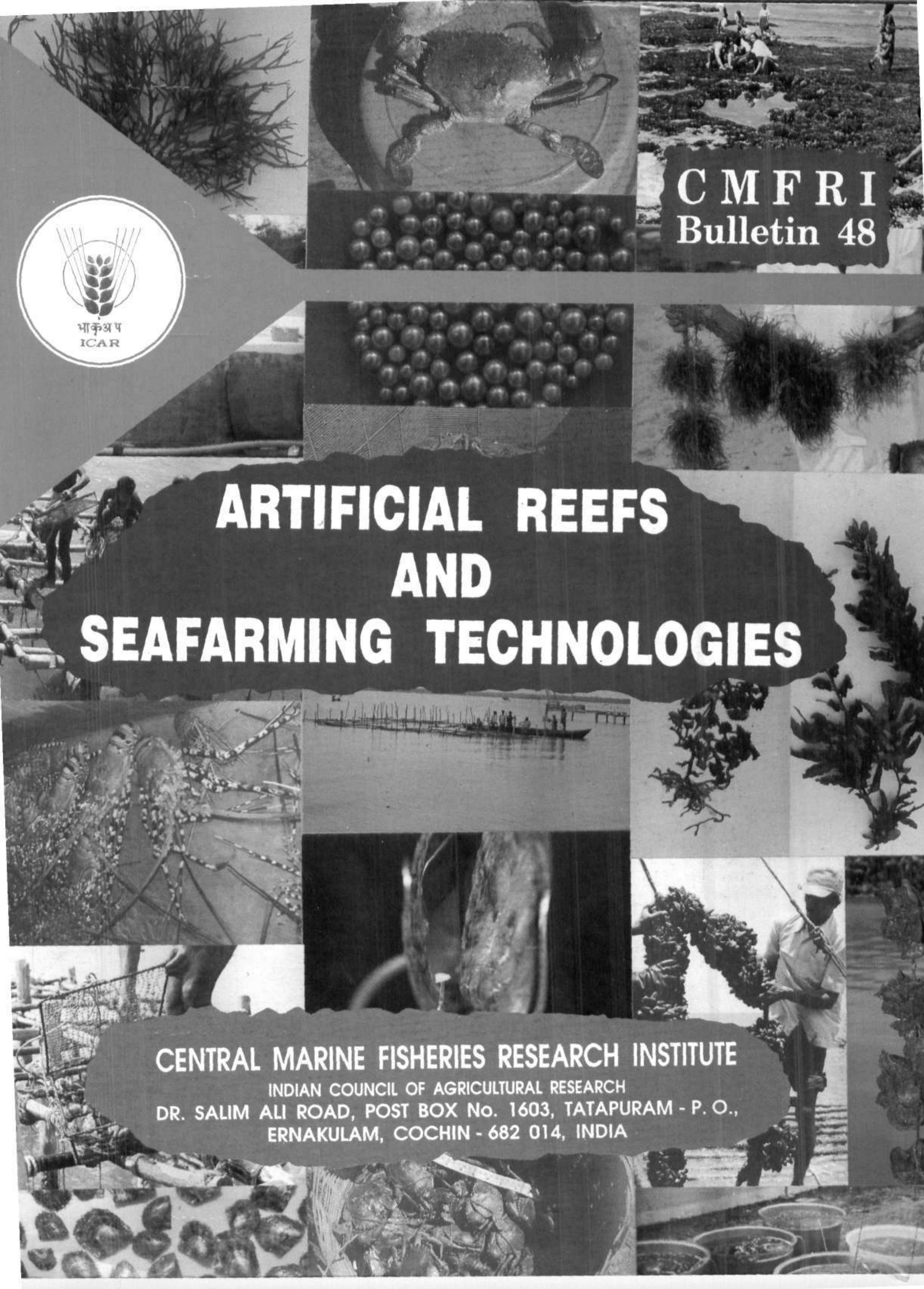

ARTIFICIAL REEFS AND SEAFARMING TECHNOLOGIES

CMFRI Bulletin 48

भाकृअप
ICAR

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
DR. SALIM ALI ROAD, POST BOX No. 1603, TATAPURAM - P. O.,
ERNAKULAM, COCHIN - 682 014, INDIA

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DR. K. RENGARAJAN

Editor

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13

CLAM CULTURE

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Introduction

Bivalves such as oysters, mussels, clams and cockles are widely distributed both in the tropical and temperate waters. In recent years, they have emerged as a delicacy and luxury food items in Japan, USA and western Europe.

The total world mollusc production through exploitation of the wild stocks was 8,885,01 tonnes in 1992 forming nearly 13% to the total world fish production (Table 1). The total mollusc production through aquaculture was estimated at 3,500,719 t in 1992 (Table 2). Due to depletion of the intensely exploited wild stocks, there is increased demand for farm grown products.

Table 1. *Mollusc production by harvest of wild stocks in 1992 (FAO, 1992)*

Group	Production (t)
Freshwater molluscs	303,491
Abalones, conchs, etc.	71,578
Oysters	1,067,403
Mussels	1,337,551
Scallops, pectens	1,044,417
Clams, cockles, etc.	1,696,468
Squid, octopus, etc.	2,758,304
Miscellaneous marine molluscs	605,789
Total	8,885,001

The world landings of clams/cockles have been increasing steadily for the past few years totalling 1,696,468 t in 1992 forming nearly 19.1% of the total mollusc production of 8,885,001 t. The clam production through aquaculture in 1992 was 766,657 t forming 22% of the total mollusc production of 3,500,719 t through aquaculture (Table 2).

