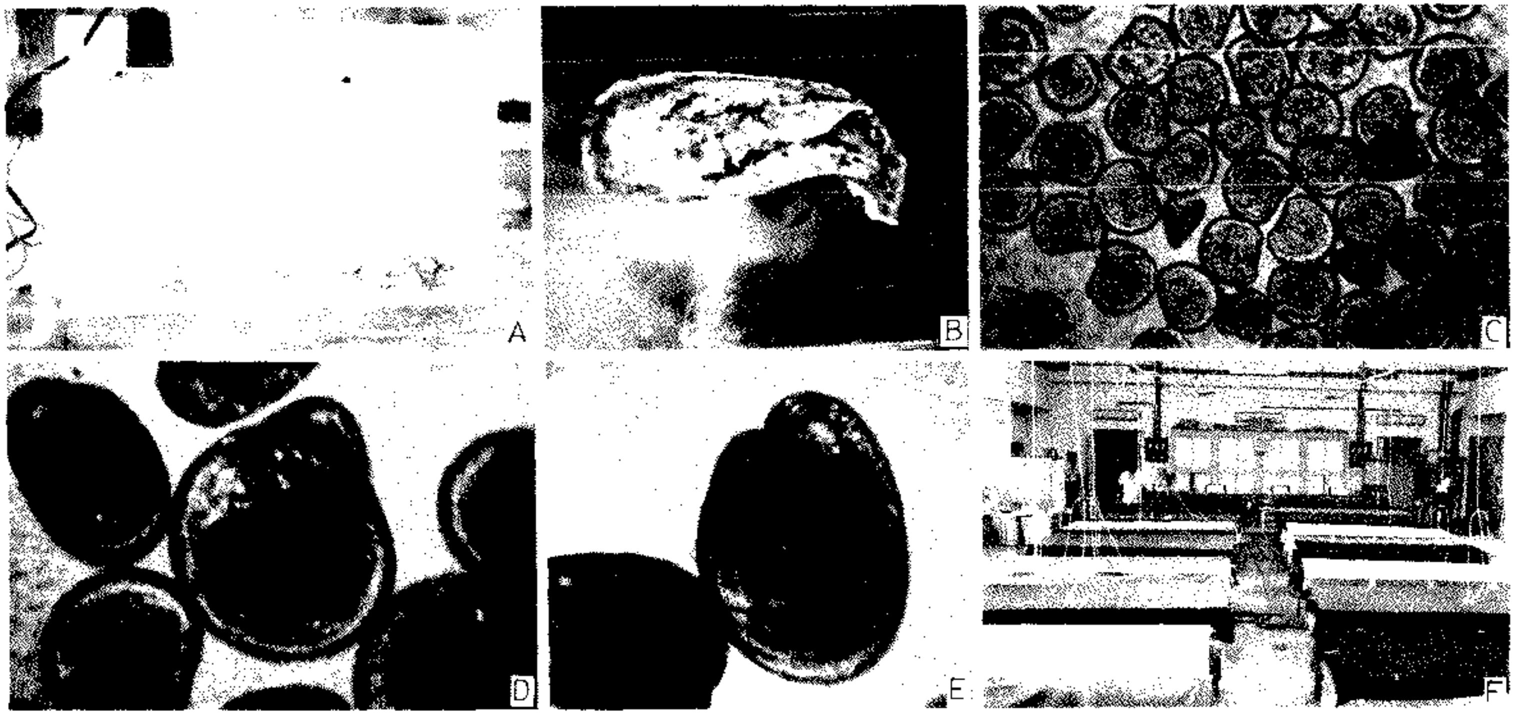


PLATE I : A. Oysters in spawning module, B. Spawning of a male oyster, C. 'D' shelled stage of Veliger, D. 'Umbo' stage of Veliger, E. Eyed stage of Veliger and F. Edible oyster Hatchery.

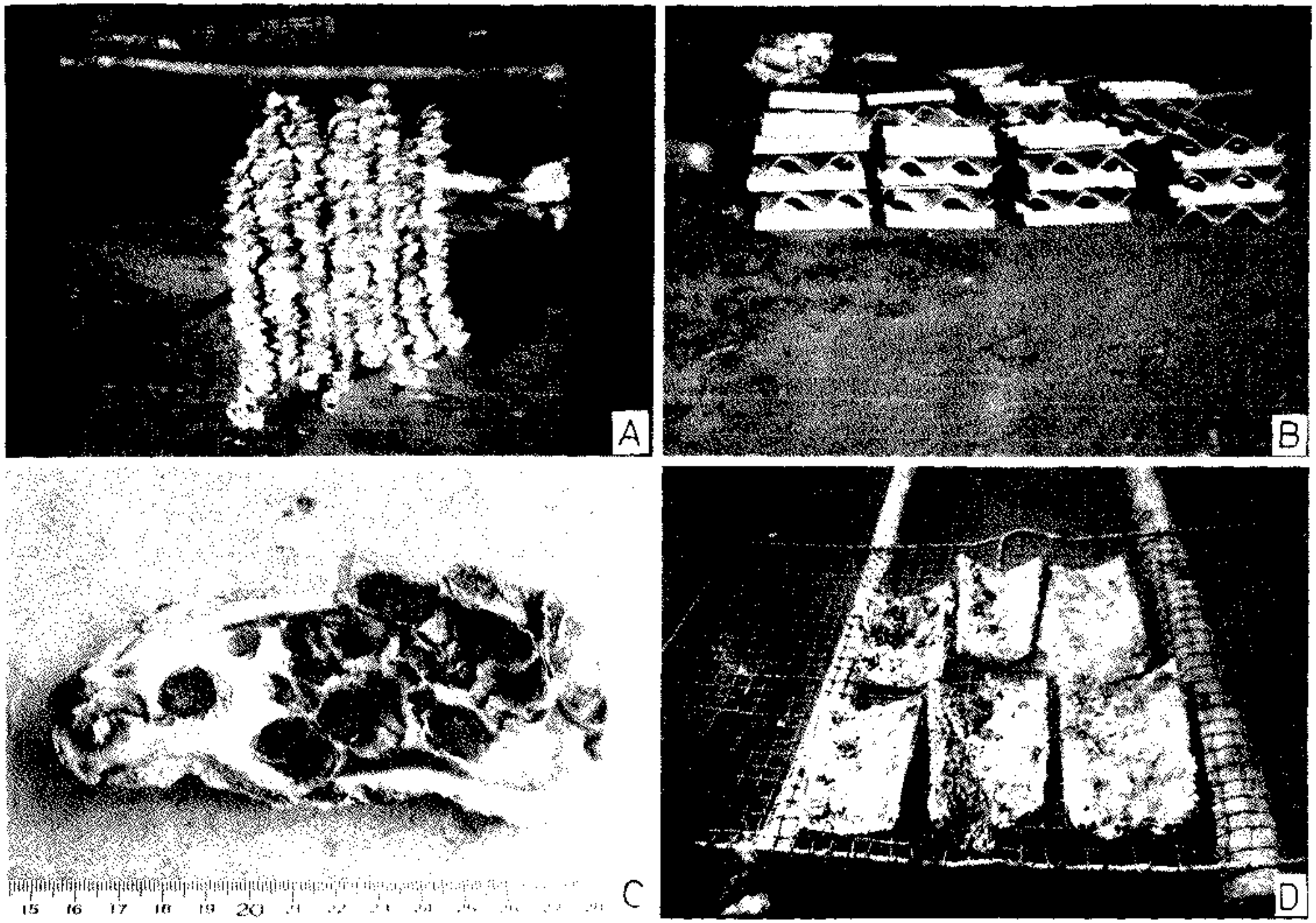


PLATE II : A. Shell strings for spat collection, B. Asbestos tiles for spat collection, C. Spats settled on oyster shell and D. Spats settled on tiles.

extracellular digestion in the stomach is effected by the chemical dissolution of crystalline style. The food waste from the midgut is passed on by the typhlosole channel into the hind gut from where the materials are further thrust by the epithelial cilia to the rectum and anus. The anus lies above the adductor muscle on the dorsal side.

The Nervous system : The nervous system is comparatively simple and consists of two pairs of ganglia - the cerebral and visceral ganglia, from which nerves lead to different parts of the body.

The Reproductive organs : In cupped oysters *(Crassostrea)* the sexes are separate. The ovary and the testis consist of a series of branching tubules or follicles on each side of the body covering the visceral organs. The ripe eggs and sperms pass along a series of tubules by the ciliary action in these tubules 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 epibranchial chamber and from there gametes are discharged to the exterior.

