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PEN CULTURE OF SHRIMP IN THE BACKWATERS OF KILLAI, TAMILNADU

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This paper describes the results of a 21-month experiment on pen culture of shrimp and finfish in the backwaters of Killai in South Arcot district, Tamil Nadu, India. It concludes that shrimp pen culture is technically feasible and that *Penaeus indicus* is the most promising of culture species.

The experiment was carried out in collaboration with the Department of Fisheries, Tamil Nadu. The authors of the paper thank Mr. A. D. Isaac Rajendran, Joint Director of Fisheries, and other officials for their cooperation and assistance.

The paper and the experiment on which it is based are activities of the small-scale fisheries project of the Bay of Bengal Programme (BOBP). Funded by SIDA (Swedish International Development Authority) and executed by the FAO (Food and Agriculture Organization of the United Nations), the project seeks to develop, demonstrate and promote technologies and methodologies to improve the conditions of small-scale fisherfolk and the supply of fish from the small-scale sector of the Bay of Bengal region. The project covers five countries in the region — Bangladesh, India, Malaysia, Sri Lanka and Thailand.

CONTENTS

1. INTRODUCTION

In recent times Tamil Nadu and other maritime states in India have laid more and more emphasis on coastal aquaculture. This emphasis derives from a combination of factors—greater demand for fish for internal consumption and export; the rising fuel costs of capture fisheries and the need to generate rural employment. The state has 56,000 ha of brackishwater spreads and another 15,000 ha of low-lying coastal land with potential for aquaculture development.

Following the fourth Advisory Committee meeting of the Bay of Bengal Programme (BOBP), Tamil Nadu made a specific request for BOBP's technical cooperation in developing coastal aquaculture in the state. In response to the request, BOBP technical staff mcde a preliminary assessment of the state's coastal aquaculture potential. This was followed by a two-week reconnaissance study (1981) by a consultant (HR Rabanal) who, along with the BOBPstaff, visited 11 potential sites from several coastal districts. Further studies of the more promising of these sites were made by a two-member mission (Kasemsant Chalayondeja and Anant Saraya of the Directorate General of Fisheries, Thailand) that visited Tamil Nadu for about a month during September—October 1981 at government request. The BOB P acted as a supporting agency for the mission in the spirit of TCDC (Technical Cooperation among Developing Countries). The mission identified pen culture in backwaters as the technology with the best potential for coastal aquaculture development in the state.

There are apparently two alternatives for developing marine shrimp culture in the state—shrimp culture in ponds constructed on lands, or its culture in parts of lagoons and backwaters enclosed with suitable nelting or screening material, a process known as pen culture. As government help was assured for developing pond culture, it was agreed that pen culture could be tried as a possible technology in the state's extensive lagoons and backwaters.

In view of the prcdominantly sandy nature of the coastal soil, the characteristically low tidal amplitude (Tess than a metre) and the combination of high temperature and high salinity as usual in the area, certain clear advantages in pen culture were envisaged. Being freely confluent with a large dynamic water system connected with the sea, it was assumed that temperature and salinity extremes and oxygen deficiency, often experienced in ponds, would not occur in pens. Moreover, this method would not call for expensive and complicated pond and sluice construction requiring highly technical expertise. It would also not require an expensive fuel-dependent pump or any mechanical assistance for filling, replenishing, exchanging and draining of water which are essential in shrimp ponds. Low investment, simple construction and removability of the pen set-up to another place were other factors favouring a trial of pen culture.

Thus, a pilot project of 21—month duration was formulated to see if pen culture could be used as a possible technology for shrimp farming. The project became operational in May 1982. The Government of Tamil Nadu provided three full-time professional staff' and secretarial facilities, three night watchmen, a driver and office facilities. The BOBP contributed expertise, equipment, temporary labour, materials and supplies, operating costs and funds for study tours and training.

An officer at the level of joint director2 experienced in brackishwater aquaculture and located at the headquarters of the Directorate of Fisheries in Madras, was in charge of coordination and liaison on behalf of the Directorate with BOBP in planning, executing and monitoring the progress of the project. The site was located in the lKillai backwaters, South Arcot district, Tamil Nadu (Appendix 1).

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2. FARM COMPLEX

The farm complex consisted of a thatched shed built on a casuarina and palmyra trunk platform with a plaster of mud, a number of pens and an observation tower made of casuarina poles.

The shed served as a laboratory, meeting room, storage room and bedroom for project officers. A pit dug near the shed was the only source of fresh water. The tower was used as a night watch post and during the day for overviewing the pen set-up.

Initially, four pens P1, P2, P3 and P4 were set up in July 1982. The larger two pens P1 and P2 measured 70 m x 25 m each, the two smaller pens enclosed an area of 25m x 25 m each. In March 1983, five more pens of various dimensions were added; P5 and P6 measured 140 mx 50 m each; P7 and P8 were 40 m x 25 m in size and P9 was the smallest, enclosing a 15 m x 15 m area.

About 20—30% of the area enclosed by P1.2,5 and 6 (second phase), which included the intertidal zone, would either be completely exposed or covered with less than 30cm of water during low tide. Those areas which were not covered with at least 30 cm of water all the time were not included in estimating the total effective culturable water area of the pen. On this basis, the effective water area in P1 and 2 was 1,250 m^2 in each pen, while the area for P5 and 6 was 5,000 m^2 each. In conformity with the bottom contour, the depth of water in the pens increased some distance from the shore and then levelled off.

Table 1 presents data on the depth distribution in various pens.

Table 1: Depth distribution of water in pens during low tide

Pen no.	Less than 60 cm	60 cm or more
	(% of total effective water area)	
1	50	50
2	50	50
3		100
4		100
5	30	70
6	25	75
7		100
8		100
9		100

The maximum depth recorded was 1.48 m during the low depression period in December 1983. The bottom was soft and muddy in the deeper parts, but firm and largely sandy in the shallower parts in the intertidal and the upper sub-tidal zones.

The pen layout was modified somewhat in February 1984. The partitions between P1 and P3, P2 and P4 and P7 and P8 were removed to merge the pairs. They were also renumbered, as in Table 2.

Table 2: Renumbering of pens

Second phase pen numbers	Changed pen number	Areas of changed pens (ha)
5	1	0.5
1, 3 (now merged)	2	0.2
2,4(-do-)	3	0.2
6	4	0.5
7,8(-do-)	5	0.2
9	6	0.0225

3. FARM PRODUCTION

Appendix 3 summarises the production results for the period July 1982-December 1983. Altogether 1.550 tonne of culture shrimp *(P. indicus* and *P. monodon)* and 704 kg of unwanted fish and miscellaneous shrimp, mostly matapenaeid species, was harvested from a cropping area of 3.62 ha (Appendix 3). Altogether 26 culture experiments were set in four trials. Three of the experiments (in P2, 7 and 8) during the fourth culture trial in 1983 were unproductive; harvesting in these pens was delayed for demonstration to a team of aquaculturists due from Indonesia and the stock perished following a drastic salinity fluctuation in December (see section 9 on Project Environment). The areas of the three affected pens are not included in the above mentioned cropping area.