The major molluscs producers include China, Japan, Korean Republic, France, Spain, USA, Italy, Malaysia, Netherlands and other Asian countries (Table 3). The major clam producing countries include China, Japan, Malaysia, Korean Republic and Thailand.

Table 2. *Aquaculture production in 1992 (FAO, 1992)*

Group	Production (t)
Mussels	10,85,223
Oysters	9,52,196
Clams	7,66,657
Scallops	5,49,613
Other molluscs	1,47,030
Total	35,00,719

The clam meat is generally processed and marketed in frozen and canned forms. A variety of valued added canned clam meat products find ready market. The global clam meat exports in 1992 was 50,955 t, valued at US $ 1,06,774.

Table 3. *Top ten molluscs producing countries through aquaculture in 1992 (FAO 1992)*

Country	Production (t)
China	15,97,467
Japan	4,54,342
Korean Rep.	3,38,846
France	1,97,854
Spain	1,45,340
USA	1,23,910
Italy	1,10,700
Other Asian countries	62,938
Malaysia	57,088
Netherlands	52,600

Resources and distribution

A number of clam species belonging to the families Arcidae, Veneridae, Corbiculidae, Tridacnidae, Solenidae, Mesodesmatidae, Tellinidae and Donacidae are exploited along the Indian

Coast. The cultivable species belong to the first four above mentioned families.

Arcidae : The arcid clams are called blood clams as their blood is red in colour due to the presence of haemoglobin. A single species *Anadara granosa* is important. It occurs all along the Indian Coast in soft muddy substratum and forms a fishery of some magnitude in the Kakinada Bay.

Veneridae : The venerid clams are the most sought after in the clam fisheries in India and three genera namely *Meretrix, Paphia* and *Katelysia* are important.

Along the Maharashtra Coast, *Meretrix meretrix, Katelysia opima* and *Paphia laterisulca* are the dominant species. In Goa, *M. casta* forms a fishery. Along the Karnataka Coast, there are 14 estuaries with varying abundance of clams. *M.*

TABLE 4. *Clam production at different centres (Narasimham, 1991)*

State	Place	Production (t/year) *Species-wise	Total (t)	Source
Maharashtra	Thane to Ratnagiri	Mm & Ko 70% Pl, Km & Dc rest	1,100	Ranade (1964)
	Gav-Khadi	Sk	3	Rao *et al.* (1964)
Goa	Goa	Vc 500, Mc 315	887	Parulekar *et al.* (1973); Ansari *et al.* (1981)
	Kalinadi	Vc 525, Mm 20	545	Rao *et al.* (1989)
	Aghnashini	Mc 500, Mm 250, Vc 5	755	"
	Uppunda	Mc 10, Ko 64, Pm 80	155	"
Karnataka	Coondapur	Mc 50, Mm 40, Ko 5, Pm 500, Vc 8	603	"
	Sita	Mc 230, Mm 5, Ko 5	245	"
	Swarna	Vc 15	15	"
	Udayavara	Mc 215, Pm 5, Vc 5	225	"
	Mulky	Mc 1814, Pm 578	2392	"
	Gurpur	Mc 300, Pm 600, Vc 375	1275	"
Kerala	Nethravali	Mc 233, Vc 149	382	"
	Vembanad Lake	Vc 21490	21490**	Achari (1988 b)
	Ashtamudi	Ko 5552, Vc 6000	11437	Appukuttan *et al.* (1988)
Tamil Nadu	Vellar Estuary	Mc over 87%	985	Sreenivasan (1985)
	Pulicat Lake	Mc 102	102	Thangavelu and Sanjeevaraj (1988)
	Kakinada Bay	Ag 2000, Mm 400, Ko 40, Pm 30, Dc 30	2,500	Narasimham (1973) Silas *et al.* (1982)
	Godavari Estuary	Mm 250	250	Narasimham (unpublished)
	Bihmunipatnam Backwater	Mc 66	66	Rao *et al.* (1980)
		Total	45,412	

* Mm - *Meretrix meretrix*, Mc - *M. casta*, Ko - *Katelysia opima*, Km - *K. marmorata*, Pm - *Paphia malabarica*, Pl - *P. laterisulca*, Dc - *Donax cuneatus*, Sk - *Solen kempi*, Vc - *Villorita cyprinoides*, Ag - *Anadara granosa*

** Average for 1974-85

casta is found in all the estuaries, *M. meretrix* in the Kalinadi and Coondapur Estuaries , *Paphia malabarica* in the Mulky, Gurpur, Udyavara and Coondapur Estuaries are found. *Katelysia opima* is found in Coondapur, Uppunda and Sita Estuaries. Along the Kerala Coast, *P. malabarica* forms a fishery in Koduvally, Azhikkal, Karyamgod and Chittari Estuaries and Ashtamudi Lake. Other venerid clams form fisheries in several estuaries in Kerala State. Along the east coast, *M. casta* occurs at several places and forms a fishery at Vellar Estuary, Pulicat Lake and Bhimunipatnam Backwater. *K. opima, P. malabarica* and *M. meretrix* contribute to the clam fisheries in the Kakinada Bay. Along the Orissa Coast *Meretrix* sp. occurs in the Chilka Lake and Sonapur Backwaters.

Corbiculidae : The black clam *Villorita cyprinoides* is the major resource in Vembanad Lake and is also exploited in several backwaters, lakes and estuaries of Kerala. It also contributes to the fisheries in Goa and in the Nethravathi, Gurpur, Udyavara, Swarna and Coondapur Estuaries in Karnataka.

Tridacnidae : It is represented in India by *Tridacna maxima, T. crocea, T. squamosa* and *Hippopus hippopus* and occur in the Andaman and Lakshadweep Islands.

