GREEN PROJECT

Medio Ambiente
y Desarrollo

Oyster Culture Feasibility in The Estero de La Barra de Santiago

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Aquaculture Consultant

Final Report and Recommendations

With Further Recommendations Regarding Cockle Culture

May 6 to June 6
1996

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SUMMARY OF FINDINGS AND RECOMMENDATIONS

Findings

The species of oysters encountered in the estuary of La Barra de Santiago were *Ostrea iridescens* *Saccostrea palmula* and *Crassostrea columbiensis* Of these the latter is most suitable for culture development because of its high tolerance for turbidity and salinity changes Oyster culture may be technically feasible in the estuary of La Barra de Santiago but several constraints must be overcome The oyster population in the estuary is very small and most larvae produced by it are likely to be flushed out before they reach setting size Spatfall is therefore likely to be very limited requiring the transplant of spat from other sites The Bahia de Jiquilisco is one such site where spatfall appears to be adequate Several types of cultch have been demonstrated and will require further testing for effectiveness

The range of salinity in the lower reaches of the estuary appears to be favorable for the culture of *C columbiensis* Periods of low salinity will limit biofouling The most serious biofouling organism is likely to be barnacles

Because of its small size and surrounding dense human population the living resources of the estuary are heavily exploited Aquaculture faces heavy competition with other user groups Theft s a debilitating problem There is almost no area of the estuary which is not exploited by fishermen or shellfish gatherers thus little space is available for oyster culture development Unfortunately the number of participants would be limited as a consequence

Recommendations

Spat collection

Cement coated tiles tire rims and plastic plates should be tested in La Barra de Santiago estuary and compared for effectiveness from June through September when it is maximum setting is anticipated Cultch should be put out only if oyster larvae are observed in the plankton samples

A cooperative effort should be organized with CENDEPESCA to carry out spat collection trials at Puerto El Triunfo in Jiquilisco Bay concurrently with trials in the La Barra estuary Cultch and racks can be constructed by Green Project staff at the CENDEPESCA laboratory at El Triunfo The cultch should be sited with ease of vigilance in mind

Grow out trials

If sufficient spat are collected a pilot project should be undertaken using long lines sufficient for the production of 5000 marketable oysters The pilot project should be located only in areas where oysters are found such as La Hojeada Growth and survival should be monitored during the grow out period by counting and measuring randomly selected samples from each of 3 size categories < 1 cm 1-2 cm and >2cm

Market size should be in the range of 7 to 10 cm Bacteriological monitoring of oyster meats should be undertaken before harvesting to insure product sanitation

User conflict resolution

The image of the project among fisherfolk should be improved through an education campaign The campaign should clearly explain the objectives of the pilot project It will be important to have a genuine dialogue with fisherfolk and reach a consensus as to the siting of the pilot project elements namely cultch and growout equipment It will be particularly important that community leaders understand the oyster culture pilot project and who its intended beneficiaries are

The growout site should have a full time watchman stationed on a raft equipped for the purpose

INTRODUCTION

Oyster culture has a long history going back to Roman times in the West and perhaps longer in East Asia Today oysters are a major aquaculture species Leading countries are Japan Korea the United States and Mexico The most important oyster producing countries in Europe are France and Spain Small scale oyster culture industries can be found in Thailand, the Philippines Malaysia New Zealand Australia the United Kingdom and even South Africa

Oysters are bivalve mollusks found only in marine and brackish water environments They are an ancient group of invertebrates whose fossil remains go back several hundred million years Oysters were so successful in developing adaptations to their environment that they have evolved little over the ages

Cultured oysters are placed in three genera *Ostrea Crassostrea* and *Saccostrea* The identifying features of each are presented in Table 1 All three genera have planktonic larvae which attach to a substrate at the conclusion of the larval phase The newly attached *spat* undergo metamorphosis during which the relatively simple internal structures of the larvae change to adult organs Sexual maturation may occur at a very young age Adult oysters may live many years - there are records of 70 year old individuals Fecundity is directly related to size A large oyster with flesh weight of 70 g may produce 100 million eggs

The vast majority of production is based on species of the genus *Crassostrea* The tremendous geographic distribution of oyster culture attests to the adaptability of the animal to culture in a wide range of water conditions In North America and Europe the bulk of seed stock now originates from hatcheries Tropical species of *Crassostrea* have been reared in hatcheries but most tropical oyster culture still depends on wild spat supplies

While *Ostrea spp* are found in the tropics commercial culture is not widespread An exception is *Saccostrea (Ostrea) palmula* which is cultured in Mexico (Angell 1986) There has been experimental culture of *O folium* and *O iridescens* (see below) Most species of *Ostrea* are relatively slow growing and prefer stable oceanic conditions which complicates their culture

Oyster culture can be negatively impacted by human activities in the coastal zone *Ostrea edulis* was a common food in coastal European countries before the industrial age but has declined dramatically due to industrial pollution and sewage runoff The same can be said of *Crassostrea virginica* the American oyster of Chesapeake Bay Major problems are bacterial contamination toxic "red" tides and diseases Diseases are usually associated with a deteriorating environment as is the case in Chesapeake Bay

Table 1. Comparative features of three oyster genera from Glude (1971), Ahmed (1975) and Stenzel (1971).

Characteristics	Ostrea	Crassostrea	Saccostrea
Chomata (denticles)	present	absent	present
Promyal chamber	absent	present	present
Umbonal cavity	absent	moderate	deep
Sexual development	protandrous hermaphrodite	dioecious	dioecious
Spawning mode	larviparous	oviparous	oviparous
Turbidity tolerance	low	high	moderate
Salinity preference	stenohaline	euryhaline	stenohaline
Shape	subcircular, flat	somewhat elongated, flat	cornucopiate or rudistiform
Shell margins	crenulated in some species	not crenulated	crenulated
Valves	equal	upper valve smaller	upper valve smaller
Size	small to moderate	may be large	small to moderate
Range	All tropical seas	All tropical seas except Polynesia and Melanesia	Indo-Pacific

OYSTER SPECIES INDIGENOUS TO EL SALVADOR

Two genera of oysters are reported from the Pacific coast of Central America *Ostrea* and *Crassostrea* (Olsson 1961) We have collected several specimens apparently belonging to a third genus *Saccostrea*, previously not reported from the Pacific coast We consider these specimens as belonging to the genus because of dentition extending the full circumference of the margin the cupped shape of the lower valve and crenelated shell margins This oyster corresponds to *O palmula* described by Olsson (1961) and Hertlein and Strong (1946)

The two genera of interest for culture are *Ostrea* and *Crassostrea* Three species of *Ostrea* have been encountered in Central American waters *O iridescens* (Fig 1) *O palmula* and *O megadon* However the latter is found only in deep water and nothing is known of its biology Oysters of the genus *Ostrea* prefer stable oceanic or near oceanic salinity They are usually found at lagoon mouths or on rocks along the open ocean coast The only species found in La Barra is *O iridescens* which we found on rocks just inside the mouth of the estero *Ostrea* is distinguished from the other genera of oyster by its flat shape and lack of an umbonal cavity Several teeth are also found dorsally, near the hinge The most distinguishing feature of the genus *Ostrea* is its brooding behavior Larvae are retained in the mantle cavity until they reach about 120 microns at which point they are released The fecundity of *Ostrea* species is considerably lower than *Crassostrea spp* seldom exceeding 500 000 larvae

Crassostrea is the most widely cultured genus of oysters Culture industries stretch from the sub arctic to the tropics The major species are *C gigas* the Pacific oyster *C virginica* the American oyster and *C iredalei* the Philippine slipper oyster Two species are reported from Central America *C corteziensis* and *C columbiensis* Only *C columbiensis* (Fig 1) is found in the lagoon of La Barra de Santiago *C columbiensis* can be distinguished from *C corteziensis* by the chalky white interior and purple margin in older specimens *C corteziensis* is very similar in appearance but has a purple adductor muscle scar (Olssen 1961)

Oysters of the genus *Crassostrea* are euryhaline and can tolerate fairly high turbidity Spat are readily transported over long distances adapt readily to new environments and grow rapidly As such they should be the main focus of oyster culture development activities

EXPERIENCE WITH OYSTER CULTURE IN EL SALVADOR

There is no commercial oyster farming in the country The market is supplied with oysters collected from natural beds However interest in oyster culture goes back several decades

