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TECHNICAL CONSULTANCY

OF

BIVALVE HATCHERY SYSTEM DEVELOPMENT

AND

COCKLE SEED RESOURCE MANAGEMENT

January 15 - March 15, 1985

Fisheries Research Institute
Glugor, Penang
Malaysia

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The International Center for Living Aquatic Resources Management
Manila, Philippines

on behalf of:

The Bay of Bengal Programme of FAO

CONTENTS

I. INTRODUCTION

A. Terms of reference.

The terms of reference supplied to the consultant were as follows:

1. Assist researchers at the Fisheries Research Institute, Glugor, Penang to develop an induced spawning/larval rearing facility for studying the aspects of the early life history of cockles important to seed resource management.

2. Make field visits to natural cockle beds and culture areas and assess prospects for recovery of natural areas which used to receive natural spatfall but are now unproductive.

3. Assess prospects and possible sites for reseeding programmes.

d. Prepare a detailed report containing recommendations on seed resource conservation and management and on research methods for studying the early life history of cockles and other Malaysian bivalves.

B. Activities summary.

The work program was divided into two phases namely laboratory work to develop the hatchery system and field visits to natural and cultivated cockle beds. The laboratory phase was concerned with modifications to the seawater treatment system, improvements in phytoplankton culture techniques, induced spawning and larval rearing.

Field visits were made to Kuala Selangor, Sungai Besar, Setiawan , Kuala Sepetang, and several sites on Penang Island. The field visits included observations of seed beds, natural cockle harvesting and culture areas. Interviews were conducted with culturists seed collectors and traders.

II. HATCHERY SYSTEM DEVELOPMENT

A. Seawater treatment.

Several serious problems with seawater quality were encountered at the initiation of work at the laboratory. The existing seawater system consisted of a settling tank of approximately 200 m^3 capacity and a sand filter designed to serve the entire laboratory. Due to highway construction immediately in front of

the institute and between it and the sea, a temporary pump and seawater intake had to be installed. However, the intake was located near highwater mark, and as a result, seawater delivered to the settling tank was extremely turbid and of very low salinity (14 to 20 o/oo). Furthermore, the intake was adjacent to waste water discharges.

Spawning was difficult to induce and larvae showed a high incidence of abnormalities. Isochrysis cultures collapsed and at the same time other culture activities at the lab experienced difficulties.

The construction company responsible for locating and operating the pump was verbally requested a number of times to relocate the pump and after abouttttwo weeks and a written request to supervisory personnel, it was moved to a location lower in the intertidal zone. Seawater quality immediately improved. Turbidity was dramatically reduced and salinity increased to 27 to 30 o/oo. It should be pointed out that with increasing urbanization which will result from the completion of the cross-channel bridge and the proximity of waste water discharges and a solid waste disposal site, the long term prospects for bivalve larval rearing at the present site do not appear promising.

Sand filtration is insufficient to remove smallerzooplankton and phytoplankton that could be prejudicial to larval growth and survival. Consequently a secondary filtration system was installed consisting of two cartridge filters of 20 and 10 microns, in series. An ultraviolet sterilizer was designed and constructed to provide near sterile water for larval rearing tanks and large volume phytoplankton cultures (Fig. 1).

B. Phytoplankton culture.

Isochrysis galbana had been cultured routinely at the laboratory for some time. However, several improvements in techniques were introduced to improve reliability, cell yield and nutritional quality.

The system previously in use consisted of three levels: 125 ml starter cultures using sterilized media, 1 liter cultures with chlorine-pasteurized media and 20 liter aquaria, also using chlorine pasteurization. Starter cultures were renewed only occassionally, which will produce senescence and provide an opportunity for contamination. Dilution of the one liter cultures without sterile techinques would also

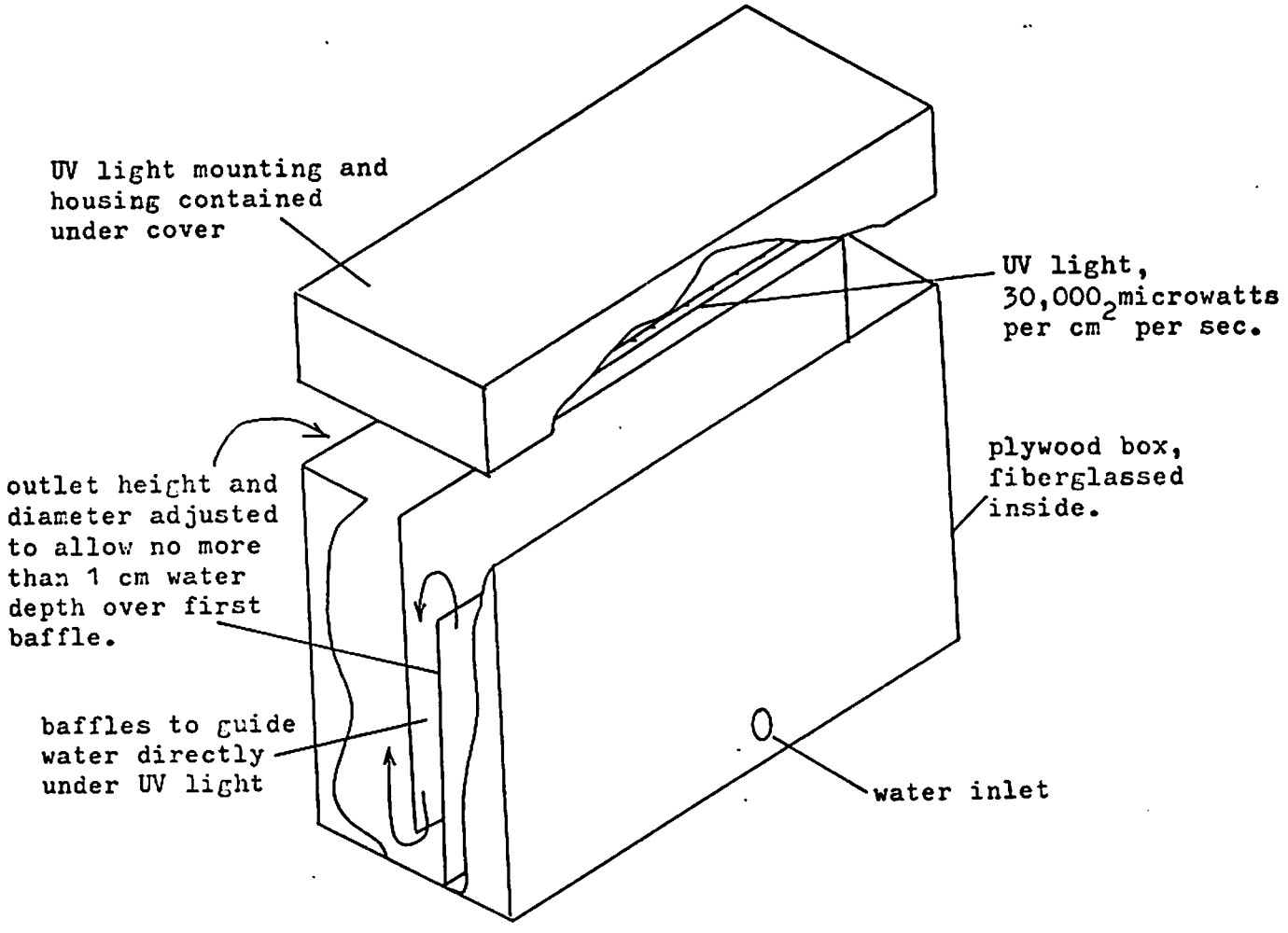

Fig. 1. General layout of UV water sterilizer.

provide an opportunity for contamination. If these one liter cultures were used to innoculate 20 liter aquarium cultures, cell densities would normally not exceed 1.5×10^6 / cc.

Culture technique was improved by introducing batch culture using sterile media in the 150 ml starter cultures and in the one liter flask cultures. It was found that a growth period of 6 days is required to obtain adequate cell densities in these cultures. This meant that both starter and flask cultures would be run on a six day cycle. Starter cultures required 6 flasks for each batch. Five were used for innoculating one liter cultures and one for innoculating new starter cultures. One liter cultures were made up of 850 ml of media and 150 mls of innoculum from the starter cultures. Each 20 l aquaria requires 2 liters of innoculum. No difference in cell yield from aquaria was found between chlorine pasteurized media or UV treated seawater. It was also suggested that back cultures be made on agar-media streak plates from time to time to check the purity of the stock cultures and to maintain a reserve should something befall the starter cultures.

The improved technique resulted in a significant improvement in cell yields. Starter cultures were not counted, but the yield of one liter cultures increased from 3.3×10^6 to as high as 13×10^6 cells/cc. Twenty liter cultures went from about 1.5 to over 4×10^6 cells per cc. These increases mean that not only can more larvae be fed from a given volume of culture, but also that the nutritional quality of the phytoplankton will be higher, since care is taken to innoculate or harvest during the log growth phase (see Fig. 2 for growth curves).

C. Brood stock maintenance and induced spawning.

Adult cockles proved unable to withstand immersion in stagnant water, although aerated, for more than about three days. Outdoor tanks were fully exposed to sunlight and afternoon water temperatures of over 30 degrees C were often encountered. On one ocassion, mass spawning occured. It would be preferrable to hold brood stock in running water, however, the seawater supply is limited.

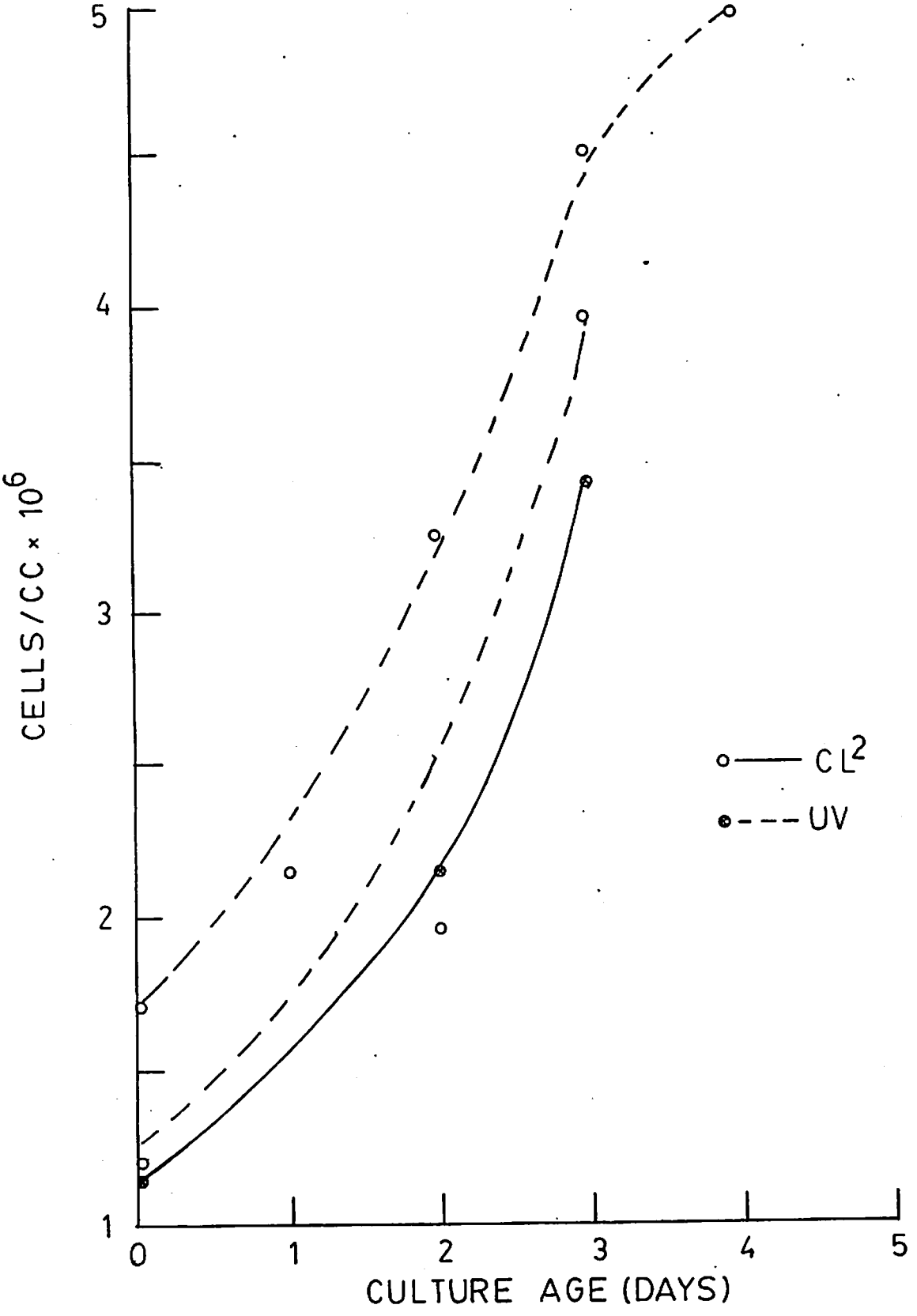

FIG. 2 REPRESENTATIVE GROWTH CURVES FOR Isochrysis galbana.