Biology

Food and feeding habits : The food of oysters mainly consists, of organic deritus and phytoplanktonic organisms such as diatoms and nanoplankters. Spores and particulate matter of seaweeds are also found in the stomach. Further, oysters are capable of absorbing dissolved organic matter in the water through the surfaces of the gills, palps and mantle.

The uptake of food largely depends on the pumping rate of the oysters. In sheltered areas under normal temperature and salinity an oyster can pump 28 to 30 litres of water/hour. Under tropical conditions in relatively sheltered areas on an average an oyster will be pumping nearly 20 hours in a day. This feature facilitates the oyster to grow fast.

However, it is not only temperature that influences the pumping rate of oyster, but also the changes in pH, salinity and concentratiion of particulate matter affect the pumping rate.

Growth and condition : Growth of oyster is expressed in terms of increment in length (height of the shell) and weight. The shell growth is correlated with the growth of the living tissues. In *C. madrasensis* the growth of spat is rapid during the first three months. A size of 38 mm is attained in 90 days registering a growth of 12.6 mm per month and at the end of one year an average size of 87 mm is recorded. However, the growth of oyster varies from place to place and is related to food availability and environmental conditions, particularly temperature and salinity. The Japanese oyster *Crassostrea gigas* reaches the marketable size of 75 to 85 mm in two years.

Condition of oyster denotes the degree of fatness of an oyster or the extent to which the meat fills the shell cavity. The size of the soft body of the oyster undergoes changes and such changes are usually associated with the breeding cycle. This is accomplished by an increase in size of the reproductive organs during maturation followed by a considerable reduction after spawning. This process is followed by a slow increase in body size. In temperate waters, the increased level of glycogen has been associated with this phase. But in tropical waters this phase of glycogen accumulation is generally distorted. Changes in the meat content of an oyster are important to the culturist as these greatly determine the meat yield and financial return. Thus the knowledge of the seasonal fatness cycle is important for successful marketing.

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

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

Breeding: Oysters generally are dioecious, but hermaphrodites are not uncommon. Young oysters (*C. madrasensis*) function primarily as males (60 - 75%) and later become female. In 'O' age group (upto 78 mm in length), 75 % are males and in one year old and above, ranging in length from 80 - 115.5 mm, females represent 72 %.

In larviparous oysters (Genus : *Ostrea*) the egg is about 100 µ in diameter and is large when compared to those of the oviparous oysters (Genus : *Crassostrea*). The eggs of *C.madrasensis* are 48 to 60 µ in diameter. Further, the fecundity of larviparous oysters is comparatively much lower than in oviparous oysters. At a time a single female *C. madrasensis* of 80 to 90 mm length will spawn 10-15 million eggs.

Along Tamil Nadu Coast *C. madrasensis* with mature gonads occurs almost throughout the year. But the percentage of mature oysters was found to be high during March - April and July - September indicating peak spawning activity in these months. Among the various factors that influence the maturity of gonads, temperature is the most important factor.

The flat oysters (*Ostrea*) and the cupped oysters (*Crassostrea*) have different spawning habits. In *Ostrea* the eggs released from the gonad are retained in the mantle cavity within the inhalent chamber. The sperms discharged by spawning males enter with the inhalent water current and fertilize the eggs. The larval life partly takes place inside the shell before being released into the water. Hence these oysters are called incubatory or larviparous forms. In *Crassostrea* both the eggs and sperms are discharged directly outside into the water where fertilization and subsequent development take place. The process by which the sperms and eggs are discharged is 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 the exhalent opening and they quickly disperse in water. The spawning process is more complex in female oysters. It 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 mantle close except for a small opening in the inhalent chamber. The female rhythmically ejects the eggs through the inhalent opening.

Eggs lose their viability totally at the end of 24 hours in temperate regions and under tropical conditions, it is lost within 4 hours. Therefore to ensure optimum fertilization freshly released eggs and sperms should be mixed instantaneously.

In fertilized eggs of *C. madrasensis*, the first cleavage occurs immediately after the formation of two polar bodies within 45 minutes. The first veliger or straight-hinge stage is reached at the end of 20 hours. In *Ostrea* the large, heavily yolk laden eggs after fertilization undergo development in the inhalent chamber and the larvae are released at a size of 220 µ at the end of 7 to 8 days.

The sequence of events in the development and growth of the larvae of *C. madrasensis* are similar to that of the American oyster *Crassostrea virginica* and the Pacific oyster *C. gigas*. The larvae of *C. madrasensis* attain eyed-stage on the 13th day and setting takes place on 14th to 15th day. Growth and setting of larvae of *C. madrasensis* largely depends on the availability of food and favourable hydrographic conditions.

TECHNOLOGY OF OYSTER CULTURE

In general the molluscs account for over 40% of the total world aquaculture production from the marine environment. Among them, the oysters with a production of 9.62 lakh tonnes contributed to 36% in 1987. The cultivated oysters belong to two genera namely *Crassostrea* and *Ostrea*. The former is more widely and intensively farmed. The important species of oysters, traditionally cultivated in temperate regions are :

The Pacific oyster	*Crassostrea gigas*
The American oyster	*C. virginica*
The Portuguese oyster	*C. angulata*
The Australian Rock oyster	*C. commercialis*
The New Zealand oyster	*C. glomerata*
The European oyster	*Ostrea edulis*
The Olympian oyster	*Ostrea lurida*

In the tropical regions Oyster culture is of recent origin and the species of oysters selected for cultivation are :

The Carribean oyster	*Crassostrea rhizophorae*
The Brazilian oyster	*C. brasiliana*
The Mexican oyster	*C. corteziensis*
The West African oyster	*C. tulipa*
The Philippine oyster	*C. iredalei*
The Malaysian oyster	*C. belcheri*
The Chinese oyster	*C. rivularis*
The Indian backwater oyster	*C. madrasensis*

The culture systems in these countries are being developed based on the practices followed in temperate zone.

In India, two decades back the Central Marine Fisheries Research Institute has initiated investigations on various aspects of culture of *Crassostrea madrasensis*. As a prerequisite detailed investigations on oyster resources, biology and the role palyed by environmental parameters have been conducted and valuable information has been collected. These data helped a lot in the development of oyster culture on scientific lines in India. After experimenting on various methods of farming for several years, the Institute has developed a complete package of viable technology for Oyster farming including hatchery production of seeds.

The technology of Oyster culture consists of two important phases namely, oyster seed production and farming to grow oyster seeds to marketable size.

after fertilization undergo development in the inhalent chamber and the larvae are released at a size of 220 μ at the end of 7 to 8 days.

The sequence of events in the development and growth of the larvae of C. *madrasensis* are similar to that of the American oyster *Crassostrea virginica* and the Pacific oyster C. *gigas*. The larvae of C. *madrasensis* attain eyed-stage on the 13th day and setting takes place on 14th to 15th day. Growth and setting of larvae of C. *madrasensis* largely depends on the availability of food and favourable hydrographic conditions.

TECHNOLOGY OF OYSTER CULTURE

In general the molluscs account for over 40% of the total world aquaculture production from the marine environment. Among them, the oysters with a production of 9.62 lakh tonnes contributed to 36% in 1987. The cultivated oysters belong to two genera namely *Crassostrea* and *Ostrea*. The former is more widely and intensively farmed. The important species of oysters, traditionally cultivated in temperate regions are :

The Pacific oyster *Crassostrea gigas*
The American oyster C. *virginica*
The Portuguese oyster C. *angulata*
The Australian Rock oyster C. *commercialis*
The New Zealand oyster C. *glomerata*
The European oyster *Ostrea edulis*
The Olympian oyster *Ostrea lurida*

In the tropical regions Oyster culture is of recent origin and the species of oysters selected for cultivation are :

The Carribean oyster *Crassostrea rhizophorae*
The Brazilian oyster C. *brasiliana*
The Mexican oyster C. *corteziensis*
The West African oyster C. *tulipa*
The Philippine oyster C. *iredalei*
The Malaysian oyster C. *belcheri*
The Chinese oyster C. *rivularis*
The Indian backwater oyster C. *madrasensis*

The culture systems in these countries are being developed based on the practices followed in temperate zone.