In India, the production of clams and the species breakup through harvest of the wild populations is not regularly monitored. However, based on the surveys conducted at important production centres, Narasimham (1991) summarised that about 45,412 t are landed annully (Table 4).

Of the estimated annual production of 45,412 t of calms, the black clam *Villorita cyprinoides* with a catch of 29,077 t forming 64%, is the mainstay of the clam fisheries. Major production centres are the Vembanad and Ashtamudi Lakes.

The venerid clams with an estimated annual production of 14,052 t, form 30.9% of the total landings. These clams are widely distributed and form fishery in all maritime States where clams are currently exploited. In this group, *K. opima* is most important with 5,552 t followed by *M. casta* (4,642 t), *P. malabarica* (1,793 t) and *M. meretrix* (965 t).

The blood clam *A. granosa* accounts for 2,000 t/year and 4.4% of the clam landings.

Of all the maritime States, Kerala leads in clam production with a catch of 32,927 t which accounts for 72.5% of the total clam landings (Table 4). The annual clam landings of the Karnataka State was estimated at 6,592 t (Rao *et al.*,1989) although considerable fluctuations in the landings have been recorded. The clam production in Goa has been estimated at 887 t/year and that of Maharastra at 1,100 t/year.

Along the east coast of India, the clam resources are smaller. In Tamil Nadu, the Vellar Estuary and the Pulicat Lake together contribute to 1,087 t ; while in Andhra Pradesh, the clam production was estimated at 2,816 t (Table 4).

TABLE 5. *Pattern of clam meat export from India (MPEDA, 1993) Quantity (tonnes) Value (Rs. '000)*

Production		1989	1990	1991	1992	1993
Frozen boiled clams	Q	329	414	1,234	940	776
	V	5,369	7,558	37,392	31,028	23,541
Clam meat pickle	Q	-	-	-	37	NEG
	V	-	-	-	2,025	15
Dehydrated clam meat	Q	42	107	164	129	124
	V	933	2,546	4,789	3,855	5,669
Total	Q	371	521	1,396	1,106	900
	V	6,302	10,104	42,181	36,908	29,225

There is no information from Gujarat, Orissa and the West Bengal. It may be due to absence of exploitation rather than the non-availability of the resources.

Distinctive characters of cultivable species

Anadara granosa : Shell thick, inflated and dark brown in colour. This species differs from other clams in having taxodont dentition (small teeth in a single straight series) and about 20 elevated ribs bearing rectangular nodules (Fig. 1).

In Venerid clams, the hinge usually bears three cardinal teeth and a single anterior lateral tooth on the left valve and a corresponding depression on the right valve. Two adductor muscle impressions, slightly unequal in size are present.

Paphia malabarica : Shell slightly inflated, surface concentrically grooved. Pallial sinus is 'U'shaped

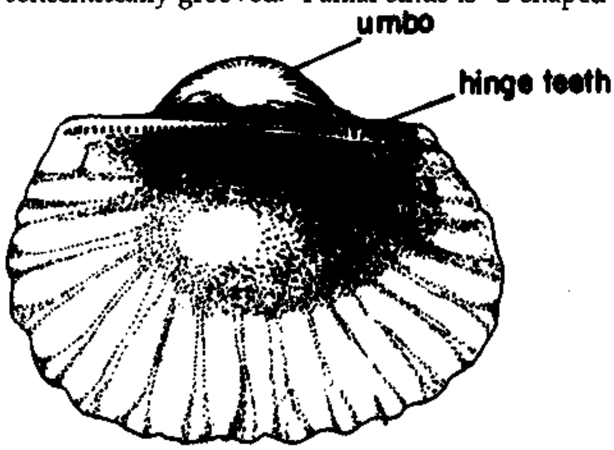

Fig. 1. Inner view of the right valve of *Anadara granosa*.

and very deep. Lunule relatively short. Shell length only one and one third times longer than height. Hinge area short with narrowly diverging teeth. Shell yellowish brown in colour, indistinctly rayed with greyish brown bands or mottled with brownish angular markings (Fig. 2).

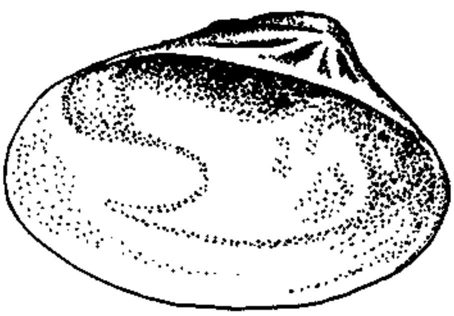

Fig. 2. Inner view of the left valve of *Paphia malabarica*. '

Meretrix casta : Shell thick, smooth, devoid of any sculpture and triangularly ovate. Outer surface

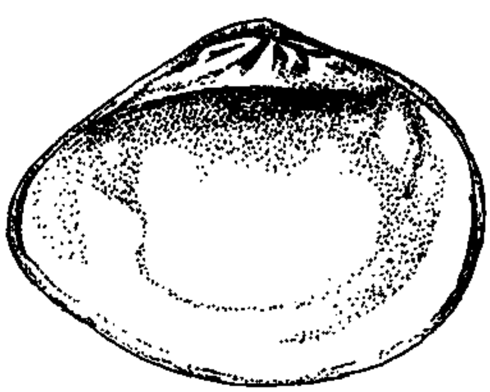

Fig. 3. Inner view of the left valve of *Meretrix casta*.

pale yellowish brown, tinted with dark grey posteriorly and very faintly rayed with greyish radial lines (Fig. 3).

M. meretrix : Differs from *M. casta* in having less elongated lateral tooth and more ovate shell, grows to a larger size (Fig. 4).