O iridescens was the object of research during 1975 to 1980 The work included larval sampling, spat collection and growout trials Larval abundance peaked in June in the sampling area (El Tamarindo to Punta La Bolsa) Spat were collected and transferred to plastic trays suspended from rafts Spat abundance peaked during July to August Oysters reached 10-13 cm in one year (Cheney et al 1988) Such a growth rate is comparable to that obtained in other tropical areas

Pacheco et al tried to collect spat of *O iridescens* 1976 in Tamarindo Bay Oyster shell and cement coated egg cartons were used as cultch Few spat were collected and the exposed location led to many problems with the long line The best setting was on cultch placed on the sea floor

Because of the lack of aquaculture production existing natural populations are declining In La Barra and neighboring El Zapote there are a few divers collecting *Ostrea spp* off shallow rocks at the mouth of the lagoon and occasionally from a shipwreck on the open coast

The population of *Crassostrea* in the lagoon of La Barra is quite limited although we observed recently set spat The bulk of the population is on the east side of Isla Venado The few examples we located were small, inhabiting mid to lower high water

Appropriate oyster culture technology for La Barra

Environment

The estero is small characterized by marked seasonal fluctuations in salinity and turbidity Species preferring stable salinity are limited to a very small area at the mouth of the estero Even within the estero the distribution of *C columbiensis* is restricted to areas where low salinity is less persistent

Because of the small volume of the estero it is likely that oyster larvae spawned by the indigenous population are flushed out to sea before they reach setting size Likewise larvae that are carried into the estero must be of setting size or they will be flushed out before attaining a size sufficient for competent setting As a result, it is likely that spat will have to be transplanted from other setting sites

Upland runoff can impact oyster culture with heavy sediment loading and bacterial contamination Heavy sedimentation can impede setting and may smother spat Bacterial contamination is a public health concern which must be addressed when production is sufficient for marketing trials Preliminary sampling in the estero has indicated that E coli counts in the water exceed public health standards at times Human pathogenic bacteria and viruses do not affect oysters which are the transmitters

Pesticide contamination is a third impact to be considered from the public health point of view, but no measurements of pesticide concentrations have yet been made in the estero

Market economics

Although no studies have been done casual observation indicates there is a good market Oysters are popular at tourist spots and are sold in La Barra during fiestas

The market is built on the harvest of natural stocks of *O iridescens* mostly in the eastern part of the country Major collecting areas are Playas Negras Playas Blancas El Tamarindo Playitas and Isla Perico There are approximately 46 oyster fishermen among these sites with the majority operating out of Playas Negras and Playas Blancas

Producer prices per dozen depend on the size of the oyster as follows 5-6 cm 6 col 8-10 cm 10-12 col and greater than 10 cm 15 col The middleman (toponero) sells to restaurants at 30 col per dz locally and 40 to 50 col /dz in El Tamarindo (Pacheco personal communication)

Retailers at La Libertad obtain 50 to 70 colones per dozen depending on size and vendor The oysters are consumed raw on the spot A few *Crassostrea spp* are mixed in with the *O iridescens* but there is no price difference

In addition oysters are widely available as cocktails in seafood restaurants in San Salvador and other cities in the country If culture trials are successful a formal market study would be very useful for the development phase

The major cost of oyster culture is the initial investment in equipment If this can be minimized it is likely that the high cost of oysters will support a culture industry However detailed financial analysis will be required based on actual costs and earnings

Socio-economic conditions

The inhabitants of the villages of El Zapote and La Barra de Santiago exploit the resources of the estero but there are significant differences between the two Agriculture is part of the economy of El Zapote but plays little role in La Barra where both sea and estero fishing predominate Household income is probably higher in La Barra nevertheless access to capital is difficult or non existent There are few local business and families depend on tourism and extraction of marine resources

Thus competition for the limited resources of the estero can be expected to increase as the local population increases While aquaculture *may* offer an alternative in the long term this competition will create immediate problems, even at the pilot stage Competition for water space between fishermen concheras and aquaculture will have to be mitigated through careful coordination and education with the local fisherfolk

OYSTER CULTURE TECHNOLOGY.

There are three methods of oyster culture on-bottom rack and suspended Variations of all of these methods can be found in tropical waters Oyster farmers have been very innovative in their search for profitable methods of osyter culture The primary ingredient for successful oyster culture is a reliable source of spat

Spat supply

The methods used to collect wild spat are as varied as the materials on which larvae will set The most traditional cultch is lime coated clay roofing tiles Oyster shell f available s one of the best substrates Plastic sheets tubes and other shapes have proven useful with the main advantage that spat are easily removed from the cultch A commercially successful system was developed in Cuba using mangrove branches as cultch Often the selection of a spat collection method will be determined by the local availability of materials

Getting a good set of spat depends on timing the cultching to coincide with the reproductive cycle of the oyster Therefore successful culture depends on a knowledge of the reproductive cycle of the local oysters This can be done by examining the female gonads for the presence of mature eggs

The presence of advanced oyster larvae in plankton samples is a more direct indication that setting is occurring Direct observation of newly settled spat is another good method used to time cultching However spat are very difficult to see on the usual cultch materials Glass slides suspended where oyster setting has been observed are excellent for this purpose since evern the smallest spat can be seen under the stereo micrscope The disadvantage is that setting may be very light with so that few or no spat are seen on the glass slides

Only very limited studies of the reproductive cyle of oysters have been done in El Salvador These studies do not indicate very clearly the major spawning peaks although it may be that most spawning takes place sometime during the rainy season (Granados 1995)

Spat are easily transported long distances Spat of 1 to 3 cm can survive several days out of water if kept well shaded If spat is not available in the estero it can be transported from other sites such as the Bahia de Jiquilisco

On bottom culture

Culturing oyster directly on the sea floor is usually not feasible in tropical estuaries due to high sediment loads occasioned by fresh water runoff and organic detritus originating in mangroves Such is the situation in this estero However on bottom culture can be done by placing rocks on the bottom or inserting concrete slabs into the bottom Oysters set on these substrates and grow to market size The great disadvantage of bottom culture is the high mortality caused by sediment and predators Considerable space is also required which would raise user conflict issues in the Estero

Rack culture

Productivity is enourmously enhanced if the oysters can be cultured off the ea bed in some way Racks are cheap to construct and simple to maintain if the rack is located in shallow water trays containing the oysters rest on horizontal bars The heighth of he bars can be adjusted to reduce biofouling while maintaining an acceptable growth rate In deeper water trays can be suspended from the rack as they would be from a raft or long line

There are several drawbacks to rack culture Oysters are susceptible to some predation from snails and crabs although the latter are not serious predators when the oysters exceed about 1 cm Growth is somewhat slower than is the case with suspended culture Racks occupy space in the lower intertidal zone which may generate conflicts with cast netters and concheros

Hanging culture

Although most oyster species are intertidal animals their growth rate is greatly accelerated if they are continually submerged Hanging culture involves the construction of long lines or rafts from which the oysters are suspended in trays or baskets Long lines are preferable for their lower cost and ease of construction but they are more expensive than racks and require a boat or canoe for maintenance Trays or baskets are easily suspended from the long lines and growth is rapid Disadvantages are susceptibility to biofouling and user competition Biofouling is the result of unwanted organisms adhering to oyster trays and the oysters themselves Observation of submerged mangrove roots indicated that the principal fouling organism is likely to be barnacles The wide changes in salinity within the estero can be expected to limit biofouling but culture trials are required to fully evaluate its effects User competition has to be taken into account as well It is possible to locate long lines in deep channels where less fishing takes place within the estero

FIELD WORK

The objectives of field work were two fold 1) assess the possibility of oyster culture in the estero of La Barra de Santiago and 2) train project staff in ovster culture methodology Consequently the following activities were undertaken larval sampling, spat monitoring, cultch fabrication long line construction and rack construction The Bahia de Jiquilisco was also surveyed as a potential source of spat

Larval sampling

Oyster larvae sampling was undertaken concurrently with sampling for cockle larvae In fact the same samples are used for both cockle and oyster larvae counts Advanced larvae of *Crassostrea* were found in samples from La Bocana and at the entrance to El Zapatero canal Water quality monitoring is also identical As staff had been trained in these sampling methods during a previous consultancy no further effort was required as far as training The long term sampling program for cockle larvae will also include oyster larvae counts as has been the practice