Of the 23 effective experiments 21 experiments featured supplementary feed; the average production in these pens was 435 kg/ha/crop of about 100 days, while the highest production in any individual pen was 736 kg/ha in about three months. Adding fish and miscellaneous shrimp—most of which when very young managed to intrude the pens and grow in them, sharing and competing forfood and space with the cultured shrimp – the highest yield in any individual pen and overall average yield respectively stood at 1184 kg/ha/crop and 657 kg/ha/crop.

Two experiments in P2 and 4 in the first trial (1982) were conducted without supplementary feed; the production rates of the culture species were 360 kg and 208 kg/ha/crop, respectively. Details of various culture experiments, including stocking rates, shrimp size, etc., in pens and production results up to December 1983 are given in Appendix 4.

The fifth culture trial during the first half of 1984 was badly upset by the unusually heavy rain in March when the environmental salinity drastically declined (see Section 9 on Project Environment). The implications of the environmental changes were unfortunately not understood until harvesting of the crop was attempted in May. Piles of mangrove and *Prosophis* branches, used as protective shelters and additional substrata for growth of various natural food organisms, did not permit comprehensive periodical sampling for shrimp survival. In May when the branches were removed and harvesting was undertaken, it was seen that the shrimp population in all the pens (P1, 2,3,4) stocked in February had mostly perished ; only 93kg of the cultured shrimps *(P. indicus* and *P. monodon)* could berecoveredfrom P1 and P4. Seventy-five kg of miscellaneousshrimpand 89kg of finfish were also removed from these two pens. Immediate stocking of the affected pens was desired, but the seed scarcity permitted stocking of only P1, a 0.5 ha pen.

PS stocked with shrimp *(P.indicus)* alone and *P6withEtroplussureterisis,* afinfish, plus *P. indicus* in April, i.e., after the extreme freshening effect was over, remained unaffected. P1, 5 and 6 were harvested on various dates in August. P1 and 5 produced 252 kg of cultured shrimp including 10kg of *P. monodon—a* prcduction of 360 kg/ha/crop. Pen 6 set for polyculture produced 17.7 kg of *E. suretensis* and 6.1 kg *P. iridicus* which together represented a production of 1058kg/ha/crop, Other details of the fifth culture trial results are shown in Appendix 5.

Taken together, the pens in which culture experiments with supplementary diets were conducted, and the four monsoon-affected pens, prcduced a total of 1628 kg of cultured shrimp (1493 kg from 21 experiments during 1982-83,93kg from the four affected pens in 1984 and 242 kg from P1 and 5, also in 1984). The production came from a total cropping area of 4.6325 ha accounting for an average production of 351 kg/ha/crop of 3-4 months.

Miscellaneous shrimp and finfish when added to the cultured shrimp raised the total yield to 2245 kg for the above-mentioned area – this production represented a rate of 484 kg/ha/crop. However, the miscellaneous shrimp and predator and non-predator finfish were undesirable in the culture system because they had a low price in the local market and produced director indirect adverse effects on the growth and survival of the cultured shrimp. Nevertheless, the overall results indicated the high production potential of the pens.

4. PEN MATERIALS AND CONSTRUCTION

Essential materials

The materials needed were the following:

—pen wall or screen

—wooden/bamboo posts to support the pen walls and hold them in position. Casuarina posts locally available in plenty at reasonable cost were found [deal.

—4-5 mm thick foot rope. High density polyethylene (HDPE) rope locally available was found convenient.

—3mm thick head rope, HDPE rope; a pen could be installed even without a head rope.

—horizontal bars to tie the head line/rope.

—H DPE twine of 0.75-1 mm thicknessfortying, lacing etc.; coir rope partially served the purpose.

Pen wall quality requirements

The pen walls must retain small-sized shrimp seed and fish in open salt water environments long enough to enable the shrimp grow to exportable size. The primary target group for the technology will be small-scale farmers with limited means. The pen wall material must, therefore, be:

—with mesh small enough to retain shrimp and fish seeds, but big enough to allow free flow of water without easily permitting silt deposits or algal growth,

—resistant to salt water and sun,

—strong enough to withstand the stretching tension and wind and wave actions,

—resistant to crab cuts,

—cheap and easily available,

—easy to handle and transport,

—such that pen construction and installation on soft or firm bottoms, pen repair and maintenance and pen removal are easy

Selection of pen wall material

Bamboo or palmyrah leaf stalk split, synthetic netting and rust resistant wire or plastic mesh were considered as probable screening material for pen walls. The possibility of using bamboo split as pen wall matorial was ruled out, since good quality bambo was not available in and around Killai. A kind of screening material (locally called s iar) made of palmyrah stalk split was available in limited quantities, but it was not strong or good enough.

Suitable wire or plastic mesh also was not immediately available in India. This left nylon and H DPE webbing, both of which appeared to have most of the desired qualities. HDPE was cheaper, but material of appropriate mesh size and strength was not available. Small and strong mesh nylon webbing which was available, was chosen for pen construction. The material was of 14 mm mesh and knotless; small mesh (14 mm or smaller) nylon webbing of about 0.75 twine size was available in commercial quantity only in the knotless forms.

The project had to be started with 14 mm mesh webbing, since enough of it was immediately available. It worked well, but big size seed shrimp, 30 mm or bigger, had to be used to retain them in the pen. Crab cuts being a problem, a reinforcement layer of various materials was used on the lower side of the pen wall in parts (see Section 8 on Pests).

Pen height

Pen height, an important aspect, had to be considered carefully. It may be seeti from Appendix 6 that a part of the wall is within the mud, and another part extends from the bottom soil level to the water surface, There is also the width above the water. The width within the mud or soil was meant to prevent the cultured shrimp from burrowing out, and eel, catfish, etc., from burrowing into the pen. This was also meant to keep the pen wall secure in its position against wind and wave actions. The width of this portion will depend on the nature of the bottom; if soft, the wall should go deeper into the mud to prevent particularly the inward flow of unwanted organisms. Shrimps do not barrow very deep, but eels do. The width of the wall above the bottom soil will depend on the depth of water during the highest high tide at the site plus a reasonable provision for a normal flood level.

At Killai, the width of the wall inside the soft mud was about 0.5 m; inside the shoreward sandy bottom it was around 0.3 m. The maximum depth of water corresponding to any normal high tide was not more than a metre at any point in the pen area. So,theoriginal heigl-.tofthepen was2m. Lateritwas observedthat during the November-February cyclones which sometimes persisted for several days, the water depth increased well over 1.15 m and reached 1.48 m for a short period. Over this height again, some free board of at least 30 cm was desirable as a barrier to predatory species like *Lates, Elops* and *Polynemus* which could jump into the pens. Thus, the overall pen height at Killai was adjusted to about 2.5 m. The pen height would obviously vary from situation to situation.