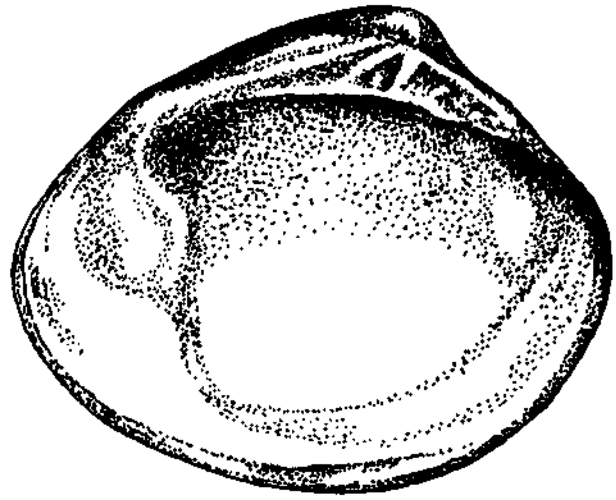

Fig. 4. Inner view of the left valve of *Meretrix meretrix*.

Katelysia opima : Shell thick, inflated, smooth, triangularly ovate. Pallial line deeply sinuate. Apex of pallial sinus bluntly angular. Lunule distinct, flattened and rather broad. Area behind umbones well defined, flattened and greatly elongated reaching almost upto hind margin of shell. Outer surface of shell polished, pale yellowish brown or straw coloured, variously mottled and rayed with purplish grey markings (Fig. 5).

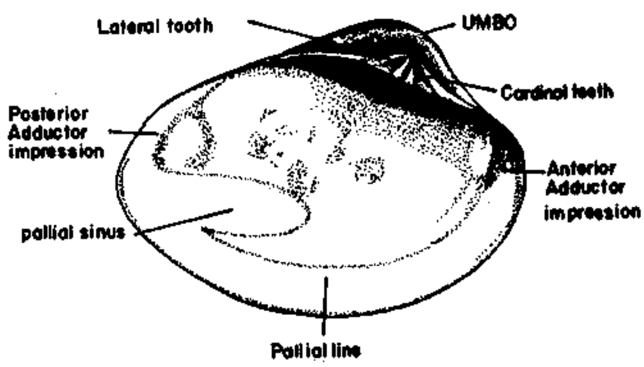

Fig. 5. Inner view of the left valve of *Katelysia opima*.

Villorita cyprinoides : Shell thick, ovately triangular with strong concentric ridges; ridges more strongly developed in anterior half. Umbones prominent, well elevated, hinge margin short and thick, always with three oblique cardinal teeth of which anterior in right valve and posterior in left valve obsolete. Pallial sinus small, lunule narrow and ligament large. Periostracum dark olive brown to blackish brown (Fig. 6).

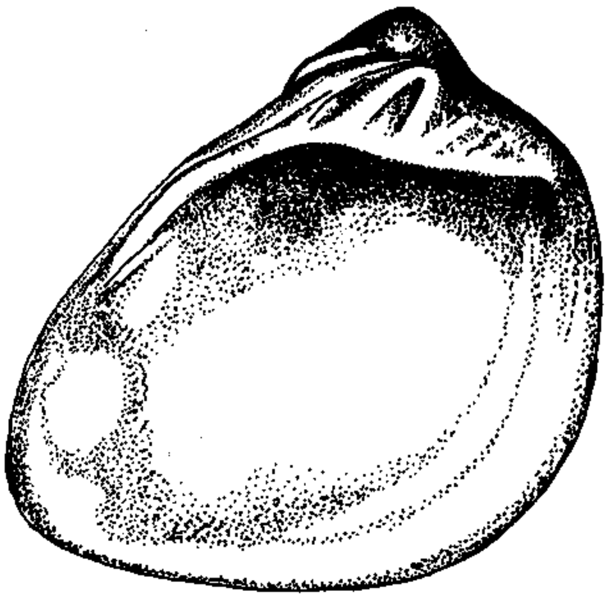

Fig. 6. Inner view of the left valve of *Villorita cyprinoides*.

The Tridacnid clams have large massive shells with broad radial ribs, sometimes bearing large fluted scales. Edges of valves usually scalloped.

Tridacna crocea (Crocus or Boring clam) : Smallest of giant clams, grows upto 15 cm. Large, thick, triangularly ovate shell with large byssal gape, 6-10 broad flattened ribs with concentric ridges. Shell greyish white, flushed with yellow or pinkish orange (Fig. 7).

Fig. 7. External view of the shell of *Tridacna crocea*.

T. maxima (Rugose giant clam) : Shell strongly inequilateral. Resembles *T. crocea*, but its 6-12 broad radial ribs have much more strongly developed concentric scales. Large byssal gape with distinct plicae at edges. Ventral margin of valve often deeply scalloped. Shell greyish white, sometimes tinged with yellow or pinkish orange. Grows to about 35 cm (Fig. 8).

Fig. 8. External view of the shell of *Tridacna maxima*.

T. squamosa (Fluted or scaly clam) : Large, thick, strongly inflated shell with small or medium sized byssal gap. 4-12 strongly convex ribs with riblets in interspaces. Broad, sometimes long fluted scales on ribs which may project beyond ventral margin considerably. Greyish white, sometimes finged with yellow. Grows to 40 cm (Fig. 9).

Fig. 9. External view of the shell of *Tridacna squamosa*.

Hippopus hippopus (Horse' hoof, Bear paw or Strawberry clam) : Large thick elongated lozenge shaped shell with tightly closed byssal area. 13-14 convex radial ribs with tube-like spines. Greyish white with yellowish orange tinges. Often

Fig. 10. External view of the shell of *Hippopus hippopus*.

dark red patches on ribs arranged in irregular concentric bands. Grows to 40 cm (Fig. 10).