Spat monitoring

Spat monitors were made of glass slides 10 slides in each monitoring unit Oyster larvae are only 320 microns when they set and are impossible to see on collector materials such as tiles and tire rims The glass slides would have been checked fortnightly by microscope and spat counted as numbers per monitoring unit Five of these collectors were placed at sites where ovsters were observed on mangrove roots, but all had disappeared during the 2 weeks they were put out

Cultch preparation

Cultch is ovster farming terminology for the substrate on which larvae attach or *set* After setting, the larvae are referred to as *spat* The origin of this term goes back to colonial days on the Chesapeake Bay when oystermen believed the small ovsters were "spat" out by their parents! The variety of materials available for cultch is limited in El Salvador I have had good success with an extruded plastic mesh (Netlon) coated with cement, but unfortunately this material is not available in the country

Cultch materials

Lime coated roofing tiles are a traditional cultch in France and the British Isles Both used and new roofing tiles are readily available in La Barra and adjacent communities The tiles were prepared as seen in Fig 2 Ovster larvae are negatively phototactic and are attracted to areas of low illumination which is why the tiles are stacked on a simple support of bamboo Tiles were coated in a mixture of cement lime and sand in proportions of about 1 5 1 1 The mixture was prepared in a large plastic basin and the tiles were dipped in it to provide a relatively thick coat The coating will allow spat to be removed with minimal damage to the animals Many of the tiles can be reused

Larvae will set on a variety of plastics At the suggestion of Wifredo Caña we purchased disposable plastic picnic plates and strung them up as cultch 10 plates to a string as in Fig 3 Spat will be easy to remove from the flexible plates The plates are positioned closely o encourage larvae to set on the underside of the inverted plates which will have less sediment than the upper sides

Tires are widely used in the Philippines and Malaysia as cultch After a few weeks aging in the seawater spat set readily on both inner and outer surfaces The problem with whole tires is overcrowding of spat on the inner surfaces accompanied by high mortality Discarded motor cycle tires have proven verv useful as spat collectors as they are easily turned inside out Unfortunatelv, very few are available We did find tire rims are sold as part of the recycling of discarded tires and as such are easily purchased in small shops specializing in this unique recycling "industry" (Fig 4) The rims cost only 3 colones which is quite cheap considering that they should last many years submerged in the water of the estero

Cultching methods

We planned to put all of the above cultch materials out in the mangroves but the theft of the spat monitors forced us to use racks directly in front of Amalunga Lime coated tiles and plastic plates are designed to produce single spat which can be removed from the cultch and cultured in trays Tire rims on the other hand will both collect spat and provide a growout surface After accumulating adequate set they can be transferred to long lines to accelerate growth

Spat collection

Since very few spat were found in La Barra a reconnaissance was made of a portion of the Bahia de Jiquilisco The CENDEPESCA laboratory at Puerto El Triunfo was used as a base Large quantities of spat were found on concrete pilings of the fishing pier within half a kilometer of the lab (Fig 5) Setting occurs in a narrow zone at about mid tide We were able to collect about 1000 spat ranging in size from 5 mm to 3 cm All the oysters found were *C columbiensis* the same species which occurs in La Barra

A search of the mangrove roots in the area of Isla La Tortuga and Isla Madresal revealed light setting Some spat were collected from the mangrove roots but considerably more time was required to collect compared to the effort expended on the concrete dock pilings it appears that the larvae of *C columbiensis* do not have a strong affinity for mangrove roots

In addition to oyster spat found on the fishing dock rocks in the intertidal zone had evidence of past sets although most oysters died due to exposure or predation The presence of spat in the area around the laboratory at Puerto El Triunfo indicates a good area for placing cultch Cement coated roofing tiles placed on racks would probably be the most appropriate method for this site The height of the rack could be adjusted to coincide with the zone of maximum setting

Spat transport

Spat were separated as much as possible into individual spat and segregated into three main size groups They were held in plastic baskets overnight in the lab at El Triunfo The following day the spat were transported to La Barra which took about 5 hours No special provisions were made other than to transport in the morning to reduce exposure to high temperature Upon arrival the baskets were hung from mangrove roots and branches at the entrance to Canal El Zapote (Fig 6) It is estimated the oysters were out of the water about 34 hours Spat were examined the following day no noticeable mortality was observed The few dead oysters had had their shells damaged during collection

Long line construction

A sample long line was constructed using six 25 liter plastic carboys tied to two parallel 3/8" lines The carboys were tied 2 m apart within which 2 plastic basket can be tied (Fig 7) The long line was anchored in shallow water directly in front of Amalunga The floats were painted with fluorescent spray paint to improve visibility and help trace them should they become lost (Fig 8) Six spat containing baskets were hung from the long line Care was taken to insure that the baskets would not touch the bottom at low tide Unfortunately the concrete blocks proved inadequate to keep the long line in position in the strong tidal current It became entangled as the anchors drug and most of the oysters were lost as a result of the baskets overturning (Fig 9) The following day the anchors were replaced with mangrove poles driven into the bottom One of the floats was subsequently stolen during the night

Theft of materials is a serious constraint In fact some fishermen have told the project social worker that they will remove anything placed in the estero by the project Although the site selected for the first trial of the long line may not be ideal the chance of theft may be somewhat reduced Cockle spat collectors made of plastic brushes have all disappeared from locations not directly visible from Amalunga If oyster culture is to be seriously tested in the estero some solution to this problem must be found We would have liked to place the long line at La Hojenda The site is completely obscured from view giving rise to justifiable concern that the installation would quickly disappear

Recommendations

The major technical constraint to developing Anadara culture remains the seed supply Knowledge of the reproductive cycle as well as spat collection technology needs to be developed

Spat collection

Spat collection should be timed with the reproductive season of the cockles According to data collected to date this appears to be from about November until April based on gonad maturity There is no need to keep collectors out in the estero outside of this reproductive period

However many more spat collectors need to be put out than has been the practice One hundred mescal collectors would be a reasonable target but the more the better The collectors should be strung horizontally from mangrove prop roots Plastic brush collectors should also be tested although there is a good chance they will be stolen

Length frequency data

The objective of collecting length frequency data should always be kept in mind That is, to construct growth and mortality curves from which the status of the population can be inferred Monthly samples will be analyzed by ELEFAN, a computer program designed specifically for population analysis based on length frquency data While data is collected on a regular fortnightly basis only monthly observations will be required for analysis After one year of data collection the best set can be selected for computer analysis It has been the practice to collect and record length data from individual concheras These data should be grouped together for analytical purposes

Gonad maturation studies

Gonad maturity indices as determined from simple smears of gonad tissue have already proved useful for defining the reproductive period This sampling should be continued The data should be entered in a data base for graphical analysis

General

Apparently none of the data has been entered in any kind of data base It is strongly recommended that this be done Any common data base such as Lotus 123 or Microsoft

Excel will serve the purpose Data can thus be easily graphed and monitored during the course of the sampling

The lack of success in finding spat of *Anadara spp* should not be discouraging The effort to date has been very limited in both the quantity of collectors locations and time Cockle spat collection is a new technology requiring several years to develop Perhaps spat collection activities could be expanded to Jiquilisco Bay concurrently with oyster spat collection

Oyster culture

The major issues are spat collection, growout and user conflicts

Spat collection La Barra

Spatfall monitoring with glass slides will not be possible because of theft If advanced oyster larvae are present cultch should be put out on racks in the intertidal zone in front of Amalunga where spat have been observed All three cultch materials tiles plastic plates and tire rims can be used on the intertidal rack at Amalunga The height of the rack should be adjusted so that the cultch is slightly above the barnacle zone (Fig 13) It had been planned to place some of the collectors in the mangrove root zone where oysters have been found Unfortunately the disappearance of spat monitors proves this approach to be impossible

When the spat have reached 5 to 2 cm or more and are easily removed from the tiles and plates they should be transferred to baskets on the long lines (see below) To reduce shell damage the edge of the shell should be starting to raise off the surface of the cultch Spat on tire rims are left to grow to market size but the rims can be moved to long lines