Thus cockles obtained from the field were subjected to induced spawning the day following their delivery to the lab.

Spawning induction was limited to thermal shock, since previous experience had shown the method to be effective. This treatment involves alternate immersion in warm and cold seawater for varying lengths of time. Generally, the use of running warm seawater is more effective and also permits the spawning of large numbers of specimens simultaneously. In the case of smaller bivalves, such as cockles, mass spawning is necessary to obtain sufficient numbers of eggs. Fertilization rates are usually high using this method. The cold shock can be given in stagnant water.

A heat exchanger is required to provide a source of warm running water. The device was easily constructed from locally available materials (Fig. 3) and supplied seawater to the spawning trough at temperatures ranging from ambient to 35°C. By controlling the flow rate through the heat exchanger, constant temperature could be maintained at the desired level. Seawater was prefiltered through 20 and 10 micron filters before passing through the heat exchanger. This was necessary to exclude as many extraneous organisms as possible from the larval rearing tanks.

Cockles were treated with a chlorine dip before being placed in the spawning trough to further reduce the possibility of contamination in the larval rearing water. The dip is made up with freshwater and about 50 ml of Clorox are added to 10 liters of water. The cockles are immersed in the treatment for about 15 minutes.

Initial spawning induction attempts involved subjecting animals to a 2 hour cold shock at 15 to 17°C, followed by heat shock for 2 hours at 33° to 34° C, another cold shock identical to the first and then a final heat shock, also at 33 to 34° C. If the cockles were mature, spawning occured within 30 minutes to two hours after initiation of the second heat shock. Spawning was never observed during the first heat shock. It later proved just as effective to eliminate the first cold shock. In future work, controlled tests should be conducted to determine if exposure times can be reduced.

It proved difficult to obtain mature cockles, since the peak spawning season occurs during the latter quarter of the year. Considerable delay was also caused by the collapse of

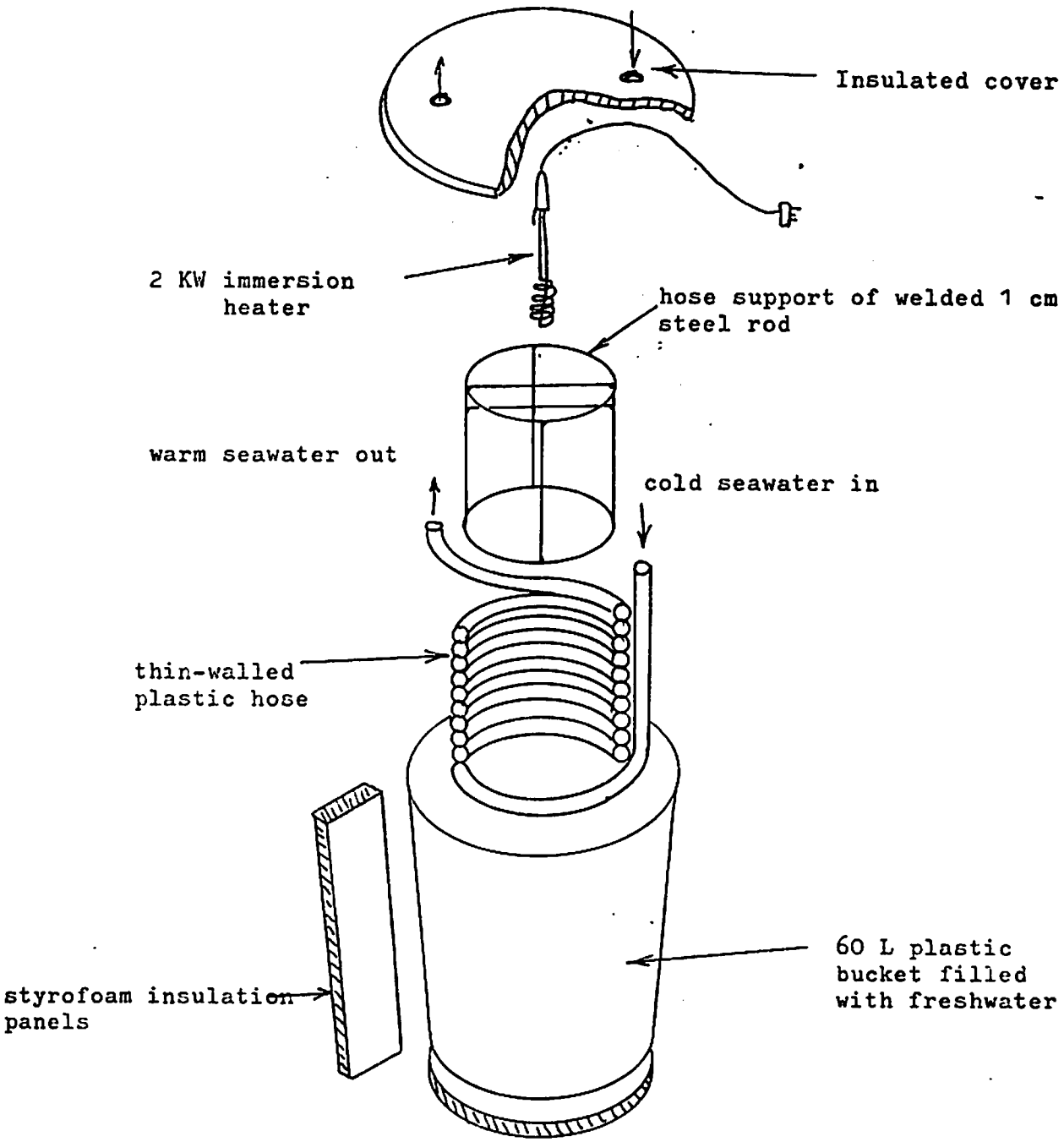

Fig. 3. Heat exchanger construction.

phytoplankton cultures in January, which meant that no food was available for larvae. Very low salinity (less than 20 o/oo) may also have affected spawning activity. Eleven attempts at induced spawning resulted in three successes (Table I).

TABLE I

Induced spawning attempts and results.

Date	Salinity, o/oo	Results
1/23/85	15	nil
1/24/85	15	nil
1/25/85	21	875,000 eggs
2/2 /85	-	nil
2/6/85	27	nil
2/15/85	30	nil
2/16/85	30	nil
2/19/85	30	2,500,000 eggs
3/4/85	28	6,500,000 eggs
3/6/85	-	nil
3/8/85	25	nil

From about fifty to over one hundred cockles were subjected to thermal shock on each run. With the mass spawning method, it is often difficult to determine the number of spawners. This is particularly true in the case of cockles, which often release small amounts of eggs in what appear to be partial spawnings. Since these eggs are impossible to separate from other spawnings, their viability could not be determined. After spawning was completed, all eggs were easily recovered by thoroughly rinsing the spawning trough.

Attempts to estimate fecundity were abandoned due to the large number of partial spawnings. However, this might be attempted again during the peak spawning season when complete spawnings are more likely. Fertilization rates were over 90% in all three spawnings, indicating a high degree of viability.

D. Larval rearing.

Larval rearing techniques were developed that would be able to provide sufficient larvae or spat for experimental work. One ton fiberglass tanks in the laboratory inventory were of sufficient size for this purpose.

The UV unit used to sterilize larval rearing water has been previously described. The efficiency of the unit remains to be tested, but this can be done in collaboration with the bacteriology laboratory at the institute.

The objective of larval rearing trials during the consultancy was to establish procedures to maximize larval survival to setting, obtain setting size larvae and train personnel in larval rearing methods.

1. General procedures and training.

Three staff members were given "hands on" training in all phases of bivalve larval culture, with the exception of setting techniqes. Procedures covered during the training were culture management, stocking rates, feeding rates and the use of antibiotics. Project personnel were provided with a copy of the practical culture handbook produced during a bivalve hatchery workshop held at Prachuab Kirikhan, Thailand in 1984.

a. Stocking rates. Due to the limited number of spawnings and high early mortality of larvae, it was not possible to test a wide range of stocking rates. All eggs obtained on any given spawning were stocked in 1000 liter fiberglass tanks, so initial rates ranged from 0.9 to 6.5 eggs-per ml.

b. Culture management. Standard procedures were used in management of the larval cultures. Water was completely changed every other day, at which time larvae were counted and measured. Observations of the condition of larvae and the presence or absence of contaminants were also noted. Feeding began with the appearance of the first D-hinge larvae, about 18 hours after spawning. An initial feeding rate of 4000 cells of I. galbana per ml. was used. The morning feeding would be followed by an afternoon feeding of 2000 cells/ml if all food was cleared during the day. However, this rarely occured due to the low number of larvae. During the water change, larvae were collected and held in a 10 liter bucket. Three replicate 1 ml subsamples were taken from the bucket and the larvae counted. An average of the three counts was used to estimate total larvae. Antibiotic treatments were begun on the second and third batch of larvae in an effort to stem the high mortality. These initial treatments used tetracycline hydrocholoride. The treatment is given while the larvae are held in the 10 liter bucket during water changes. The treatment level is 10 ppm. It may prove necessary to apply the antibiotic to the 1000 l rearing tank, however further testing of the present method with a variety of antibiotics should be carried out, since applying medication to the large rearing tank will be expensive. Tests should be extend-

to include sulmet, streptomycin, auromycin and combistrep. Most of these are available from veterinary shops. They should be tested singly and in combination.

2. Results.

The results of each spawning are tabulated below in Table II.

Table II

Spawning Date: 1/25/85 No. of eggs obtained: 870,000

Date	Temp. (°C)	So/oo	Count	Size (μ)	Feeding	Remarks
1/26						Still trochophores
1/28		20.0	20,000		5,000	Many abnormal larvae.
1/29		18.0	0			Culture discarded.

Spawning Date: 2/19/85 No. of Eggs obtained: 2,530,000

2/20	26	30.0			5,000	
2/21	25.5	30.0	330,000	78 - 100	8,000	Water change, larvae healthy.
2/22	26.2	-	-	-	none	Larvae not feeding well.
2/23	27.3	30.0	150,000		5000	Water change
2/24	28.0	30.0	-		5000	
2/25	29.0	29.0	100,000		4000	Water change
2/26	29.5	29.0	-		4000	
2/27	29.5	30.0	75,000	110	4000	Water change
2/28	27.5		-	-	4500	
3/1	27.5	29.0	60,000		4000	Water change
3/2	26.7	29.5	-	-	4000	
3/3	27.0	29.0	58,000	-	4000	Water change, rotifer contamination.
3/4	-	-		154	4000	Very heavy rotifer contamination.
3/5	-	-	23,300	144	4000	Rotifers are now terrible!

Table II (cont.)