Clam Culture - Global Scenaria

Clams are bivalves which burrow into the substratum with the help of a usually well developed foot. A few clam species are also known to attach to hard substrates with byssus threads.

Among bivalves, clams are by far, the most abundant and widely distributed resource. They are commercially important and fished in fairly large quantities in several countries. In India, clams form subsistence fisheries all along the coast. Clam meat is nutritious and is a cheap source of protein rich seafood. Clam culture is practised in several countries such as Taiwan, Thailand, Malaysia, Indonesia, Singapore, U.K., Australia. However, it is not as advanced an art as is the case with oysters or mussels. In clam culture, the seed is generally collected from natural grounds and replanted in areas with a suitable substratum, but where seed is not abundant. They are then allowed to grow to market size.

Selection of site

Clams are cultured on the bottom and therefore site selection depends on the substrate. The occurrence of natural clam populations is indicative of the suitability of the site with particular reference to the tide level, substratum and salinity. Clam farms are located in estuaries, bays and other sheltered areas close to the shore. About 1-2 hrs exposure at low tide is desirable as it is easy to remove the predators.

Too long an exposure results in poor growth due to reduced feeding and in summer there may be mortality due to desiccation. Farms located further in subtidal area have the disadvantage when predators are to be eradicated.

The type of substratum preferred varies with the species. For example, *M. casta* thrives well on sandy bottom, while *A. granosa* prefers mud flats. Also the salinity range tolerated differs between species. While *V. cyprinoides* prefers low saline waters few species tolerate prolonged low saline conditions which are generally prevalent in areas subjected to heavy rains and freshwater drain from the land. Clam farms are located in areas where there is little wave action. Areas prone to frequent changes of contour and vulnerable to pollution are avoided.

Hatchery production of spat

Mature clams of 35-45 mm shell length are used as brood stock. The brood stock is conditioned in unfiltered seawater of 25 ppt and at 22-24°C and then transferred to spawning troughs. Spawning is induced by thermal cycling; the spawning trough is part filled with cooler water to a depth of 10 cm and a small amount of cultured microalgae (*Isochrysis galbana*) to stimulate the clams to extend their siphons and start pumping activity. After 15-30 minutes, the water is drained and replaced with water at 28-30°C, again with small addition of algae. This water is drained after a similar period of time and replaced with cooler water and the procedure is repeated. The number of cycles which are necessary to induce spawning depends on the readiness of the clams to spawn.

Eggs are separated through a 60 µm nylon mesh seive and transferred to filtered seawater at 25°C. The larvae are grown in flat bottomed vessels, or in conically based fibreglass tanks fitted with bottom drains, at 15,000-20,000/lt, but optimum density for good growth is 10,000/lt.

Good aeration at the rate of 200 lt/hr depending on the size of the container and filtered and sterilized seawater of 25 ppt and 24-26°C provides optimum conditions for larval growth. Unicellular alga such as *Chaetoceros calcitrans*, *Isochrysis galbana*, *Tetraselmis suecica* and *Thalossiosira pseudonana* are suitable food species. Diets of mixed algae are beneficial. A suitable diet for "D-shelled" larvae is a mixture of *Chaetoceros* and *Isochrysis*, the most suitable cell densities are 125 cells/µl respectively.

Air-lift downwelling recirculation systems of 100 lt capacity are generally used for growing 0.5 million spat to a size retained on 440/µm mesh size.

Nursery rearing

Nursery upwelling systems are generally used in several European countries for spat rearing.

The upwelling system used at the Fisheries Laboratory at Conwy for *Mercenaria mercenaria, Tapes decussatus* and *T. philippinarum* is shown in Fig. 11.

