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TROPICAL OYSTER FARMING

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Contents

There are two varieties of native oysters in the Australian tropics which are eminently suitable for farming, but which have been subject to marginal exploitation only by aboriginals and Europeans in the Northern Territory and Queensland. There have been no private farming efforts at all in the Northern Territory, and Government experimentation which began there in 1973 was cut short by cyclone Tracey which destroyed Darwin in December 1974.

I have been experimenting for over 20 years, at first on a part time basis and later full time, at Magnetic Island near Townsville. This work has led through observation, trial and error, to the method described in this report.

The farm was almost completely destroyed by cyclone Althea in December 1971 but the cyclone also served to help design a farming technique to survive future cyclones.

The techniques described here are in use at Magnetic Island. In 1974 I was asked by Applied Ecology Pty Ltd, a company sponsored by the Federal Department of Aboriginal Affairs, to investigate the potential of oyster farming at Palm Island, an aboriginal reserve 50 km from Magnetic Island. I have subsequently taken over the Palm Island project for Applied Ecology,which is providing funds for the eventual establishment of a commercial oyster farm there.

In 1975 I received a grant from the Australian Fishing Industry Research Trust Account to finance materials for his farm. That grant also made possible preparation and publication of this report.

It should be remembered that the methods of oyster farming described in this report are not definitive, and many areas for further experimentation are suggested.

THE RESOURCES

1. Species

The intertidal zones around islands in the Great Barrier Reef, parts of the Northern Territory coastline and even the southern mainland coast of Papua New Guinea, display similar zonations of oysters.

In exposed situations, a small purple-pink oyster, with more or less distinct wavy grooves on the upper shell running parallel to the long axis of the oyster, predominates in dense colonies. This is Crassostrea amasa. The flesh is characterised by a milky white gonad (in season) and a golden edge to the mantle which covers the other parts. These features are reflected in the popular names, milky and goldlip. It generally grows to 60 mm.

In more sheltered situations, amasa is not as common. When present it is at the upper end of the oyster zone and is replaced below by a second variety. This variety varies in size in different places, being sometimes smaller than amasa, but growing up to at least 75 mm. It may or may not have the purple colour of amasa, does not possess the wavy grooves, but often has a serrated lower shell. The flesh has a thin black mantle edge or lip. In view of its broad similarity to amasa and similar textured gonad, it is generally called "milky" also. In point of fact, it has features of both amasa and the third variety normally seen, the black lip or mangrove oyster, Crassostrea echinata.

The black lip is characterised by its thick black mantle edge or lip. The gonad is more creamy coloured than white, and the upper shell generally exhibits dark brown overlapping growth processes, like tiles on a roof. In more exposed positions the growth processes are confined to the very edge of the shells.

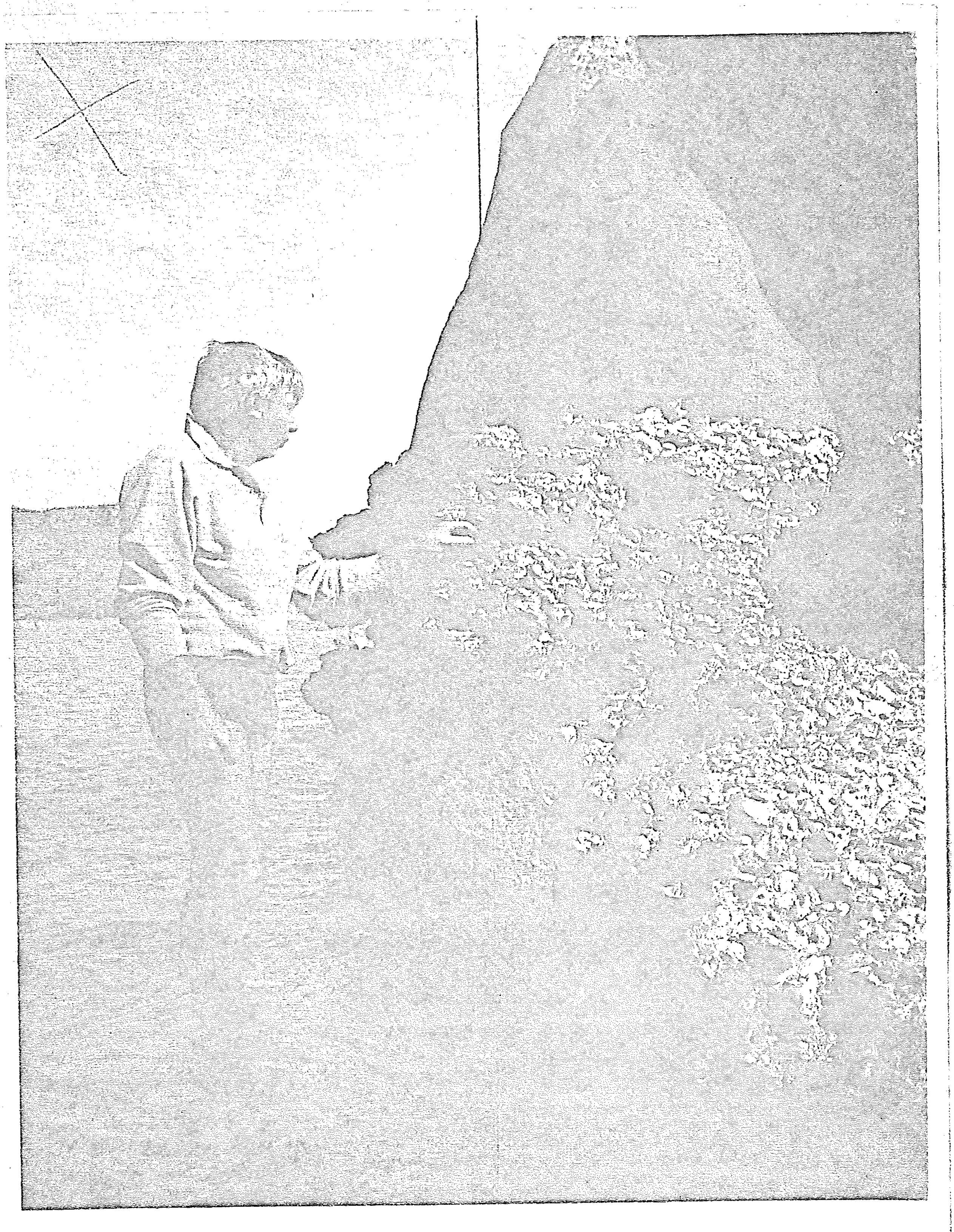

Figure 1
A typical semi-protected intertidal zone, Magnetic Island. There is a thin band of amasa at the top of the oyster zone. Most of the remainder are milkies with a few large black lip just above the (low tide) water level.

Young black lips usually have a number of fine spines projecting a few mm at right angles to the shell. This characteristic is thought by some to be unique. However some of the "hybrid" oysters mentioned above possess these spines.

Black lip oysters generally occur as isolated large individuals towards the low tide level. The bulk of oysters in sheltered intertidal zones appears to be of the "hybrid" type. Since this "hybrid" and the black lip are the varieties suited to farming, the term "milky" will be used here in reference to the "hybrid", and the third variety will be called amasa.

For farming purposes, the blacklip has greatest potential, since it grows fastest and can be sold in-shell or processed. Unfortunately it is usually rare in natural situations. An exception is the west coast of Palm Island where there is almost a pure natural black lip spat fall.

2. Distribution

In Australia, amasa ranges northward from Maryborough around through the Northern Territory. The black lip appears to have much the same range, but its southward distribution ends in the Gladstone area.

3. Habitat

C. amasa prefer more exposed positions, while black lips have a decided preference for more sheltered areas. In times of extensive rain and subsequent run off there have been occasions when heavy mortality of milky oysters and amasa has occurred. On these occasions black lips suffered no mortality. Such tolerance of fresh water might be expected in a species adapted to sheltered intertidal areas.

4. Spawning

The three varieties of tropical oysters are rock oysters of the genus *Crassostrea*. These oysters all shed their spawn into the sea, where fertilisation takes place and the larvae lead a brief swimming life in the plankton after which they settle permanently as spat in the intertidal zone on suitable objects.

In the Barrier Reef area tropical oysters appear to have a peak spawning period in late November-early December since heavy settlement has occurred consistently in December.

Nevertheless spatfalls occur until and including June. By then, parent oysters are starting to develop condition, and show no sign of spawning until the following November.

The time of spatfall may be associated with the lunar cycle. Settlement occurs around the time of neap tides following full moons. Based on a 12 day larval period, this would mean that spawning takes place during full moon spring tides. Such behaviour would certainly result in the widest dispersal of larvae and provide for a settling at a time when tidal exchange and water movements are at a minimum. It would also ensure the spat were always covered for part of the tide, which would not be the case if they settled between the neap and spring high tide levels.

5. Growth

Detailed recordings of tropical oyster growth rates have not been made.

For black lips, the average length at two months after spatfall is about 20mm, and at three and half months, 30 mm. In some instances, the average size has been 30 mm at two and a half months. If there are few oysters to a plate, they reach 70mm at twelve months. Most attain a marketable size (75 mm) and shape in 18 to 24 months.

The cultured black lip oysters in fig. 2 were 2.5 years old, when they were 90-120 mm long. However, they had been in trays at Magnetic Island for about 9 months, and were too large for in-shell sale. Size of the meats of 12 such oysters averaged 20 gms or 50/litre. Black lip oysters can grow to a shell length of at least 210 mm in the wild.

There is very little data on growth rates of milkies. Like black lips, in-shell market size is reached at 18-24 months. The best growth rate to date of milkies has been a length of 60 mm in 15 months. This was achieved by oysters growing "wild" under a moored drum, where they were close to the surface, sheltered from sun and permanently submerged.

In general, the best growth rates of oysters occur in the months April to June in Barrier Reef waters. These months are at the end of the spawning season and an upsurge in growth could be expected then.

The period April to June is also a time when oysters are submerged for long periods at night due to the tidal pattern. Planktonic organisms on which oysters feed are present in greater numbers in the upper water column at night, so providing the oysters with excellent feeding conditions.

Growth slows down later in winter, but good growth is maintained if south westerly winds predominate in winter.

6. Condition

For all varieties, saleable condition of oyster flesh is attained from June to November inclusive. Sometime in November - December there is a major spawning period, followed by intermittent spawning which may continue into June.