In India, two decades back the Central Marine Fisheries Research Institute has initiated investigations on various aspects of culture of *Crassostrea madrasensis*. As a prerequisite detailed investigations on oyster resources, biology and the role palyed by environmental parameters have been conducted and valuable information has been collected. These data helped a lot in the development of oyster culture on scientific lines in India. After experimenting on various methods of farming for several years, the Institute has developed a complete package of viable technology for Oyster farming including hatchery production of seeds.

The technology of Oyster culture consists of two important phases namely, oyster seed production and farming to grow oyster seeds to marketable size.

Oyster Seed Production

Spat collection from nature

The seed requirement for culture is met from natural spat collection or through hatchery system. For collection of spat from natural grounds, suitable spat collectors or cultch materials are provided at appropriate time. The choice of spat collectors depends on the culture method adopted, material availability, and economic and practical considerations. In Oyster culture experiments carried out at Tuticorin, Oyster shells, coconut shells, asbestos sheets, mussel shells and semicylindrical roofing tiles were tried on a large scale.

Shells of oysters, mussels and coconuts are arranged on nylon rope or G.I. wire as strings and suspended from racks. Bundles of corrugated asbestos sheets and lime-coated tiles are arranged on trays and placed on racks. The timing of placement of the spat collectors is very important for obtaining good spat settlement. If the collectors are placed in the water much earlier to the occurrence of spatfall, the materials get silted or fouled, rendering the collectors unsuitable for the settlement of spat. The condition of the spat collector and methodology of exposure are the prime factors for spat collection. The spat collectors must be finely roughened, free from slime and without any secretion such as gums and resins. The collectors must be strong enough to retain the oysters till they reach marketable size. They should also withstand wave action and attack of boring organisms. Spreading them on the bottom or placing them on racks or suspending them from raft are the methods of exposure of spat collectors in the water column. Raft suspension method is efficient, but the cost of floatation is high. The rack system for spat collection is efficient as attack by benthic predators is minimum and recovery rate of spat collectors with seed is high.

Spatfall prediction

The prediction of spatfall is based on the study of the ripeness of gonads of the population of oysters and the appearance of oyster larvae in the plankton samples of the area. The presence of early stages of oyster larvae indicates the occurrence of recent spawning and the abundance of the larvae in plankton samples shows the peak or intensity of spawning. Based on the information on larval growth and duration of larval life, a prediction of the approximate time (days) of spat-fall is possible. The larval period of C. *madrasensis* is 15 to 20 days. The exposure of collectors will be ideal just after a week or 10 days of peak spawning activity.

Mass production of oyster seed in hatchery system

In 1980, the Central Marine Fisheries Research Institute initiated experiments to produce oyster seed through the hatchery technique. On the establishment of Shellfish Laboratory at Tuticorin, the Institute succeeded in mass production of both cultched and cultchfree spat. The production of oyster seed by hatchery techniques is accomplished in six phases of operation *viz*. 1. Selection and holding of broodstock, 2. Induced spawning, 3. Larval rearing, 4. Preparation of cultch materials, 5. Production of spat and 6. Culture of algal food (Plate I).

Selection and holding of broodstock

The broodstocks are selected keeping in view the area, condition factor and age of oysters. As far as possible it should

Oyster Seed Production

Spat collection from nature

The seed requirement for culture is met from natural spat collection or through hatchery system. For collection of spat from natural grounds, suitable spat collectors or cultch materials are provided at appropriate time. The choice of spat collectors depends on the culture method adopted, material availability, and economic and practical considerations. In Oyster culture experiments carried out at Tuticorin, Oyster shells, coconut shells, asbestos sheets, mussel shells and semicylindrical roofing tiles were tried on a large scale.

Shells of oysters, mussels and coconuts are arranged on nylon rope or G.I. wire as strings and suspended from racks. Bundles of corrugated asbestos sheets and lime-coated tiles are arranged on trays and placed on racks. The timing of placement of the spat collectors is very important for obtaining good spat settlement. If the collectors are placed in the water much earlier to the occurrence of spatfall, the materials get silted or fouled, rendering the collectors unsuitable for the settlement of spat. The condition of the spat collector and methodology of exposure are the prime factors for spat collection. The spat collectors must be finely roughened, free from slime and without any secretion such as gums and resins. The collectors must be strong enough to retain the oysters till they reach marketable size. They should also withstand wave action and attack of boring organisms. Spreading them on the bottom or placing them on racks or suspending them from raft are the methods of exposure of spat collectors in the water column. Raft suspension method is efficient, but the cost of floatation is high. The rack system for spat collection is efficient as attack by benthic predators is minimum and recovery rate of spat collectors with seed is high.

Spatfall prediction

The prediction of spatfall is based on the study of the ripeness of gonads of the population of oysters and the appearance of oyster larvae in the plankton samples of the area. The presence of early stages of oyster larvae indicates the occurrence of recent spawning and the abundance of the larvae in plankton samples shows the peak or intensity of spawning. Based on the information on larval growth and duration of larval life, a prediction of the approximate time (days) of spat-fall is possible. The larval period of *C. madrasensis* is 15 to 20 days. The exposure of collectors will be ideal just after a week or 10 days of peak spawning activity.

Mass production of oyster seed in hatchery system

In 1980, the Central Marine Fisheries Research Institute initiated experiments to produce oyster seed through the hatchery technique. On the establishment of Shellfish Laboratory at Tuticorin, the Institute succeeded in mass production of both cultched and cultchfree spat. The production of oyster seed by hatchery techniques is accomplished in six phases of operation *viz.* 1. Selection and holding of broodstock, 2. Induced spawning, 3. Larval rearing, 4. Preparation of cultch materials, 5. Production of spat and 6. Culture of algal food (Plate I).

Selection and holding of broodstock

The broodstocks are selected keeping in view the area, condition factor and age of oysters. As far as possible it should

Oyster Seed Production

Spat collection from nature

The seed requirement for culture is met from natural spat collection or through hatchery system. For collection of spat from natural grounds, suitable spat collectors or cultch materials are provided at appropriate time. The choice of spat collectors depends on the culture method adopted, material availability, and economic and practical considerations. In Oyster culture experiments carried out at Tuticorin, Oyster shells, coconut shells, asbestos sheets, mussel shells and semicylindrical roofing tiles were tried on a large scale.

Shells of oysters, mussels and coconuts are arranged on nylon rope or G.I. wire as strings and suspended from racks. Bundles of corrugated asbestos sheets and lime-coated tiles are arranged on trays and placed on racks. The timing of placement of the spat collectors is very important for obtaining good spat settlement. If the collectors are placed in the water much earlier to the occurrence of spatfall, the materials get silted or fouled, rendering the collectors unsuitable for the settlement of spat. The condition of the spat collector and methodology of exposure are the prime factors for spat collection. The spat collectors must be finely roughened, free from slime and without any secretion such as gums and resins. The collectors must be strong enough to retain the oysters till they reach marketable size. They should also withstand wave action and attack of boring organisms. Spreading them on the bottom or placing them on racks or suspending them from raft are the methods of exposure of spat collectors in the water column. Raft suspension method is efficient, but the cost of floatation is high. The rack system for spat collection is efficient as attack by benthic predators is minimum and recovery rate of spat collectors with seed is high.

Spatfall prediction

The prediction of spatfall is based on the study of the ripeness of gonads of the population of oysters and the appearance of oyster larvae in the plankton samples of the area. The presence of early stages of oyster larvae indicates the occurrence of recent spawning and the abundance of the larvae in plankton samples shows the peak or intensity of spawning. Based on the information on larval growth and duration of larval life, a prediction of the approximate time (days) of spat-fall is possible. The larval period of *C. madrasensis* is 15 to 20 days. The exposure of collectors will be ideal just after a week or 10 days of peak spawning activity.

Mass production of oyster seed in hatchery system

In 1980, the Central Marine Fisheries Research Institute initiated experiments to produce oyster seed through the hatchery technique. On the establishment of Shellfish Laboratory at Tuticorin, the Institute succeeded in mass production of both cultched and cultchfree spat. The production of oyster seed by hatchery techniques is accomplished in six phases of operation *viz.* 1. Selection and holding of broodstock, 2. Induced spawning, 3. Larval rearing, 4. Preparation of cultch materials, 5. Production of spat and 6. Culture of algal food (Plate I).