Spat collection, El Triunfo

Spatfall is much more intense in the Bahia de Juiquilisco compared to La Barra The success of oyster culture trials in La Barra is likely to depend on spat collected in La Bahia de Juquilisco Therefore spat collection should be organized with the collaboration of the staff of the CENDEPESCA laboratory at El Triunfo A spat collection program at El Triunfo must include larval sampling Samples can be taken at sites as shown in Fig 12a and 12b Cultching can be started when advanced umbon larvae are present in the samples

Cement coated roofing tiles would the most appropriate cultch material for El Triunfo The tiles should be placed on racks in the intertidal zone There are sutiable sites very close to the laboratory where spatfall was observed on rocks (Figs 13 and 15) The cultch should be prepared in advance and kept ready in the event that oyster larvae are caught in the plankton samples

Lacking any previous experience it is difficult to say how much cultch should be put out If the production target is 5000 oysters about 6300 spat will be needed assuming 80% survive For the first year's work 100 cement coated tiles may be sufficient at each site (La Barra and El Triunfo)

When enough spat have accumulated on the tiles and are 5 to 2 cm they can be removed from the cultch and transported to La Barra

Growout trials

Longlines are recommended for growout in the Estero de La Barra de Santiago While racks are cheaper long lines may generate less user conflict since they do not occupy space in the intertidal zone Furthermore in the area of the estero where oysters are common there is little intertidal space available

Plastic trays suspended from the long line at a depth of 1 meter should be used s Care must be taken to anchor the longline in water of sufficient depth to prevent the plastic trays from touching the bottom at low tide

If a target production of 5000 oysters is set assuming 50 marketable oysters per basket then 100 baskets would be required Our trial longline was set up to hold 2 baskets between each float Each longline could carry 20 baskets and would require 12 floats Five lines would carry enough baskets to reach the target production

A raft would also be required to house the watchman and to serve as a working platform Two hundred liter plastic barrels can be used as floats to support a wooden frame measuring 6 5 by 4 5 m The frame should be bolted together and a platform of planks nailed to the frame A small shelter cabin and roof over the entire raft would complete the structure The raft should be anchored with heavy concrete blocks or anchors and heavy chain

Growth and mortality should be recorded at monthly intervals The most convenient indicator of growth is the measurement taken from the edge of the shell next to the hinge to the opposite shell margin (Fig 14) While often referred to as length it is actually the height of the shell Only indvidual oysters should be used for measurement The wide size range of wild spat requires they be separated into size groups say 3 groups starting with 1 cm or less, followed by 1 to 2 cm and greater than 2 cm Spat of each size group are to be put in separate labelled baskets set aside for growth and mortality sampling Two hundred, 100 and 75 spat randomly selected from the small medium and large groups should be placed in their respective baskets Initially all of the individuals in each of the sample baskets should be measured and the standard deviation calculated The sample size to be taken at monthly intervals can then be determined as per Appendix 2

Community interactions

Competition for space with other user groups and theft of oyster culture materials are the most immediate problems the project will face in its relationship with surrounding communities

Competition

In the initial stages of oyster culture trials very little space is occupied by the various collectors and the one long line However if these initial trials vield positive results and production is expanded opposition from some local inhabitants can be expected as well as vacation home owners Therefore, even at this early stage it would be wise to carry out an information and education campaign to inform fisherfolk what the project is doing and why Judging from comments made to the project social worker some activities are viewed quite negatively by certain sectors of the community If more installations are added much closer cooperation with various users will be required The sociologist on the project has extensive contacts in local communities and can be a central part of the education effort Discussions with community leaders and fisherfolk should be held to try to develop a consensus as to the need for the project and the best site If there is not broad agreement in the community of users to go ahead with the pilot project it should be delayed until such a consenus can be arrived at or abandoned

There are several groups that could become involved in a pilot project The oyster fishermen of El Zapote is one of these Another is the ' Friends of Playa Alegre " Perhaps an arrange could be made whereby the proceeds from sales of pilot project production would go to the group (but the group should decide the mechanism for this)

It might be worthwhile to bring in a Latin American consultant who has had experience developing fisherfolk management and/or participation in aquaculture There been some interesting work done in Chile with the management of an abolone substitue called "loco" and with seaweed farming and harvesting Dr Gary Newkirk of the Dept of Biology at Dalhousie University has the names and addresses of some of the sociologists who have been involved in this type of work

Vigilance

The estero and its waters constitute a typical common property resource As such anything placed in the estero other than fishing gear is fair game There is no aquaculture tradition which recognizes the property rights of shellfish farmers The only practical way to avoid theft is permanent vigilence If a site for oyster farming activities can be found watchmen can be stationed on a small raft equipped with a shelter The raft would be anchored alongside the longlines

In the event that spat collection activities are centered in Puerto El Triunfo measures must be taken to avoid removal of spat collectors there as well Cultch can be located just in front of the fish ponds at the CENDEPESCA laboratory where they can be controlled by the regular night watchman employed at the lab

The collaboration of the fishermen's cooperative can also be sought to keep watch on cultch placed along side the causeway leading to the fishing pier located a few hundrred meters from the coop

Suggested work plan for 1996-97

The work plan for oyster culture trials should emphasize spat collection grow out trials and coordination with users' groups A proposed time frame for activities is shown in Appendix 1 Spat collection activity is confined to the June - September period because we anticipate this will be the main spawning season

General recommendations

Bivalve hatchery

The major problem we have confronted during 2 consultancies has been the unavailability of cockle and oyster spat Given the excellent market potential in Central America for these shellfish a small hatchery would be a good investment

As recommended in my previous report it would be quite feasible to modify the existing facility at El Zope for production of bivalve larvae in such a way that it would not interfere with shrimp PL production If sufficient funds were available a specialized hatchery could be built at the same site It would be considerably smaller than the present shrimp hatchery With reliable seed production a reality cockle and oyster culture could be developed in all the major esteros of the country

Bacteriological monitoring

Bacterial contamination is a serious threat to bivalve culture because of the risk of enteric diseases carried by contaminated shellfish There is no time series data base of bacterial contamination which could be used as a basis for harvesting decisions Monitoring should continue for both water and shellfish flesh so that a data base can be constructed Initially samples should be taken fortnightly This is particularly important during the rainy season when contamination is likely to be particularly high These data should be graphed and reported at quarterly intervals during oyster culture pilot trials so that harvesting can be timed with safe periods

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APPENDICES

Work plan for 1996-97
Statistical method for calculating sample size

Appendix 1 Proposed work plan, June 1996 – May 1997

Activity	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Community education and coordination	■	■	■	■	■	■	■	■	■	■	■	■
Larval sampling												
La Barra	■	■	■	■								
El Triunfo	■	■	■	■								
Cultch preparation												
La Barra	done											
El Triunfo	■	■										
Spat collection												
La Barra	■	■	■	■								
El Triunfo		■	■	■								
Construct longlines				■								
Transfer spat from El Triunfo					■							
Growout trials, La Barra					■	■	■	■	■	■	■	■