Quantity of various materials required

An account of the quantities of various materials required for an isolated 0.5 ha pen under Killai conditions is given below:

	Description of the materials required	Approximate quantity required
1	Knotless nylon webbing, 10-14mm mesh, 0.75 twine thickness	40-50 kg
2	Casuarina posts, 9-10 cm dia at base end, 3.5 m long	2 tonne
3	Casuarina horizontal bar, 4-5 cm dia at base, 3mlong	lOOnos.
4	Foot rope, HDPE, 4-5 mm dia	400 m
5	Coir rope, 2-3 mm dia	6 kg
6	HDPE twine,1 mm thickness (for tying loop to posts)	1 kg
7	Reinforcement webbing of HOPE, 16-18 mm mesh, 40 mesh depth, 0.75-1 mm twine thickness	21 kg
8	Metal furrower to make furrows for inserting pen webbing into firm ground	1 no.

Pen construction

Pen construction was simple. The webbing was cut into pieces of appropriate width and a 4-5 mm thick HDPE foot rope tied to the bottom line of the webbing. A loop was worked out in the foot rope initially at 5 m intervals but later the loop-to-loop distance was reduced to 3.25 m (Appendix 16). Casuarina posts were used for installation of the pen walls. The broader ends of the posts were chiselled to a sharp point and half a metre above the pointed end a shallow groove was cut. The pen was then ready for installation.

Pen installation

The pen wall, the foot rope and the casuarina poles were taken to the site in boats. Posts were fixed at four predetermined corners. One end loop in the bottom line of the pen wall was tied to the groove of a strong post and driven one metre in, so that the bottom line went half a metre into the mud. The next loop, 3.25 m apart, was then tied to another post and driven into the mud in the same way and so on. Care was taken not to stretch the bottom line too much. While the loop-to-loop distance was 3.25 m, in actual installation the post-to-post distance was kept at about 2.5 m. This made installation easy.

The foot rope in between any two posts did not go straight into the mud, there was a hump in the middle. By stepping on the foot rope, it was pressed down to the desired depth (Appendix 7). This needed much patience.

In areas where the bottom was sandy and firm, the pen wall could not be sunk. So a deep furrow was made with a suitable furrower (Appendix 7). The foot rope was then fixed into it with the feet. Depending on the depth, the workers had to dip into the water to do the job. Since the possibility of eels and other species burrowing in sandy bottoms was low, the insertion of the foot rope in such bottoms was mainly to keep the pen wall fixed to the bottom, so that it did not come up loose because of wind, wave and current action. About 30cm insertion into sandy bottom was enough. In places where the low tide water mark was close to the high water mark, the two sides of the pen vertical to the shore line were extended up to the supratidal level to avoid a fourth side of the pen. This not only saved cost, but also made the following easier:

—Netting for pest removal, harvesting the product

—Getting into the pen for feeding, pen checking, maintenance, sampling and growth monitoring

—Stocking of fry.

The webbing wall in between two posts of one or more sides of the pen had some loose portions which could be lowered to allow a boat or a floating cage to get into the pen for feeding, releasing fry, sampling, etc. The loose part could again be raised and tied to the horizontal bar.

The pens were installed side by side with common w?lls, saving extra material and cost.

5. SEED

Collection areas and gears

All shrimp seed for project use was collected from the Killai backwaters. For seed collection various types of gear were used: the simplest was a rectangular piece of velon screen 3 m x 1 m size of 16-20 mesh per 25 mm length. Two persons were needed to drag it by holding the two ends. Seed caught by this gear was mostly small post-larvae. A dragnet—consisting of a length of nylon webbing 3-5 m x 1 m with mesh size 10-14 mm, and two wooden sticks at two sides to facilitate dragging—was one of the fry-collection gears. Three persons were required to operate this, two persons for dragging, one person for holding the footline in position. The gear was suitable for juvenile shrimp. Castnets of 8-9 mm mesh size were also used. Bundles of twigs, coconut leaves, straw, etc., were kept suspended in water; this helped the gathering of *P. monodon* post-larvae in particular. The gathered seed was collected by operating large hand nets underneath the suspended bundles. A push net consisting of a semi-circular frame attached to a small-mesh conical net with a cod end was developed as the project was implemented (Appendix 8a). Requiring only one person to operate it, the net proved very efficient in shallow areas of sandy or firm bottoms with or without rooted submerged vegetation. The size of the seed caught depended on the mesh size used for the conical net. The collected seed was removed by untying the cod end rope.

Monitoring and survey

Seed monitoring was a regular activity of the project. Routine seed monitoring and a specific survey under a socio-economic study over two months (July and August 1983) yielded valuable information about shrimp seed availability in the area. *P. indicus, P. semisu/catus, Metapenaeus monoceros, M. dobsoniiandAcotes* were the most common species. Attention was on *P. indicus* and *P. monodon* for their quick growth, big size and high price in the local markets.

P. indicus occurs in the backwaters almost throughouttheyear. Their number peaked in January-February and July-August, when a man could collect and sort out on an average at least 1500 *P. indicus* seeds an hour with a push net. During March-April and July-November, the collection rates averaged 200-400 an hour. December and May ware the leanest months. During January-February, *the* peak period, the species comprised about 80% of the collection.

P. monodon seed which was always poorly represented in the collections, was in abundance in January1984; the collection rate by push netwasover 200seed an hour. In 1983 the peak occurred during June-July when 100 seed could be collected in an hour.

The size range of 90% of the seed collected for culture was 1 5-25 mm; the rest was bigger.

The placeswhere *P. indicus* and *P. moriodon* seed collection efforts were mostrewarding were:

1. Vadakkumuttu having a muddy bottom with various macrophyta, *Halophila, Chaetomorpha, Enteromorpha.*
2. Naduthittu, having intertidal sandy and sub-tidal muddy areas with *Ha/ophila* and *Gracillaria.*
3. Chinnavaikkal having sandy shallow and muddy deeper areas with *Cymadocea* and *Gracil-lana;* a part of the area was covered by an oyster bed.
4. Salt pan area near Porto Novo having a shallower sandy bottom and a deeper muddy bottom with *Cymadocea.*

Seed sorting and transportation

After a haul, the collection was placed in large plastic bowls or buckets partially filled with water; vegetation, trash, large animals, mud, etc., were quickly removed. The sample was then washed with clean water and transferred into a shallow, light coloured, preferably white, container for sorting. A collapsible shed with canvas or sail cloth was erected for seed sorting on sunny days. The selected species of seed were put in another bucket with clean water. The seeds were periodically transferred to one or more *hapas* or floating cages placed in the water.