Selection and holding of broodstock

The broodstocks are selected keeping in view the area, condition factor and age of oysters. As far as possible it should

Oyster Seed Production

Spat collection from nature

The seed requirement for culture is met from natural spat collection or through hatchery system. For collection of spat from natural grounds, suitable spat collectors or cultch materials are provided at appropriate time. The choice of spat collectors depends on the culture method adopted, material availability, and economic and practical considerations. In Oyster culture experiments carried out at Tuticorin, Oyster shells, coconut shells, asbestos sheets, mussel shells and semicylindrical roofing tiles were tried on a large scale.

Shells of oysters, mussels and coconuts are arranged on nylon rope or G.I. wire as strings and suspended from racks. Bundles of corrugated asbestos sheets and lime-coated tiles are arranged on trays and placed on racks. The timing of placement of the spat collectors is very important for obtaining good spat settlement. If the collectors are placed in the water much earlier to the occurrence of spatfall, the materials get silted or fouled, rendering the collectors unsuitable for the settlement of spat. The condition of the spat collector and methodology of exposure are the prime factors for spat collection. The spat collectors must be finely roughened, free from slime and without any secretion such as gums and resins. The collectors must be strong enough to retain the oysters till they reach marketable size. They should also withstand wave action and attack of boring organisms. Spreading them on the bottom or placing them on racks or suspending them from raft are the methods of exposure of spat collectors in the water column. Raft suspension method is efficient, but the cost of floatation is high. The rack system for spat collection is efficient as attack by benthic predators is minimum and recovery rate of spat collectors with seed is high.

Spatfall prediction

The prediction of spatfall is based on the study of the ripeness of gonads of the population of oysters and the appearance of oyster larvae in the plankton samples of the area. The presence of early stages of oyster larvae indicates the occurrence of recent spawning and the abundance of the larvae in plankton samples shows the peak or intensity of spawning. Based on the information on larval growth and duration of larval life, a prediction of the approximate time (days) of spat-fall is possible. The larval period of *C. madrasensis* is 15 to 20 days. The exposure of collectors will be ideal just after a week or 10 days of peak spawning activity.

Mass production of oyster seed in hatchery system

In 1980, the Central Marine Fisheries Research Institute initiated experiments to produce oyster seed through the hatchery technique. On the establishment of Shellfish Laboratory at Tuticorin, the Institute succeeded in mass production of both cultched and cultchfree spat. The production of oyster seed by hatchery techniques is accomplished in six phases of operation *viz.* 1. Selection and holding of broodstock, 2. Induced spawning, 3. Larval rearing, 4. Preparation of cultch materials, 5. Production of spat and 6. Culture of algal food (Plate I).

Selection and holding of broodstock

The broodstocks are selected keeping in view the area, condition factor and age of oysters. As far as possible it should

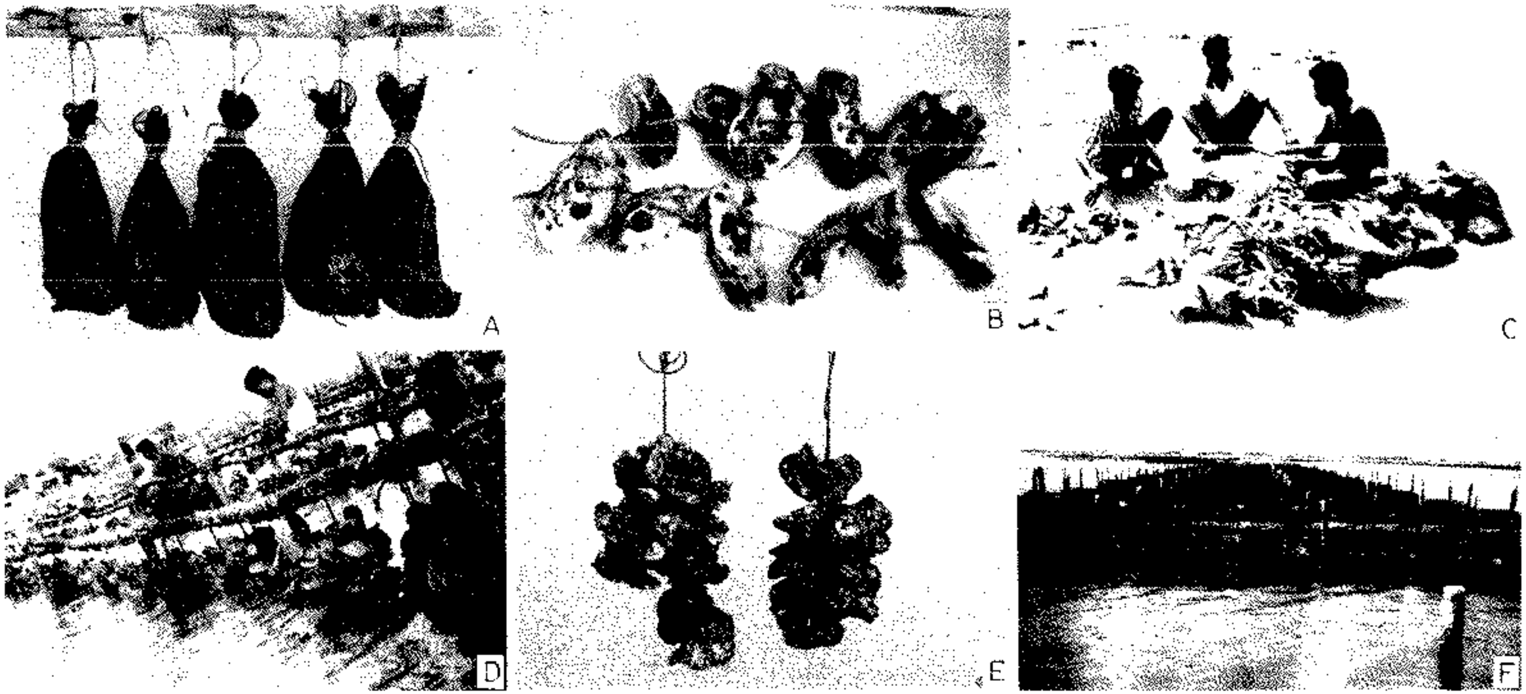


PLATE III : A. Oyster seeds in net bags for nursery rearing, B. Spats in shell strings, C. Cleaning of nursery reared oysters, D. An Oyster Farm by Ren method, E. Fully grown oysters on shell strings and F. An Oyster Farm by Rack and Tray method.