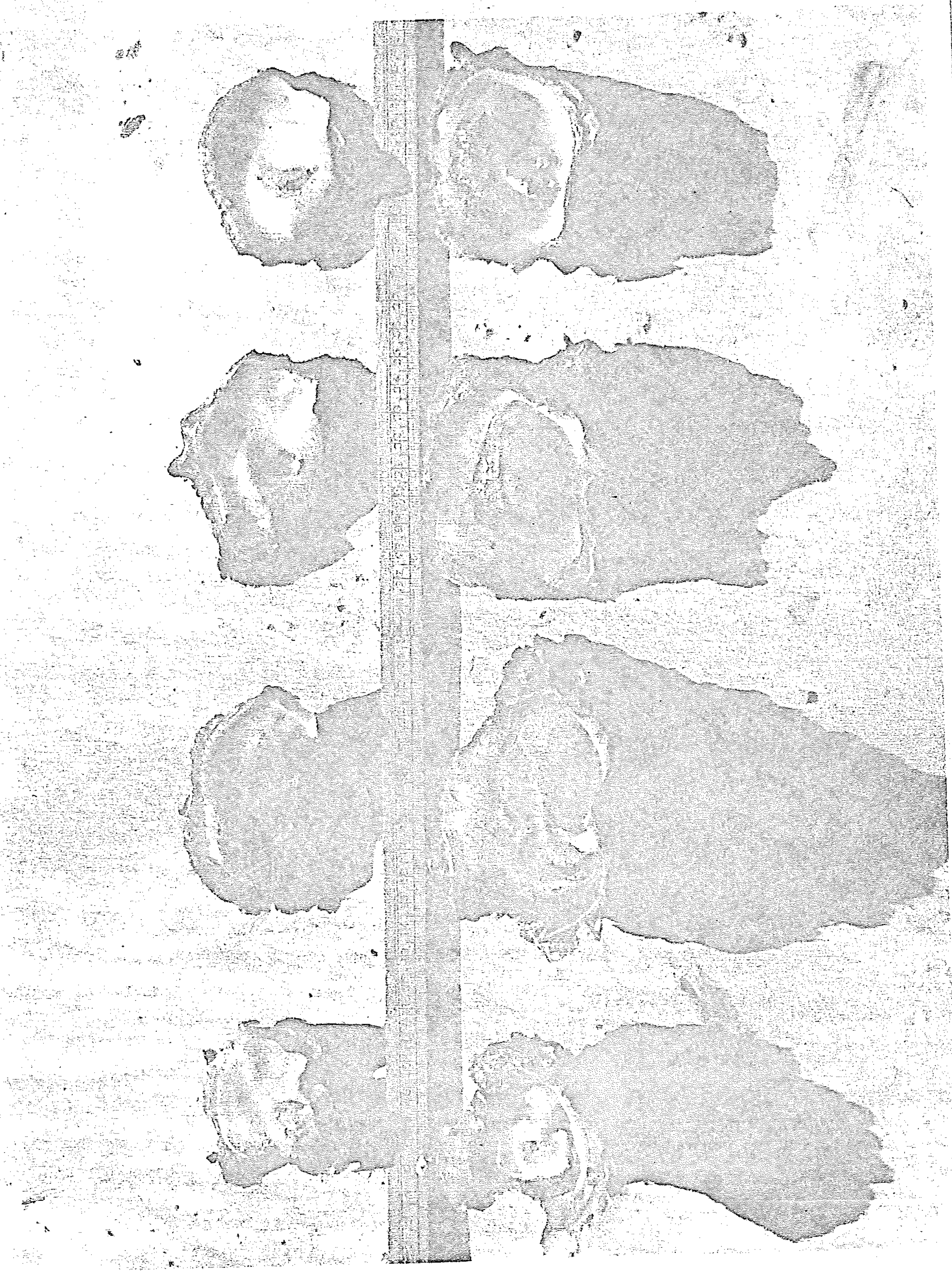

Figure 2
Comparison between wild black lip oysters (the two opened specimens on the right) and cultured oysters (two on left) in June 1976. The cultured oysters have reduced black lip, creamy flesh indicating improving condition. Wild oysters have coarse black lip, unacceptably dark flesh and poor condition.

The spawning act empties the oysters' gonads either partially or fully, after which the flesh is more or less flaccid and watery, since the gonad is virtually the only opaque part of the organism. It is the "fattening" of the gonads which store carbohydrates, that produces the creamy appearances of oysters in good condition.

Hence, the time when tropical rock oysters begin to develop condition depends on the duration of the spawning season beyond the major spawning in November/December.

Development of condition can be accelerated by putting oysters in continually submerged conditions. This has been done effectively in April, that is towards the end of the spawning season. Whether or not continuous submergence stopped further spawning activity is yet to be determined.

In either case, the condition of intertidal oysters is not as good as that of continuously submerged oysters even in non-spawning months of the year. This is no doubt due largely to the continuous exposure to food enjoyed by these oysters, and the position of the flotation units in deep water with stronger current flow.

Milky oysters in "good" condition have milky white gonads, while black lips are creamy. The mantle edge or lip of milky oysters is very fine, but that of blacklips has a distinct thick black edge.

This characteristic is undesirable from the marketing viewpoint, and one of the great advantages of a period of continuous submergence is a reduction in the thickness of the lips.

7. Mortality

There are no obvious diseases affecting the oysters in farm conditions. Mortality in the plates is estimated at less than 0.1%.

As noted elsewhere, milky oysters are sensitive to fresh water, and significant mortality has occurred in times of flood.

FARMING TECHNIQUES

1. Background

My first oyster farming efforts were directed towards adopting the stick and tray method used so successfully in New South Wales estuaries and rivers. In an excellently sheltered bay on the western side of Orpheus Island (in the Palm Island Group), trays and mangrove sticks were set out. Local oysters were placed in the trays, situated about 0.3 m above the coral sand bottom in that part of the intertidal zone occupied by oysters on adjacent rocks and mangrove trees.

Great numbers of predators gathered in the trays - drills, whelks and stingrays. Stingrays also dug under the trays and buried oysters in sand. In spring, the oysters were covered with filamentous algae 0.5 m long. Summer exposure killed the weed, but as it floated away, the oysters, still attached, floated away with it. The fate of oysters growing on mangrove sticks was no better. Reef fish devoured them all, leaving only crushed shell on the bottom.

However, the nutrient poor tropical waters themselves seemed a greater problem. In nutrient rich temperate estuaries there is adequate food for virtually limitless numbers of oysters on sticks or trays at the one level of the intertidal zone.

For a number of reasons (see site considerations) tropical oyster farming should be most sucessful on offshore islands which, however, have no enriched estuarine waters. Protected intertidal areas of these islands are generally limited in size; the expanses of intertidal flats required for tray and stick culture are not generally available.

It seemed logical then to utilise the greater tidal depth available in the tropics to compensate for lack of nutrients. At the time, a new Japanese technique for oyster farming was being acclaimed. This was longline culture of oysters, in which spat is collected and grown on long strings of oyster or scallop shells suspended below rafts.

I experimented with strings of drilled oyster shells, experienced good spatfall and there were no losses. Following the success of these experiments, I tried salvaged fibro plates instead of shell to increase the spat collecting capacity of each unit, and was again successful.

The occasional oysters removed from under my boat were always fatter for their size than intertidal oysters, I next experimented with growth of oysters in continuously submerged trays. Black lip oysters treated this way lost their characteristic black lip.

These findings formed the basis of the farming technique used today. It is centred around vertically hanging fibro (asbestos cement) plates in the intertidal zone. After about two years growing on the plates the oysters undergo a brief fattening period when they are continuously submerged.

The strings of plates act both as spat collectors and growing plates. The plates on each string are placed close together to attract spat, and separated as the oysters grow. Strings of plates are hung on steel or wooden fences stretching out at right angles to the shore to attract spat which pass in the currents sweeping parallel to the shore.

2. <u>Fences</u>

The fences need to be separated some distance to allow

(i) even catching of spat on plates under each fence and

(ii) even water flow over the plates.

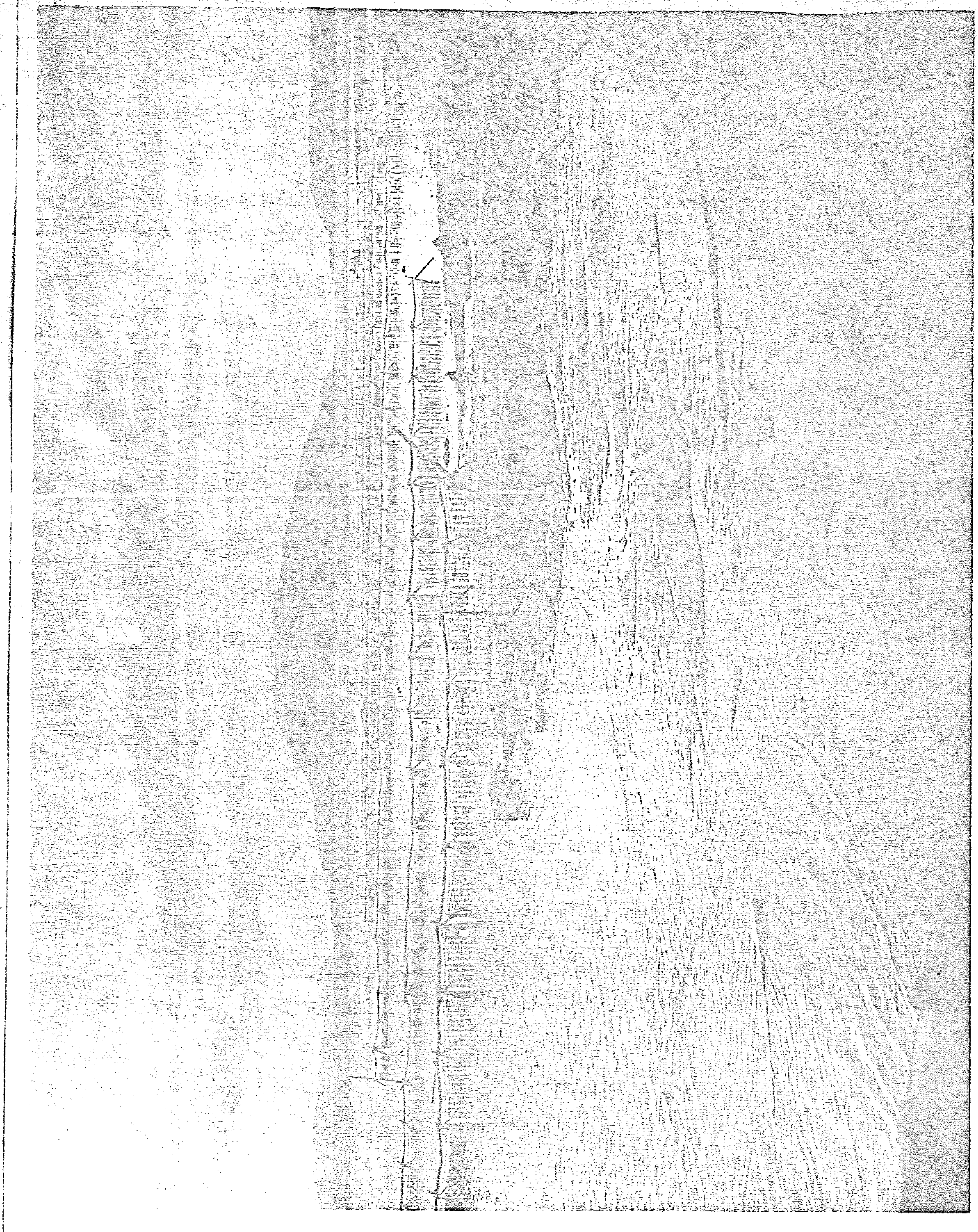

Figure 3

General view of the experimental oyster farm at Palm Island, looking to the northwest. The six fences bear a total of 35,000 plates of oysters.