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List of figures

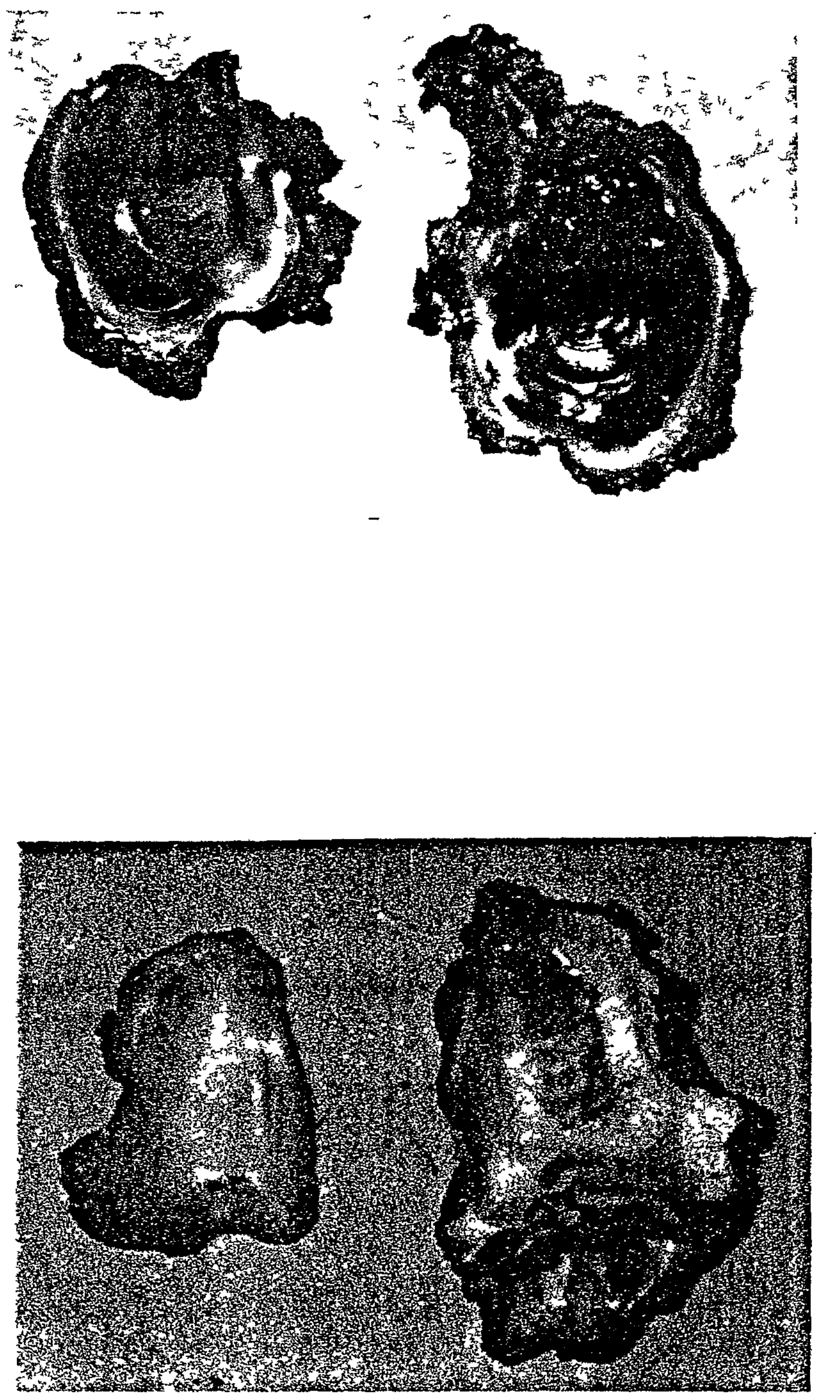

Fig 1 Ostrea iridescens, above and Crassostrea columbiensis, below

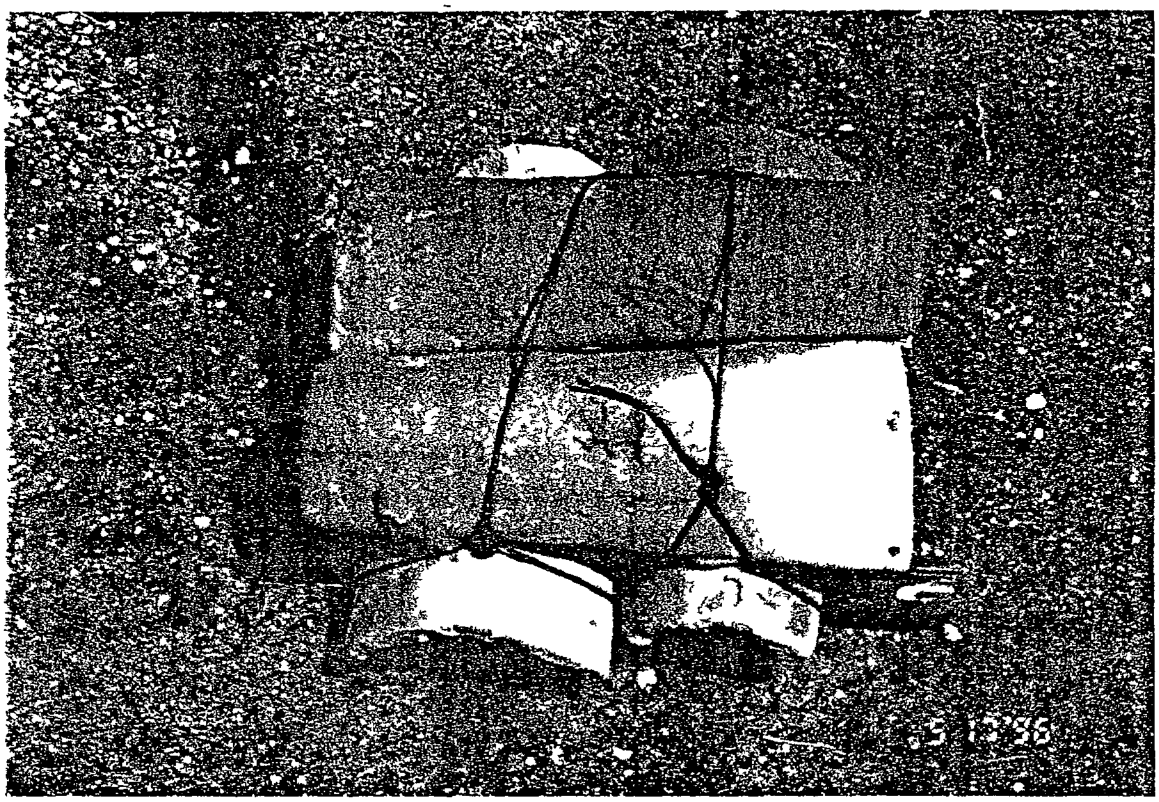

Fig 2 Cement coated clay roofing tiles stacked for spat collection

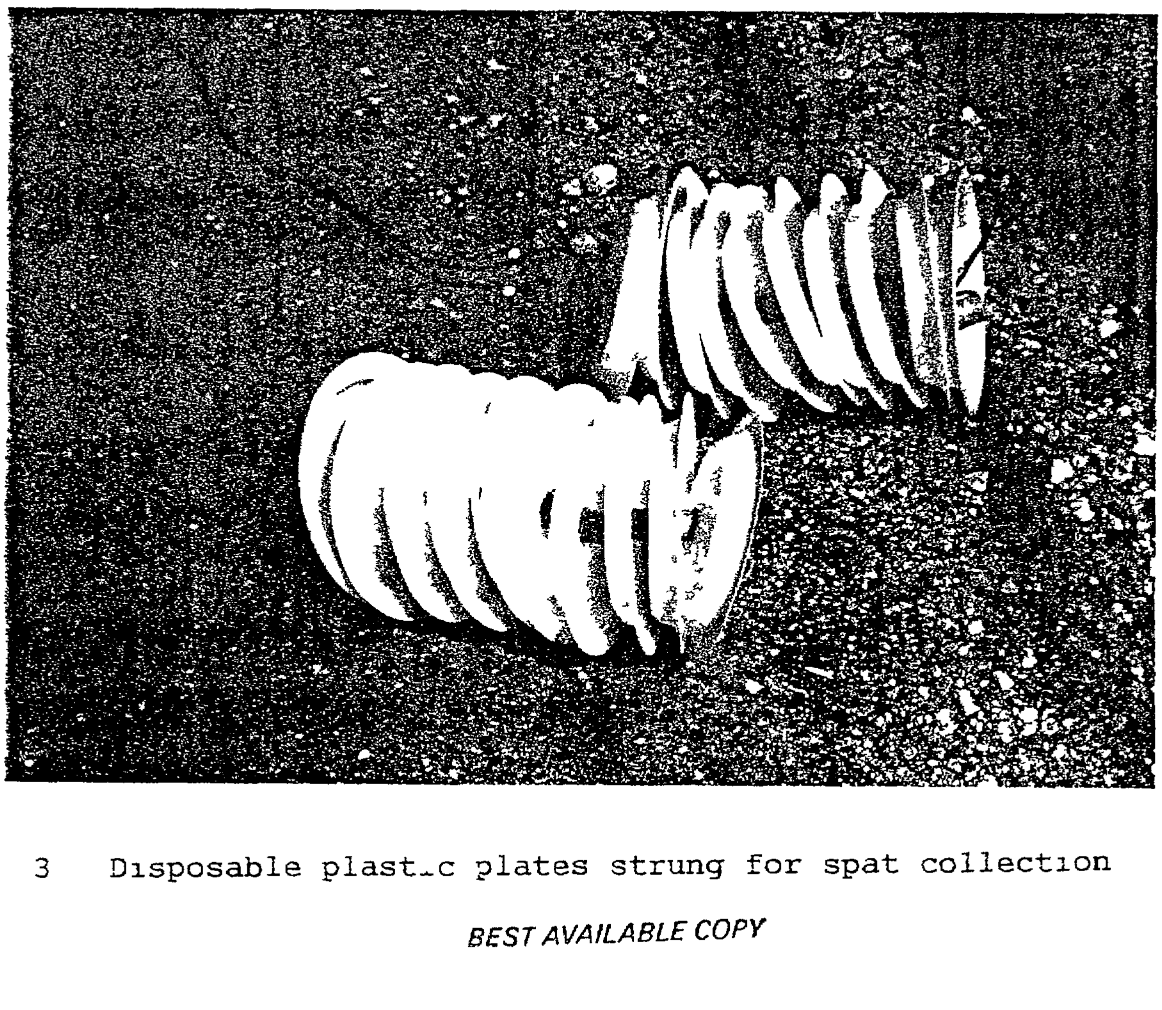

Fig 3 Disposable plastic plates strung for spat collection

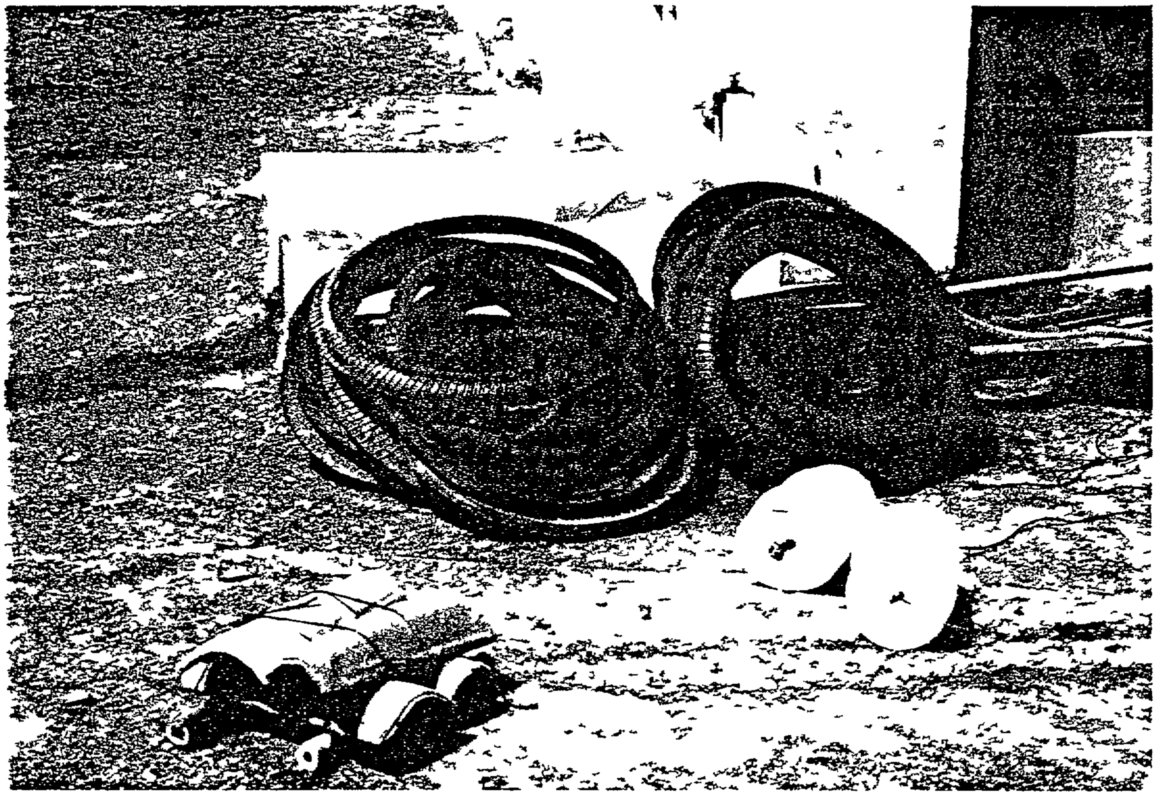