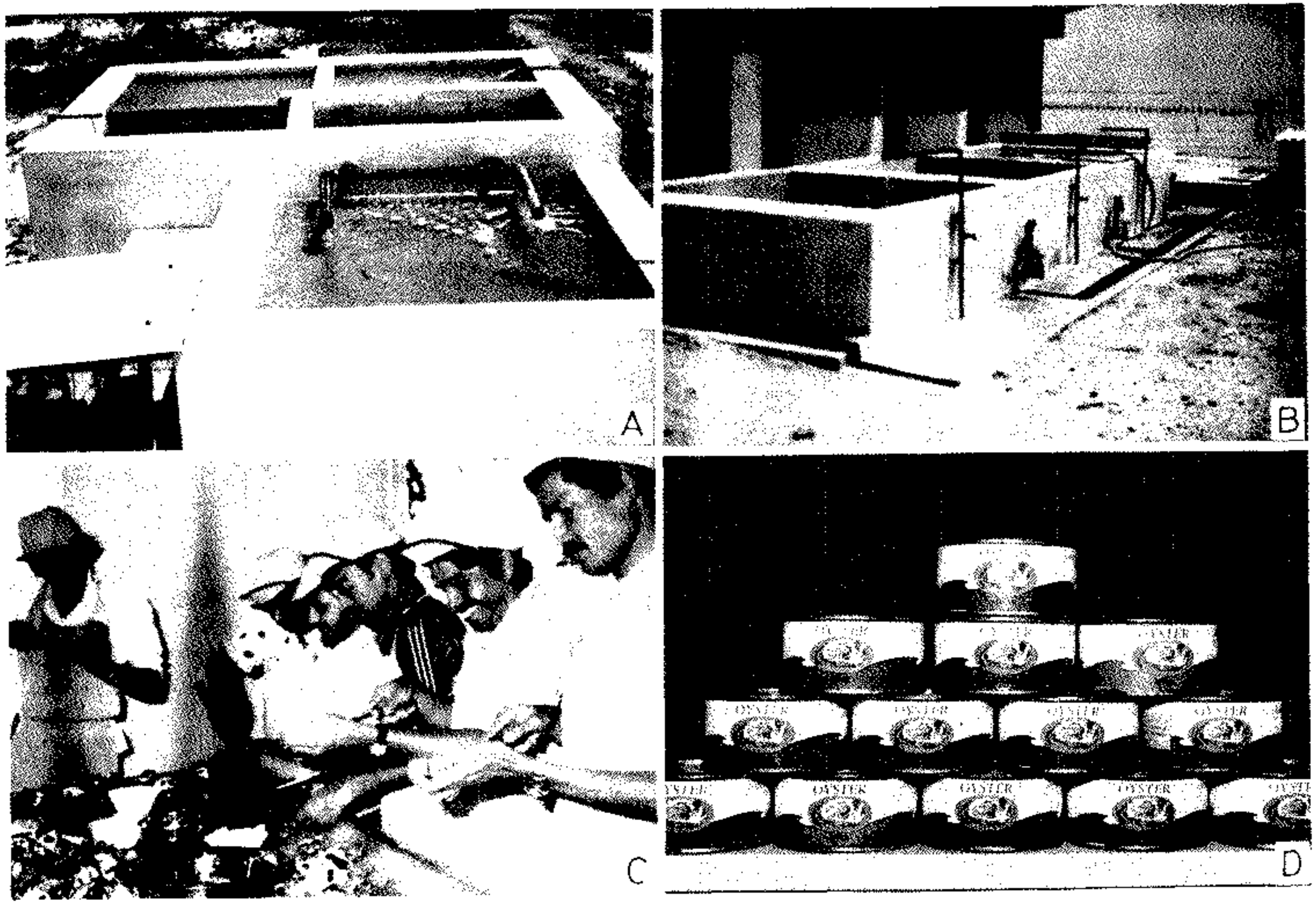


PLATE IV : A. Sea water purification unit, B. Depuration tanks, C. Shucking of oysters and D. Farm grown Edible oyster products in cans.

be a mixed and heterogenous stock, selected from several areas. The oysters selected for conditioning for breeding are collected from areas where salinity regime is comparable to that of the hatchery. Otherwise the oysters have to be acclimatised before they are conditioned. The prevailing temperature of the collection area has to be first recorded, since based on this, manipulation of temperature regime is effected for conditioning of the oysters for induced spawning.

Oysters of the length range 60 mm to 90 mm are ideal and 30% of them should be of 'O' age group (60 - 75 mm) in order to be assured of the availability of males in the broodstock. Oysters which show dominance in maturing and ripe stages of gonad development are selected.

The selected oysters, comprising 25 in each batch are cleaned thoroughly and placed on synthetic twine knit P.V.C frame in a 100 l fibreglass tank (75 x 50 x 25 cm) and natural precooled seawater (at 20° to 22°C) is filled in the tank and aerated. About 2 to 3 l of mixed algal culture, precooled to 20 to 22°C is added to the tank twice a day. The algal cell concentration should be around 1.5 to 2.0 million cells/ml. The oysters are conditioned at a temperature 10°C below the ambient.

Induced spawning

The conditioned oysters are induced to spawn by suddenly transferring them to seawater with a temperature of 34 to 35°C. The sudden change of water temperature stimulates spawning of oysters. The spawning oysters are immediately transferred to separate spawning trays containing filtered seawater at ambient temperature. Once spawning is completed, the oysters are removed from the tray.

Fertilization and early development

The gametes are mixed and held in containers and gently aerated. The fertilized eggs undergo first cleavage within 45 minutes and further cell divisions follow. At the end of 4 hours the eggs attain morula stage and begin to swim. At the end of 20 hours the straight-hinge or 'D' shelled larval stage is attained.

Larval rearing

The sequence of development of the larvae from straight-hinge to pediveliger stage is as follows.

Stage	*Size in μ*	*Hours/days*
Straight-hinge	60 to 70	20 hrs
Early umbo	100	3rd day
Mid umbo	150	7th day
Advanced umbo	260 to 270	12th to 15th day
Eyed larva	280 to 290	13th to 17th day
Pediveliger	330 to 350	14th to 18th day

Rearing density and feeding of larvae

As the larvae grow, the concentration of larvae in the rearing medium is reduced since the growing larvae require greater space for optimal feeding and growth. The rearing density of larvae at various stages and feeding protocol are as follows :

Stage of larvae	*Density of larvae/ml*	*Algal cell concentration in ml/larva/day*
Straight-hinge	5	3000 - 4000
Umbo	3	4000 - 5000
Advanced umbo to Eyed stage	2	5000 - 8000
Pediveliger	2	10,000 - 12,000

Preparation of cultch materials and setting of spat

The spat collectors used in the hatchery are non-toxic and clean. These materials should not alter the quality of the rearing medium especially salinity and pH. The most preferable spat collectors are oyster shells. A hole is drilled at the centre of the shell, brushed well, washed in chlorinated water and pretreated by soaking and repeated washings in seawater. By this process the pH of the water in rearing tanks will not be affected.

These shells are spread uniformly at the bottom of FRP tanks containing filtered seawater and several rows of shell rens are also suspended in order to increase the surface area for settlement in the tank. When majority of the larvae pass off the eyed stage (300 -350 µ) they are released into the tanks at a concentration of 1 larva/ml and the seawater is well aerated. During the next few days the larvae set on the shells and majority of the larvae settle on the concave side of the shells (Plate II).

Oyster shell grit and polyethylene sheets are used for the production of cultchless spat. Oyster shell grit of 0.5 mm in size are washed thoroughly, sterilized in 10 ppm chlorine, washed once more in running filtered seawater and dried. The shell grit are uniformly spread at the bottom of one tonne capacity FRP tank and the larvae at setting stage are released. The bottom and sides of the tank are lined with pretreated polyethylene sheet and the released larvae settle on the sheet.

Culture of algal food

The success of the hatchery operation depends mainly on the availability of adequate larval food - the microalgae. The phytoflagellates namely *Isochrysis galbana, Pavlova* sp., *Dicrateria* sp. and *Chromulina* sp. are suitable as food for the larvae. All these flagellates measure 7-8 µ and have 26 - 38% of protein by weight. The algal culture is carried out in Conway or Walne's medium. The medium contains the nutrients, trace metals and vitamins (B_1 and B_{12}).

The culture is carried out in glass carbouys, polythene bags or perspex tanks depending on the requirements of the hatchery. Adequate illumination and aeration are provided for the culture. The temperature of the algal culture room is maintained at 23-25°C.

The culture is harvested at the growing phase within 3 to 4 days after the inoculation of the medium when the cell concentration reaches 1.0 to 2.0 million cells per ml.

The selection of site for the hatchery is an important aspect. The seawater source at the location of hatchery should be free from pollutants both domestic and industrial and water with wide range of salinity will not be suitable. An efficient seawater filtration system is one of the essential requirements for the hatchery. Systems for air circulation, temperature control and for continuous production of algal food are other important requisites.

Farming Methods

Selection of an appropriate method of culture for any given area is evaluated on the basis of the following factors. They are salinity, depth, substrate, tidal flow, wave action, turbidity, productivity, growth of oysters, fouling, predation and pollution. A quantitative evaluation of the various factors will be helpful in selecting the site for farming. However, the critical levels of various parameters will be differing with different species and methods of culture. For instance among Indian oysters, *Saccostrea cucullata* thrives well in marine environment and can withstand currents and wave action, whereas *C. madrasensis*, *C. rivularis* and *C. griphoides* are euryhaline forms mainly inhabiting in backwaters. Further the on-bottom culture method is substrate specific and the area should be under constant influence of tidal flow and free from predators and silting. Off-bottom method has little to do with the type of sediment, benthic predators and silting. Rich availability of food for oysters and proper farm management are other requirements for a good yield of oysters.

Bottom culture

As the name implies, the oysters are grown directly on the bottom, either intertidally or subtidally. In either case the bottom should be reasonably firm. Also in the case of intertidal areas, the ground should be submerged for a minimum period of 16 hr per day to ensure food availability to the oysters. Strong currents and wave action are negative factors.

In this method the seed oysters attached to the spat collectors, like oyster shells and tiles are planted on the bottom and allowed to grow. The growth is initially rapid as the oysters attain 38 mm in 90 days, registering a growth rate of 12.6 mm per month. At the end of one year the oysters attain an average length of 86 mm and are ready for harvest.