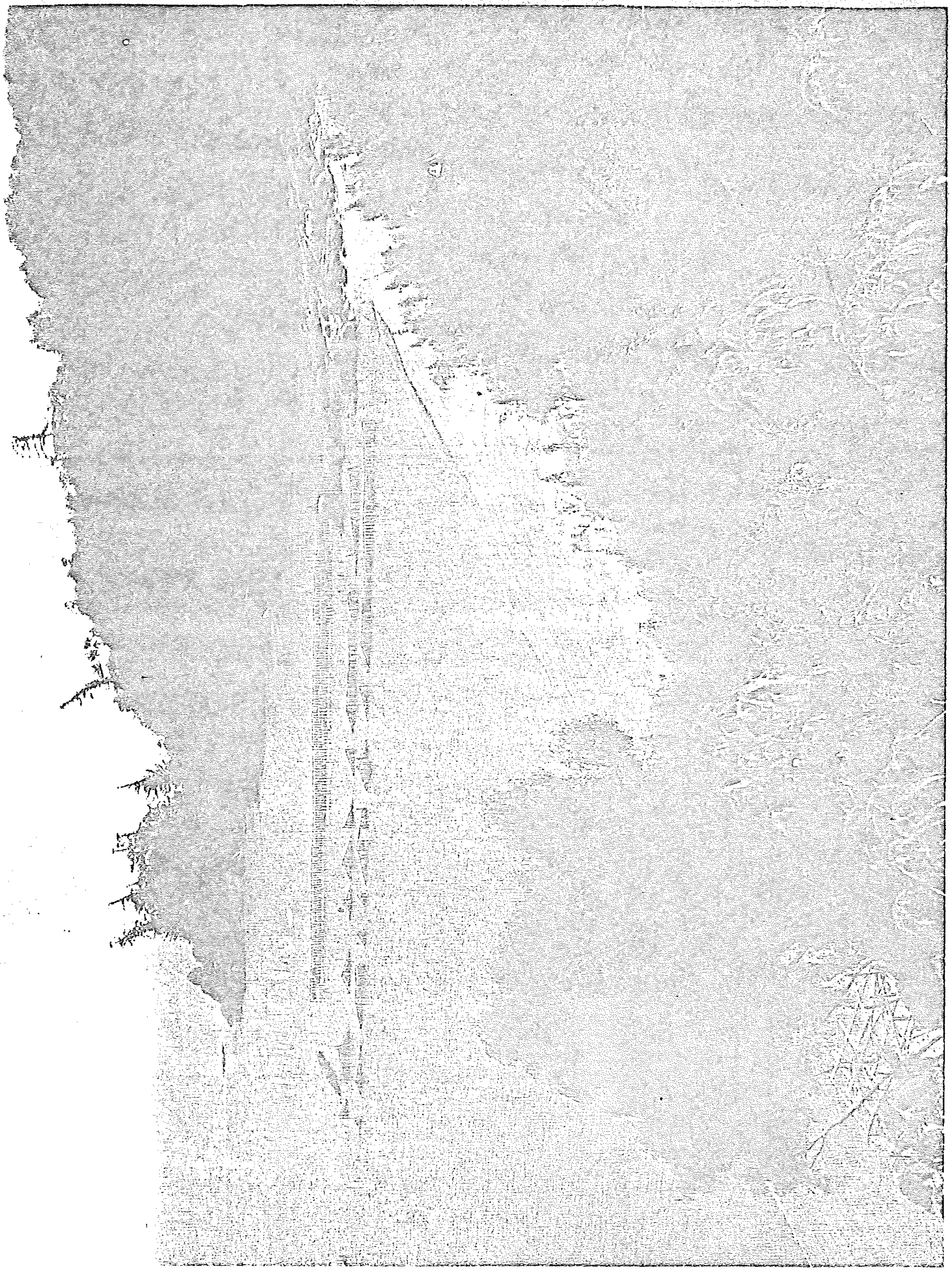

Figure 4
The oyster farm in Horseshoe Bay, Magnetic Island, showing strings of plates suspended below steel railway line supports. The nearer rails collapsed during the 1971 cyclone. Twisting prevented the salvage of many.

The minimum distance between fences had not been determined. Those at Palm Island are 50m apart but this probably excessive. However it has been found that if rows of plates are placed about 0.3m apart, the plates receiving the current first obtain most spat, while by the fourth row almost none are obtained. The minimum spacing at which this effect of plate crowding is nullified needs to be found by experimentation.

The height of strings of plates above the low tide level does not appear to be critical. Although black lip oysters in most areas settle as isolated individuals in the lower intertidal zone, they settle uniformly over the plates on fences at Palm Island to the almost complete exclusion of other varieties. There, the top plates are about 0.6m below average high tide, stretching down one metre. This depth limitation is governed purely by the depth of the intertidal platform. Ideally, 2m or more of the intertidal zone could be "fished" for spat, since the tidal range is 0.8 m (neap) to 3.4 m (spring).

The situation at Palm Island must be rare. In almost all natural intertidal areas, amasa and the milky oyster predominate, and this is reflected in the spat settling on plates at Magnetic Island. They are predominantly milky oysters and amasa.

3. Spat Collection

In the Great Barrier Reef area, strings of clean "cured" (see materials section) fibro plates should be set out in early December to take advantage of the major spatfall which for many years has consistently fallen in December some time after full moon in November, which usually occurs towards the end of the month. Spatfalls occur in varying quantities until May, but if good settlement occurs in December few more spat will be able to settle in the subsequent period.

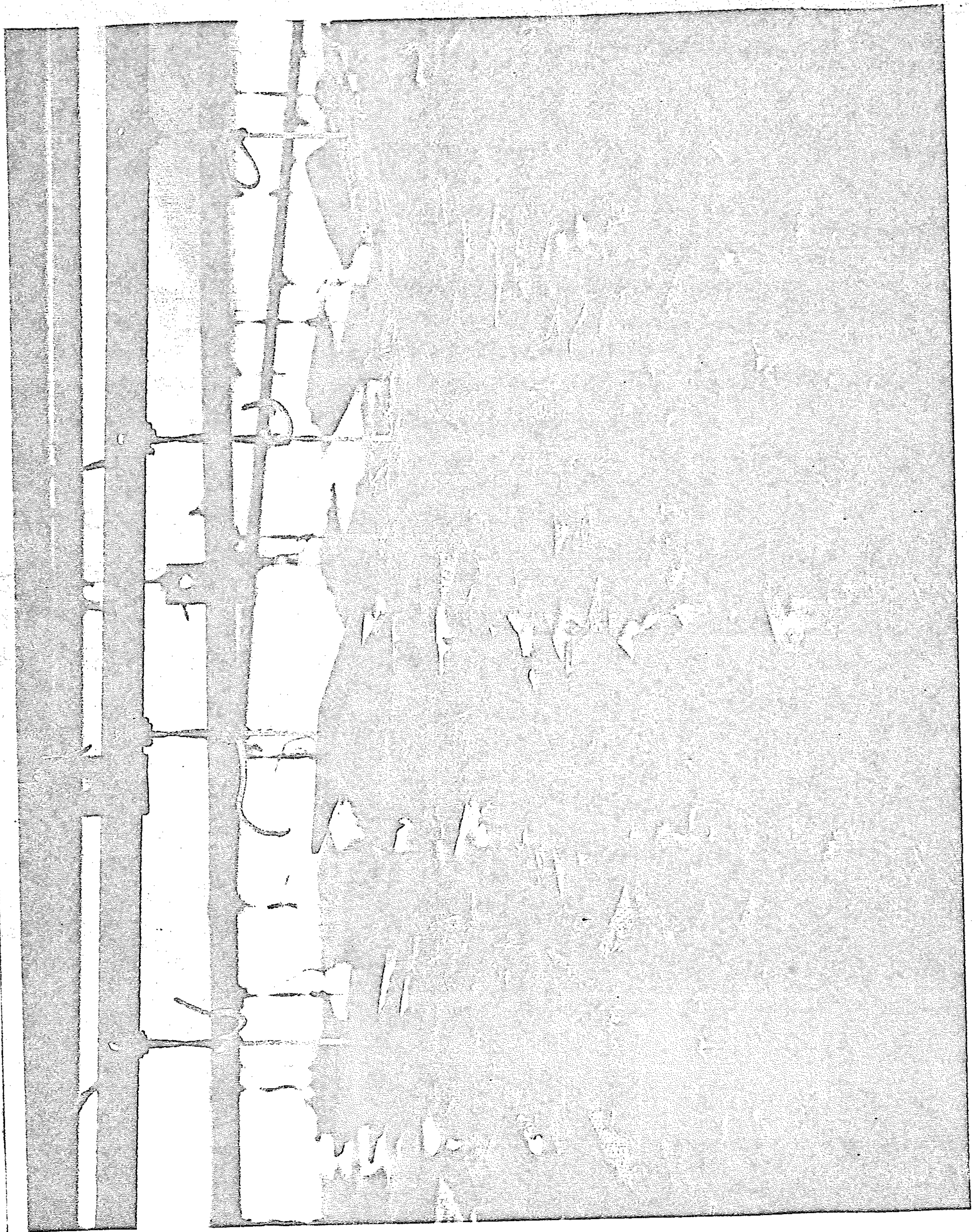

Figure 5
Strings of collector plates, Palm Island, with moderate spat settlement about 5 months old. Note clean horizontal supports and the simple hitch for attaching plastic coated strings.

At Palm Island, where black lip oysters dominate, plates with few oysters on them receive no new spat once separated. Algal growth etc. prevents the settlement of more oysters. Unseparated plates collect some spat, but an insignificant number in comparison to settlement on fresh plates. Separated plates with moderate numbers of black lip oysters remain free of algae and consequently receive some spat.

Magnetic Island presents a different picture. There, algal growth is less, milky oysters dominate, and the farm is more exposed to surge. Here spat falls on all available space between plates and on last year's settlement.

The shell of black lip oysters grows in layers or scales, which slough off taking with them fouling organisms such as newly settled spat. Milky oyster shells are smooth so that overspatting is a continual problem. The only control feasible seems to be to place virgin plates for spat collection upstream from the fences holding last year's settlement.

This situation can eliminate the need for setting up separate fences for spat collection away from the farm site. It does appear though, in view of the differences between these two islands alone, that collecting plates could be set out to advantage in a number of selected areas to catch either black lip or milky oysters and to examine the relative advantage of different sites with regard to overspatting.