Spawning Date: 3/4/85 No. eggs obtained: 6,700,000

Date	Temp.(°C)	So/oo	Count	Size(μ)	Feeding	Remark
3/5	-	-	-	79	4000	95% are D-hinge, some with "bent hinge", others straight.
3/6	-	25.0	2,500,000	89-98	4000	Larvae look very good. Actively feeding.
3/7	-	-	-	-	4000	
3/8		25.0	1,300,000	88-100	4000	Larvae look excellent, hinge ligament visible.
3/10	27.6	25	1,160,000		5000	
3/12	27.1	30.0	1,510,000	88-132	5000	EDTA and tetracyclene treatments

Setting size larvae have not yet been produced, so there has not yet been an opportunity to test various setting methods. Rotifer contamination appears to present a serious problem and it is not yet clear how it can be prevented. If appropriate screen sizes were available, it might be possible to filter them out when the cockle larvae are small.

E. Problems encountered during the course of attempts to rear cockle larvae.

1. Water quality is highly suspect given the location of the seawater intake and the intense construction acitivity in progress in the area. A new intake is being prepared on a nearby jetty and this should be completed as soon as possible. Even before that, it is highly recommended to conduct bioassays of local water quality. Controls can be reared in artificial seawater or seawater collected far enough offshore to be free of any contamination from coastal sources. The simplest method is the D-hinge bioassay method. The controls are as described and the treatments consist of dilutions of seawater being used in the laboratory. Each treatment is replicated and the percentage of abnormalities and mortality compared between treatments. Larvae are reared from egg to D-hinge only, so that any influence from feeding is eliminated. Genetic inluence on growth and development at this early stage is also less pronounced. The initial density of eggs must be constant in controls and treatments. The diluent would be the pure seawater. It should be noted that other culture activities, namely prawn larvae culture, is experiencing difficulties and we have had problems maintaining stable cultures of I. galbana.

2. It has proven difficult to obtain sufficient gravid cockles. The principal cause is probably the lateness of the season, as peak spawning occurs during the latter quarter of the year. If laboratory work begins in September, there should

be an ample supply available.

3. An adequate stock of screen sizes will be required for larval rearing. Unfortunately, the range of sizes and quality of screen required is not available locally. The only size at hand for early larvae was 39 microns, which is too fine and means that dead larvae and contaminants will be carried on between water changes. A full range of sizes and specifications are available from Tetko, 420 Sawmill River Road, Elmsford, N.Y. 10523, USA (Telex 01 37331).

4. High early mortality and an excessive amount of abnormalities have been commented on earlier in this report. At this point it is not possible to attribute any one cause to this. Scientists working at the Marine Laboratory of the Science University of Malaysia have experienced high early mortalities, although they have not reported abnormal larvae. Very sophisticated equipment exists at the IPP with which it should be possible to analize seawater, algae and larvae for heavy metals. Of particular interest are copper, cadmium, nickel, zinc, mercury and selenium. Some of these metals are known to have synergistic effects on bivalve larvae. Papers by Anthony Calabrese and his colleagues will provide a starting point for work in this field. Further work with antibiotics, as pointed out earlier, is also necessary.

5. Unstable cultures of I. galbana have plagued efforts to provide adequate food for cockle larvae during the present consultancy. Remedial measures were taken which greatly improved reliability but the level of efficiency required has not yet been reached as cultures still ocassionally collapse. In collaboration with the bacteriology lab, cultures are presently being tested for contamination. However, it is strongly suspected that problems with algae are related to poor water quality.

6. It is highly recommended that weekly cleanings of the seawater delivery system be undertaken. This would require cleaning and disinfection of the 200 ton storage tank, thorough backwashing of the central sand filter and flushing the pipes with hypochlorite or Clorox solution.

III. FIELD VISITS

Two types of cockle environments were observed; natural beds and culture plots. Natural beds are legally open to only seed harvesting at officially licensed periods and cockle fishing. No culture is permitted, although there are some exceptions.

Natural beds were observed in Pinang (Sungai Pinang and Pantai Acheh), Selangor (Kuala Selangor and Sungai Besar) and Perak (Sungai Limau to Pasir Panjang). Cockle farms were visited at Kuala Juru, Pinang; Kuala Selangor, Selangor and Kuala Sepetang, Perak. Obviously, such limited visits, both as to locations and time, do not permit any definitive conclusions , but possible approaches to research and data collection can be suggested. What follows is a brief account of information collected during the field work. Recommendations regarding seed conservation will be found in the appropriate section.

A. Natural cockle beds.

1. Sungai Penang. This site was visited on February 14. It is located on the west coast of the island, which is predominantly agricultural. Although there was no spatfall in 1983, cockle seed first appeared in November 1984 and harvesting was permitted in January. According to local informants, 35 tins were harvested and sold for $7.00/tin. The seed collection area is a narrow band at about the 0.5 meter tide level. Seed is usually collected over a two month period. The seed on the bed at the time of the visit was mostly over the legal minimum of 6.4 mm, but rather sparse.

2. Pantai Acheh. Spatfall occured in 1984 and was just beginning to appear. Seed cockles were 3 to 5 mm. Adult cockles are also harvested, mostly for local consumption. The price of seed presently being offered by fishermen's cooperatives is $7.00 per tin, considered to low by seed collectors who are asking $9.00/tin.

3. Kuala Selangor.
The natural bed lies approx. 500 meters offshore. The benthos was diverse compared to other areas surveyed (see illustrations). In addition to cockles,

six other species of bivalves and three of gastropods were found. One of the gastropods is a predator on bivalves. In addition, a toothed goby and Scylla serrata were abundant. The other common fish was a cynoglossid flatfish. Cockles on the bed ranged in size from about 5 mm to over 25 mm. Distribution of cockles was extremely patchy and abrupt changes in the benthos were encountered. The natural bed extended from Kuala Selangor to Sungai Tambah Jawa. Salinity at the time of the visit was 27 o/oo. Selangor state is the major spat producing area, but in 1983-84, spatfall ocurred at only two or three locations. According to one respondent, the low price of seed ($7.00/tin for 3000-5000 per kati) is due to reduced demand as the result of very heavy stocking in previous years. The same respondent reported that yield of the preferred seed size is 4 to 5 bags of marketable cockles per tin of seed. One bag contains four tins or approximately 70 kg of cockles. Seed is marketed through middlemen and prices have ranged from $20.00 to $100.00 per tin in the past. If a culturist requires seed during periods of low availability, the higher price will be paid for illegally collected seed.

4. Sungai Limau-Pasir Panjang, Perak. A local informant reported that spatfall was first noticed in January. Several estimates of density were made, ranging from 2900 to 5700 spat/m^2. A sample of seed consisting of 23 individuals ranged in length from 5.1 to 7 mm with an average of 6.0 mm. Licenses had not yet been issued to collectors at the time of the visit. The informant referred to above reported that in Janaury seed measured about 15,000 per kati but by February had decreased to 5000/kati.

The seed bed was about 70 meters from the shoreline. One of the two seed buyers in the area supplied information on seed marketing and prices, as well as stocking strategies used by several of his customers. According to this informant, seed prices rose to $60.00 per tin in 1983 due to the combination of low spatfall and high demand brought on by

extensive harvesting. The following year, 1984, seed supply was abundant, with prices dropping from $10/tin to $6.00 at the end of the season. The price decrease is partly due to the decline in seed quality as the collecting season progresses. Seed purchases continued until seed had increased in size to a count of 400/kati with a price of $3.00/tin. Seed this year (1985) will sell for about $16.00 per tin. The informant reported that with the exception of 1983, there has always been an adequate seed supply. The informant's customers preferred seed of 10,000 per kati. Shipping time has an important bearing on seed survival and varies with seed size. Seed of 800 - 1000/ kati can withstand up to 24 hours, while that of 10,000-20,000/kati must be delivered within 12 hours. Two types of seed are recognized by growers supplied from this area. One is very slow growing and requires up to two years to reach a size of 60 per kati while the other requires 6 to 8 months if planted at a seed size of 3000/kati (4800/kg). Seed is purchased directly from the collectors and sold to individial farmers. Our informant was not tied to any particular farmer. The seed is sold in Kuala Sepetang, Kuala Gula and Kuala Kurau.

B. Cockle farming areas.

1. Kuala Juru. The cockle farm at Kuala Juru is operated by a fishermen's cooperative (Persatuan Nelayan) and occupies a total registered area of 40 acres, according to our informant Unfortunately, the leader of the cooperative was not available. Ten acres are used for a nursery and the remainder for grow-out. In March of 1984,6000 tins of 3000 - 4000 / ati (5000-6700/kg.) seed were planted in the nursery. The seed was obtained from Selangor for $13.00/tin. The cooperative does not plan to buy seed this year since the beds are still heavily stocked. Expansion is limited by predators and strong tidal currents in deeper water. The cooperative sells the harvest for $19.00 per bag of 70 kg. The income is divided between members and the coop, with $9.00 going to the coop and $10.00 to the member. The cooperative was established with contributions from the members, but now operates with its own funds. Operations include seed purchases.

The farm's production is exported to Thailand. Cockles are harvested ten days per month and each member is allocated a harvest quota of 5 bags. The cockles are sold by tender. Members are involved in cockle farming on a part time basis. Last year they received $21.50 per bag.

2. Kuala Selangor. Two farms were visited at this site. One of which was private (Sea Producers, Inc.), and the other belonged to LKIM. In the state of Selangor there are only three cockle farms. Sea Producers, Inc. operates a registered area of 77 acres. They also buy cockles from fishermen who harvest natural beds. Last year, the company stocked 11,000 tins (143/acre) at a cost of $7.00/tin. They expect a yield of 4 bags per tin or 44,000 total from that stocking. The optimum seed size is considered to be 3000 - 5000/ kati (5000-8,300/kg.). Using these figures, a rough estimate of seed survival to market size can be derived as follows:

1 tin = 16.5 kg.

1 kati = 0.625 kg.

1 tin contains 16.5/.625 x 5000 seed, or 132,000

1 bag = 70 kg. or about 6000 cockles

$$\text{survival} = \frac{4 \text{ bags} \times 6000/\text{bag}}{132{,}000} \times 100 = 18\%$$

The company buys from its harvesters for $5.00 per bag and sells directly to retailers at $24.00, delivered. The price at Kuala Selangor is $19.00/bag.

The marketing manager of the LKIM project at Kuala Selangor supplied information on the operation of their farm. The farm is divided into eight plots of 200 acres each, or a total area of 1,600 acres. Seed is planted in one plot and transferred to an adjacent one once it has reached an appropriate size. Seed of 3000 - 5000/ kati is used. If the seed is planted in a nursery area which will be thinned, the rate is about 1000 tins per acre. If the cockles will be grown to market size without thinning, 100 tins are sown per acre. In the case of nursery plots, cockles are thinned at a rate of 50% after 3 or 4 months. Nineteen thousand tins were sown in 1983, which has produced 40,000 bags to date with no additional plantings. It was estimated that harvesting could proceed for another six

months. It requires 15 months, including the nursery phase, for cockles to reach the legal harvest size of 31.8 mm. Twenty percent of cockles on a given plot remain undersize after that time. When the project began in 1980, it was claimed that only eight months were required to reach a marketeable size of 60/kati. Fifty to 100 bags are harvested per day by the 14 boats belonging to the project. A random sample of 13 cockles taken from the project area had a range of 27 - 42 mm, a mean of 34.9 mm and 31 % were undersized. The informant estimated that a tin of seed would yield 4 bags. Using the same estimating method as previously described, seed of 3000/kati would have a survival rate of 30% and 5000/kati, 18%.

3. Kuala Sepetang. Two cockle farmers were interviewed to obtain general information on farming practices in the area. Both operators had farms inside the river mouth, where growth is reported to be slower than on those operated off the coast. The first respondent provided rather scanty information, although the site was visited. Apparently seed ranging from 3000 to 10,000/kati is planted in the nursery plots and thinned after 4 months. If half of a sample is over 1.25 cms the cockles are transferred to grow-out plots. The second respondent obtains seed from Kuala Selangor, Sungai Besar and Lekir. His last planting was in 1983. The farm is 112 acres on which he planted 2000 tins of 3000/kati seed during that year, although 5,000/kati seed gives the best results. This year, the farmer has planted 240 tins and will ultimately seed 2000 tins. Seed of 9000/kati count is used and is priced at $20 per tin. Seed of 3000/kati will yield 10 bags of marketeable cockles per tin, while finer seed (9000/kati) produces 20-25 bags per tin. The respondent reported that the survival of seed was very much dependent on transport time from the collection area to his farm. He felt that seed supply was adequate. Seed is thinned when it reaches a size of about 300 per kati, which takes about 9 months. An additional 15 months is required to reach the legal minimum of 31.8 mm. This farmer pays collectors $3.00 to $5.00 per bag, the higher price being paid at the end of the harvesting period. Cockles are sold

to wholesalers for $16.00 per bag, who then sell to retailers in Singapore, Kuala Lumpur, Malaka and Jahore Baru. The respondent reported that wholesalers receive 23 cents per kilo. However, this appears low since it works out to only $16.10 per 70 kilo bag. Demand fluctuates seasonally and is highest during the main festival days, namely Chinese New Year and Hari Raya, the Malay festival at the end of the fasting month of Ramadan.