On-bottom method culture is practised extensively in U.S.A. and the oysters grow to marketable size at the end of 3 to 4 years. The oyster production by this method is low and amounts to 5 t/ha/year in U.S.A. and 7.5 t/ha/year in France. In India the bottom culture is yet to be experimented

Off-bottom culture

Off-bottom culture is a method whereby the growing oysters are reared off the bottom by various structures such as rafts, racks or stakes. This method is advantageous over the former method in the following aspects.

1. Relatively rapid growth and good meat yield.
2. Facilitates three dimensional utilization of the culture area.
3. Makes it possible to carry out functions such as filtration, feeding, etc. irrespective of the flow of tide.
4. Silting and predatory problems are minimum.

Rack and string method

This method is practised in two phases.

1. Nursery rearing of seed oysters.
2. Growing of oysters to marketable size.

The oyster spats collected on shell string are enclosed in velon screen bags and suspended from racks in nursery areas which are relatively calm with good movement of water by tides. A string can hold six shell valves containing around 80 to 100 spats and 3 to 4 strings are enclosed in a bag. After 40 to 50 days the bags are removed and the strings are transferred to farm area.

In the farm the shell strings are suspended from racks. From each rack 90 strings are suspended and each rack occupies 80 sq.m area. In one hectare 125 racks can be constructed. Periodic monitoring is carried out and broken or damaged poles are replaced. The growth of the oysters has been recorded as 8.3 mm per month. At the end of 12th month, on an average, each string weighs around 7 to 7.5 kg. The production rate per hactare is estimated as 80 tonnes.

Rack and tray method

The young cultch free seed oysters are stocked in box type nursery trays and suspended from racks. After 60 days of nursery rearing the seeds are transferred to large rectangular trays of the size 90 x 60 x 15 cm and placed on the racks. Each rack occupies 25 sq. m and in one hectare area 400 racks can be constructed. At the end of twelve months the oyster attains an average length of 85 mm and the average growth rate is 7.0 mm/month. The annual production per hectare is estimated at 120 t. Although the production rate is very high when compared to other methods, costwise this method involves large investment (Plate III).

Stake culture

The stake is the support used to keep the spats with the spat collectors above the bottom. A stake with a nail on the top end, two nails on the sides, is driven into the ground. The nail holds in place, a shell with the spat. Each stake occupies an area of 0.6 sq.m. To protect the spat against predation, initially the top of the stake with the shell is covered with a piece of velon screen. Once the oysters attain 25 - 30 mm, the velon screen is removed and the oysters are grown on stakes for 10 months. The growth of oysters in this method is almost the same as that of the oysters raised by string method. The production per hectare has been estimated to be 20 t/ha/year.

Harvesting of Oysters and Post-harvest Management

Oysters are harvested when the condition of the meat reaches high value. In *C. madrasensis*, at Tuticorin the condition of meat is found to be good during March-April and August-September. Harvesting is done manually and oysters are transported to shore in dinghies.

Depuration

During depuration the shellfish are placed in cleaning tanks under a flow of filtered seawater. In this system 10-20% of the seawater is continuously replaced in the tanks and the oysters are held for 24 hours. As a result the bacterial load of the shellfish is reduced. During depuration at the end of 12 hours the water in the tank is drained and the oysters are cleaned by hosing a strong jet of water to remove the accumulated faeces. Again the tanks are filled with filtered seawater and the flow is maintained for another 12 hours. At the end of this period, the tanks are drained again and flushed by hosing water. Finally the oysters are held for one hour in 3 ppm chlorine seawater. Then the oysters are washed once more in filtered seawater and kept ready for marketing (Plate IV).

tides. A string can hold six shell valves containing around 80 to 100 spats and 3 to 4 strings are enclosed in a bag. After 40 to 50 days the bags are removed and the strings are transferred to farm area.

In the farm the shell strings are suspended from racks. From each rack 90 strings are suspended and each rack occupies 80 sq.m area. In one hectare 125 racks can be constructed. Periodic monitoring is carried out and broken or damaged poles are replaced. The growth of the oysters has been recorded as 8.3 mm per month. At the end of 12th month, on an average, each string weighs around 7 to 7.5 kg. The production rate per hactare is estimated as 80 tonnes.

Rack and tray method

The young cultch free seed oysters are stocked in box type nursery trays and suspended from racks. After 60 days of nursery rearing the seeds are transferred to large rectangular trays of the size 90 x 60 x 15 cm and placed on the racks. Each rack occupies 25 sq. m and in one hectare area 400 racks can be constructed. At the end of twelve months the oyster attains an average length of 85 mm and the average growth rate is 7.0 mm/month. The annual production per hectare is estimated at 120 t. Although the production rate is very high when compared to other methods, costwise this method involves large investment (Plate III).

Stake culture

The stake is the support used to keep the spats with the spat collectors above the bottom. A stake with a nail on the top end, two nails on the sides, is driven into the ground. The nail holds in place, a shell with the spat. Each stake occupies an area of 0.6 sq.m. To protect the spat against predation, initially the top of the stake with the shell is covered with a piece of velon screen. Once the oysters attain 25 - 30 mm, the velon screen is removed and the oysters are grown on stakes for 10 months. The growth of oysters in this method is almost the same as that of the oysters raised by string method. The production per hectare has been estimated to be 20 t/ha/year.

Harvesting of Oysters and Post-harvest Management

Oysters are harvested when the condition of the meat reaches high value. In *C. madrasensis*, at Tuticorin the condition of meat is found to be good during March-April and August-September. Harvesting is done manually and oysters are transported to shore in dinghies.

Depuration

During depuration the shellfish are placed in cleaning tanks under a flow of filtered seawater. In this system 10-20% of the seawater is continuously replaced in the tanks and the oysters are held for 24 hours. As a result the bacterial load of the shellfish is reduced. During depuration at the end of 12 hours the water in the tank is drained and the oysters are cleaned by hosing a strong jet of water to remove the accumulated faeces. Again the tanks are filled with filtered seawater and the flow is maintained for another 12 hours. At the end of this period, the tanks are drained again and flushed by hosing water. Finally the oysters are held for one hour in 3 ppm chlorine seawater. Then the oysters are washed once more in filtered seawater and kept ready for marketing (Plate IV).

Transport and storage of live oysters

Oysters can survive out of water for several days, if carefully handled and kept moist and cool. However, it is desirable that the oysters reach the consumer market within three days of harvest, if they are to be in prime condition. Experiments indicate that live marketable size oysters packed in wet gunny bags can safely be transported for 25 - 30 hours without mortality and in good condition. Small holding tanks having filtered seawater or artificial seawater and provided with adequate aeration, would keep the oysters alive for a few days at the wholesalers premises.

Shucking

Shucking is the removal of meat from the oyster. One develops skill in shucking after some experience. The materials required for shucking are the shucking table, shucking knives, a perforated stainless steel table and rubber gloves for preventing cuts from the sharp edges of the oyster shell. The shucking knife is made of stainless steel, 30 mm long with a stout wooden handle and the farther end of the knife is flattened into a cutting edge of 2.5 to 3.0 cm.

The flat valve or the right valve is removed by inserting the blade of the shucking knife between the two valves of the shell close to the hinge. After the knife edge has entered inside, the blade is forced further into the shell cavity of the oyster to about 2 to 3 cm in order to cut the adductor muscle attached to the upper valve. The upper valve is removed, the oyster meat is separated by cutting the base of the adductor muscle attached to lower valve and flipped into the container. If the oyster is to be served on the halfshell, it is cleaned from shell fragments and retained in the cupped lower valve.

Several methods have been tried to render shucking easy. These include the shearing of the hinge of the oysters by guillotine and a wide range of treatments that cause the shell to gape open such as the use of chemicals (weak hydrochloric acid), heat, cold, vacuum, microwaves and lasers. Among these methods, the easiest are freezing the oysters before shucking or placing them in a hot water tank in which the temperature is not high enough to cook the oysters, but sufficient to open the valves.

Processing of whole oyster and oyster meat

Freezing : After purification, whole oysters (shell-on) can be frozen by spreading, in single layers in an air blast freezer. Oysters can also be frozen in half shell. The oyster should be laid in a single layer of trays in an air blast freezer with polypropylene film stretched over each tray to protect the open surface of the oyster meat. Frozen whole oysters packed in polythene bags can be kept in good condition for six months in a cold storage at -25°C. The liquid within the shell acts as a glaze to protect the meat from dehydration. Shucked oyster meat, frozen either individually or in blocks (in 1 kg or 2 kg slabs) yields excellent product after thawing.