4. <u>Separation of plates</u>

Initially, the spacing of the individual plates is either 10 or 13 mm. Both spacings should attract sufficient spat. I am currently experimenting with even closer plates, 6 mm apart. There are indications that adequate spatting is obtained, and that algae competition is lessened. However, the plates would require very early separation. Growth of the oysters is such that if 10mm spacing is used the plates need separating 3-4 months after spatfall. This step can be postponed for a further 8 months if initial separation is 13mm. However, if spatfall is heavy, separation needs to be carried out by 8 months after spatfall.

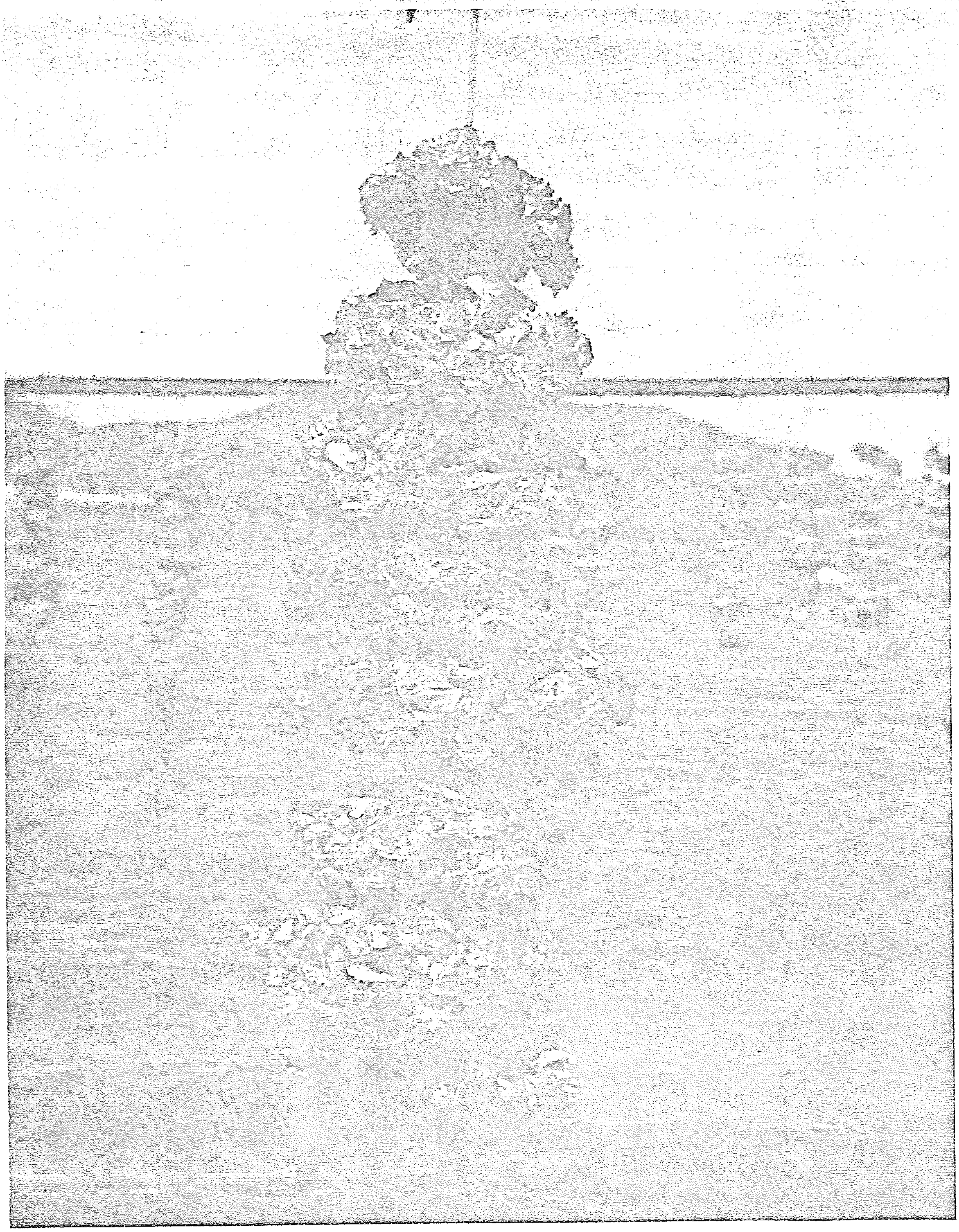

Figure 6

Close up of overgrown separated plates, Magnetic Island. The oysters, all milkies, are overdue for removal from the plates. Some could be placed in trays, some opened for bottling.

Separation is the simple process of tipping the plates off the original string and re-stacking them using 10cm spacing on further strings. There will then be only 7 plates per string at this spacing, and a supply of spare lengths of "string" (plastic coated rope) are required, as well as provision of space on the fences for them.

The timetable for these operations largely depends on the density of spatfall on the plates.

If initial spatfall was very light on some or all plates, those plates are regrouped together on new strings to act as spat collectors for the remainder of the spatting season. Should they fail to attract more spat, a decision has to be made whether to (a) allow the few existing oysters to die off by drying out, and placing the plates aside for next year's spatting season, or (b) to retain the plates on the fences.

Oysters on such plates have different growth characteristics to those on more densely occupied plates. They spread out remaining flat rather than cupping and use the plate as part of their lower valve or shell. These oysters are useful only for bottling if harvested at the same time as the remainder of that year's crop. After two years spreading however, they begin to cup away from the plate, but would require three years on the plate before becoming suitable for in-shell sale.

The decision on whether or not to retain these oysters is simply a matter of whether such plates are a minority or majority of the total. If the overall spatfall was adequate, most plates will be well covered, and it is better to concentrate one's attention on their maintenance, discarding the poorly settled plates. On the other hand if spatfall was inadequate over most of the plates, the oyster farmer has to be more selective as to which plates can be discarded.

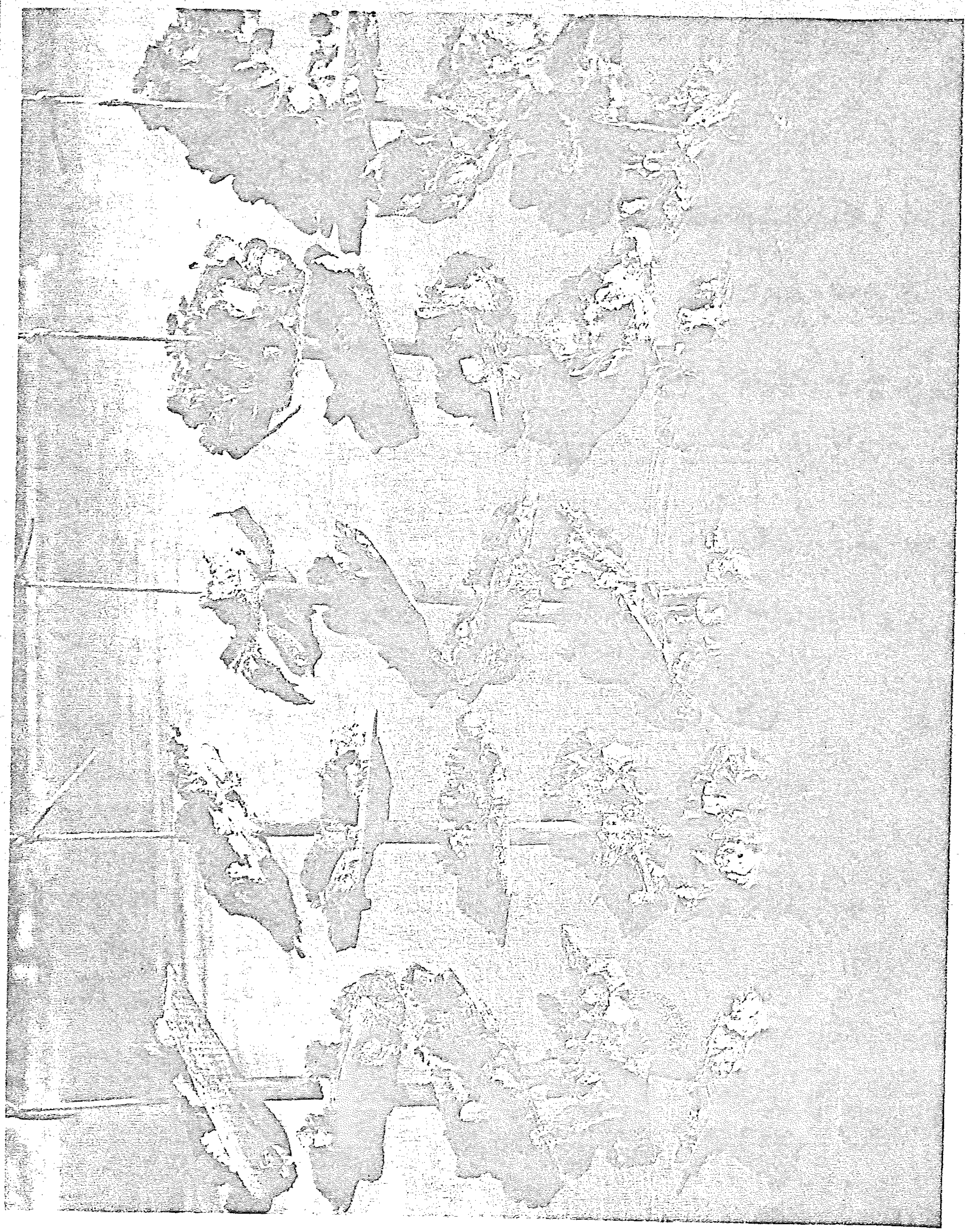

Figure 7

Separated plates (7 per string) of black lip oysters, Palm Island.

Where the oysters are closer together, better cupping can be seen.

Plastic 10cm hosepipe spaces are in use.

At the other end of the scale, when spatting is heavy, the oysters grow well cupped and the attachment of each to the plate remains small. However, they push away from the plates rapidly and the latter should be separated as soon as it becomes apparent that further growth will be impaired.

Following separation, plates can be left on he intertidal fences until the oysters are at least 18 months old.

5. Removal from plates

At this stage they can be removed from the plates if there are many oysters on the plate, i.e. from a heavy spatfall. In that case the oysters probably won't be large enough for in-shell marketing, and should be set out one layer deep in trays. The latter are left submerged, except for periodic cleaning, until ready for marketing.

Oysters removed to trays require about 3 months submersion to become marketable, a total of 21 months from spatfall. A proportion of the oysters will be too small for the trays. Any such rejects should be opened and bottled rather than put into submerged trays for long periods.

It is preferable however to keep oysters in the intertidal zone as long as possible to minimise handling. Indications from the work to date are that if the oysters are left on plates until after the height of the next spatting season (when they will be 27-31 months old), they will all have reached a size suitable for in shell sale after 2-3 months in the trays. Sorting to eliminate undersize oysters should be minimal.