IV. ACTIVITIES EVALUATION

A. Hatchery system development.

In spite of problems encountered during the course of the hatchery work, a number of improvements were accomplished, among which are:

1. An improved method of phytoplankton culture was introduced which resulted in more reliability and greatly improved yields from the cultures of Isochrysis galbana. Staff were also trained in methods of checking phytoplankton cultures for contamination.
2. An efficient induced spawning system for obtaining large numbers of cockle eggs was installed and demonstrated and staff trained in its operation.
3. Improvements were made in the hatchery water supply to insure near sterile seawater for larval cultures.
4. Staff were trained in procedures for the maintenance of large volume larval cultures including feeding regimes, methods of sampling, counting and measuring larvae, the identification of various larval stages, the use of antibiotics and sodium EDTA to reduce larval mortality and hatchery record keeping procedures.
5. Cockle larvae have been kept continuously for 23 days and their growth and mortality determined. In addition, characteristics of possible use in identifying cockle larvae in plankton samples have been found.
6. Potential water quality problems have been identified and remedial measures have been suggested.

B. Field visits.

While quantitative data supplied by respondents during the course of field visits may be questionable, the visits served to impart a sense of the scale of the cockle culture industry in Malaysia. Information and insight was also gained into management techniques, harvesting methods and general features of cockle seed collection and marketing. During the short time available for field visits, it was only possible to formulate several hypothesis for whose verification or rejection further field and laboratory studies will be necessary.

C. Data analysis.

This activity was not included in the terms of reference but there was time available for the consultant to assist staff with several problems relating to the calculation of condition indices from a large amount of primary data and the analysis of length frequency data. A program was written in CPM Basic for use on the laboratory's Apple IIe which will enable the calculation of condition indices by individual lengths and months or by grouped data. This should shed light on size at first spawning and the frequency of spawning by different size groups in different areas. After debugging, staff were instructed in the use of the program and interpretion of data output. Staff were also instructed in the use of the ELEFAN series of programs prepared by ICLARM. A copy of the condition index program is included in the report as Annex 1.

V. RECOMMENDATIONS

A. Recovery of natural spatfall areas.

1. Background. There is very little published literature to draw upon as a basis for assessing the prospects of activities aimed at the "recovery" of presently unproductive areas. However, what limited information is available indicates natural shifts in beds may be a permanent feature of cockle ecology. Pathansali (1958) reported that natural beds on the west coast of peninsular Malaysia shifted from year to year. The causes of these shifts are unknown, but could be due to shifting currents at the time of setting, redistribution of sediment following high winds or changes in the biomass of spawning populations. Much more detailed knowledge of the distribution mechanism of larvae and factors affecting setting must be obtained before any judgement can be made as to the possible effectiveness of any human intervention. Although setting occurs throughout the range of the cockle, there is circumstantial evidence for a southward trending distribution pattern. Limited drift bottle experiments by Pathansali (1958) indicated a southerly flow through the channel between Penang Island and the mainland, with a westerly component along the south coast of the island. Spatfall occurs at several locations along the west coast of the island. A map of the distribution of culture beds and main seed collecting areas clearly shows that the largest biomass of cockles is concentrated in Perak state on the extensive culture beds there, while the major seed collection area is to the south, in Selangor state. Some limited seed collection occurs even as far south as Johore state (Fig. 4).

2. Two methods are suggested for investigating larval distribution; drift bottle releases and plankton sampling. Both are complicated by year-round spawning and spatfall throughout the range of the cockle. Plankton sampling is feasable year-round, whereas drift bottle releases might have to be limited during peak spawning periods. Data presently being collected on seasonal variations in condition indices will be very helpful in fixing sampling locations and dates, as well as sites for drift bottle

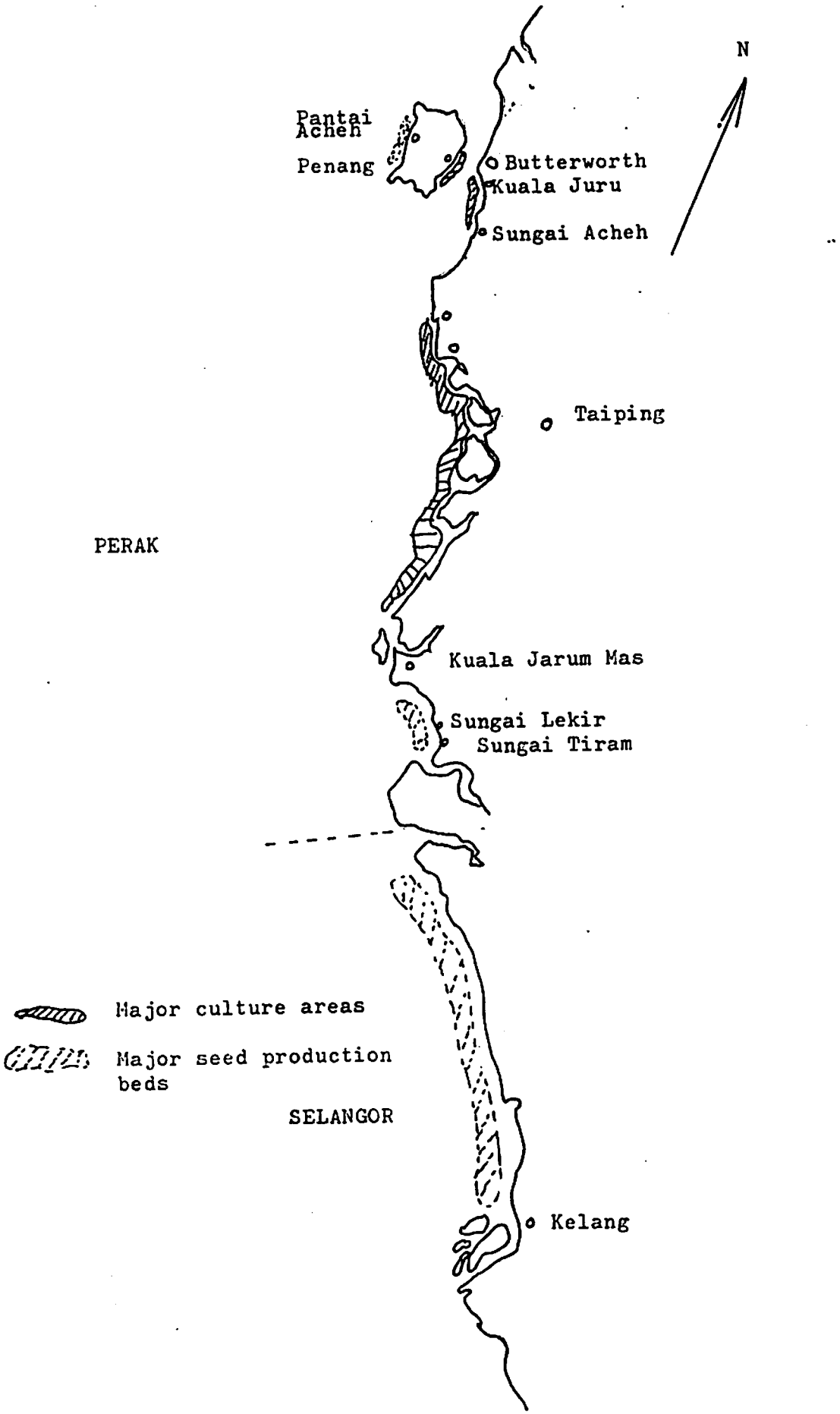

Fig. 4 The general distribution of culture and seed areas.

releases.

a. Drift bottle releases. Releases could be done in collaboration with the oceanography section of the institute, whose staff has had experience. Sufficient numbers of bottles would have to be released to insure an adequate return. The bottles would be painted with bright flourescent paint and a label inserted along with a small amount of lead or steel shot for ballast. The bottles would be recovered through a well advertized reward program.

b. Plankton sampling. A sampling program could be combined with the existing cockle study program. Quantitative sampling of cockle larvae requires a net with a flowmeter. Since small boats are used in the cockle field studies, a plankton net with an opening of 50 cms. should be adequate. A mesh size of 45 microns would insure that all stages of larvae woold be sampled. Enough weight should be added to the net line to insure that the net would be completely submerged. Due to the shallow waters at the sampling sites, a timed horizontal haul at mid depth should give a representative sample. However, an initial series of horizontal tows at the surface, mid-depth and near the bottom should be made to determine if there are any significant differences in the depth distribution of cockle larvae. In the laboratory, bivalve larvae are easily separated from the plankton sample. They can be concentrated in the bottom of the sample jar or in a beaker by "swirling" the container and pipetting them out after allowing the sample to settle for a few minutes. Cockle larvae have acquired a hinge ligament by a relatively small size of about 100 microns, whose shape and size is probably species-specific. The hinge ligament, as well as the shape of the larvae as it approaches setting should be sufficient for identification. Other major bivalve species can be reared in the hatchery so that their larvae will be available for comparison.

Plankton samples should be preserved in alcohol or buffered formalin to insure that the larval shells do not dissolve.

c. Environmental factors. If setting size larvae can be made available through the hatchery, controlled experiments can be carried out to assess the effects of salinity and turbidity on setting rates. An adequate supply of advanced larvae should be available if the problems of early larval mortality and food supply can be overcome (see recommendations on hatchery system development). The present sediment analysis program may shed some light on the stability of sediments in natural areas. It is unlikely that pollution has affected setting in most of the areas. Field visits indicated that there is very little industrilization along the coasts of Selangor and Perak where culture and seed collecting activities take place. There had been a pollution problem at Kuala Juru and anecdotal evidence indicates sedimentation may still be a problem there. The west coast of Penang where spatfall occurs is primarlily agricultural.

Conclusions. It seems likely that larval distribution and setting are predominantly influenced by natural factors and that there is little that can be done be human intervention, other than conserving the coastal environment, particularly mangrove forests and limiting or preventing the establishment of polluting industries on the watersheds of rivers discharging near the areas of natural spatfall. However, more knowledge of larval distribution patterns and environmental factors affecting setting is required.

B. Reseeding.

1. Background. There are no estimates available of the biomass of cockles on natural grounds, so it is not possible to make any quantitative comparisons between the contribution of natural vs. cultured cockles to the seed supply. However, it is not unreasonable to assume

that cultured cockles make the major contribution. If this is the case, it is difficult to see how a reseeding program, unless prohibitively expensive could have a detectable impact on seed supply. A number of problems confront any attempt at reseeding. Firstly, there is inadequate knowledge of larval distribution mechanisms, as mentioned above. Secondly, natural beds or potential reseeding sites may have a high population of predators. This has to be carefully evaluated and such predators eliminated or avoided. Thirdly, it may be very difficult to determine if reseeding has any noticeable affect on seed supply. There is no way that seed originating from reseeded stocks can be differentiated from that of cultured or existing natural stocks. The only attempt known of a significant stocking program to establish a broodstock in Thailand failed. If a virgin area could be stocked, then seed produced by artificially planted cockles might be detectable. However, such areas do not appear to exist on the west coast.

2. Conclusions. Reseeding has a very limited chance of success or impact on the seed supply. However, if such a program is initiated, it should be preceeded by studies described in the section on recovery of natural setting areas (section A). The results will greatly assist in allocating reseeding sites.