Canning of oyster meat

Oyster meat is chilled, washed and blanched in 3% brine containing 0.1% citric acid for 4 to 5 minutes. The blanched meat is packed in cans and hot 2% brine with 0.1% citric acid is added to the cans. The packed cans are seamed and sterilized at 115°C for twentyfive minutes. The cans are then chilled immediately and stored.

For preparation of smoke oyster meat, the meat is washed, treated with 5% brine for 5 minutes, drained, dipped in edible oil, spread in a single layer of nylon wire mesh, drained again and loaded into a smoking chamber. The meat is held in dense smoke and maintained at a temperature of 40°C for 30 minutes and later at 70°C for 90 minutes. The smoked oysters are packed in cans and sufficient quantities of hot refined edible oil is added. The cans are seamed, sterilized at 115°C for 25 minutes and immediately chilled and stored.

Utilization of oyster shells

The shell constitutes about 85% of the total weight of oyster and contains 52 - 55% of Calcium oxide and is used in the manufacture of Calcium carbide, lime, fertilizers and cement. Further the oyster shells are useful as spat collectors of oyster spats. The shells are broken to suitable size and used as poultry grit.

Problems and Prospects of Oyster Farming

Sudden changes in hydrological parameters, mainly salinity cause much damage to the oyster population. At a 50% drop from the ambient salinity level feeding is affected first followed by slow degeneration of tissues and cessation of the gametogenesis. Further drop in salinity totally prevents the oyster from feeding and eventually it dies. Similarly higher saline condition of above 40 ppt affects the feeding of the oysters. Once normal feeding declines the animal becomes susceptible to diseases. Several instances of mass mortalities were reported in oysters under low saline and hypersaline conditions.

Diseases and parasites

Large scale mortalities of oysters were reported from time to time from temperate waters. Recently histopathological studies have thrown some light on the possible factors responsible for many instances of large scale mortalities. Some epizootic viruses are suspected to be responsible for the cause of diseases and mortalities.

'Dermo' a dreaded disease caused by a fungus *Perkinsus marinus* inflicted heavy mortality among East American oysters. Gill disease and shell disease attributed to pathogenic fungus, caused heavy mortalities among Japanese and European oysters. A disease caused by the haplosporidian parasite *Minchinia nelsoni* (formerly known as MSX) was responsible for heavy mortality in American oysters.

Oyster beds affected by the above disease have revived after a long time. Large and thick oyster beds often are prone to be affected by diseases. Super intensive farming of oysters has to be avoided in order to avoid these problems.

Predators and foulers

Crabs, fishes, starfishes, polychaetes and gastropods are the predators that affect the oyster population. Predation is generally size specific and young oysters are more vulnerable than grown-up oysters. However, fouling organisms such as barnacles, ascidians, other molluscs and algae are considered mainly a nuisance, involving additional labour to make the oysters free from these organisms and prepare them for at 115°C for twentyfive minutes. The cans are then chilled immediately and stored.

For preparation of smoke oyster meat, the meat is washed, treated with 5% brine for 5 minutes, drained, dipped in edible oil, spread in a single layer of nylon wire mesh, drained again and loaded into a smoking chamber. The meat is held in dense smoke and maintained at a temperature of 40°C for 30 minutes and later at 70°C for 90 minutes. The smoked oysters are packed in cans and sufficient quantities of hot refined edible oil is added. The cans are seamed, sterilized at 115°C for 25 minutes and immediately chilled and stored.

Utilization of oyster shells

The shell constitutes about 85% of the total weight of oyster and contains 52 - 55% of Calcium oxide and is used in the manufacture of Calcium carbide, lime, fertilizers and cement. Further the oyster shells are useful as spat collectors of oyster spats. The shells are broken to suitable size and used as poultry grit.

Problems and Prospects of Oyster Farming

Sudden changes in hydrological parameters, mainly salinity cause much damage to the oyster population. At a 50% drop from the ambient salinity level feeding is affected first followed by slow degeneration of tissues and cessation of the gametogenesis. Further drop in salinity totally prevents the oyster from feeding and eventually it dies. Similarly higher saline condition of above 40 ppt affects the feeding of the oysters. Once normal feeding declines the animal becomes susceptible to diseases. Several instances of mass mortalities were reported in oysters under low saline and hypersaline conditions.

Diseases and parasites

Large scale mortalities of oysters were reported from time to time from temperate waters. Recently histopathological studies have thrown some light on the possible factors responsible for many instances of large scale mortalities. Some epizootic viruses are suspected to be responsible for the cause of diseases and mortalities.

'Dermo' a dreaded disease caused by a fungus *Perkinsus marinus* inflicted heavy mortality among East American oysters. Gill disease and shell disease attributed to pathogenic fungus, caused heavy mortalities among Japanese and European oysters. A disease caused by the haplosporidian parasite *Minchinia nelsoni* (formerly known as MSX) was responsible for heavy mortality in American oysters.

Oyster beds affected by the above disease have revived after a long time. Large and thick oyster beds often are prone to be affected by diseases. Super intensive farming of oysters has to be avoided in order to avoid these problems.

Predators and foulers

Crabs, fishes, starfishes, polychaetes and gastropods are the predators that affect the oyster population. Predation is generally size specific and young oysters are more vulnerable than grown-up oysters. However, fouling organisms such as barnacles, ascidians, other molluscs and algae are considered mainly a nuisance, involving additional labour to make the oysters free from these organisms and prepare them for marketing. Some of them compete for food with the oyster. In some cases, excessive growth of algae on oyster beds may however, smother the oysters or create anoxic conditions leading to their mortality.

Pollution

Pollution plays an important role in the ecology of oyster beds. In coastal waters domestic sewage and factory wastes are common. The sewage water increases the bacterial load of the coastal waters. The degree of pollution is determined by *Escherichia coli* found in the water. When the MNP (Mean Probable Numbers) is in excess of 70 per ml, the area is considered as unsafe for oyster culture.

Considerable quantity of industrial waste waters, agricultural run-off, dust from thermal power stations and oil enters the sea. The organisms found in coastal waters and estuaries become exposed to toxic substances such as heavy metals and pesticides. Oysters, particularly accumulate certain heavy metals and pose health hazards to those who consume them. Hence assessment of the level of pollution has to be made before starting culture work. Further continuous pollution monitoring is to be carried out in oyster growing areas in order to ensure the quality of the meat.

Prospects

Information is available on various aspects of biology of the commercially important oysters of India. Among them the Indian backwater oyster *Crassostrea madrasensis* which has been studied in considerable detail is a highly suitable candidate species for cultivation as it is euryhaline, widely distributed along the Indian Coast, grows fast and attains large

Depuration process in tanks

size. Techniques for spat collection from the natural ground and also for production of seed in a hatchery system have been developed. Several off-bottom methods of culture of this species have been experimented and consistent results obtained. As a result of about two decades of research effort at the CMFRI, complete package of Oyster culture technology is now available in the country.

Along the Indian Coast, are present vast stretches of backwaters, estuaries and bays spread over several lakhs of hactares. Many of these areas harbour natural populations of oysters, suggesting the suitability of the habitat for Oyster culture. Being filter feeders, the oysters convert primary production in the water into nutritious seafood. Such direct food conversion without any link in the food chain results in high production of oysters per unit area by aquaculture. Lack of awareness among the entrepreneurs about the benefits that would accrue by taking up Oyster culture and the limited domestic demand for oyster meat as it is not conventionally eaten, are two important factors that require immediate attention so as to realise the potential of Oyster culture.

Commercialisation of Oyster culture technology in the country requires major thrust. Concurrent action is called for in developing suitable hygienically prepared low cost and also value added products from the oyster meat and concerted efforts are needed to expand the domestic market and explore overseas markets.

ECONOMICS OF OYSTER CULTURE

Even in its most advanced stages, shellfish culture requires continuous experimentation either by the grower himself or by the shellfish biologist to increase the efficiency of the system by innovations. Hence economic analysis of any aquaculture venture is based on the "state of the art" technology at a given time.