Removal of oysters from plates is easy if spatfall was adequate, since only a small proportion of the lower shell of each oyster will be attached to the plates. This is due to the oysters' cupping as they compete for space. It also makes separation of individual oysters easy.

6. Longlines

Where the density of oysters on plates is not excessive, strings are taken from the fence, usually in groups of 13 comprising a fence unit (see materials), and resuspended directly under a flotation unit. The age at which oysters are so transferred depends on their size. Between 18 months and 24 months seems to be the norm.

The reasons for placing oysters in continuously submerged conditions are that they are then in a situation where they can feed continuously, rather than during a portion of the tidal period only, and are kept at a more uniform temperature. The effect on oysters is rapid increase in meat content and shell growth. It is most important for black lip oysters which also lose much of their black lip during submersion.

Watery oysters submerged after spawning have been brought into marketable condition in as little as six weeks.

Note that the flotation units should be placed beyond the intertidal platform in deep water.

However time spent by the oysters under the flotation units should be kept to a minimum, since

(i) their regular maintenance during this period adds a considerable labour burden to the overall workload,

(ii) maintenance of the flotation units themselves, including supporting ropes and floats would add further to the workload,

(iii) the longer they are kept under flotation the more units are required to cater for the rotating crop. If all oysters were submerged on separation, capital outlay for the farm would be increased severalfold,

(iv) if units are lost or broken in storms, their recovery is more difficult in deep water than those which fall off fences in the intertidal zone,

(v) skeletons of fouling organisms such as coral polyps will accumulate on the oyster shells despite regular drying out and/or dipping in brine,

(vi) the longer the oysters are submerged, the greater the likelihood of soft coral cover (see predators, etc.) which can stop oyster growth between maintenance times,

(vii) the oysters need to be sorted and spread out into new trays as they grow, otherwise they will crowd and eventually kill one another. This can happen in as little as three months.

Once the collecting plates have been separated to 10 cm spacing, they become virtually maintenance free under the fences until placing under flotation units.

The number of flotation units should therefore be kept to a minimum compatible with what the operator(s) can handle (see quantities, etc. section).

The use of the flotation units is further limited by seasonal factors. The months of December to March inclusive are unsuitable since (i) this period is the rainy season, when severe storms and cyclones are possible, and (ii) the oysters are spawning, such that short term (3 months) submersion is unlikely to produce marketable oysters at this time.

It is preferable to take the units from the water for safety and concentrate on intertidal operations and preparation of trays, etc. during these months.

Yet to be determined is whether it may be better in the long term to use vertical rows of trays in the intertidal zone. Oysters could be trayed either at the time of plate separation, or at 18-24 months of age when they might have been ready for transfer to submerged conditions. Indications are that maintenance problems could offset any benefits of long term intertidal tray culture, while short term traying of older oysters may not produce the benefits of continuous submersion, i.e. rapid growth and fattening.

SITE CONSIDERATIONS

The prime requisite for any tropical oyster farming site is that it be sheltered from prevailing winds - south easterly trade winds and north westerly monsoonal winds.

The site must have a good proportion of deep water in the lease area. An area behind the beachfront or shoreline for a workshop and processing sheds is also necessary.

Of course, the area must contain oyster stocks, if not at the site itself, at least close by. The ideal site is one where objects in the intertidal zone are covered with large black lip oysters. Unfortunately, such sites are rare.

Intertidal zones in the majority of possible farming areas in the Northern Territory and Queensland display mainly milky oysters, some amasa and few black lips. Such sites are suitable for production of these oysters where the naturally growing oysters are large. However, where only small milky oysters or amasa are present, it does appear that they are unlikely to grow much larger in culture conditions.

It may well eventuate that two sites are necessary, a spat collecting area and separate farming area.

The farm site should be accessible to a marketing centre, whether by road, sea or air. Otherwise the farmer has to construct his own facilities. Practically speaking, remote areas are out of the question unless a great deal of capital is available.

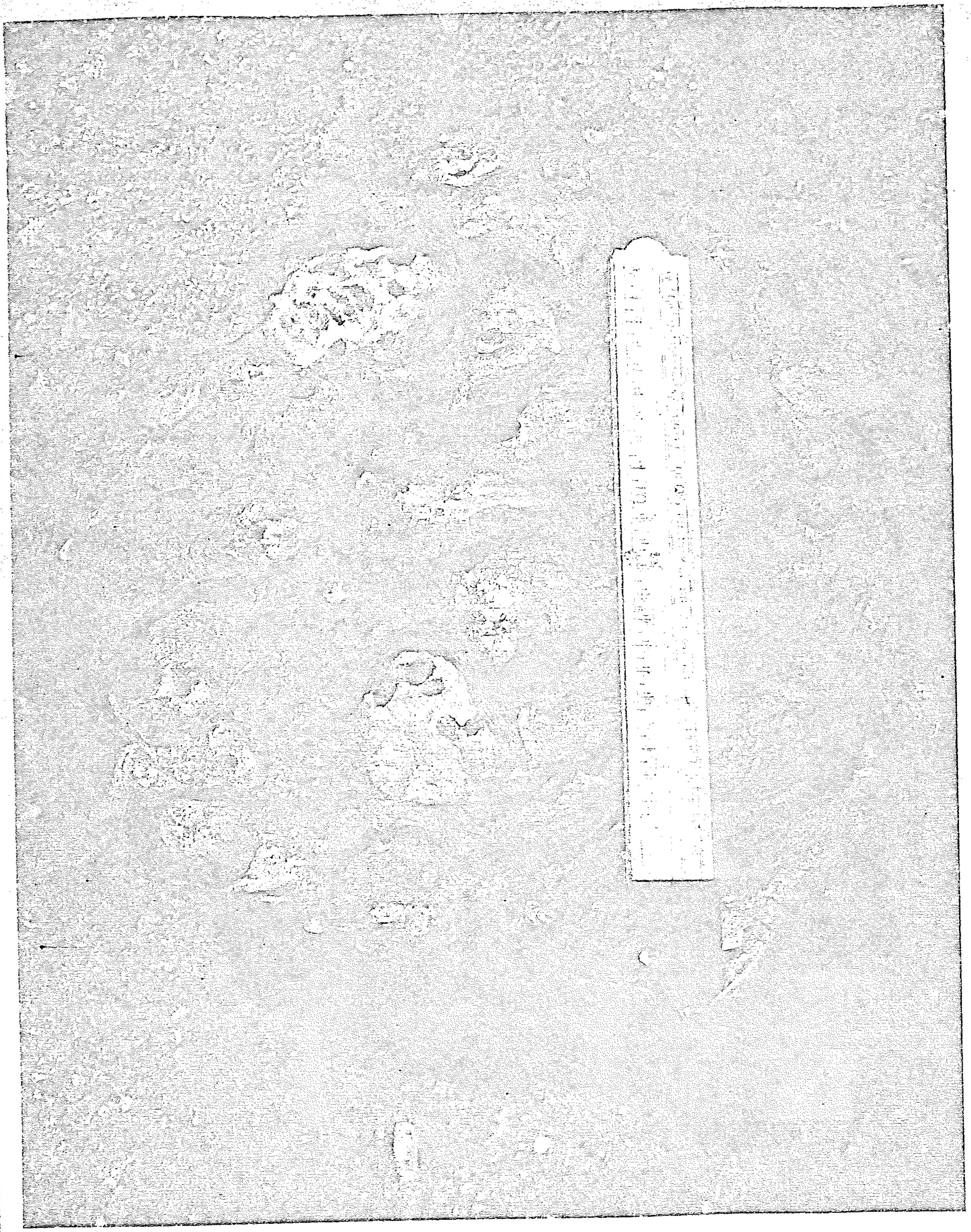

Figure 9
"Wild" black lip oysters on a rock near the low water mark at Magnetic Island. They average 70 mm in length, a good sign that oysters of marketable size can be grown there.

No detailed surveys to select farming sites have been carried out. There are very promising areas in the Townsville district. The main oyster areas are from Palm to Dunk Islands Palm Island itself has proven exceptionally well suited for oyster farming. To the north are islands where large oysters are prolific, such as Port Hitchinbrook and Missionary Bay (west and north Hitchinbrook Island respectively) and Gould Island. The mainland in this region suffers from various forms of pollution, including alluvial tin mining which discolours the Herbert River whose waters flow into the Hitchinbrook channel, effluent from Australia's largest sugar mills, pesticide residues from extensive cane farms and the large nickel smelter in Halifax Bay.

Apart from pollution, much of Queensland's coastal waters are prone to dilution by seasonal floodwaters which can adversely affect the oysters. To the north, in Princess Charlotte Bay however, are areas on the mainland where an oyster farming venture could thrive, if suitably developed.