C. Research methods for studying the early life history of cockles and other Malaysian bivalves.

1. Background. Both field and laboratory studies will provide information on the early life history of cockles and other commercially important bivalves. Field studies through plankton sampling on a regular basis will enable estimates of the length of the plankton phase, seasonal variations in abundance and distribution and the prediction of setting locations and time of ocurrance. Laboratory rearing of larvae can provide identifying characteristics for species or at least families of bivalve larvae, as well as confirm field data on the length of the larval period. The effects of temperature, salinity, turbidity, and common pollutants can be studied using various stages of larvae from eggs through pediveliger.

2. Field studies. The methodology for plankton sampling has been described in earlier sections. Samples should be taken offshore, rather than in river mouths since the larvae of cockles may avoid low salinity water, at least in the early D-hinge and umbo stages. However, this can be varified by a series of plankton tows perpendicular to the shore, beginning within the river mouth. In the case of cockle larvae, after identification they should be measured so that length frequencies can be analyzed and related to spatial and temporal distribution. This will establish the length of the planktonic phase and possibly indicate the origin of the larvae, particularly if combined with data from drift bottle releases. If large numbers of larvae are present in a sample, they can be separated from the sample and then subsamples by the use of a plankton splitter. The use of a flowmeter with the plankton net will allow a quantitative estimate of larval abundance and relative setting intensity.

3. Laboratory studies. The problems encountered during the hatchery development phase of the consultancy have been documented in section II. If the results of the bioassay of water taken from the new pump intake the water to be polluted, it is possible to carry on small scale larval rearing using 20 to 60 liter plastic buckets. and water brought to the laboratory from offshore A fishing boat can be chartered and supplied with one or more fiberglass tanks and a portable pump, either gasoline or 12 volt DC powered. There are plenty of tanks available now at the laboratory for both transport and storage of several tons of seawater. A truck could be rented to transport the seawater in covered tanks from the landing site to the laboratory.

Some modification to the laboratory will be required to insure that algal stock cultures do not become contaminated, especially during innoculation. A separate room with independent air conditioning should be created by partitioning the main laboratory. Since the room would be small, the air conditioning requirment would be minimal.

A second possibility, discussed during meetings with IPP, ICLARM and BOBP staff, is to contract larval work to the University Sains Malaysia to be carried out at their field station where quality is presumed to be good. This has the disadvantage that the progress of studies would depend upon the availablity of students to carry out the necessary studies. On the other hand, IPP should consider if a larval rearing program is worth the staff time and modifications that will have to be made. Also, to insure the smooth flow of work in the laboratory, continuous monitoring of natural stocks of bivalves will be required to supply the hatchery with gravid specimens. At least two staff members would have to devote full time to the program.

4. Conclusions. Provided that certain modifications are made to the laboratory and seawater supply, a successful larval rearing program for experimental purposes can be carried out at the laboratory. In combination with field work, valuable information will be obtained relating to larval distribution, setting prediction and the effects of physical environmental parameters and pollutants on larval survival, growth and setting.

D. Seed resource management and conservation.

1. The importance to the cockle industry of protecting the seed resource is obvious. However, at the present time there is no clear indication of a seed shortage, particularly if one looks at seed prices. In fact, from historical trends, one could infer there is an oversupply. Although there was very limited setting in Selangor in 1983-84, none of our respondents interviewed in the field mentioned seed supply as a problem. Further complicating the picture is the fact that the seed requirements of the industry are not known and in any event are very difficult to ascertain since farming practices vary from area to area and among farmers. In addition, the total area under culture is probably underestimated due to the use of unlicensed areas for culture. Annual seed production is also very difficult to estimate since there is no effective registration of sales, as well as clandestine harvesting. Studies of seed growth and mortality also need to be improved and expanded. There is some indication

that the present minimum seed harvesting size of 6.4 mm may also result in seed loss due to mortality on the seed beds. In fact, most farmers seem to prefer a seed size somewhat under the present legal minimum.

2. Field studies of seed survival and growth. This research has been initiated on a limited scale by IPP, but could be improved and perhaps expanded to a few more areas. Methods for doing this were discussed in several meetings held recently between IPP and ICLARM staff. The major problem is identifying setting areas before harvesting begins, which will obviously severely skew any data on density and size. However, this can be overcome by regular larval sampling in the vicinity of known setting areas, particularly those that recieve regular spatfalls. If pediveliger larvae are obtained in the samples, setting will be imminent, and preparations can be made to begin sampling. Seed bed monitoring would be done in a fixed quadrant marked off by poles. An area of ten by ten meters has been suggested as being sufficiently large to allow sampling without replacement and without affecting density in any significant way. A small Ekman dredge should be adequate for sampling seed. An initial sample can be taken to determine how many replicates are needed to determine density distribution and mean seed size within the desired statistical limits. Sampling should be done at weekly intervals. The west coast of Penang (Pantai Acheh or Sungai Penang) and at least one location in Selangor should be sampled. A concerted effort should be made to obtain the understanding and cooperation of local people in hopes that the quadrants would remain undisturbed. The results of these studies would permit a reevaluation of the minimum seed size regulation.

3. Brood stock conservation. Probably one of the best ways to insure continuing seed supply is to allow for adequate spawning by cultured cockles, since they probably form the largest spawning biomass. Studies already underway on the seasonal variations in condition indices should indicate which size groups are contributing most strongly to spawning.

4. Environmental conservation and protection. As in the case of natural beds, protecting the shoreline environment and insuring water quality is an effective way of assuring an adequate seed supply to the industry. The tremendous decline of the Chesapeake Bay oyster industry in the United States is one of many examples of the near extinction of a shellfish resource due to the effects of declining water quality on spawning and setting. Along with insuring adequate spawning by cultured cockles, it is probably the best approach to conserving seed stocks.
5. Conclusions. Further field studies are required to determine growth and survival of seed so that the present minimum size regulation can be reviewed. Important elements of seed resource conservation are environmental protection and adequate brood stock spawning, mainly of cultured cockles.

E. Experimental farms.

1. Background. There are many questions regarding culture procedures, growth rates and mortality, as well as farm management techniques that can only be answered by the operation of a farm completely under IPP control from stocking through harvesting. In addition to answering the above questions, more efficient methods of management could be developed leading to better utilization of seed, and more efficient nursery, growout and harvesting techniques. Farmers frequently complain of slow growth rates on old culture beds. Although this may in some cases be due to the accumulation of old shell, particularly on less well managed farms, it might be due to other causes. The biomass of cockles on a farm is very high compared to a natural bed and it is concievable that after a period of years the metabolic wastes of the cockles themselves have modified the sediments to such a degree that growth is directly affected. After all, it is an age old practice of terrestial farmers to let fields lay fallow for varying lengths of time. In Japan, certain bays were so heavily utilized for pearl oyster culture that bottom sediments and benthos were dramatically altered and the growth of the oysters and pearl quality affected. If IPP had its own cockle farm or farms, such hypothesis could be tested.

Improvements in farming procedures could be passed on to cockle culturists through the extension system.

2. Location and mode of operation. An initial farm might be established on Penang to simplify logistic problems. Day-to-day management might be done through contract with a private grower or through direct hire. Experimental design would follow procedures normally used in agricultural experimentation. Initial work could focus on determining optimum seed size and planting density in the nursery and growout plots. Succeeding work could investigate the effects of fallowing plots.
3. Conclusions. An experimental farm would be valuable in answering questions about current culture practices and in developing more efficient culture techniques.