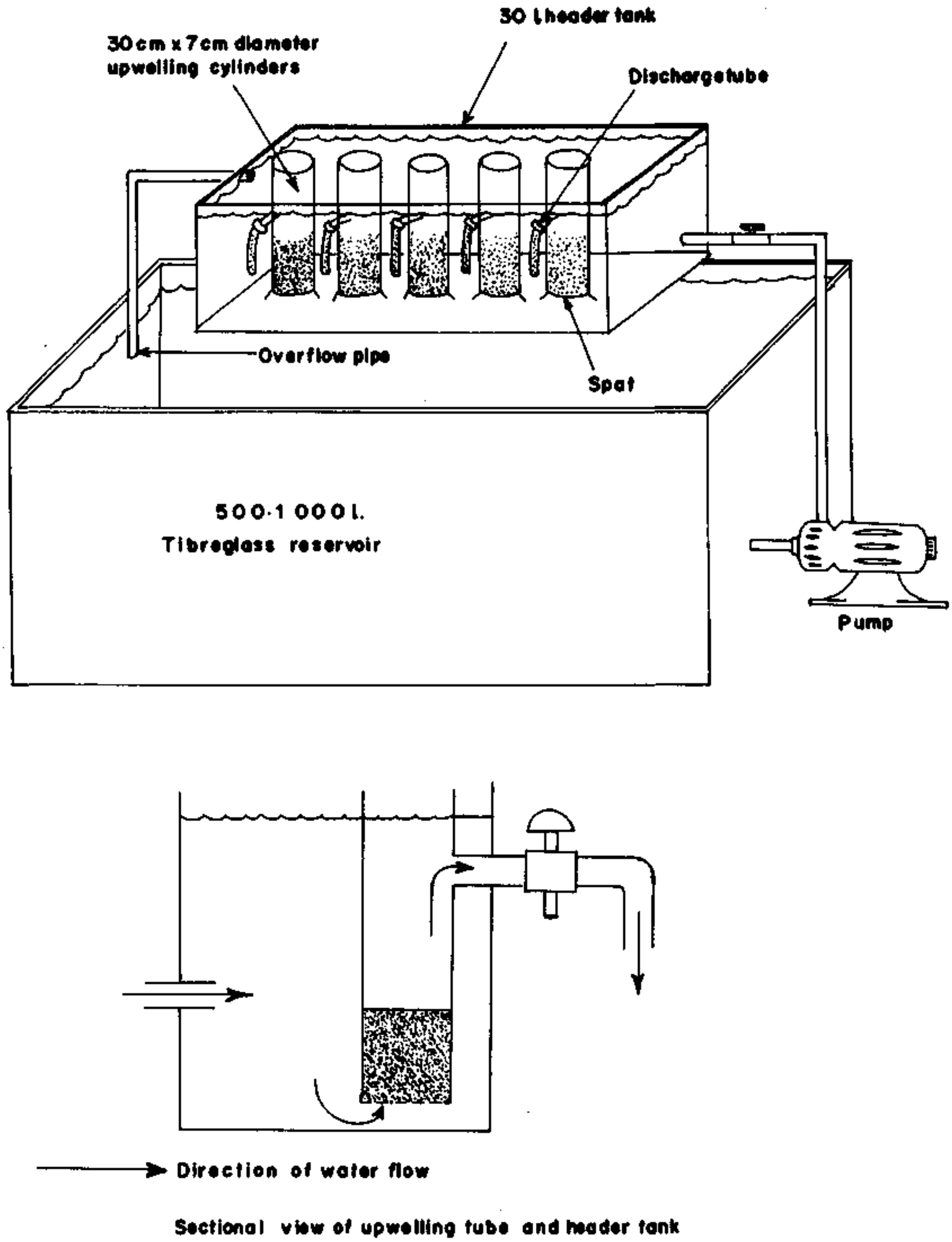

Fig. 11. A nursery upwelling system used in the Fisheries Laboratory at Conwy (Utting and Spencer, 1991).

Water flow is induced through cylinders (30 cm x 7 cm diameter) placed in a 30 lt header tank, by creating a difference in the head of the water. The header tank is placed over the 500-1000 lt fibreglass reservoir tank. Valves are fitted to the overflow of the upwelling cylinders, since spat growth is strongly influenced by water flow rate. Flow rates of 20-50 ml/minute per gram is used.

Seawater, coarsely filtered through a 45 µm mesh is used so that the spat are benefitted from the presence of naturally occurring algae, in addition to those offered as food.

Nursery upwelling systems need relatively large volume, since only small biomasses of spat can be grown successfully per unit volume of water.

Grow out culture and production

The ground is levelled and cleaned of predators such as boring gastropods, starfishes, crabs and skates. Bamboo poles are planted on the boundary of the farm as markers. The movements of the clams are limited and in many areas fencing is not necessary. Synthetic fibre net pens are erected to protect clams against strong water currents in the USA, bamboo stakes with nylon netting are used in Taiwan.

At high tide, seed measuring 10 - 25 mm in length are taken in a boat and planted in the farm, taking care to get even dispersal as far as possible. Uneven distribution is set right at the next low tide. In Malaysia, *A. granosa* is stocked at 1000-2000/m^2 and thinned more than once to achieve final density of 300-600/m^2. The stocking density varies with the species and a stocking density of 400/m^2 for 10 mm seed and 300/m^2 for 20 mm seed is usually optimum.

After seeding the farm, 10 mm mesh synthetic netting is laid and held in position by stakes driven into the substratum at the periphery of the farm, to offer protection to the young clams. Except for watch and ward and eradication of predators, no other maintenance job is necessary during the grow out phase. The clams are harvested after 5 or 6 months either by hand picking or by hand operated dredge.

In Malaysia, wild seeds of *A. granosa* are stocked/ranched in pre-prepared coastal mud flats, generally bound by natural landmarks and where these are lacking, are marked by other means. The stocking/seeding density is between 2-6.5 kg seed/m^2. An average production of 40 t/ha is obtained.

In Thailand also the same method is followed for *A. granosa* and 50 cm long bamboo stakes are used to fence the intertidal mud flats to prevent escape of clam from the culture beds. Clam seeds are also sown in the central elevated areas of shrimp ponds and fenced with bamboo stakes. The seeds used here are larger than those used for the intertidal flats. These methods yield 31-109 t/ha annually.

In China, *Sinonovacula constricta* (razor clam), *Arca (Anadara) granosa* and *Tapes philippinarum* (small-necked clam) are cultivated. Seed clams (1 cm long) of *S. constricta* are collected and sown into rearing beds during January, at 9-18 x 10^6 clam seeds/ha. The average yield is 15-22 t/ha after 6-7 months. *A. granosa* seed are also raised from natural spat and reared in enclosed waterpools. They are thinned several times, transplanted to rearing grounds in the lower tidal zone. It takes 2-3 years to reach marketable size of 2 cm and yield is 22.5-60 t/ha. The small necked clam is also cultivated on pre-prepared culture beds by stocking 1.4 cm seed clams at 1.8 x 10^6 seed/ha. The yield is about 18.7 t/ha, but sometimes as high as 45 t/ha.

Clams are rarely grown in ponds, but in recent yaers, due to adverse impact of the viral diseases in shrimp culture, there is growing interest in many Southeast Asian countries to utilize the shrimp ponds for clam culture. In Taiwan, *Meretrix lusoria* is grown in ponds formerly used for milkfish and shrimps and also in the outlet and inlet canals of these ponds.