For transport of seed from the collection centre to the project site, a project Landrover or boat was used. The seed was usually carried in small-mouthed tin containers as used for carp fry transport (Appendix 8b). The possibility of water spilling from such containers was much less than that from a wide-mouthed bucket or bowl. The container water was not artificially oxygenated. Small and shallow floating cages were found convenient for short distance transport; the cages were either towed or carried ashore. Transport in floating cages ensured that there was no risk of oxygen deficiency, pollution or temperature rise, which could have happened in the other modes of transport. However oxygen deficiency or rise in temperature of the container water was never a problem, since the collection centres were notfar and the time to cover the distance was never long.

6. NURSERY REARING

As mentioned earlier, 90% of the seed collected within a reasonable length of time was in the 15—25 mm size range. These could not be retained in pens of 14 mm mesh webbing. Therefore, they had to be raised to at least 30 mm size in a nursery, for which *hapas* or cages and pens were used.

Cages (hapas): Velon screen cages of three sizes, 10 m x 3 m x 1.5 m, 10 m x 4 m x 1.5 m and 15 m x 4 m x 1.5 m, were used. Mesh sizes of the screens were 3.2 mm and 1.6 mm. The cages were fixed in the water with vertical posts and horizontal bars. The cage bottom was in close contact with the bottom, the mud acting as a natural substratum to the shrimp. To prevent the cage bottom being lifted by a strong wind the lower side of the cage was tied to the bottom horizontal bars. In addition, some bricks wrapped in polyethylene paper were placed at various points to keep the bottom from floating up. Bundles of straw and twigs were placed in the cages; this provided shade and shelter to the baby shrimp besides presenting substrata for the growth of periphytic food organisms.

Cages were stocked at 0.6-0.7 million a hectare. Wet feed at 200% of the shrimp's body weight was provided for the first fortnight and from the second fortnight the feeding rate was reduced to 100%. Shrimp-head meal, minced squid offal or trash fish mixed with groundnut oilcake formed the nursery feed. The ratio between the animal and plant matter was generally 1:1. The survival percentage was 69—86%. The average increment in length and weight was 36.7 mm and 2.42 g, respectively in 40 days. The results of rearing are found in Appendix 9.

Nursery pen

An effective area of 960 m^2 was enclosed by HOPE webbing of 1 mm mesh size. The vertical height of the pen wall was 1.40 m of which 15—20 cm reriresented the part embedded into the bottom mud/sand; the balance was above the floor level. Repeated netting, hand picking, etc., were employed to remove all unwanted animals from the pen. After allowing the pens 2 or 3 days **to** settle, shrimp seed was stocked in it for rearing.

In the first instance, *P. inc/icus* was stocked at 105/m2. The feeding rate was equivalent to 100% **of the shrimp's body weight. The feed consisted of boiled and chopped clam meat or minced** squid offal. After 55 days, the recovery rate was only 35%. The stocking rate used in the second nursery rearing was 90/rn2. The feeding rates during the first, second and third fortnight were 200%, 150% and 100%, respectively of the body weight of the standing population of the shrimp. The feed consisted of a mixture of minced squid offal and rice bran. At the end of 50 days of nursery rearing, 57% of the shrimp could be recovered. The results of nursery rearing in the pen are given in Appendix 10.

The recovery rate from the pen was much less than from the cage, because harvesting the pen was more difficult. In the case of the cage, complete harvesting of all the survivors was possible by lifting the cage part by part.

Transferring seed to grow-out pens

The nursery-raised seeds were harvested from the pen using avelon screen drag net, push net and **castnet. The cages were first untied and then progressively lifted from one end to the other; this concentrated the seed shrimp** in a small area from where they were scooped **out by a handnet. Seed in required number from the pens and cages were first put** in smallfloating cages which were **towed into various pens** interconnected with collapsible passages. The cages were turned upside **down to release the seed.**

7. FEED

The shrimp in the grow-out pens were given supplementary feed in all but two of the experiments. The feed, consisting of both animal and plant matter, had the following composition:

Animal matter -	squid offal, octopus, clam meat, trash fish (silver bellies, sardines, anchovies, *Ambassis, Thryssa,* etc.)	50%
Plant matter -	Groundnut oilcake, de-oiled rice bran	30-40%
Polished wheat flour and tapioca powder as feed binders		10%

Some kind of crude feed processing was required in view of the shrimp's feeding behaviour and the nature of the culture environment. Shrimp cannot effectively use either very large or very small food matter. Unlike fish which swallow food, the shrimp normally grabs the food particles with its thoracic appendages, carries it to a safe distance and then eats it, bit by bit. The food particles must, therefore, be large enough so that they can easily hold it, but small enough to be easily carried away. The animal matter was, therefore, chopped into small pieces. Fish and other animal matter were often crushed or mashed and then chopped. Rice bran, wheat bran and oilcake were in the form of small particles and suitable for the post-larvae and the juvenile shrimp, but not for bigger shrimp. It was, therefore, necessary to prepare water-stable lumps of feed.

The required quantity of animal matter was first washed clean and then minced with a grinder, manual or motorized. The minced meat was mixed with rice bran and water-soaked groundnut oilcake. The binding agent, boiled into a glue, was then thoroughly mixed with this material until the whole mass turned into a sticky dough this was divided into smaller lumps and distributed to various pens according to a predetermined rate.

The feed was dispensed in trays (made of plant material) distributed in three rows—two along the two walls vertical to the shore and one along the middle line. The trays were placed on the bottom at places marked with sticks. It was observed that feed with minced animal ingredients retained its lumpy form for more than two hours, while feed with chopped animal flesh retained stability for an hour.

On occasions, the feed consisted only of plant ingredients since animal matter was not available for various lengths of time either for biological reasons or when there was no fishing because of bad weather.

Feed was normally supplied in the evening, at 5-10% of the body weight of the shrimp.

A short-term survey under a separate socio-economic feasibility study of pen culture of shrimp revealed useful information about feed availability in and around the Killai area. According to the survey report, enough animal feed in the form of prawn heads, crabs, trash fish and squid and various molluscs required for farming a 80-100 ha pen could be procured from the area. Clam, oyster and mussel could be collected from the intertidal and sub-tidal zones extending over a 450 ha area. It was estimated that in about 450 ha potential area, the clam population at the rate of 17,030/$100 m^2$ would be about 778.5 million. The survey team found that 2618 nos. of clam (2-6 cm size) could produce 2.5 kg of meat. On this basis, 778.5 million clam could produce 743.4 tonne of meat

Assuming yearly shrimp production of 1.5tonne/ha/yr and a food conversion rate of 4:1, the estimated availabTe clam meat alone could sustain a culture operation in a 124 ha pen. One worker was able to collect enough clams to produce 7-8 kg meat a day. At a prevailing daily wage, the cost of 7-8 kg of clam meat plus the labour required for deshelling would be around Rs.15. The survey further showed the availability of 104 tonne of trash fish/yr from the nearby landing centres. This could support 15 ha pens at 7:1 conversion rate maintaining the same level of production as with clam meat.

8. PESTS

Many species of sea life and some species of plants interfered with shrimp culture in various ways. The problems they created related to one or more of the following:

- Predation of the cultured shrimp,
- Competition with the cultured species for food and space,
- Cutting holes in pen walls, boring tunnels in posts, pericdic blocking of pen mesh, and fouling and polluting the water.