Fig 4 Discarded tire rims which can be used for both spat collection and growout Tiles and plastic plate collectors shown in the foreground.

Fig 5 Removing spat from the fishing pier at Puerto El Triunfo Note the position of the oysters above the zone of heaviest barnacle setting

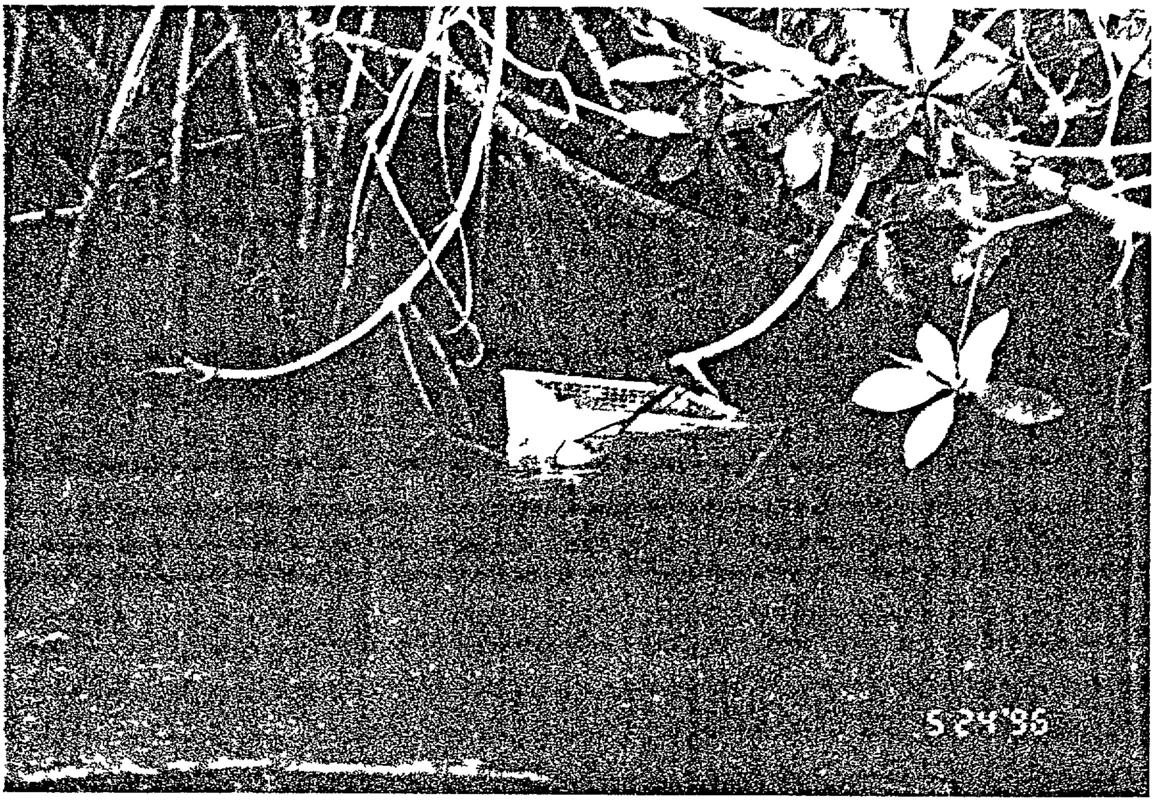

Fig 6 Plastic baskets containing oyster spat hung from the mangrove roots in the estero of La Barra