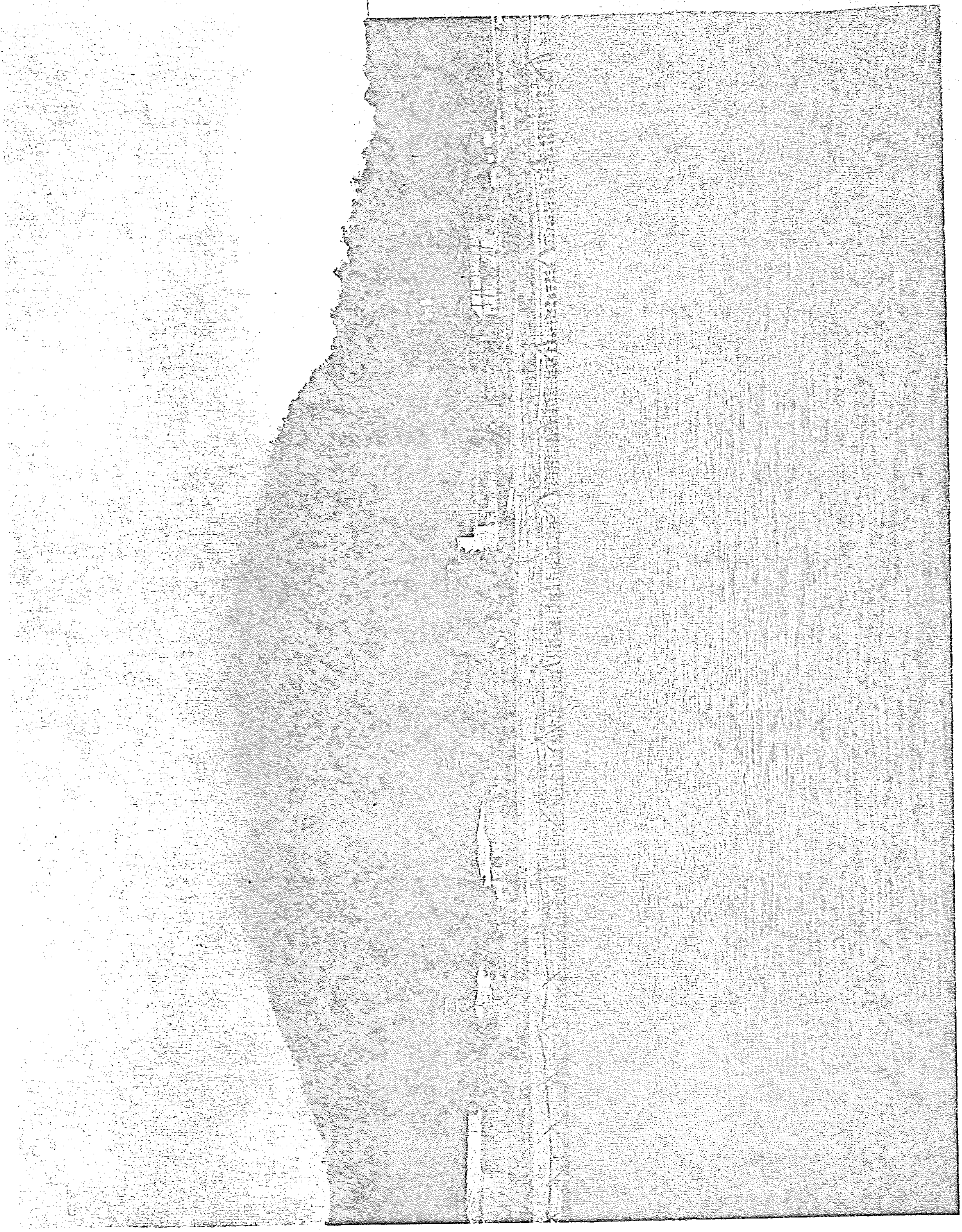

Figure 11
Raincloud over Palm Island. With a limited watershed and no rivers, effective runoff from these offshore islands is low in comparison to the mainland, where seasonally flooding rivers can bring virtually freshwater conditions to coastal areas.

MATERIALS

1. Fences

Oysters in the intertidal zone are grown on fibro plates, strung together and suspended above the bottom. The supporting system, called a fence, is composed of horizontal and vertical posts set out at right angles to the shore.

The intertidal platform around tropical islands is usually coral based, overlayed by varying thicknesses of sediment. At Magnetic Island the sediment is thin and old coral growths below it make staking hazardous. The posts are likely to disappear through hollows amongst the coral skeletons. At Palm Island there are alternating layers of sediment and coral. The posts tend to sink slowly.

The earliest supporting posts used were steel railway lines from sugar cane fields. The advantages - strength and durability if adequately protected - are offset by high costs. As well, the steel is constantly eroded at the point of entry into the coral substrate, despite coatings of tar epoxy.

The obvious alternatives are local materials. Timber resources of Barrier Reef islands are mainly eucalypts and swamp ti trees. Fresh eucalpyt trunks were found to bend under weight and were eaten away by sea water in twelve months. Ti-trees on the other hand can be used fresh and resist bending. There are old derelict fish trap verticals of ti tree at the oyster farm on Magnetic Island which have withstood the action of sea and weather, including the cyclone of 1971, for at least 15 years. The disadvantage with ti trees is their vulnerability to white ants. For practical purposes they need to be cut only when immediately needed.

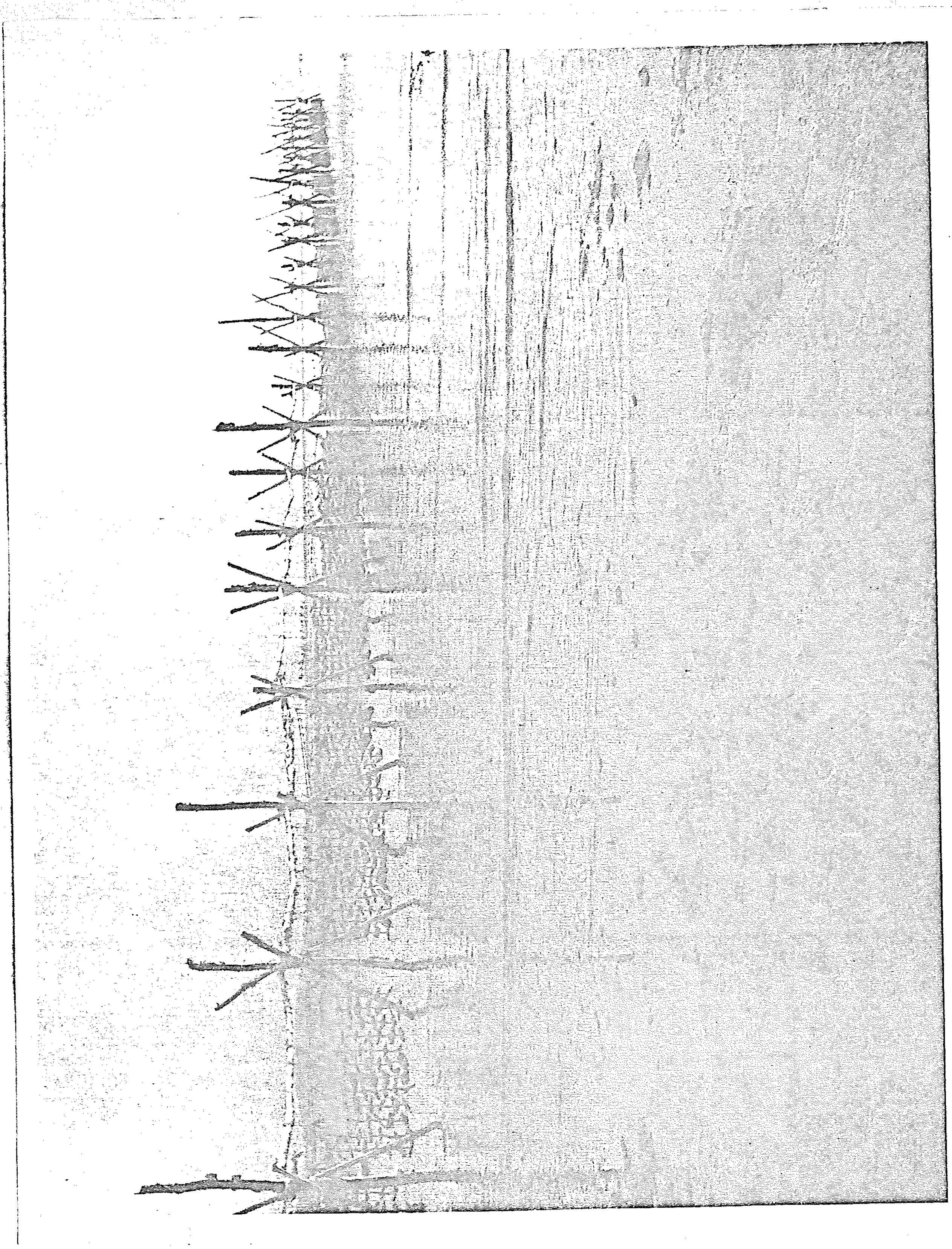

Figure 12
The most recent fence design, Palm Island. Uprights and horizontals are all ti tree. Strings of separated plates are being tried at different levels of the intertidal zone. The inner three horizontal string supports are steel pipe, the remainder bamboo. Note 13 strings per horizontal support. Tripod members are extra high so they are visible to passing boats. Warning signs are to be placed on them.

The fences presently in use at Palm Island consist of vertical ti tree posts up to 3m long, supported by two angled posts. They are 3 m apart. Horizontal posts 3.6 m long rest in the angles between the upright and angled posts. Polypropylene rope ties the units together.

When first erected, the horizontal members need anchoring to prevent them floating downstream. Convenient anchors can be made from cement filled 5 gallon drums. The lid is first removed and a plastic hose covered steel rod is imbedded in the wet cement in an inverted U for attachment of ropes.

The fences are designed in such a way that they can collapse in a cyclone. Oysters on plates can later be retrieved in groups of strings on steel horizontal supports.

It may prove better where timber is not freely available to use reinforced cement posts for uprights if they can be securely fixed to the substrate.

2. String supports

The collecting plates on strings are not attached directly to the ti tree horizontals. Instead parallel supports of 13mm or 19mm steel pipe or 25mm x 6mm angle iron, 2.5m long are suspended about 20cm below the wooden members. The parallel supports are supported in three places, the ends and centre, by 6mm polypropylene rope looped around pipes or tied through drilled holes in angle iron.

Bamboo lengths are being tried on an experimental basis, in place of steel. They seem to resist bending, but stands of bamboo are not common in the area. If they last well, it is felt that they should be grown to provide material for this purpose and for spacers between plates (see below).

The purpose of these horizontal bars in parallel below the ti tree lengths is (i) to absorb some of the movement caused by wave action, (ii) to facilitate removal of sets of plates from fences to shore or to long lines without upsetting the fence structure, and (iii) to compensate for the irregular nature of the timber horizontals allowing ease of setting up the strings. As noted above, they also simplify retrieval of oysters in the event of a cyclone.

To each horizontal bar are hung 13 strings of plates 20cm apart. They are not hung directly onto the bars, since the material of the strings is difficult to tie successfully to the bars. This point in the suspension of oysters is a critical one where most breakages have occurred. Even 6mm rope connections doubled and tied with 2 half hitches lasted only a few months. Surprisingly, 3mm polyethylene monofloat rope has proven ideal, lasting several years. A 0.3m length is looped and the ends spliced and melted together. The unit is hung over the horizontal bar such that the spliced end passes down through the loop. The string of plates is joined by a simple hitch through the loop near the spliced end.

3. Plates

Plates are made of roughly broken up fibro or asbestos cement of the type used in housing. This has been freely available so far wherever old fibro buildings are being demolished. The size of the plate is between 10 and 12.5cms square. They are drilled through the centre for stringing.

Curing of the plates in seawater is necessary before they will attract spat efficiently. Plates should be left submerged for two weeks and then dried off to remove any algal growth.

Any paint on the fibro is removed by dipping plates into a caustic soda solution (1 kg/101 water) for 5 minutes. It can be done at low tide on the beach. The incoming tide washes off the solution.

4. Strings

Cleaned plates are strung onto a one metre length of 5mm plastic coated rope, normally sold as clothesline. This rope is knotted at the lower end and plates are strung on with a 13mm or 10mm space between each. The spacer is 13mm diameter plastic hose pipe or PVC water pipe. If 13mm spacing is used, 24 plates can be hung on each string, or 32 plates with 10mm spacers. A half hitch secures the strings to the loop of the spliced rope above.

The growing ends of bamboo can be used as spacers instead of plastic. Again, a constant supply is needed.