While installing the pens, many undesirable organisms were trapped inside the pens. Repeated netting with small-mesh castnet, dragnet (Kondavalai), gillnet and hand picking were practised for removal of these organisms before the pens were stocked with seed shrimp. During the culture period, the pen was accessbile to all kinds of animals below a certain size range. While very young, they only competed with the shrimp for food and space, but latter the predatory species turned to be a direct threat to the shrimp. Periodic pest removal was, therefore, practised as a matter of routine.

The worst predators were the eel species, *Muroene* and *Congresox,* and the catfish species *Plotosus* and *Tachysurus.* Other species of concern in varying degrees were *Lates, Johnius, Pomadasys, Polynemus, Elops, Thenaponi, Belone, Epinephelus, Gobids,* etc.

It was suspected that big-sized eel could find their way into the pens beneath the foot line. Hand-line and hook was found to be the most effective method for catching the eel. Hand picking and spearing also helped remove cathsh and eel. Castnetting, gillnetting and dragnetting helped remove other fish.

Crabs not only competed for food, but also caused considerable damage to the pen wall, cutting holes into it. About 30 cm width of the bottom part of the pen wall was most vulnerable to crab cuts. Daily checking was necessary to locate the holes and mend them under water. The work was quite laborious, time-consuming and cumbersome.

To counteract the problem of crab cuts, the following types of reinforcement materials were tried:

- hand woven HDPE webbing of 12-14 mm mesh and 0.75-1.25 mm thick twine
- tar coated bamboo split
- galvanised iron chicken mesh coated with red oxide and aluminium paint
- an extra layer of nylon webbing of the same quality as the pen wall itself.

Each type of reinforcement material, about 50-70 cm in width, was attached/seamed with the penwall at various points. The lengths of various materials were as follows:

— HOPE webbing	— 12m
— Bamboo split	— 25 m
— Galvanised wire mesh	— 2 m
— Nylon webbing (14 mm mesh, 0.6 mm twine)	— 25 m

The performance of different materials was observed for 10 months. The tar-coated bamboo split, though it reduced crab cutting, broke into fragments in three months' time. Similarly, the galvanised wire mesh rusted and crumbled in four months. The nylon reinforcement layer could not protect the pen wall from crab cuts. The incidence of crab cuts on the HOPE reinforcement webbing was, however, insignificant. The webbing also did not show any clear sign of wear and tear.

Some boring organisms damaged a few casuarina posts supporting the pen wall. However, the occurrence of wood-borers was not frequent, and the damage they caused was negligible. Plant organisms, e.g., seaweed *Grad/aria,* algae *Enteromorpha* and *Chaetomorpha,* broken leaves of a submerged rooted plant, *Halophila,* and a branched coelenterate tended to block the pen meshes periodically; these organisms disappeared sooner or later without causing any real problem. But, the plants which often drifted in the wind gathered on the shore where they decayed, sometimes causing oxygen deficiency in limited areas.

9. PROJECT ENVIRONMENT

The Killai backwater system, fringed and frequently intercepted by the Pichavaram reserve mangrove forests (mainly of *Rhizophora* and *Avicennia),* covers an area of 1300 ha as estimated from Government of India topographic sheet maps. The system opens to the Bay of Bengal through two perennially open bar mouths—the Vellar river bar mouth on the north and the Coleroon bar mouth on the south. Thirunalthoppu, the nearest village, is 3 km and Chidambaram the nearest town, 15 km from the project site.

Tide

The tidal amplitude, characteristically low in the area, has somewhat improved since December 1983 apparently because of two physical changes. Firstly, the closed Chinnavaikkal bar mouth near Killai has been cut open through government efforts. Secondly, the very strong discharge at the unusually heavy monsoon flood in November-December 1983 and in February 1984 has substantially deepened and widened the Coleroon and Vellar bar mouths. Tidal amplitude to the extent of 20-50 cm has become usual. Earlier, the value was 5-30 cm only.

Water depth in the pens always remained below 1 m except in early November 1982 when for a few days the water depth was as much as 115 cm. Throughout November and December 1983, and again in February 1984, the depth of water was 1.0-1.5 m. The changed tidal amplitude necessitated readjustments in the pen wall height. Appendix 11 shows the tide gauge readings at the highest high water and the lowest low water levels as recorded for each month from September 1982 to July 1984. Tidal amplitude by month is also presented in Appendix 1

Temperature and salinity

The recorded minimum water temperature was 22°C in January 1983 and the maximum was 36°C in May 1984. The maximum difference between the lowest and the highest temperature for any month was 10°C; this diference was noticed in August. Daily or weekly fluctuation of temperature was much less than the above figure and caused no problem to the shrimp. No temperature stratifications worth mention were encountered.

High salinity (over 30 parts per thousand) condition was a characteristic feature of the area (Appendix 13). From the beginning of January to the end of July 1983, salinity was always above 30 ppt. The maximum salinity was 40-42 ppt during June-August apparently because of prolonged drought; this period also corresponded to the high temperature period of the year. However, the salinity value during the period was in a rather narrow range without any rapid fluctuation. During other periods, various degrees of salinity fluctuation corresponding to the monsoon rains were usual.

In culture trial no. 2(November '82) salinity gradually declined from 10 ppt to 2 ppt over 10 days. The low salinity level persisted for 5 days, then gradually improved. The shrimp stock, mostly *P. indicus* of average weight of 8 g, not only successfully adjusted itself to the salinity change but also grew fairly well (see Appendix 4) through the low saline period; 70% of the shrimp was recovered at the end of the culture operation. In culture trial no. 4, the stock in P2, 7 and 8 perished when (December 1983) salinity dropped from 10 ppt to 0.7 ppt in just 24 hours following heavy influx of monsoon flood water through the nearby irrigation canals. The shrimp in the other pens had been harvested but harvesting of P2, 7 and 8 was postponed in order to demonstrate the culture operations to an aquaculture mission from Indonesia. Barring the above situations the physico-chemical parameters did not fluctuate too steeply to cause any real danger to the cultured shrimp during 1982 and 1983. A sudden salinity drop (from 31 pptto 4 ppt over a period of four days) in March during the 5th culture trial in 1984 also proved detrimental — the stocks in P2,3, 7 and 8 perished.

Oxygen, pH

Dissolved oxygen content was normally above 4 ppm: the value was below 2 ppm at times near decayed masses of aquatic vegetation just outside the pen wall on the intertidal zone. The pH value was consistently around 7.5.

Water area survey

A quick water area survey was undertaken under a socio-economic feasibility study for pen culture of shrimp in Killai area. The purpose was to demarcate water areas suitable for pen culture of shrimp. A minimum depth of 30 cm and a maximum of 80 cm during the lowest low water level (LLWL) were considered suitable for pen culture of shrimp under tidal conditions prevailing in the Killai area.