Giant clam culture

Giant clams are the only autotropic farm animals known to man. The unique feature of the giant clams is the symbiotic relationship with the dinoflagellate algae, zooxanthellae in their mantle tissue. They retain their filter feeding habit and food is supplemented by the nutrients gained from the photosynthesis of zooxanthellae. They mature as males at two or more years of age and later develop female gonads also. The initial growth of the giant clams is slow and they reach 2-4 cm in shell length after a year. Thereafter growth is rapid in larger species. Estimations of the life spans of giant clams have been speculative and some of them do live for a few decades.

In giant clam culture, four phases are involved.

(a) *Hatchery phase* - rearing the larvae from eggs in indoor or outdoor tanks.

Six out of the eight known species of giant clams have been successfully spawned in the Philippines by injecting serotonin into the gonad of mature clams and also by introduction of macerated gonad materials into the mantle cavity through the exhalent siphon.

The development stages are similar to those in other clams and settlement takes place in about 7-10 days after spawning. *Isochrysis galbana* is given as food. The spats attach with the byssus, but they may break the attachment and creep along the substrate. At this stage the symbiosis with zooxanthellae is established. The larval rearing is done in both indoor and outdoor tanks.

(b) *Nursery phase* - rearing juvenile clams in onshore tanks for metamorphosis (0.2 mm) to about nine months of age and 20 + mm shell length (seed clams).

The tanks are provided with flow of raw seawater. The clams acquire the zooxanthellae from seawater in about 3 weeks after fertilization and they become increasingly autotrophic.

(c) *Ocean nursery phase* - rearing juvenile clams in protective containers in the field from about 20 mm shell length to 200 + mm shell length.

(d) *Grow out phase* - rearing clams of 200 + mm shell length, without protection in the field to market.

T. gigas the largest among the giant clams, grows to 18.6 mm (total wt. 0.55 g) in 0.83 years, 121.1 mm (193.8 g) in 2 years, 206.4 mm (923.3 g) in 2.66 years and 221.3 mm (1.15 kg) in 3 years. The wet meat forms 12% of the total weight in 18.6 mm clams and it increases to 26 % in 221.3 mm clams. A production of 29 t of wet meat/ ha has been estimated in *T. gigas* culture for three year old clams. The field culture techniques, survival and production for various giant clam species are still in experimental stage.

Clam culture in India

The Central Marine Fisheries Research Institute has developed the technology for culture of the blood clam *Anadara granosa* in the Kakinada Bay. Although complete package of technology including seed production under controlled conditions has been developed in the country for the blood clam *A. granosa* and the venerid clam *P. malabarica,* it is yet to be commercialised.

Site selection

The criteria to be adopted are the same as given for clam culture in an earlier section.

Hatchery production of seed

Hatchery production of seed technology has been developed for *A. granosa, M. meretrix, M. casta* and *P. malabarica.*

In clams, spawning occurs both at elevated water temperature of about 34°C and also at the lower temperature of about 24°C on transfer to the conditioning room, after the thermal shock. Spat settlement takes place between 7th and 26th day after spawning in different clam species studied. The clam spats attains 2-3 cm in length in the hatchery in two months after fertilization and are transferred to the nursery. A survival rate of 15-20% in spat production in the hatchery is considered as satisfactory. In the hatchery the microalga *Isochrysis galbana* is given as food to the larvae and mixed microalgae, reared in outdoor tanks as food to the spat.

Nursery rearing

The 2-3 mm hatchery produced clam seed are transferred to 40 x 40 x 10 cm box type cages. These cages are covered with fine velon screen mesh and for additional protection against damage by crabs and fishes, a 10 cm mesh nylon fish net is stitched over the cage. The cages are suspended from racks in shallow calm waters. They are periodically cleaned of silt, predators and foulers which enter the cages as larvae. In 6-8 weeks, the clams grow to about 10 mm in length and are ready for planting on the grow-out grounds.

Recently rearing of the hatchery produced spat of *P. malabarica* (2-3 mm length) in 25 x 25 mm nylon bags of 1-2 mm mesh at a density of 1000 spat/bag and suspended from a rack in the Tuticorin Bay gave highly encouraging results. This method is cost effective when compared to rearing in cages (Shri D. Sivalingam, Pers. comm.).

Grow out and production

In the blood clam *A. granosa* culture at Kakinada, seed clams of 21.8 to 25.1 mm average length (5.53 - 7.08 g average wt) were stocked at 240-175/m^2. They attained 39.2 to 42.7 mm average length and 25.53 to 32.9 g average weight at harvest. The retrieval is 83.4% to 88.6% when pen enclosures are used and 41.5% without pen. Production rates of 39.0-41.6 t/ha/5.5 months are obtained when pen culture is practised and 21 t/ha/6 months when pen is not used. Thus both retrieval and production rates are reduced by about 50% in the blood clam culture if pen is not used. At a stocking density of 300/m^2 the production is estimated at 70 t/ha with pen enclosure.

In the Mulky Estuary in Karnataka, in experimental culture, *M. meretrix* has grown from 23.6 mm average length to 37.5 mm in 4 months and the survival rate is 75.5%. In the Vellar Estuary, *M. casta* has grown from 7.3 mm to 40.6 mm length in one year.

In a ranching experiment in Ashtamudi Lake in Kerala, *P. malabarica* seeds of 11.5 mm average length and 0.27 g average weight were stocked at 3566 nos./m^2. They attained an average length of 31.58 mm and 8.54 g average weight at harvest after 3.5 to 5.5 months. The retrieval was 7.5%. At Munambam, *P. malabarica* seed of 2.4 mm average length and 0.2 g average weight was stocked at 1500 nos./ m^2. After 4.5 months, they attained 34.6 mm average length and 9.05 g average weight. The retrieval was 17.64%. The production works out to be 1.5 to 2 kg/m^2.