Unfortunately, grades of fibro have changed over the years and new fibro is unsuitable for plates for two reasons; (i) it wears rapidly in seawater such that the central hole enlarges and plates fall together so they are unable to gather spat, or if already containing oysters the latter cannot open and soon die, and (ii) "new" fibro plates invariably break when oysters are being chipped off. The old fibro has a 20% breakage rate. Smaller pieces resulting can be re-used of course.

The alternatives are to use scallop shells, coconut shells, etc. Grey PVC plates 5mm thick were used experimentally and proved ideal. They seem to be invulnerable to seawater erosion and after 5 years use were as good as new. Culling is simplified as breakage is nil, and their flexibility allows bending to facilitate removal of oysters. The disadvantages are (i) cost, a 12.5cm square plate would cost around 15¢, and (ii) strings of PVC plates need weighting until spat have grown to a certain extent on the plates.

Scallop shells being smaller attract less spat per string such that handling costs are greater. They would be useful where the full intertidal zone is available for collecting.

The present sites have allowed only 1m spat "fishing" depth. However, when ready for separation of the growing oysters, a metre of plates weighs about 23-27 kg, so extra length could make them unwieldy.

Prior to plastic coated rope, a number of materials were used for strings. Galvanized wire for instance lasted around 6 months only. Monel wire very rapidly electrolysed and disintegrated. The recommended stainless steel (No. 316) for salt water was found to corrode and electrolyse, some lasting a matter of months, a few pieces lasting over a year. With plastic coated electrical wire, the copper strands within broke. Subsequently, the plastic cover quickly stretched and broke under the weight of the plates. Ropes such as polyethylene gradually stretched and were worn away by the fibro plates.

Plastic coated rope on the other hand has lasted over 6 years with no sign of wear, even through a cyclone.

5. Longlines

The "longline" operations consist of strings of separated plates or trays of culled oysters continously submerged under moored flotation units.

The original flotation units at Magnetic Island were suitably coated 1.8m x 2.5m angle iron rafts supported by 22 litre drums.

The problem with drums is their buoyancy. Too much of their surface is exposed to wind and wave action. This is a particular problem in the event of cyclones. Even small spots of corrosion can lead to leaks. On occasions when the weight of fouling organisms attracted to the rafts and suspended oyster trays had submerged the whole unit, the drums were crushed by water pressure, and broke open. Retrieval of the rafts and

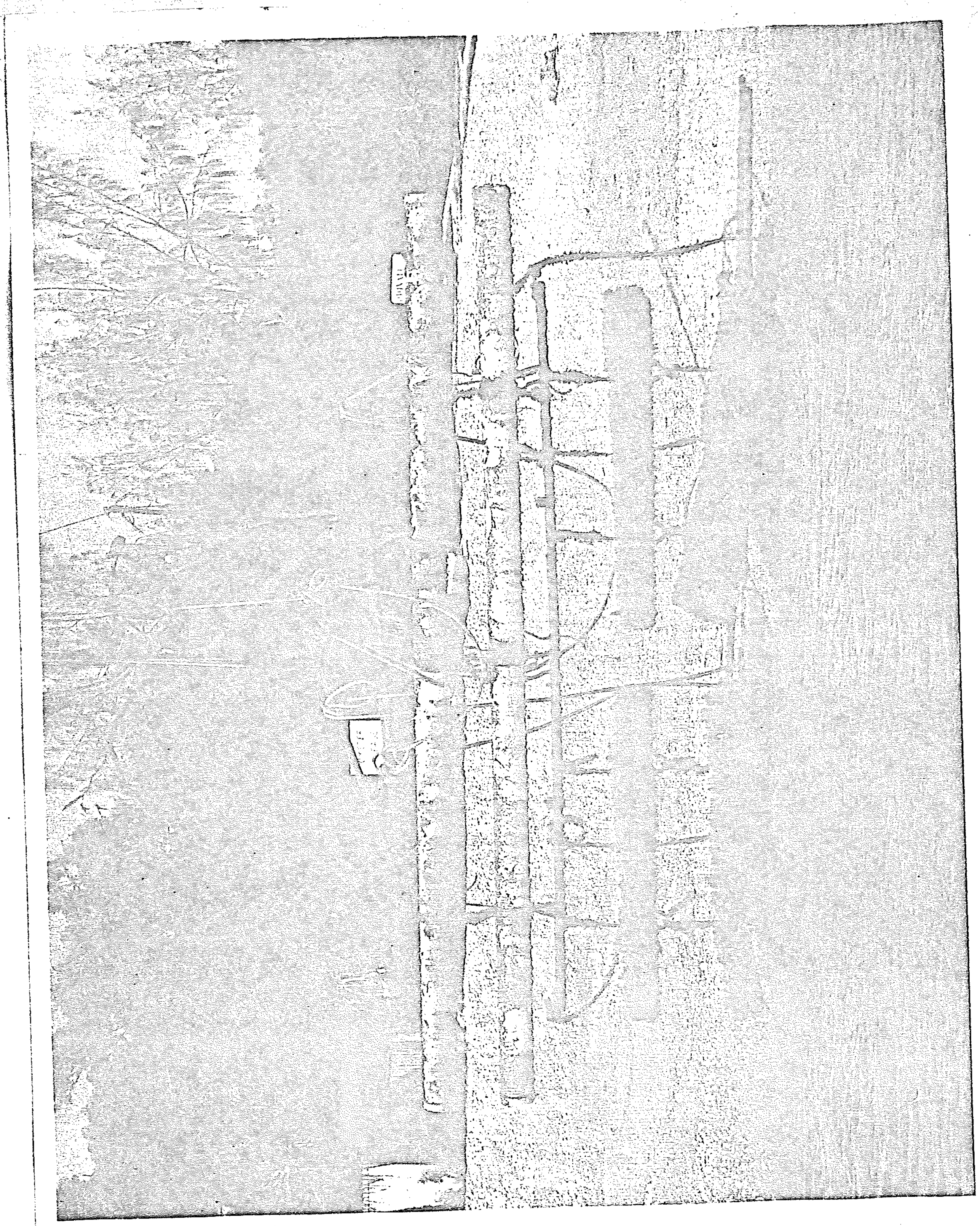

Figure 13

A flotation unit carrying trays, hoisted up on a flying fox, Magnetic Island. Note two PVC pipes, one below the other with the steel horizontal bar beneath; 4 trays, each joined above by two central hooks; trays are encrusted in bastard pearl oysters, light fouling on pipes; about 3 months submersion.

oysters was extremely difficult due to negative buoyancy of all parts of the unit.

PVC pipes for flotation are being used for mollusc culture in a number of countries. Their advantages are (i) they are virtually indestructible, since neither sea water nor fouling organisms affect them, (ii) when pulled under by weight of fouling they are very easily lifted, and (iii) little of the pipe need protrude above the surface, such that wind and waves are not a problem, (iv) fouling is easily removed and does not affect any protective coatings as with steel. The units used at Palm and Magnetic Islands are composed of two pipes, one below the other, under which are suspended trays or strings of oysters. The whole unit is designed to minimise effects of waves and winds by a system of swivels.

These pipes, 11.5cm diameter, are sold in 6m lengths. For ease in use they are cut into 3m lengths in flotation units. PVC caps are carefully glued to each end to make watertight tubes. Steel collars of 25mm x 3mm flat steel are bolted with 10mm diameter bolts towards each end and in the centre. The collars are easily made by hand. To the collars are bolted short connecting plates (50mm x 38mm x 6mm flat steel), drilled to take hooks for suspension of a second PVC pipe below. The hooks are "S" shaped round steel, 10mm x 230mm long. Again they are easily turned by hand. The lower pipes are connected to the hooks. A second series of collars on these lower pipes is placed beside the first for attachment below of further connecting plates and hooks.

This apparatus constitutes a flotation unit, and is ready for suspension of trays or strings of oysters.

In the case of strings, a horizontal bar with attached 13 strings of plates can be lifted by boom from a fence and hooked directly to the flotation unit.

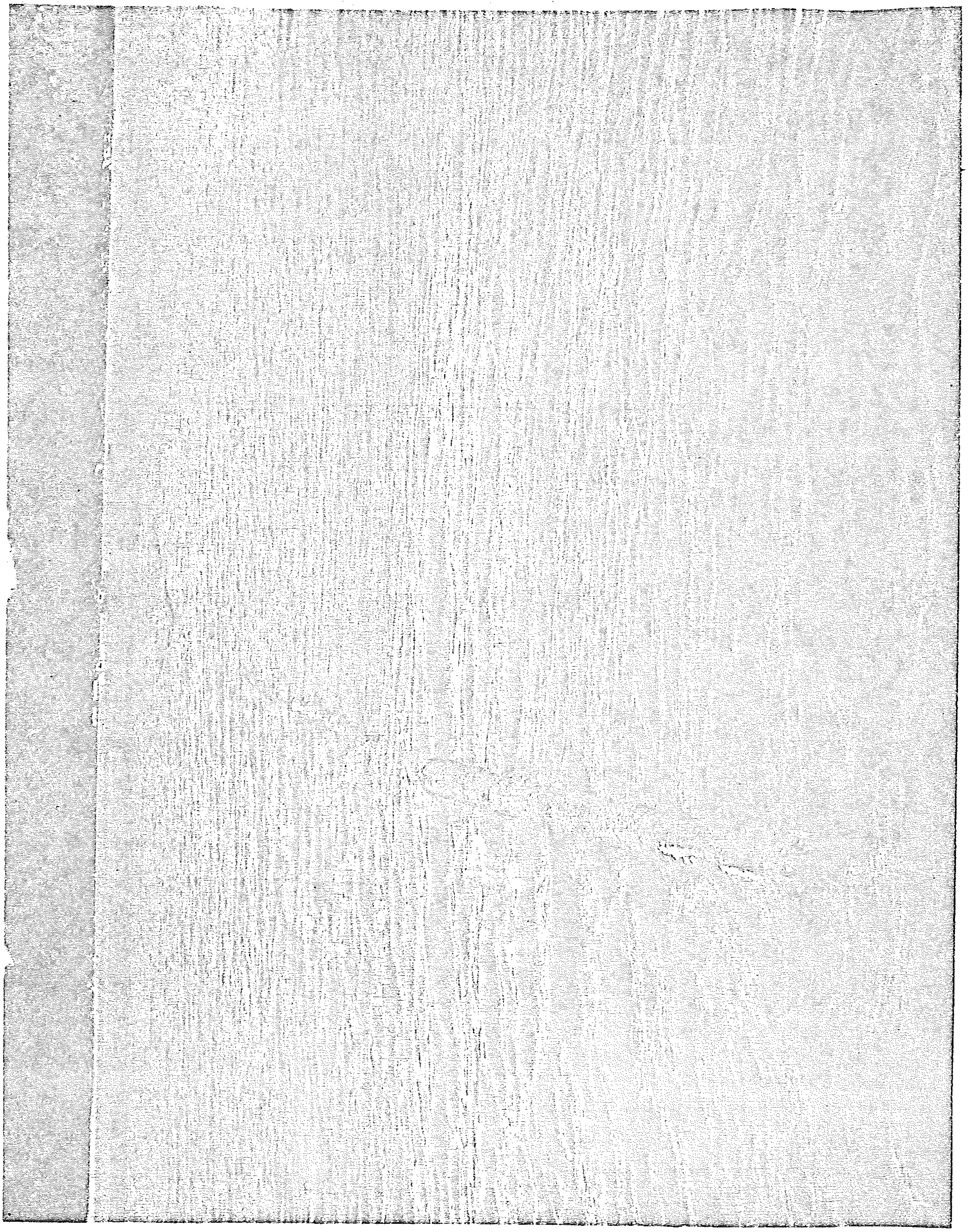

Figure 14

Boat's eye view of flotation units. There is little exposed to wind and wave action. The units are linked end to end by ropes.