ANNEX I

COCKLE CONDITION INDEX DATA PROCESSING PROGRAM, WRITTEN FOR AN APPLE IIe MICRO-COMPUTER WITH CPM

```
10 OPTION BASE 1
20 DIM C(12,30,6),LI!(12,30),M%(12),D%(12),Y%(12),NS%(12),NOL%(12,30)
30 PRINT"ANADARA CALCULATES CONDITION INDICES FOR COCKLES, INCLUDING"
40 PRINT"VOLUMETRIC, COMMERCIAL, STANDARD AND % SOLIDS."
50 PRINT"INPUTS INCLUDE INDIVIDUAL  LENGTHS, TOTAL WEIGHT, TOTAL VOLUME,"
60 PRINT"SHELL VOLUME, MEAT VOLUME, WET MEAT WEIGHT AND DRY MEAT"
70 PRINT"WEIGHT."
80 INPUT"PRESS [C] TO CONTINUE";S$:IF S$="C" THEN GOTO 90 ELSE 80
90 HOME
110 HOME
120 INPUT"IS DATA INPUT FROM KEYBOARD OR DISK(K/D)";S$:IF S$="D" THEN GOSUB 2050
 ELSE 145
130 INPUT"DO YOU WANT A PRINTOUT OF SAMPLE DATA(Y/N)";S$:IF S$="Y" THEN GOTO 600
 ELSE 1235
140 REM ********ENTER SAMPLE DATA ***********
145 GOSUB 2440
170 INPUT"FILE NAME";A$
180 INPUT"HOW MANY MONTHS (SAMPLES) DO YOU WANT TO ENTER";K
190 PRINT"ENTER THE DAY,MONTH, YEAR  FOR EACH SAMPLE"
200 FOR A=1 TO K
210 PRINT"SAMPLE NO. "A:INPUT D%(A),M%(A),Y%(A)
215 INPUT "IS THE DATE CORRECT(Y/N)";S$:IF S$="Y" THEN GOTO 220 ELSE GOTO 210
220 NEXT A
230 HOME
240 FOR A=1 TO K
250 PRINT"HOW MANY SUBSAMPLES ARE THERE FOR SAMPLE "A:INPUT NS%(A)
255 INPUT"ARE YOU SURE(Y/N)";S$:IF S$="Y" THEN GOTO 260 ELSE 250
260 FOR L=1 TO NS%(A)
270 DIM Z(20)
274 PRINT"HOW MANY LENGTHS ARE THERE IN SUBSAMPLE "L:INPUT NOL%(A,NS%(A))
276 INPUT"ARE YOUR SURE(Y/N)";S$:IF S$="N" THEN GOTO 274 ELSE 280
280 PRINT"ENTER INDIVIDUAL LENGTHS FOR SUBSAMPLE "L
290 LI!(A,L)=0
300 FOR J=1 TO NOL%(A,NS%(A))
310 PRINT"NO. "J" = ";INPUT Z(J)
330 NEXT J
340 INPUT"ARE ENTRIES CORRECT(Y/N)";S$:IF S$="Y" THEN GOTO 362
350 INPUT"TYPE NO. OF INCORRECT VALUE (1-10), NEW VALUE";J,Z(J)
360 INPUT"PROCEED(Y/N)";S$:IF S$="N" THEN GOTO 350
362 FOR J=1 TO NOL%(A,NS%(A))
365 LI!(A,L)=LI!(A,L)+Z(J)
367 NEXT J
370 LI!(A,L)=LI!(A,L)/NOL%(A,NS%(A))
380 ERASE Z
390 NEXT L
400 NEXT A
410 HOME
420 V$="                TOTAL WEIGHT     TOTAL VOLUME     SHELL VOLUME     MEAT VOLU
ME     WET MEAT WEIGHT DRY MEAT WEIGHT
    "
425 IF ZZ=1 THEN GOTO 755
430 REM ************ INPUT VARIABLES **************
440 PRINT"YOU CAN NOW ENTER WEIGHT AND VOLUME DATA"
450 INPUT"IF DISK IS INSERTED, TYPE [R] WHEN READY";S$:IF S$="R" THEN GOTO 460
460 HOME
470 FOR A=1 TO K
480 PRINT"************ AREA "A$", SAMPLE "D%(A)"/"M%(A)"/"Y%(A)" **************"
490 PRINT
500 FOR B=1 TO NS%(A)
510 PRINT"FOR SUBSAMPLE "B
520 FOR D=16 TO 96 STEP 16
530 H=D/16
540 PRINT MID$(V$,D,15):INPUT C(A,B,H)
550 NEXT D
```

```
560 NEXT B
570 NEXT A
580 LPRINT"************************** ERROR CHECK **************************"
590 LPRINT
600 FOR A=1 TO K
610 LPRINT TAB(5)A$TAB(20)"SAMPLE DATE; "D%(A)"/"M%(A)"/"Y%(A)
620 LPRINT
630 LPRINT TAB(49)"WET"TAB(57)"DRY"
640 LPRINT TAB(6)"MEAN"TAB(17)"TOTAL"TAB(25)"TOTAL"TAB(33)"SHELL"TAB(41)"MEAT"
B(49)"MEAT"TAB(57)"MEAT"
650 LPRINT "NO."TAB(5)"LENGTH"TAB(17)"WEIGHT"TAB(25)"VOLUME"TAB(33)"VOLUME"TAB(
1)"VOLUME"TAB(49)"WEIGHT"TAB(57)"WEIGHT"
660 FOR S=1 TO 62:LPRINT"_";:NEXT S
670 LPRINT
680 FOR B=1 TO NS%(A)
690 LPRINT B TAB(5)LI!(A,B)TAB(17)C(A,B,1)TAB(25)C(A,B,2)TAB(33)C(A,B,3)TAB(41)
(A,B,4)TAB(49)C(A,B,5)TAB(57)C(A,B,6)
700 NEXT B
710 NEXT A
715 LPRINT:LPRINT
720 HOME
730 INPUT"ARE ALL ENTRIES CORRECT(Y/N)";S$:IF S$="Y"THEN GOTO 870
740 REM ********** ERROR CORRECTION **********
750 HOME
752 IF ZZ=1 THEN GOTO 420
755 FOR L=16 TO 96 STEP 16
760 H=L/16
762 U$=MID$(V$,L,15)
765 PRINT"VARIABLE #"H"="U$
770 NEXT L
775 PRINT"ENTER SAMPLE NO., SUBSAMPLE NO., VARIABLE# OF INCORRECT VALUE"
780 INPUT A,B,H
785 PRINT"ENTER CORRECT VALUE FOR "MID$(V$,H*16,15):INPUT C(A,B,H)
820 GOTO 840
840 INPUT"ANY MORE CORRECTIONS(Y/N)";S$:IF S$="Y" THEN GOTO 750
850 INPUT"DO YOU WANT A PRINTOUT OF CORRECTED DATA(Y/N)";S$:IF S$="Y" THEN GOTO
580
870 HOME
890 INPUT"DO YOU WANT TO STORE DATA ON DISK(Y/N)";S$:IF S$="N" THEN GOTO 1230
900 HOME
910 REM ********** STORE DATA **********
920 RESET
930 OPEN "O",#1,A$
940 WRITE#1,K
950 FOR A=1 TO K
960 WRITE#1,D%(A);M%(A);Y%(A);NS%(A)
970 FOR I=1 TO NS%(A)
980 WRITE#1,LI!(A,I)
990 FOR G=1 TO 6
1000 WRITE#1,C(A,I,G)
1010 NEXT G
1020 NEXT I
1030 NEXT A
1040 CLOSE#1
1090 CLOSE#1
1220 HOME
1230 REM ********** CALCULATE AVERAGE VALUES **********
1235 INPUT"DO YOU WANT SAMPLE C.I.'S(Y/N)";S$:IF S$="N" THEN GOTO 1460
1240 HOME
1260 FOR A=1 TO K
1270 TW=0:TV=0:TSV=0:TMV=0:TWW=0:TDW=0
1280 FOR I=1 TO NS%(A)
1290 TW=TW+C(A,I,1):TV=TV
,TDW=TDW+C(A
```

```
W-TDW%S%(4)
1320 DIM P!(4)
1330 P!(1)=(ANV/(ATV-ASV))*100
1340 P!(2)=(AWW/AIW)*100
1350 P!(3)=(ADW/AUW)*100
1360 P!(4)=(ADW/(ATV-ASV))*100
1370 LPRINT"******************  AREA CODE "A$", SAMPLE "D%(A)"/"M%(A)"/"Y%(A)"
**********"
1380 LPRINT
1390 LPRINT TAB(20)"VOLUMETRIC C.I. = "P!(1)
1400 LPRINT TAB(20)"COMMERCIAL C.I. = "P!(2)
1410 LPRINT TAB(20)"PERCENT SOLIDS  = "P!(3)
1420 LPRINT TAB(20)"STANDARD C.I.   = "P!(4)
1425 ERASE P
1427 LPRINT:LPRINT
1430 NEXT A
1440 HOME
1450 REM ********** C.I. BY FREQ INTERVAL ************
1460 PRINT"YOU CAN CALCULATE C.I.'S FOR EACH SUBSAMPLE OR ANY GROUPING"
1470 INPUT"PROCEED(Y/N)";S$:IF S$="N" THEN GOTO 2020
1480 HOME
1490 PRINT"TYPE [EACH] IF YOU WANT C.I.'S FOR EACH SUBSAMPLE, OTHERWISE TYPE [G
OUPED]":INPUT S$:IF S$="GROUPED" GOTO 1650
1500 FOR A=1 TO K
1505 LPRINT:LPRINT
1510 LPRINT"************** ***AREA: "A$", SAMPLE "D%(A)"/"M%(A)"/"Y%(A)" ******
**********"
1520 LPRINT
1530 LPRINT "NO."TAB(5)"LENGTH"TAB(15)"VOLUMETRIC C.I."TAB(33)"COMMERCIAL C.I."T
AB(50)"% SOLIDS"TAB(60)"STANDARD C.I."
1540 DIM Q(4)
1550 FOR I=1 TO NS%(A)
1560 Q(1)=(C(A,I,4)/(C(A,I,2)-C(A,I,3)))*100
1570 Q(2)=(C(A,I,5)/C(A,I,1))*100
1580 Q(3)=(C(A,I,6)/C(A,I,5))*100
1590 Q(4)=(C(A,I,6)/(C(A,I,2)-C(A,I,3)))*100
1600 LPRINT I TAB(6)LI!(A,I)TAB(15)Q(1)TAB(37)Q(2)TAB(50)Q(3)TAB(62)Q(4)
1610 NEXT I
1615 ERASE Q
1620 NEXT A
1630 INPUT"PROCEED TO GROUPED DATA(Y/N)";S$:IF S$="Y" THEN GOTO 1650 ELSE 2020
1640 END
1650 HOME
1655 PRINT K
1660 FOR A=1 TO K
1665 IF A>K THEN GOTO 1690
1670 PRINT "SAMPLE NO. "A"      DATE:  "D%(A)"/"M%(A)"/"Y%(A)
1680 NEXT A
1690 INPUT"WHICH SAMPLE NO.";A
1700 PRINT
1730 GOSUB 2350
1740 PRINT"SAMPLE "A" HAS THE FOLLOWING SUBSAMPLE LENGTHS:"
1750 FOR  L=1 TO NS%(A)
1760 PRINT TAB(10) L TAB(15) LI!(A,L)
1770 NEXT L
1800 PRINT
1810 PRINT"ENTER THE SAMPLE NUMBERS OF THE SMALLEST, LARGEST LENGTHS"
1820 PRINT"YOU WANT TO COMBINE":INPUT L1,L2
1830 HOME
1840 TW=0:TV=0:TSV=0:TMV=0:TWW=0:TDW=0
1850 FOR II=L1 TO L2
1860 TW=TW+C(A,II,1):TV=TV+C(A,II,2):TSV=TSV+C(A,II,3):TMV=TMV+C(A,II,4):TWW=TW
+C(A,II,5):TDW=TDW+C(A,II,6)
1870 NEXT II
1880 DIFF=L2-L1+1
1890 TW=TW/DIFF:TV=TV/DIFF:TSV=TSV/DIFF:TMV=TMV/DIFF:TWW=TWW/DIFF:TDW=TDW/DIFF
```

```
1900 Q!(1)=(TMV/(TV-TSV))*100
1910 Q!(2)=(TWW/TW)*100
1920 Q!(3)=(TDW/TWW)*100
1930 Q!(4)=(TDW/(TV-TSV))*100
1940 LPRINT"******** AREA CODE "A$", SAMPLE "D%(A)"/"M%(A)"/"Y%(A)"  *********
"
1950 LPRINT
1960 LPRINT"CONDITION INDICES COMBINED BETWEEN LENGTHS "LI!(A,L1)" AND "LI!(A,L
)
1970 LPRINT TAB(20)"VOLUMETRIC C.I. = "Q!(1)
1980 LPRINT TAB(20)"COMMERCIAL C.I. = "Q!(2)
1990 LPRINT TAB(20)"PERCENT SOLIDS  = "Q!(3)
2000 LPRINT TAB(20)"STANDARD C.I.   = "Q!(4)
2010 INPUT"CONTINUE WITH MORE COMBINATIONS(Y/N)";S$:IF S$="Y" THEN GOTO 1650
2020 PRINT"******************************** END OF PROGRAM ************************
***"
2030 END
2040 REM ***************** READ FILE ************************
2050 INPUT"ENTER FILE NAME";A$
2055 ZZ=1
2060 OPEN "I",#1,A$
2070 INPUT#1,K
2080 FOR A=1 TO K
2090 INPUT#1,D%(A),M%(A),Y%(A),NS%(A)
2100 FOR I=1 TO NS%(A)
2110 INPUT#1,LI!(A,I)
2120 FOR G=1 TO 6
2130 INPUT#1,C(A,I,G)
2140 NEXT G
2150 NEXT I
2160 NEXT A
2190 CLOSE#1
2330 RETURN
2340 REM ***************** SORT LENGTHS ****************
2350 FOR Z=1 TO (NS%(A)-1)
2360 FOR L=1 TO (NS%(A)-1)
2370 IF LI!(A,L)<LI!(A,L+1) THEN GOTO 2410
2380 T= LI!(A,L)
2390 LI!(A,L)=LI!(A,L+1)
2400 LI!(A,L+1)=T
2410 NEXT L
2420 NEXT Z
2430 RETURN
2440 PRINT"THE FILE NAME CONSISTS OF A LOCATION CODE AND A DATE, WITH THE"
2450 PRINT"TOTAL NUMBER OF CHARACTERS NOT TO EXCEED 8"
2460 RETURN
```

Sample Printout

A147185 SAMPLE DATE; 30 / 10 / 84

NO.	MEAN LENGTH	TOTAL WEIGHT	TOTAL VOLUME	SHELL VOLUME	MEAT VOLUME	WET MEAT WEIGHT	DRY MEAT WEIGHT
1	24.28	52.31	31.5	13	10.5	10.18	1.66
2	25.29	57.3	36	14	12	11.71	1.84
3	26.37	67.57	41	16	14	13.2	2.22
4	27.29	73.72	46	18	15	14.59	2.4
5	28.33	82.83	52	20	17	16.82	2.87

A147185 SAMPLE DATE; 27 / 11 / 84

NO.	MEAN LENGTH	TOTAL WEIGHT	TOTAL VOLUME	SHELL VOLUME	MEAT VOLUME	WET MEAT WEIGHT	DRY MEAT WEIGHT
1	23.43	50.04	32.5	12	11	10.43	2.01
2	24.52	56.16	35.5	15	13	12.16	2.32
3	25.46	64.02	39.5	18	16	15.23	3.07
4	26.5	70	45	19	17	16.8	3.21
5	27.48	74.42	48	20	18	18.38	3.56
6	28.47	86.61	56	22	21	21	3.96
7	29.45	90.99	58	24	22	22.89	4.21
8	30.55	99.44	64	26	24	24.3	4.77
9	32.5	112.8	75	30	28	28.8	5.58
10	22.94	45.96	29	12	10	10.13	1.78
11	24.4	55.9	35	16	13	13.82	2.39
12	25.4	61.11	40	17	15	14.73	2.57
13	26.24	64.92	42.5	18	16	16.19	2.88
14	27.5	75.08	50	20	20	19.45	3.56
15	28.31	81.27	53	21	21	21.05	3.96
16	29.39	85.74	56	22	23	23.33	4.69