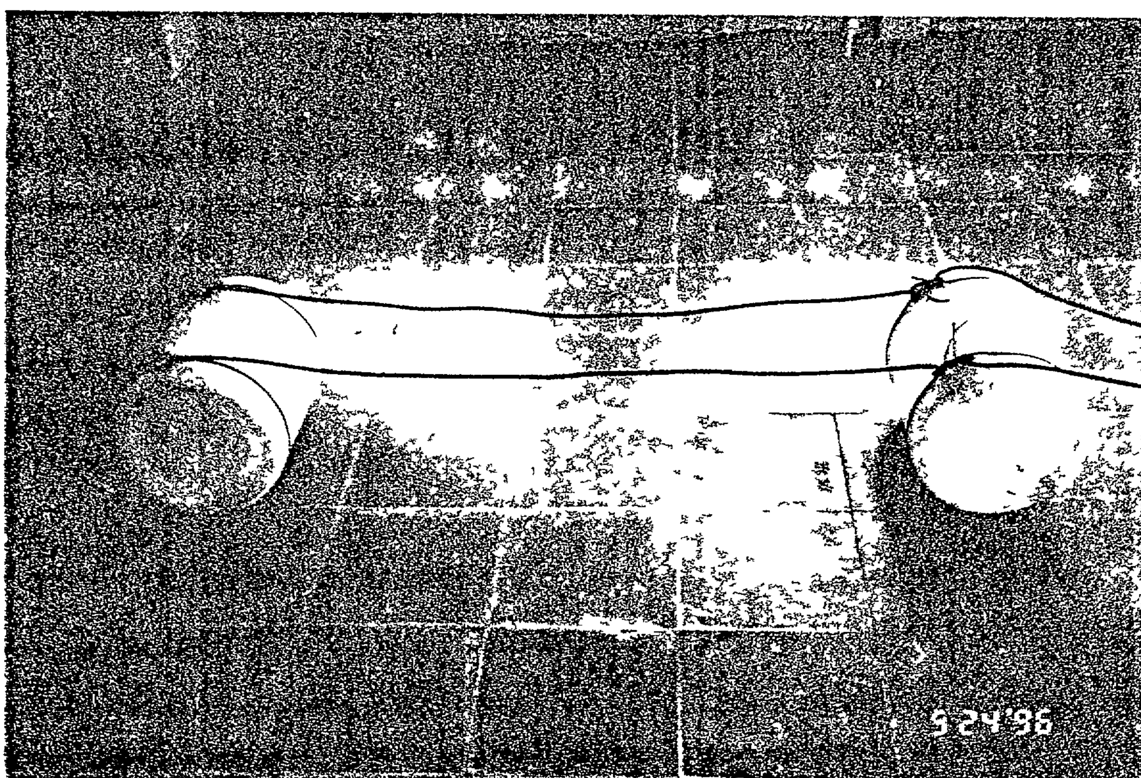

Fig 7 Floats tied to parallel 3/8" lines The assembly is shown in an inverted position

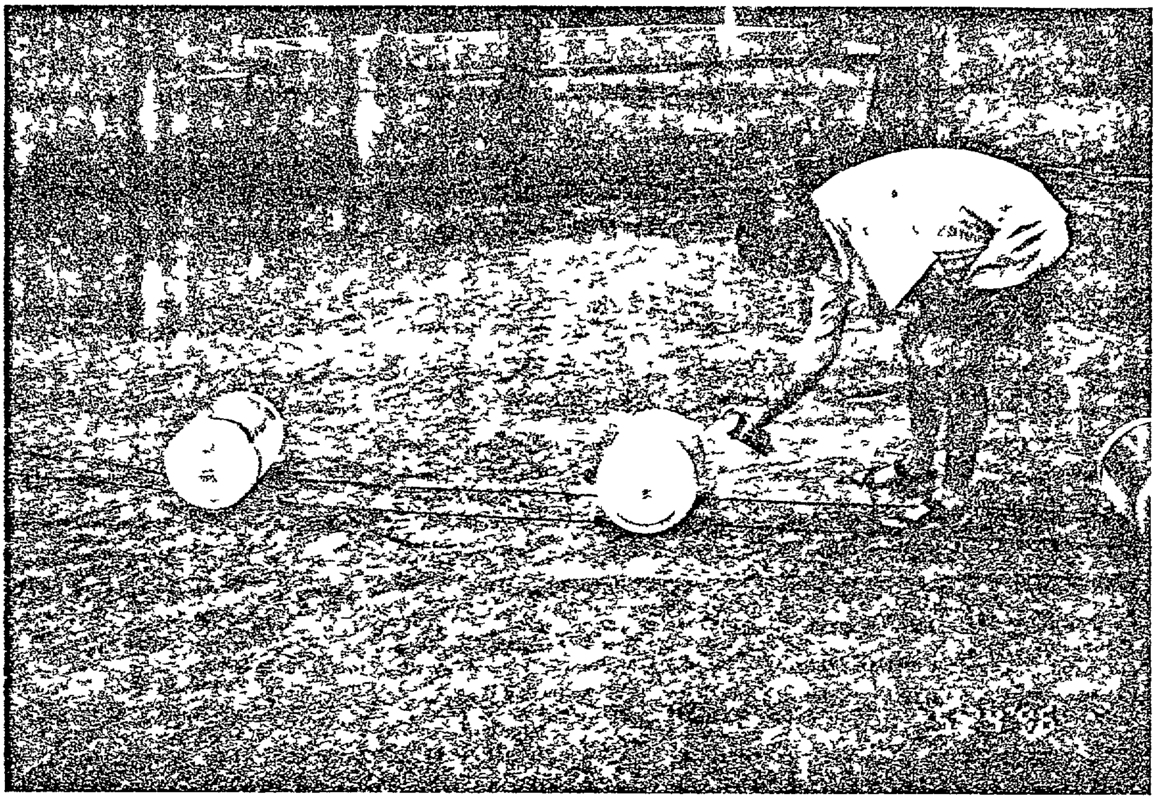

Fig 8 Painting long line floats with flourescent spray paint

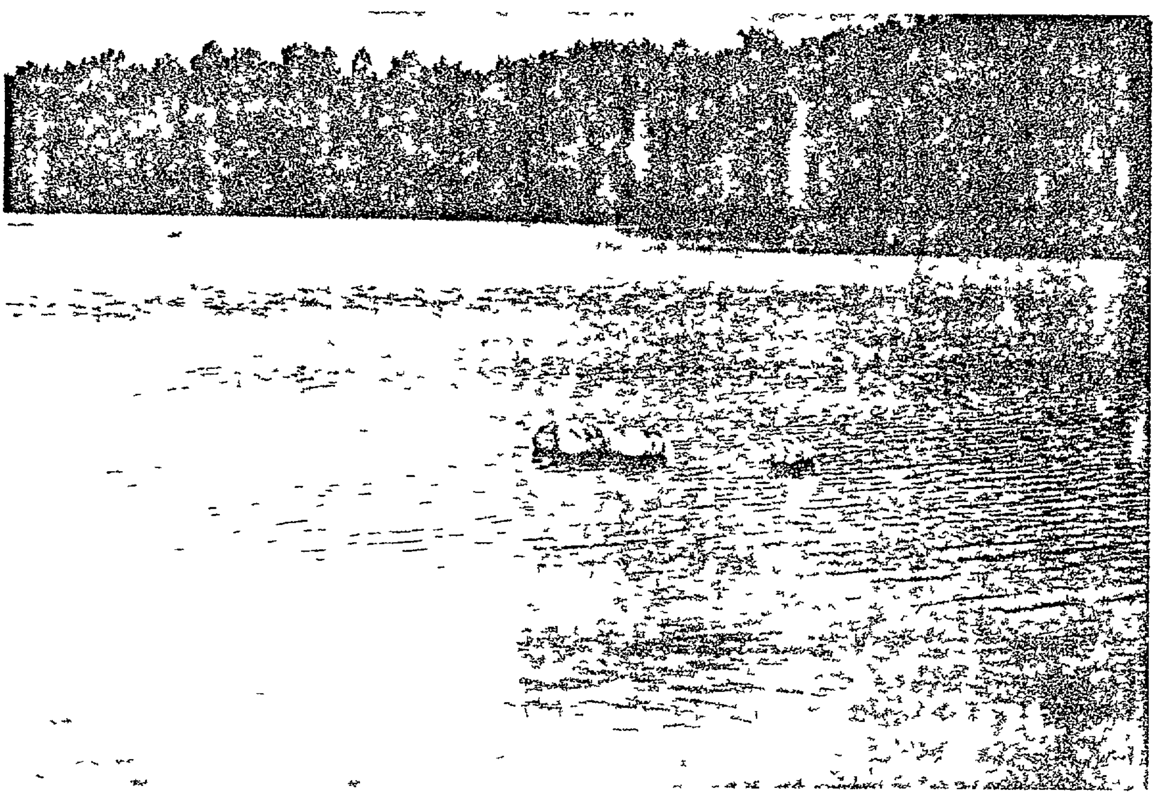

Fig 9 The effects of inadequate anchoring!