The lower limit of 30 cm was decided in view of the shrimp's physiological needs and limitations. The higher limit of depth was decided keeping in view the general tidal range which largely determined the pen construction cost and pen management procedures.

The backwater areas, except the main river courses used as wdterwOys, were very shallow. There were vast expanses with depths ranging between 10 and 20 cm during the LLWL conditions; such shallow tidal flats were not suitable for aquaculture.

In the whole of the backwater system, 15 potential water pieces satisfying the minimum and maximum depth requirements were identified. In an area map, 15 sounding charts for identified areas were prepared. From these scaled charts, the gross potential area for each water piece could be estimated. The areas of these waters varied from 1.4 ha to 19.4 ha. The total gross area, estimated at 128 ha, included ferry sites, regular waterways used by canoes and boats; these areas, excluding the net area likely to be available for pen culture, might be in the range of 80-90 ha. The names of the potential sites with the estimated area, maximum flood level for each site, etc., appear in Appendix 14.

Of the available area, about 65-75% was within a depth range of 30 to 60 cm, the rest in the range of 60 to 80 cm. Areas more than 80 cm deep were only river courses and deep channels used as waterways.

The recent changes in the tidal features have, however, somewhat offset the above findings.

10. HARVESTING AND DISPOSAL

Castnetting and dragnetting were practised for harvesting the shrimp. Harvesting was done in the morning and as far as possible during low tide. On occasions when the water level was high, castnets were operated from the canoes. Complete harvesting of any pen took 3-7 days depending on the pen size.

Due to their quick sinking ability, relatively large mesh castnets with thinner twine were found more effective for harvesting the cultured shrimp which were large in size and quick in movement. Small-mesh nets were used to remove metapenaeid shrimp and all other undesirable small organisms. Hand pickers were engaged to remove catfish, eels, crabs, etc., which were difficult to catch with a net.

The harvested shrimp were usually stored in *hapas* fixed in water in an attempt to keep them alive until the day's work was finished. The catch was then brought ashore, graded and sold, usually to the local buyers who in turn sold the product to the processing factory at Cuddalore, about 65 km from the project site.

11. STUDY TOURS AND TRAINING

Study tours of coastal aquaculture projects were organized for all the three professional staff. The BOB P-assisted shrimp culture project in Andhra Pradesh was one of these projects. The staff spent a week at the projects in and around Kakinada exchanging views and ideas with the farmers and scientists. A proposal has been made for an overseas study tour by the team leader of selected aquaculture establishments in a few south-east Asian countries. This awaits government clearance.

A 9-day training course in pen culture of shrimp at Killai for fairly high-level officials was implemented in July 1984. There were 1 6 trainees representing 5 organizations: Directorate of Fisheries. Tamil Nadu-6; Directorate of Fisheries, Andhra Pradesh-4; Marine Products Export Development Authority (a Central Government organization), Machilipatnam, Andhra Pradesh-4; Centre for Advanced Studies in Marine Biology (Annamalai University), Porto Novo, Tamil Nadu-1 ; Tata Oil Mills Company Ltd., Madras-i.

BOBP offered practical training in all apsects of pen culture, including water area survey, seed collection, pen construction and installation, feed processing, pest removal, pen checking for crab cuts, harvesting and water analysis. Twenty-three background papers were prepared and distributed to the trainees (Appendix 15). Discussions were held every evening with visual aids. Theoretical lectures included subjects on socio-economic feasibility studies and extension of new technologies. An evaluation of the training course was conducted and the response was very favourable.

Requests were received from the Directorate of Fisheries, Andhra Pradesh, and the Marine Products Export Development Authority, to organise more training courses in pen culture for farmers. Subject to the availability of funds, farmer-level training courses will be designed and implemented in due course.

12. DISCUSSION AND CONCLUSIONS

1. Despite occasional setbacks caused primarily as a result of unexpected and untimely heavy rain, the average production of shrimp during the study period was sufficiently high and consistent, indicating the technicalfeasibility of shrimp culture in pens in the Killai area.

2. The species of shrimp with the greatest promise for culture in the area is *P indicus* which is available more or less throughout the year with two peaks of abundance—January to March and again July to August. *P. monodon* which occurs in limited numbers, can be used as a supplementary species along with *P. indicus.* Subject to the creation of demand and good sale price at the local markets, the pearispot *Etroplus suretensis,* a herbivorous finfish, makes an excellent species for polyculture with the shrimp. From limited observation, fry availability of this fish in the project area appears to be good. Subject to seed availability and good price, mullet and milkfish can also be cultured in pens. In fact, it isa common practice in the Philippines.

3. Three culture operations a year are possible with *P. indicus* as the main species. However, culture operations should be carefully designed keeping in view the seed availability seasons and monsoon periods. The three culture cycles may be designed as follows:

January – February	–	First phase seed collection and nursery rearing
March – May	–	First culture
April – May	–	Second phase seed collection and nursery rearing
June—August	–	Secondculture
July – August	–	Third phase seed collection and nursery rearing
September – November	–	Third culture

4. Pens of 14 mm mesh as used in the project worked well, except that rather large-size seed shrimp had to be used for retention in the pens, for the mesh allowed easy access to all kinds of small and young stages of big predators. The production results, as presented in Apendix 4, show that each pen during every culture operation produced a substantial quantity of low-priced finfish and miscellaneous shrimp which grew in the pens as unwanted species. These either competed with the cultured species for space and food or preyed on them. Efforts were made to remove the undesirable organisms by netting, hand picking, etc., but this scared the shrimp too often and disturbed the bottom soil, seriously interfering with the production of bottom micro-fauna and flora, the natural food of the shrimp. Moreover, the pest-removal process involved more work and extra cost.

Pen 9 made of 8 mm mesh webbing was left undisturbed and the pests were not removed. Crab cuts were repaired only a little, that too from outside the pen. Prcduction in this pen was consistently good.

An important improvement in the culture technology could, therefore, be to use smaller mesh webbing. Eight mm mesh webbing, with its poor stretching capacity, would be quite expensive for large pens. Knotless nylon webbing of 10 mm mesh of about 0.65-0.76 mm thick twine could be a good compromise between quality and cost.

5. Frequent crab cuts in the pen wall was a major problem. Checking the pen walls under water for detecting and mending the cuts was time-consuming, laborious and cumbersome. The efficacy of HOPE webbing of 0.75-1.25 mm thick twine as a highly effective protective layer against crab cuts was a useful finding of the project. However, further studies are required before recommmending its general use. Some of the pens more vulnerable to crab cuts could be completely enclosed with HOPE webbing of 0.5, 0.75 and 1.00 mm thick twine and its capacity to resist crab cuts could be watched during the culture cycle.

But small mesh (less than 18 mm) HOPE webbing of the above specifications is not manufactured by any net factory in India, for there is no immediate large-scale demand. The material used in the project was hand-woven by fishermen on special order.