A147185 SAMPLE DATE; 7 / 1 / 85

NO.	MEAN LENGTH	TOTAL WEIGHT	TOTAL VOLUME	SHELL VOLUME	MEAT VOLUME	WET MEAT WEIGHT	DRY MEAT WEIGHT
1	25.94	68.88	42	18	16	15.25	2.4
2	27.61	74.1	46	18	18	16.61	2.51
3	28.4	83.45	50	20	20	19.05	2.89
4	29.4	92.24	56	22	23	22.32	3.34
5	30.48	102.68	63	25	25	23.31	3.45
6	31.49	113.9	70	29	26	24.6	3.54
7	32.72	116.88	73	29	29	27.83	4.02
8	33.52	129.15	80	32	32.5	31.84	4.62
9	35.32	147.21	96	36	34	33.27	4.68

********** AREA CODE A147185, SAMPLE 30 / 10 / 84 ********

VOLUMETRIC C.I. = 54.5817
COMMERCIAL C.I. = 19.9263
PERCENT SOLIDS = 16.5263
STANDARD C.I. = 8.75697

********** AREA CODE A147185, SAMPLE 27 / 11 / 84 ********

VOLUMETRIC C.I. = 64.4295
COMMERCIAL C.I. = 24.5807
PERCENT SOLIDS = 18.8853
STANDARD C.I. = 12.1969

********** AREA CODE A147185, SAMPLE 7 / 1 / 85 **********

VOLUMETRIC C.I. = 64.4092
COMMERCIAL C.I. = 23.0568
PERCENT SOLIDS = 14.6908
STANDARD C.I. = 9.0634

********** ***AREA: A147185, SAMPLE 30 / 10 / 84 **********

NO.	LENGTH	VOLUMETRIC C.I.	COMMERCIAL C.I.	% SOLIDS	STANDARD C.I.
1	24.28	56.7568	19.4609	16.3065	8.97297
2	25.29	54.5455	20.4363	15.7131	8.36364
3	26.37	56	19.5353	16.8182	8.88
4	27.29	53.5714	19.7911	16.4496	8.57143
5	28.33	53.125	20.3067	17.063	8.96875

********** ***AREA: A147185, SAMPLE 27 / 11 / 84 **********

NO.	LENGTH	VOLUMETRIC C.I.	COMMERCIAL C.I.	% SOLIDS	STANDARD C.I.
1	23.43	53.6585	20.8433	19.2713	9.80488
2	24.52	63.4146	21.6524	19.079	11.3171
3	25.46	74.4186	23.7894	20.1576	14.2791
4	26.5	65.3846	24	19.1071	12.3462
5	27.48	64.2857	24.6977	19.3689	12.7143
6	28.47	61.7647	24.2466	18.8571	11.6471
7	29.45	64.7059	25.1566	18.3923	12.3824
8	30.55	63.1579	24.4368	19.6296	12.5526
9	32.5	62.2222	25.5319	19.375	12.4
10	22.94	58.8235	22.0409	17.5716	10.4706
11	24.4	68.4211	24.7227	17.2938	12.5789
12	25.4	65.2174	24.1041	17.4474	11.1739
13	26.24	65.3061	24.9384	17.7888	11.7551
14	27.5	66.6667	25.9057	18.3033	11.8667
15	28.31	65.625	25.9013	18.8124	12.375
16	29.39	67.6471	27.2102	20.1029	13.7941

********** ***AREA: A147185, SAMPLE 7 / 1 / 85 **********

NO.	LENGTH	VOLUMETRIC C.I.	COMMERCIAL C.I.	% SOLIDS	STANDARD C.I.
1	25.94	66.6667	22.14	15.7377	10
2	27.61	64.2857	22.4157	15.1114	8.96429
3	28.4	66.6667	22.828	15.1706	9.63333
4	29.4	67.6471	24.1977	14.9642	9.82353
5	30.48	65.7895	22.7016	14.8005	9.07895
6	31.49	63.4146	21.5979	14.3902	8.63415
7	32.72	65.9091	23.8107	14.4448	9.13636
8	33.52	67.7083	24.6535	14.5101	9.625
9	35.32	56.6667	22.6004	14.0667	7.8

******** AREA CODE A147185, SAMPLE 30 / 10 / 84 **********

CONDITION INDICES COMBINED BETWEEN LENGTHS 24.28 AND 25.29

VOLUMETRIC C.I. = 55.5556
COMMERCIAL C.I. = 19.9708
PERCENT SOLIDS = 15.989
STANDARD C.I. = 8.64198

******** AREA CODE A147185, SAMPLE 30 / 10 / 84 **********

CONDITION INDICES COMBINED BETWEEN LENGTHS 26.37 AND 27.29

VOLUMETRIC C.I. = 54.717
COMMERCIAL C.I. = 19.6688
PERCENT SOLIDS = 16.6247
STANDARD C.I. = 8.71698
******** AREA CODE A147185, SAMPLE 7 / 1 / 85 **********

CONDITION INDICES COMBINED BETWEEN LENGTHS 25.94 AND 27.61
VOLUMETRIC C.I. = 65.3846
COMMERCIAL C.I. = 22.2828
PERCENT SOLIDS = 15.4112
STANDARD C.I. = 9.44231
******** AREA CODE A147185, SAMPLE 7 / 1 / 85 **********

CONDITION INDICES COMBINED BETWEEN LENGTHS 28.4 AND 29.4
VOLUMETRIC C.I. = 67.1875
COMMERCIAL C.I. = 23.5472
PERCENT SOLIDS = 15.0592
STANDARD C.I. = 9.73438
******** AREA CODE A147185, SAMPLE 7 / 1 / 85 **********

CONDITION INDICES COMBINED BETWEEN LENGTHS 30.48 AND 31.49
VOLUMETRIC C.I. = 64.557
COMMERCIAL C.I. = 22.1212
PERCENT SOLIDS = 14.5899
STANDARD C.I. = 8.8481
******** AREA CODE A147185, SAMPLE 7 / 1 / 85 **********

CONDITION INDICES COMBINED BETWEEN LENGTHS 32.72 AND 33.52
VOLUMETRIC C.I. = 66.8478
COMMERCIAL C.I. = 24.2531
PERCENT SOLIDS = 14.4796
STANDARD C.I. = 9.39131

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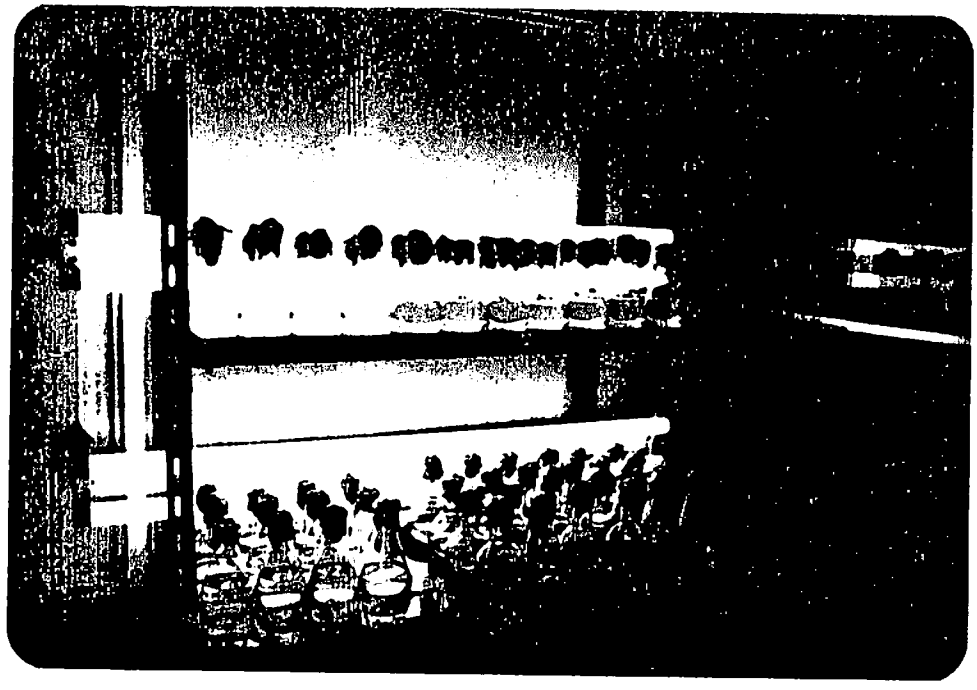
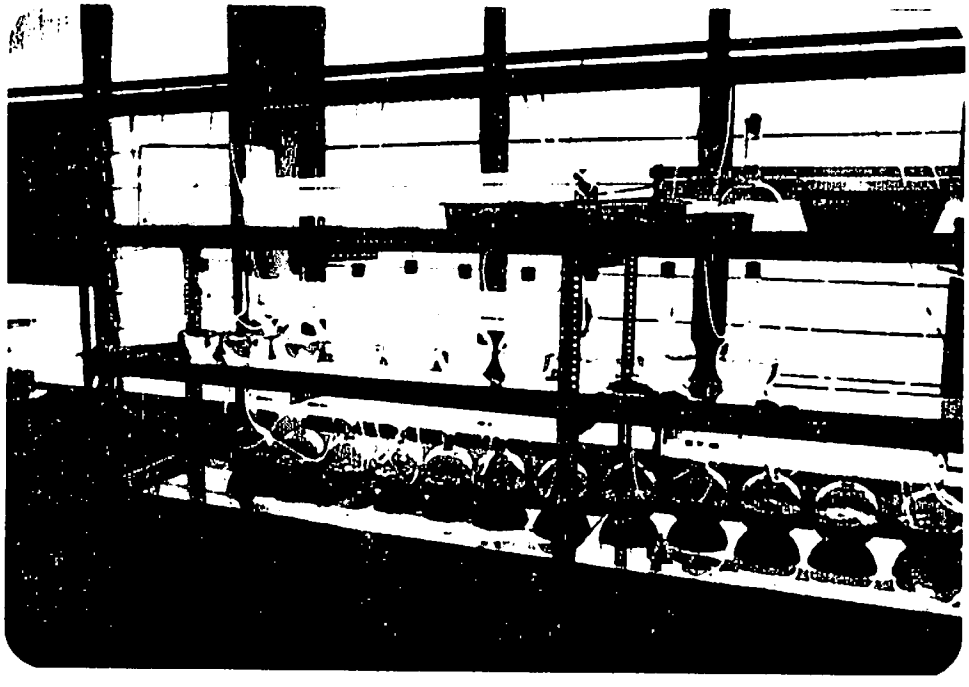
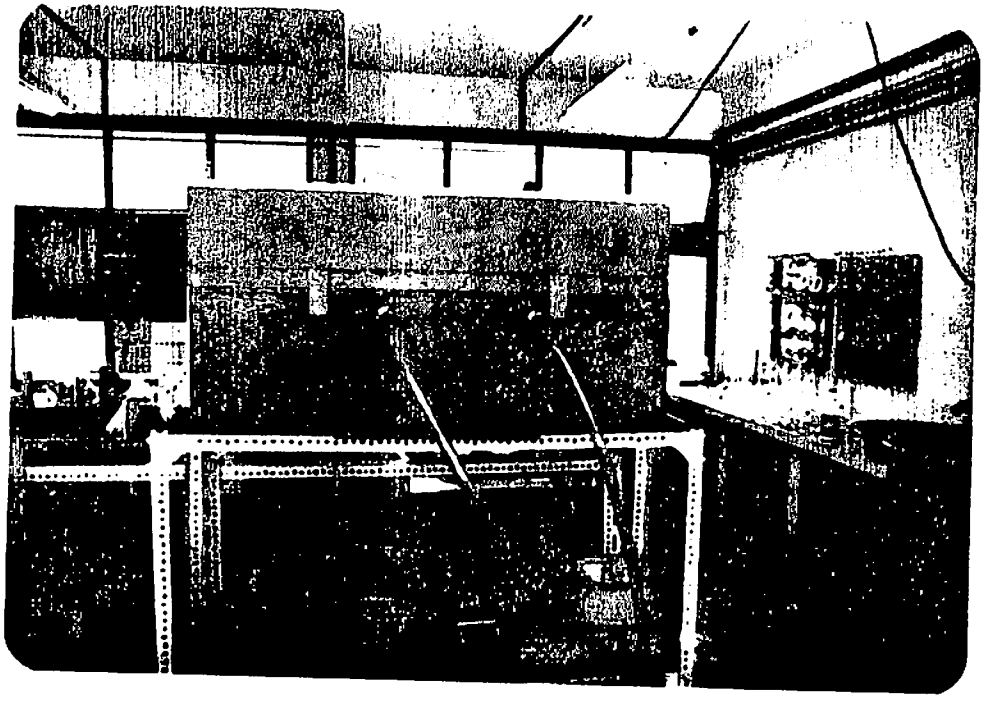