6. Trays

The units are designed to take the weight of up to six trays of oysters, where dimensions of each tray are 10cm x 38cm x 106cm.

Construction is as follows: The body of the tray is composed of 16 gauge 25mm square weldmesh. A flat lid of 17 gauge weldmesh is attached by lengths of galvanised wire running through hooks attached to the tray. The tray is divided into 6 compartments by weldmesh as used in the lid. All parts are held together by turning the mesh onto itself. No welding is needed.

The tray is supported by two hooks 50cm apart along the middle. First, two plates of 18cm x 13cm galvanised iron sheet are drilled to take a 10mm round steel hook; the corners of the plates are cut and folded over the weldmesh under the tray to attach them firmly where the hooks are to be placed.

The hooks themselves, of 10mm round steel, begin as 60cm lengths. A tight loop is made at the lower end. The galvanised plate under the tray rests on this loop. Above the loop the rod is left straight for 30cm and the remaining length, about 15cm, is bent down to form a V with the straight section. This is the upper end which hooks into the tight loop under a tray above or directly to a 244 cm horizontal bar under the flotation unit.

Movement of trays around the hooks is prevented by horizontal brackets, centrally drilled to take the hooks, with the ends bend down at right angles over the sides of the tray. The are of 3mm x 25mm flat steel, and situated under the lid.

To prevent chafing of these horizontal brackets against the sides of the trays, pieces of galvanised sheet 76mm x 64mm are placed where they touch, the corners of the sheet cut as before to secure them to the outside of the tray.

A tray is filled with oysters only one layer deep. Otherwise they jam together during growth and eventually reach a point where some cannot open and die. Division of trays into 6 sections greatly assists maintaining the positions of the oysters. The division also prevents the trays overbalancing since they are supported along the central axis only.

Note that all steel, plain or galvanised, must be treated with rust preventatives before use. A satisfactory procedure is to allow each part 2 coats of tar epoxy by careful dipping, followed by two coats of preservac. Trays are constructed before dipping. All other components, collars, hooks, etc., are dipped before they are joined together.

PREDATORS, COMPETITORS AND POLLUTION

1. Predators

In the tropical Queensland intertidal zone, the most consistant predators of oysters are large flatworms which enter the oyster between the shell valves and wrap around the flesh. There are brown and grey varieties, their undersurface being white. These worms curl up in sheltered inner parts of the fibro collecting plates during low tide and are consequently difficult to locate. Their presence is indicated to the practised eye by a lack of growth of oysters in the vicinity as opposed to those on worm free plates. The oysters apparently sense the flatworm and remain closed until they are forced to respire, when the worm enters. Incidence of flatworms is greatest when plates are closest together. On separation of the plates to 10 cm apart, flatworm infestation is negligble on the fences. In the long line situation, flatworm infestation is a constant problem. Attacks occur at any time, but major occurrences are in spring and summer. The worms have been identified by the Australian Museum as belonging to the genus *Stylochus*.

The "cure" is to dip the strings in a brine solution (55-65 parts per thousand). A few minutes dipping is sufficient to kill most predators and competitors. Flatworms float away from the strings after a few seconds. Dipping should be repeated every two months. The dip also kills most of the crustaceans, sponges and seaweeds adhering to the plates.

Heavy mortality from flatworm infestation, especially of milky oysters, sometimes occurred before dipping facilities were available.

Figure 15

Upper, flatworm predators; the largest is 75 mm long. On the right is a large whelk, and at the bottom, several bastard pearl oysters.

Other intertidal predators include mulberry whelks and oyster drills (gastropods) of various sizes, though at Palm Island they have been a minor problem only, boring into young oysters on plates under a wharf. Many thousands of oyster drills have been removed from oysters in the farm at Magnetic Island, falling off plates into the punt when strings are recovered from the bottom. Crabs also shelter between plates and break open small oysters. Crabs rapidly destroy oysters that fall to the bottom where the substrate is coral, as at Magnetic Island. When a string breaks and oysters are strewn on the bottom, crabs, about 5 cm in carapace (shell) width, immediately emerge from the coral and crush the oyster shells with their large claws.

Common toadfish eat small oysters on the edge of plates. Movement of strings in the water current seems to afford protection from most other fish, since oysters that fall off are devoured by various reef fish.

Bottom living predators, usually a headache for mollusc farmers, are of little concern in this suspended farming operation. When a string of plates has been left on the bottom, however, the oysters are killed by drills and whelks. Silt also causes mortality of such oysters, and the occasional starfish has been observed on them.

2. <u>Competitors</u>

Competition for space on the plates and consequently for nutrients in the passing current is a more serious problem to the tropical oyster farmer. A wide variety of organisms settle on plates and trays during the course of time. Some small crustaceans and worms may benefit the oysters by grazing on algae etc., which would otherwise overgrow them. But most present problems of one sort or another. Intertidal competitors include small scallops, pearl oysters and sea squirts. Barnacles have been rare on intertidal plates, but do settle on continuously submerged objects near the surface. The upper PVC floats for example, are prone to colonisation. Barnacles could be of concern at other sites.

Figure 16
A plate of oysters from an intertidal string, Palm Island, covered with brown soft coral. This growth can kill oysters, but itself is by dipping in strong brine. A similar subtidal growth requires only exposure in air to destroy it.

A potentially serious problem is fouling by green filamentous algae which settle on plates mainly in summer months. Attacks begin during full moon tides when the preceding weather has been sunny. No algal settlement takes place if these tides occur during cloudy weather. Infestation generally lasts only one or two weeks after which the growth dies off and floats away in sheets.

Full moon tides in summer also seem to be associated with times of spatfall, so it is a time when virgin plates are set out in the intertidal zone to collect spat. A settlement of algae would prevent subsequent settlement by oyster spat.

At Palm Island when there was continuous cloud cover for 6 weeks in the 1975 wet season, a green mat grew over everything from sandbanks to oyster plates. It killed young blacklips on lower plates. The eventual combination of spring low tide and sunny weather killed the algae which lifted off in sheets.

The same growth had covered new spat collectors at Magnetic Island. They were left out of the water for several days to kill the algae, replaced and a few days later were covered in oyster spat. Algae covered plates received no spat.

This algae only fouls clean plates or those with young oysters. It never develops on plates of large oysters, the suggestion being that the larger oysters consume the invading algal cells. This is quite probable since individual adult oysters can filter water through their gills at about 8 litres/hour.

At Palm Island, a soft coral growth sometimes covers whole plates of oysters, regardless of their size. If forms a thin blanket which, unless removed (it peels off), eventually smothers the oysters beneath. It requires shade, and dies off when sunny weather and spring tides coincide. It remains and consolidates when spring tidal exposure is offset by rainy weather. Affected oysters which survive retain a distinct brown coloration of the shell for some time.

Subtidal competitors, which foul continuously submerged oysters, include a soft coral growth similar to that described in the intertidal zone. It also covers the oysters, but dies on exposure to air. It necessitates regular lifting of units from the water to kill the coral.

Another regular subtidal competitor is the bastard pearl oyster, a small (3-10 mm), translucent bivalve that settles in massive numbers over all submerged objects. Exposure to air over night kills these and most other subtidal competitors, including a vast number of corals, sponges, seasquirts and seaweeds.

Quite apart from their effects on the edible oysters is the effect of the sheer weight of these bastard pearl oysters on the flotation units. An invasion of them on one occasion onto a crop of oysters suspended below the older drum type of raft resulted in the loss of the entire crop. The rafts sank in deep water under their weight, the drums burst and the weight of the whole unit was too great to lift back to the surface. PVC floats, as noted elsewhere, retain their bouyancy on sinking and units are easy to lift to the surface.

Two varieties of seaweed often cause fouling problems at Magnetic Island but not at Palm. One is a floating filamentous green weed with hooked filaments that tangle around each other. It is locally called tangle weed. The other grows from a bottom holdfast and in a matter of weeks can fill the water column, making access difficult to oysters suspended from fences.

Tangle weed occurs in the spring months and when a ground swell develops it is released from the coral and settles on the beach where it dries out between tides and is then carried to sea again by next tide where it tangles in the fences.

The other weed is a sargassum type weed which becomes so thick that it blocks the water current from the oysters and so stops their growth. This occurred in 1976 when an exceptionally heavy crop stopped growth of oysters on the fences at Magnetic Island for three months. On first exposure to the sun in the winter daylight spring low tides, the weed disappeared. During heavy weather in these three months, constant breaking up of the weed fouled the fences.

Some other problems affect oysters both intertidally and subtidally. The first is siltation. The degree of settlement of mud on the oysters is entirely dependant on weather. South easterly winds, characteristic of winter months, bring turbid water and result in mud covered oysters on longlines. A ground swell associated with these winds keeps plates in the intertidal area (on fences) clean. A change to south westerly winds brings clean water when the oysters quickly lose their coat of mud. Turbid water does not seem to affect growth of black lips and is mostly a nuisance, in as much as oysters harvested during this time need to be washed. Also silt tends to thicken again the black mantle edge of blacklip oysters on longlines. Growth of milkies may be slowed down. Washing can be done by simple dipping of strings several times in sea water. Since a tray of oysters at this stage weighs at least 30 kg., the method is laborious. A high pressure hose would solve the problem, but probably create its own maintenance problems.

The second general problem is human predation, which is a constant problem to the oyster lessee.

The third is pollution, which can become significant even in industry-free tropical islands. At Palm Island for example, there is oil discharge from the powerhouse and vessels at the wharf, occasional leakage of diesel fuel from tanks, and effluent from the island's hospital. At Magnetic Island, there is concern that effluent from the nickel smelter on the mainland may affect oysters, for example by adding to their trace metal loads.

Conclusion

The techniques described in this report are the result of many years of experimentation. Growing oysters on strings of plates suspended from intertidal fences followed by a short period of fattening while completely submerged is a practicable means of cultivating tropical oysters.

The commercial viability of tropical oyster farming in Australia has not been fully proven and methods of processing and marketing the product require further development.

However, this project indicates farming techniques developed during its course will provide the foundation for a vi able industry in tropical Australia.