Depuration, processing, byproducts and utilization

Depuration

Clams like other filter feeding bivalves, accumulate pathogenic organisms in their body. By depuration the bacterial load is brought down to permissible levels; also faeces, sand particles and silt are removed from the alimentary canal. Clams are depurated in the same way as other bivalves.

They are placed for 24 hrs in cleaning tanks under a flow of filtered seawater. About 10-20% of the seawater is continuously replaced. At the end of 12 hrs the water in the tank is drained and the clams are cleaned by a strong jet of water to remove the accumulated faeces. They are further held in filtered seawater for 12 hrs and for about one hr in 3 ppm chlorinated seawater, washed once again in filtered seawater before processing. In several countries, they are eaten raw and also steamed and eaten.

Processing

The various techniques followed in processing the clam meat are similar to those used for other bivalve molluscs. The clam meat is frozen as blocks or individual quick frozen, canned and smoked. Other products are clam juice, clam stripes, clam streaks, stuffed clams, clam pickle and chowder.

The adductor muscle is the valued part of the giant clam. In a 20 cm clam, it weighs about 500 g. Except the liver all parts of the soft body of the giant clams are eaten. The mantle of the giant clam is used to make the Japanese salads, spaghetti, marinara, clam crackers and minced clam.

Byproducts and utilization

In clam culture, shell is the byproduct. It is used in the manufacture of cement, calcium carbide, sand-lime bricks and lime. The shell lime is used for manuring coffee plantations, as a mortar in building constructions, in the treatment of effluents, as a pesticide by mixing with copper sulphate and in glass, rayon, polyfibre, paper and sugar industries. The shells of several clams have ornamental value and are used in making curios.

Truck loads of blood clam shells are transported from Kakinada to southern districts of Tamil Nadu for use in the shell craft industry.

Giant clam shells currently find a ready market as decorative objects, ash trays, salad bowls and wash-basins. *T. squamosa* shells are most valued in this trade. Philippines is the centre for shell craft industry.

Export market for clams

The pattern of clam meat export from India is given in Table 5. The export demand for clam meat has been increasing over the past few years, particularly from Japan, western Europe and USA. The clam meat export from India has increased from meagre 371 t in 1989 to 900 t in 1993. In terms of value, almost fivefold increase has been recorded at Rs. 63.02 lakhs in 1989 to Rs. 292.25 lakhs in 1993.

Economics of clam culture

The economics of the on-bottom blood clam (*A. granosa*) culture are given here. The area of the farm is 10 ha and the duration of culture is 6 months. The stocking density of the seeds at 300/m^2 was considered as the optimum and at this density production of 70 t/ha is envisaged. There is much demand for the shell of this species in the shell-craft industry and currently it fetches Rs.1000/t.

A.	*Capital expenditure*	Rs.
	1. FRP boat with outboard motor	80,000
B.	*Operational cost*	
	1. Casuarina poles	2,500
	2. Cost of pen enclosure	10,000
	3. Cost of seed @ Rs.55/1000	16,50,000
	4. Running expenditure of boat	6,000
	5. Labour cost	6,000
	6. Harvesting, depuration & shucking of meat charges	50,000
	7. Contingencies	6,000
	8. Salary to Manager @ Rs.2,000 for 6 months	12,000
	9. Watch and ward for 6 months	12,000
	Total	17,54,500
C.	*Interest at 15% for A for one year*	12,000
D.	*Cost of production*	
	1. Depreciation @ 10% of A	8,000
	2. Operational cost	17,54,500
	3. Interest	12,000
	Total	17,74,500
E.	*Income*	
	Shell-on weight of harvested clams 700 t	
	Wet meat weight 105 t	
	Shell weight 525 t	
	Sale of 105 t meat @ Rs. 25,000	26,25,000
	Sale of 525 t shell @ Rs. 1,000	5,25,000
	Total	31,50,000
F.	*Profit* (Rs.31,50,000 - Rs.17,74,500)	**13,75,500**

Net profit on investment works out to 77.5%.

Prospects and constraints

The prospects for developing clam culture in India on commercial lines are very bright and the advantages are given below.

1. Clams feed low in the food web on detritus and phytoplankton and give high production per unit area. They are efficient converters of primary production into nutritious sea-food, suitable for human consumption.
2. Clam culture is essentially a relaying practice of collecting the seed from high density areas and stocking them in suitable grow out areas. The farm management involves periodic site inspection and eradication of predators; the technology is simple and easy for adoption by the farmers.
3. On-bottom clam culture does not involve high labour or cost input.
4. Clam culture can easily be blended with capture fisheries and can be taken up as an income and employment generation programme in rural areas.
5. In the export market there is demand for some species of clams only. From India there

is insatiable demand for the frozen meat of *P. malabarica.* There are large tracts of derelict water bodies such as the Kakinada Bay and they can be utilized for the culture of this species.

6. In clam culture fertilisers and feeds are not used and it is eco-friendly. Clams are good biological filters and the introduction of clams in areas of high eutrophication such as shrimp ponds helps to reduce the pollution due to high load of suspended matter.

7. After the outbreak of shrimp disease in Taiwan, the farmers have switched over to culture of the clam *Mercenaria lusoria* in shrimp ponds for export to Japan. Similar practice can be followed in Andhra Pradesh and Tamil Nadu. Also fattening of the clams in shrimp ponds as followed in Thailand deserves merit.

Constraints

1. The major constraint for the large scale propagation of clam culture in the country is the absence of laws to allot water bodies to prospective farmers.

2. Mapping of sites suitable for clam culture, based on species-site interaction are needed for developing culture.

3. Consumption of clams is still localised, close to the production centres and only a small segment of the population take them as food. They still remain as non-conventional food. Vigorous extension drive is needed to make them popular.

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