1. Isochrysis galbana stock cultures



2. I. galbana one liter cultures

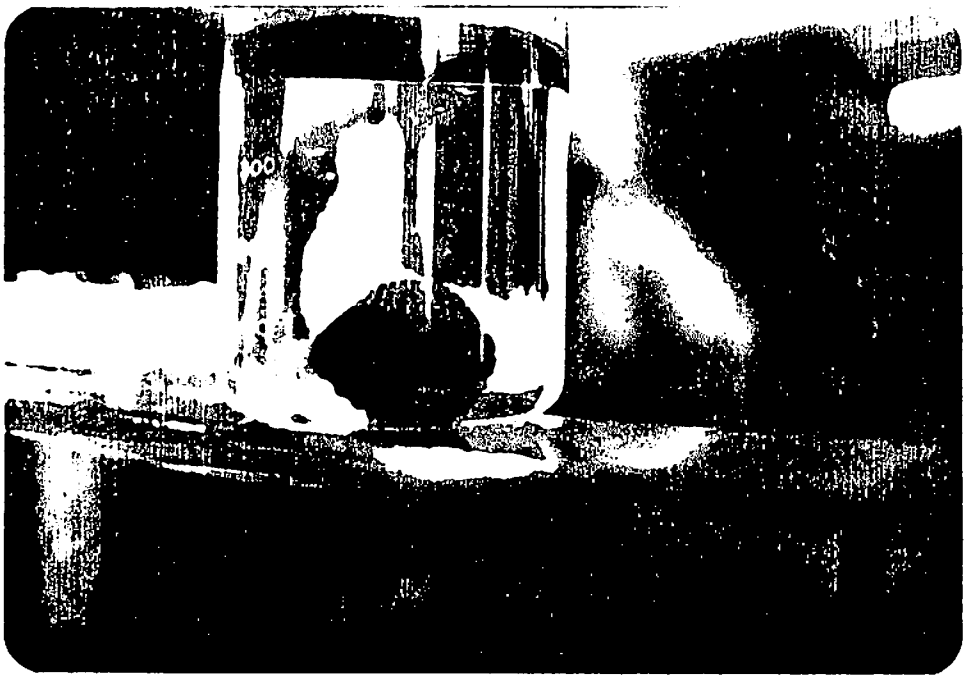
3. Twenty liter cultures of I. galbana



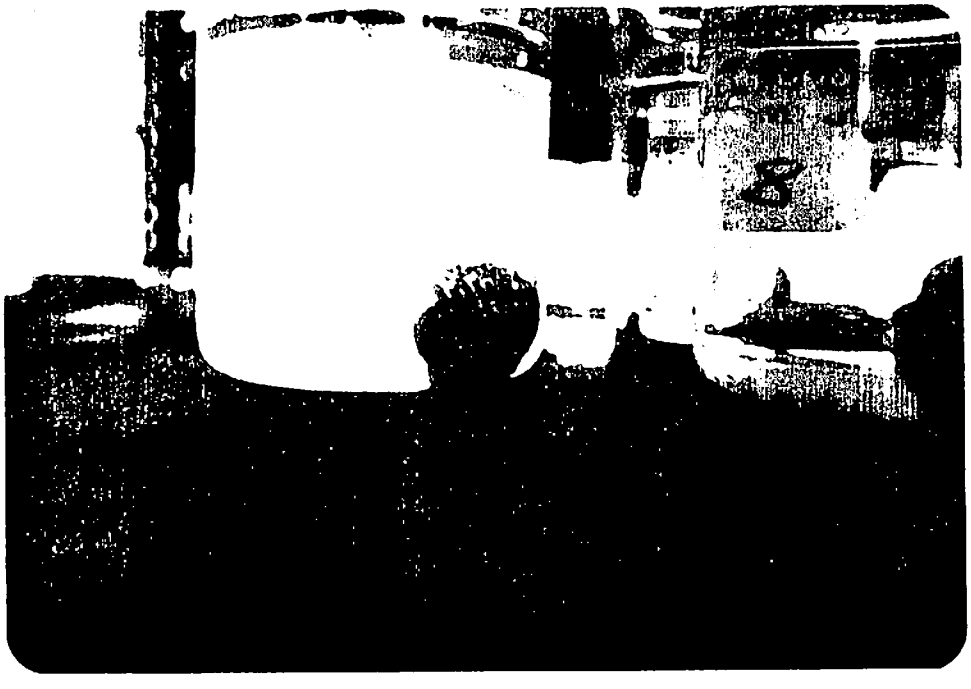
4. Ultraviolet light water sterilizer showing outlet ports.

5. Heat exchanger fed through cartridge filters and supplying spawning trough.

6. Spawning trough



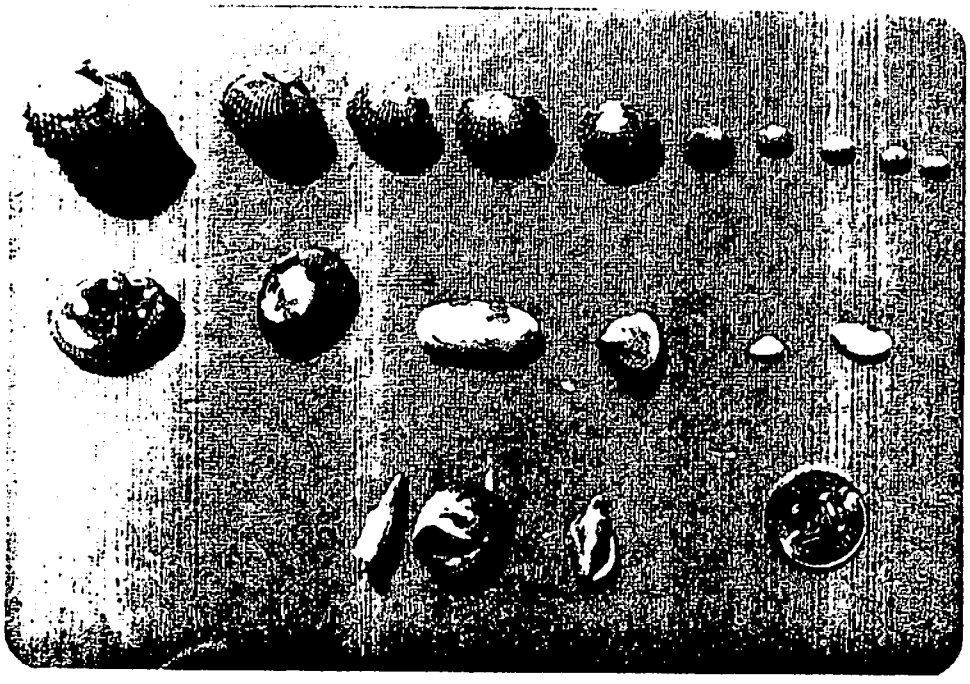
7. Spawning female Anadara granosa



8. Spawning male A. granosa

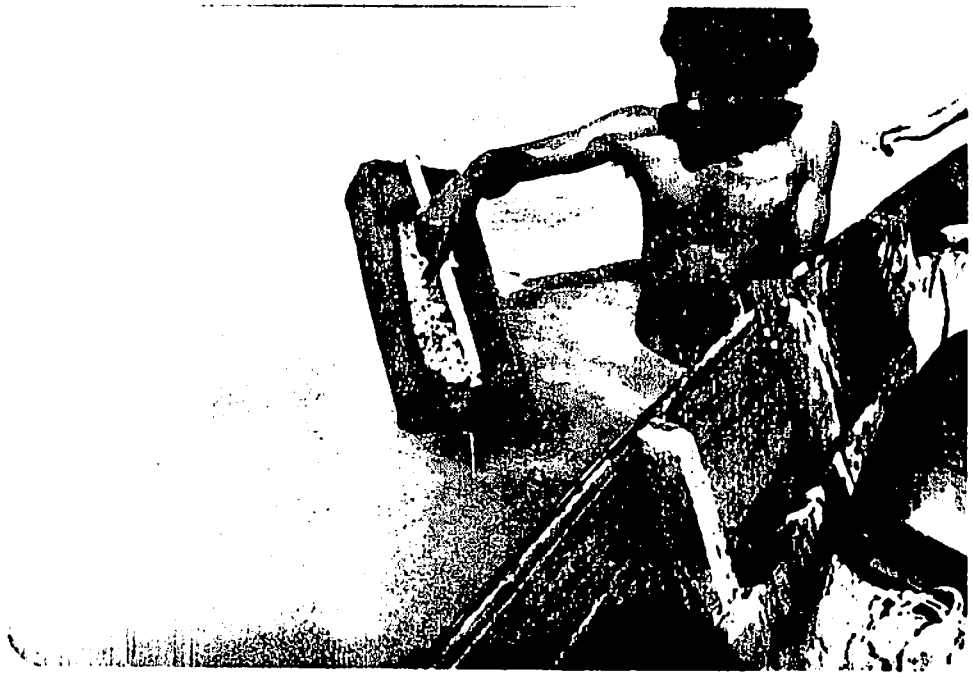
9. Larval rearing tanks.

10. Benthos and fish associated with a natural cockle bed, Kuala Selangor



11. Bivalves associated with cockles (top row), natural cockle bed, Selangor

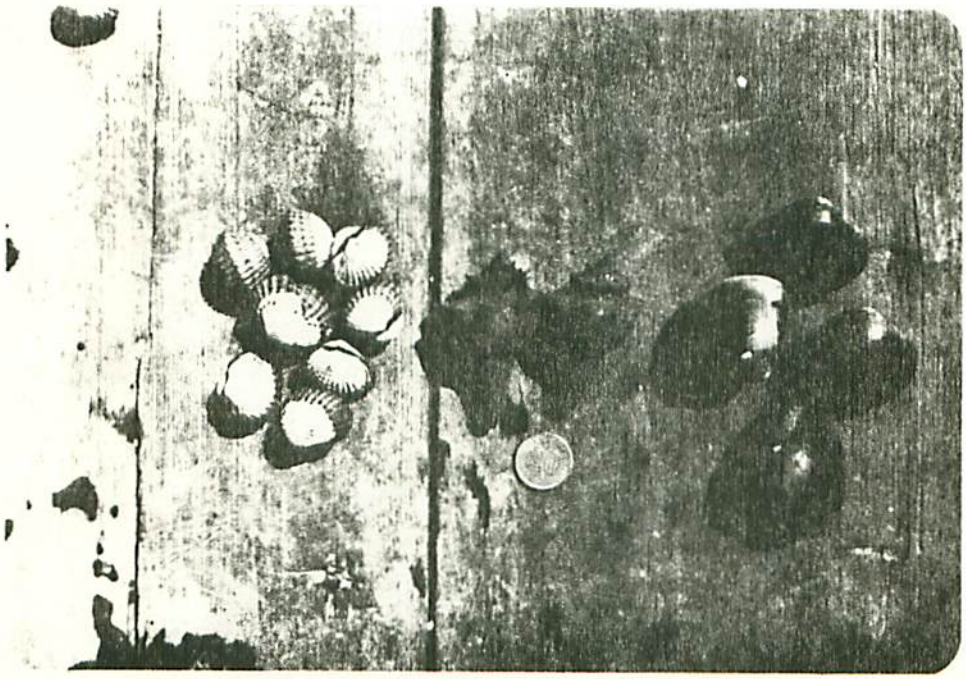
12. Benthos, natural cockle bed, Kuala Selangor.



13. Seed collector's scoop, Sungai Limau, Perak

14. Cockle seed, Sungai Limau, Perak

15. Cockle harvester's scoop.



16. Bivalves and gastropods associated with cockles (far left) on culture beds, Kuala Sepetang, Perak.