Provided an appreciable demand for small-mesh, thick twine HDPE webbing could be generated, it might be worthwhile for pen farmers to come to an agreement with a net factory for regular manufacture of the material. It is believed that some of the net making factories could manufacture the desired webbing by re-setting/readjusting their machines.

6. Knotless nylon webbing of the specifications required for shrimp culture pens being quite expensive, parts of the pen wall as indicated below could be made from HOPE webbing which is at least 50% less expensive.

— 0.5 m width embedded into the mud to fix the pen wall in position or prevent other animals, mainly eels, from burrowing into the pen. This portion may be of 0.5-0.75 mm thick HOPE twine and 16-20 mm mesh size.

— A width of 0.4-0.5 m used on the nylon webbing as a reinforcement layer against crab cut; this material could be of 0.75-1 mm thick HOPE twine and 16-18 mm mesh size. Since crabs are largely benthic organisms the reinforcement layer should go at least 5 cm into the mud.

—The upper portion (about 0.5 m) of the pen wall above the normal high tide may also be HOPE material of 0.5mm thick twine and 16-18mm mesh.

In all then, 1 m of the 2.5 m high wall could be of HOPE material, plus, of course, 0.5 m of reinforcement layer. A design of the proposed wall is shown in Appendix 16.

Hand seaming of long pieces of various webbing would, however, be a difficult task involving extra labour and time. It would be useful to compare the cost of a hand-fabricated wall as per the above design with a completely nylon wall. It would be also worthwhile to explore the possibility of seaming the long pieces of webbing in a factory.

7. In future, if small-mesh HOPE webbing of 0.50-1 mm thick twine and 10-16 mm mesh could be manufactured, the whole pen wall could be of H DPE material.

8. For ordering material of certain width (height of the pen), the required mesh depth of the material rather than the height of the pen wall should be mentioned. The question then arises – what will be the mesh depth for a certain height of the pen? This will depend on the extent of stretch being applied vertically and horizontally while installing the pen, and on the mesh size, twine thickness, and the extent to which the pen wall is embedded.

On actual installation of a length of knotless nylon webbing 0.6 mm thick twine and 8 mm mesh, it was seen that an effective width of 1.8 m required 450 mesh depth. The horizontal line needed 2000 meshes to get 10 m running distance. With 10mm mesh, the same width could be achieved by 300 mesh depth. The horizontal line in this case needed 1440 meshes to get 10 m running length.

One or more trial installations could be made to determine precisely the required mesh depth for a given set of conditions before ordering the entire material; this may save unnecessary adjustment of the mesh depth later or unnecessary waste of material.

9. The quantity needed, and so the cost, will depend on the area and size (not on area alone) of the pen. For a given area, a square pen will require the minimum material. A 0.5 ha square pen will have a perimeter of 292.8 m. A pen measuring 25 x 200 m^2 will still have the same area, but its perimeter will be 450 m; this will account for 59% higher cost on pen webbing material alone, even without considering the cost of ropes and installation. From the cost point of view, a square pen is the best.

A one-unit large pen will cost less than a few pens totalling the same area as the large unit. Management, including pest removal and harvesting, is however, much easier in small pens. Taking cost and management aspects into consideration, a 0.5 ha unit is a good compromise. Although a square shape is preferable if construction cost is to be reduced, it is suggested that the pen be not more than 50 m wide.

It is difficult to effectively net either for pest removal or for harvesting in a pen wider than 50 m. A 0.5 ha pen could, therefore, be 100 m 50 m in dimension. For better use of scarce culturable water resources, one may, of course, have to adjust the pen size and dimension to some extent.

10. If there are a number of pens with common walls, the cost can be substantially reduced. For example, if there are six pens each 100 mx 50 m in a row as in Appendix 17a, 5 walls measuring at least 500 m can be avoided. If 9 pens of the same dimension are arranged as in Appendix 17b, a length of 900 m webbing can be obviated, saving much expenditure.

11. During the nursery stage in large cages, the prevailing wind along with current generated by wind, often floated the middle portion of the bottom of the cage, thus greatly reducing the carrying capacity of the cage. The seed was forced up in the warm upper layer of water leading to overcrowding and stresses. In order to ensure that the bottom uniformly remained in close contact with the mud layer, a few narrow casuarina posts weighted with sinkers should be placed on the bottom, length-wise as well as breadth-wise. This not only keeps the bottom down, but also ensures a good substratum of soft mud for the shrimp to take shelter in.

12. Feeding the shrimp with supplementary diet was on several occasions very late, because of late arrival of trash fish or other animal matter. Sometimes, this feed was not provided at all as it was not available. The best thing to do in such situations would have been to collect fish, small shrimp and crab, which are abundant in the immediate vicinity. But the project could not exploit the easily available natural resources for shrimp feeding, because of the many other development activities in the area. In fact, wherever opportunities exist, the free feed resources should be used by any shrimp farm to ensure high production and curtail production costs at the same time.

13. The culture operation for *P. indicus* should not be unduly prolonged in the hope of obtaining bigger size shrimp. It was found that growth rate beyond 15 g was very slow. Keeping the

stock longer would mean extra cost on feed and management. Moreover, the longer the culture operation, the greater is the chance of mortality or loss of the cultured animals.

The cultured stock should be periodically sampled for average growth data. It would be advisable to harvest the shrimp at a stage of growth beyond which the shrimp will not grow fast enough to justify further expenditure. In the case of *P. indicus* the shrimp should be harvested when **its size is in the 10-15 g range. Depending on the market price, the length of culture can be** adjusted as far as practicable.

14. Supplementary feed was the single major cost component. One of the most important minus points of pen culture is that a very substantial quantity of the supplementary feed is removed by the unwanted animals. Undue sharing of the feed by these animals is not the only problem related to feeding. At every feeding congregation, the cultured shrimp is exposed to easy predation.