In the farm at Tuticorin, Oyster culture by the shell-string method was tested in 0.4 ha area with 50 numbers of racks, each of 30 m length. Each rack occupies an area of 80 sq. m and 100 strings are suspended from it; each string contains six numbers of shells bearing oyster spat. The initial weight of the string is 0.5 kg. At the end of one year the weight of the string is 7.5 kg on an average

The economic analysis is based on the capital investment of Rs.55,000/-. In each of the three years the operational cost comes to Rs.46,000/- (see Table). While calculating the fixed cost, depreciation @ 33.3% on capital and interest @ 18% on both the capital and operational costs have been accounted. Most of the expenditure under operational cost is to be incurred at the beginning of the farming activity and hence interest on operational cost is also considered. Thus an amount of Rs. 36,495 has been taken as fixed cost per year. At the end of the year the revenue comes to Rs. 1,05,000 resulting in a net profit of Rs. 22,505. For the following two years fixed cost, operational cost and the income are same. So the total profit at the end of third year is calculated at Rs.67,515.

TABLE

ECONOMIC EVALUATION OF OYSTER CULTURE BY SHELL STRING METHOD

Farm area : 0.4 ha
Period : 3 years

size. Techniques for spat collection from the natural ground and also for production of seed in a hatchery system have been developed. Several off-bottom methods of culture of this species have been experimented and consistent results obtained. As a result of about two decades of research effort at the CMFRI, complete package of Oyster culture technology is now available in the country.

Along the Indian Coast, are present vast stretches of backwaters, estuaries and bays spread over several lakhs of hactares. Many of these areas harbour natural populations of oysters, suggesting the suitability of the habitat for Oyster culture. Being filter feeders, the oysters convert primary production in the water into nutritious seafood. Such direct food conversion without any link in the food chain results in high production of oysters per unit area by aquaculture. Lack of awareness among the entrepreneurs about the benefits that would accrue by taking up Oyster culture and the limited domestic demand for oyster meat as it is not conventionally eaten, are two important factors that require immediate attention so as to realise the potential of Oyster culture.

Commercialisation of Oyster culture technology in the country requires major thrust. Concurrent action is called for in developing suitable hygienically prepared low cost and also value added products from the oyster meat and concerted efforts are needed to expand the domestic market and explore overseas markets.

ECONOMICS OF OYSTER CULTURE

Even in its most advanced stages, shellfish culture requires continuous experimentation either by the grower himself or by the shellfish biologist to increase the efficiency of the system by innovations. Hence economic analysis of any aquaculture venture is based on the "state of the art" technology at a given time.

In the farm at Tuticorin, Oyster culture by the shell-string method was tested in 0.4 ha area with 50 numbers of racks, each of 30 m length. Each rack occupies an area of 80 sq. m and 100 strings are suspended from it; each string contains six numbers of shells bearing oyster spat. The initial weight of the string is 0.5 kg. At the end of one year the weight of the string is 7.5 kg on an average

The economic analysis is based on the capital investment of Rs.55,000/-. In each of the three years the operational cost comes to Rs.46,000/- (see Table). While calculating the fixed cost, depreciation @ 33.3% on capital and interest @ 18% on both the capital and operational costs have been accounted. Most of the expenditure under operational cost is to be incurred at the beginning of the farming activity and hence interest on operational cost is also considered. Thus an amount of Rs. 36,495 has been taken as fixed cost per year. At the end of the year the revenue comes to Rs. 1,05,000 resulting in a net profit of Rs. 22,505. For the following two years fixed cost, operational cost and the income are same. So the total profit at the end of third year is calculated at Rs.67,515.

TABLE

ECONOMIC EVALUATION OF OYSTER CULTURE
BY SHELL STRING METHOD

Farm area : 0.4 ha

Period : 3 years

A. Initial investment for capital equipment, etc.

	(In Rupees)
a. Construction of pond for nursery purpose	20,000
b. FRP dinghy - 1 No.	10,000
c. Out-board motor (8 Hp) - 1. No.	15,000
d. Pump set (3.5 Hp) 1 No.	5,000
e. Major farm accessories	5,000
Total	55,000

1st year

B. Operational cost

a. Seed of oysters	6,000
b. Cost of stakes - 50 No.	15,000
c. Nylon rope 50 Kg	5,000
d. Other farm materials, repair, etc.	3,000
e. Labour	10,000
f. Harvesting charges	7,000
Total	46,000

C. Fixed cost

a. Depreciation @ 33.3%	18,315
b. Interest on total amount spent @ 18%	18,180
Total	36,495

***D. Total cost* (B + C)** 82,495

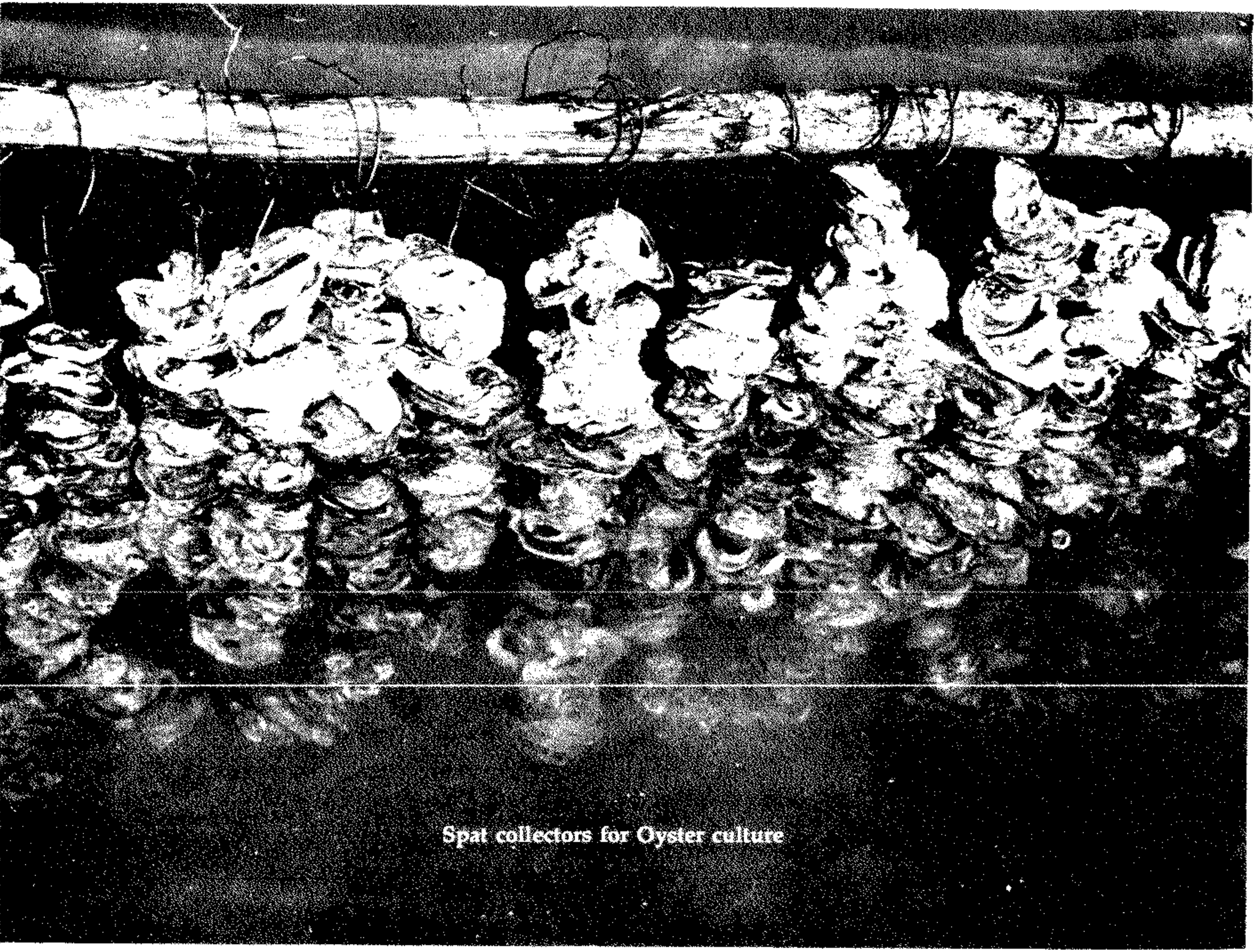
E. Income at the end of 1st year

a. Total harvest - 3.25 t of meat	97,500
b. Sale of oyster shells @ Rs.300 per tonne for 25 tonnes	7,500
Total	1,05,000

F. Profit at the end of Ist year (E-D) 22,505

Note : For II and III year the fixed cost, operational cost and revenue are the same as in first year

Profit at the end of 3rd year **67,515**



Spat collectors for Oyster culture