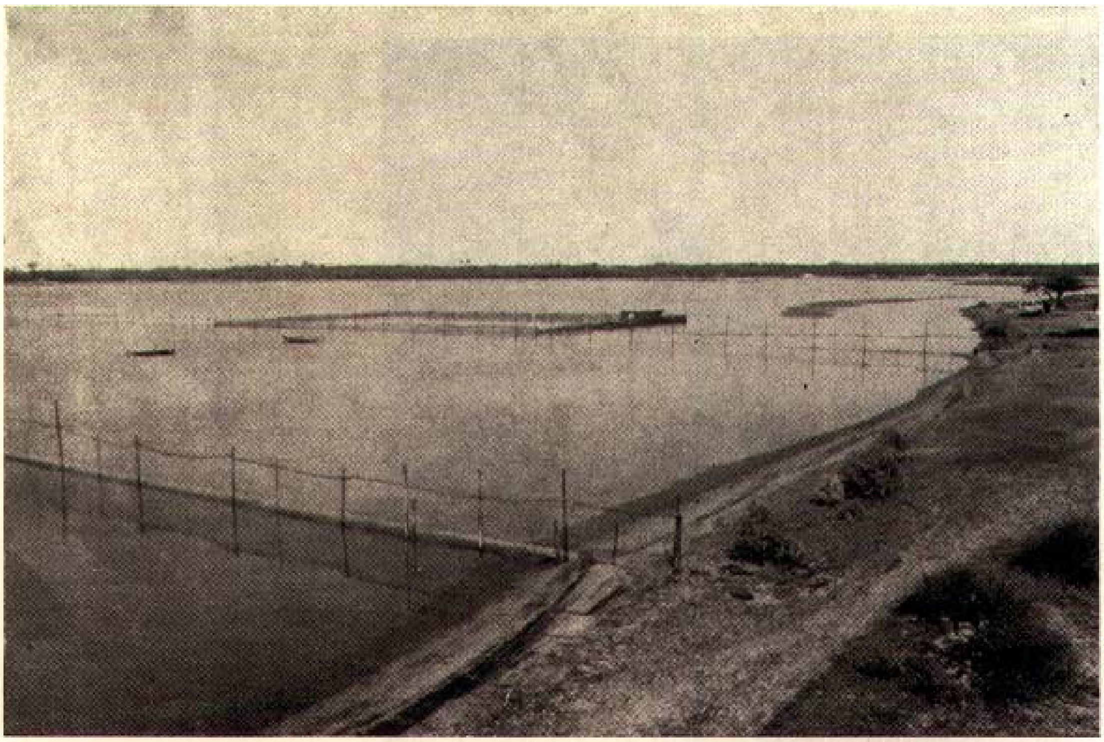
In order to reduce (it is not possible to completely stop) unwanted sharing of the feed by bigger organisms and to reduce predation of the cultured shrimp at feeding time, the feeding tray could be placed within specially designed large covers (Appendix 18). The covers could be made of bamboo, plastic, synthetic twine, metal or a combination of two or more of these materials. Basically, the cover could be a simple structure with holes or mesh big enough for shrimp of a certain size range to pass through easily, but small enough to stop the big fish, crabs, etc. Small fish will of course reach the feeding tray as easily as the cultured shrimp.

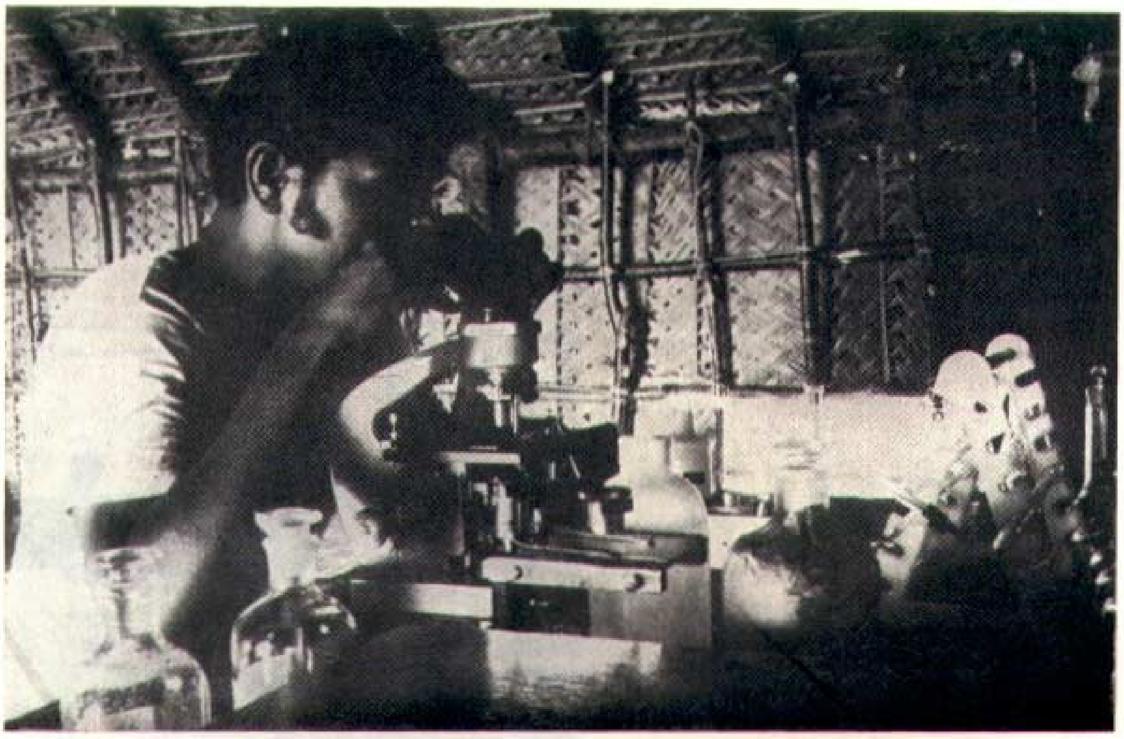
Instead of the cover mentioned above, a removable fence of any of the above material could **be fixed a few meters below the low tide level (Appendix 19). The feed could be supplied within** the fenced area. By nature the shrimp come very close to the shore for grazing as the sun sets and would find their way easily to the feed trays. The fence will prevent the bigger animals from reaching the feed trays.

KILLAI PEN CULTURE
PROJECT IN PICTURES

Right: Erection of pens.

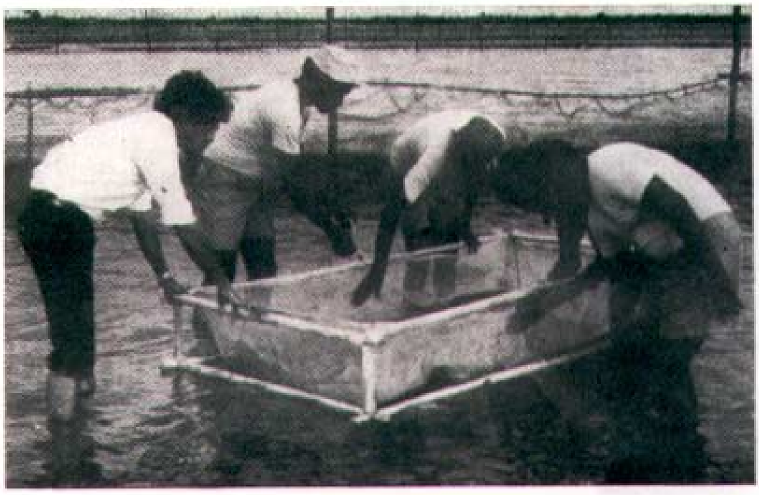
The project consists of nine pens. Hare is an overview.





A project scientist at work in the pen cottage at Kll/ai — examining water quallty, studying environmental data.

Specially designed push net for seed collection.



Floating raft used to transport shrimp seed to the pen.

Preparation of supplemental feed for the shrimp.

Hand-picking of predators.

Close-up of the pests and predators—which include crabs and catfish.

Hurllng a cast net to harvest cultured shrimp.

Project staff sort harvested shrimp.