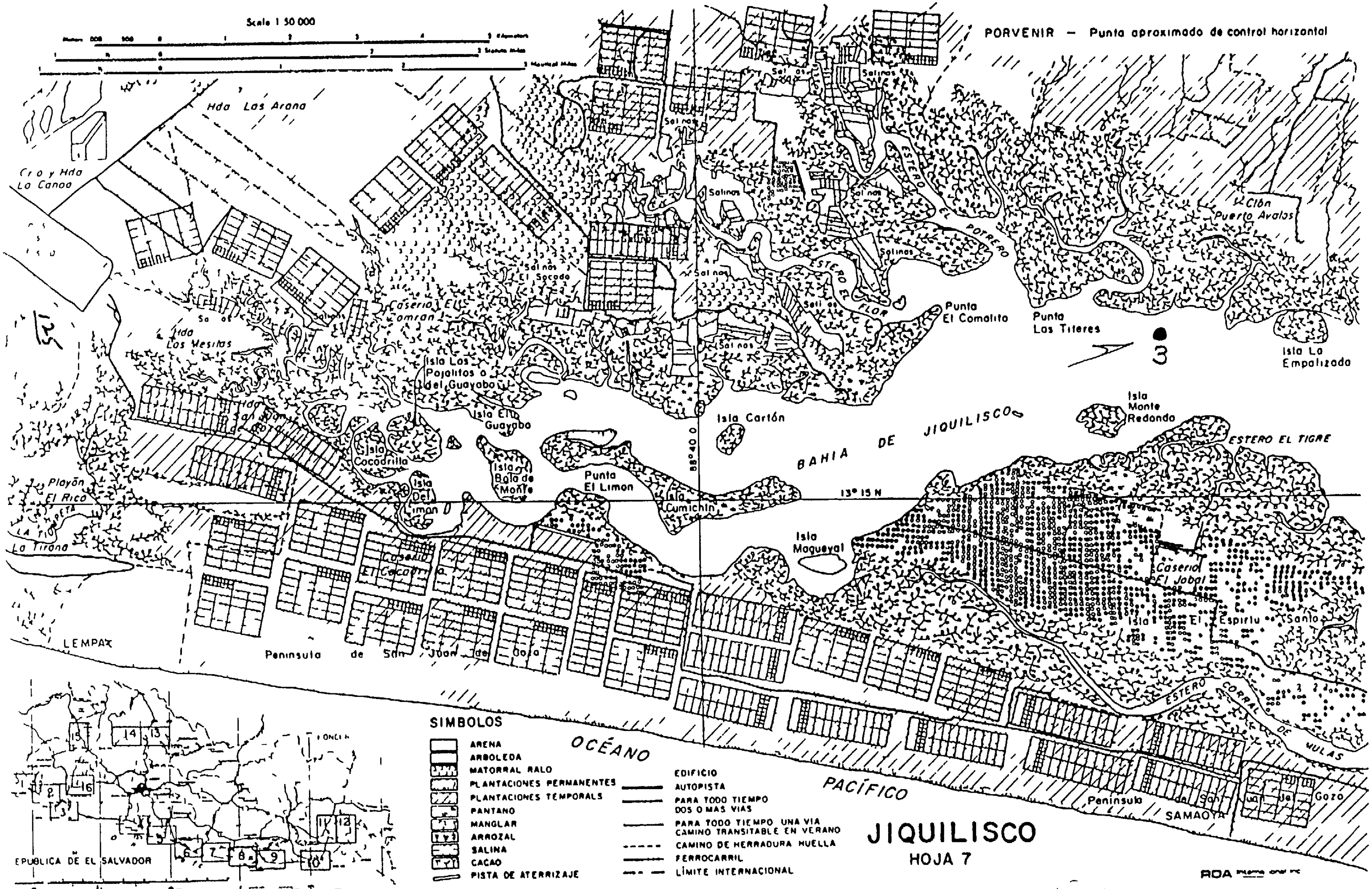

Fig 12 Larval sampling sites, Puerto El Triunfo

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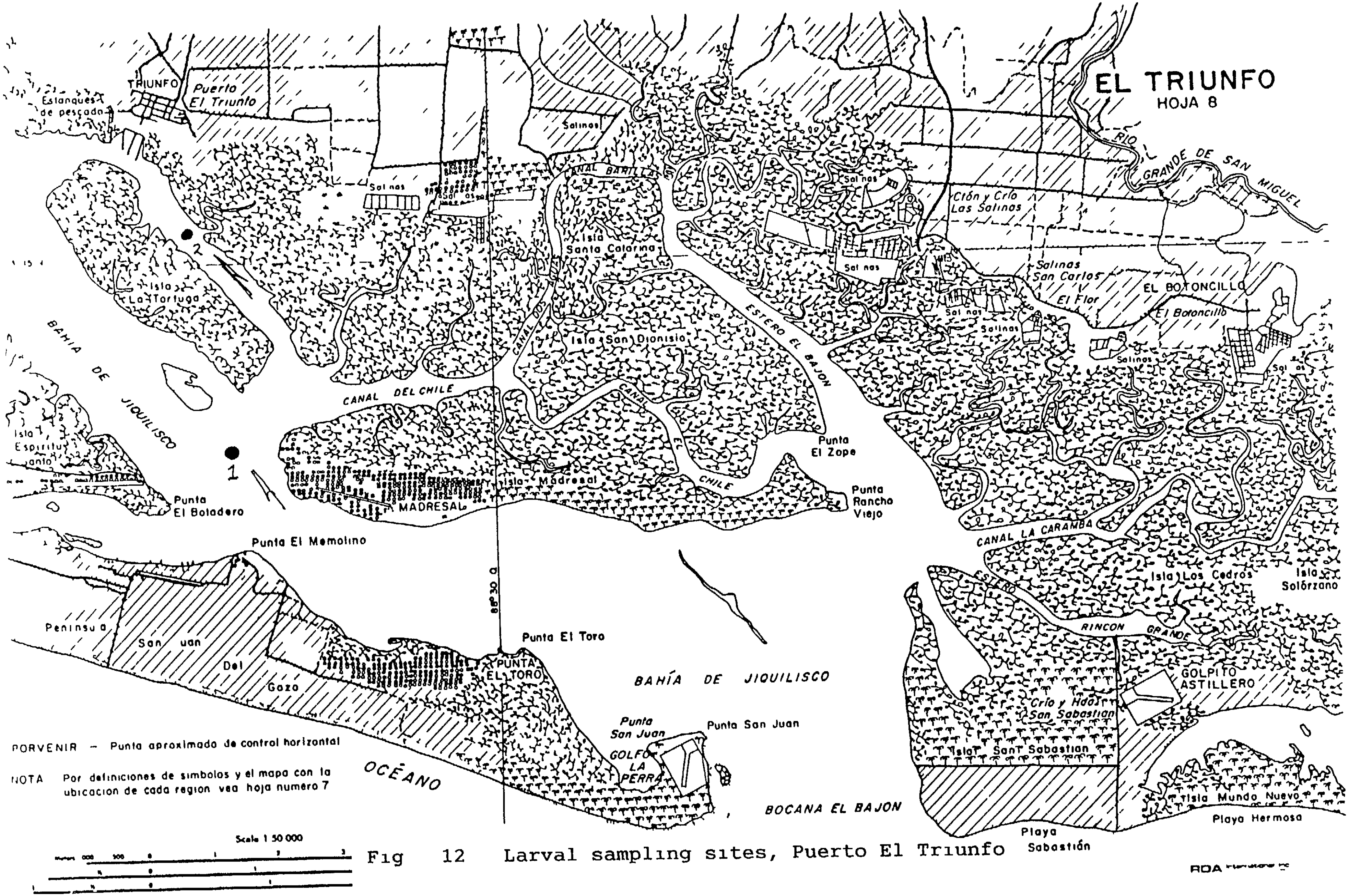

Fig 12 Larval sampling sites, Puerto El Triunfo

Fig 10. The long line held in place by stakes driven about 1 m into the bottom

Fig 11 A potential spat collection site along side the approach to the fishing pier, El Triunfo

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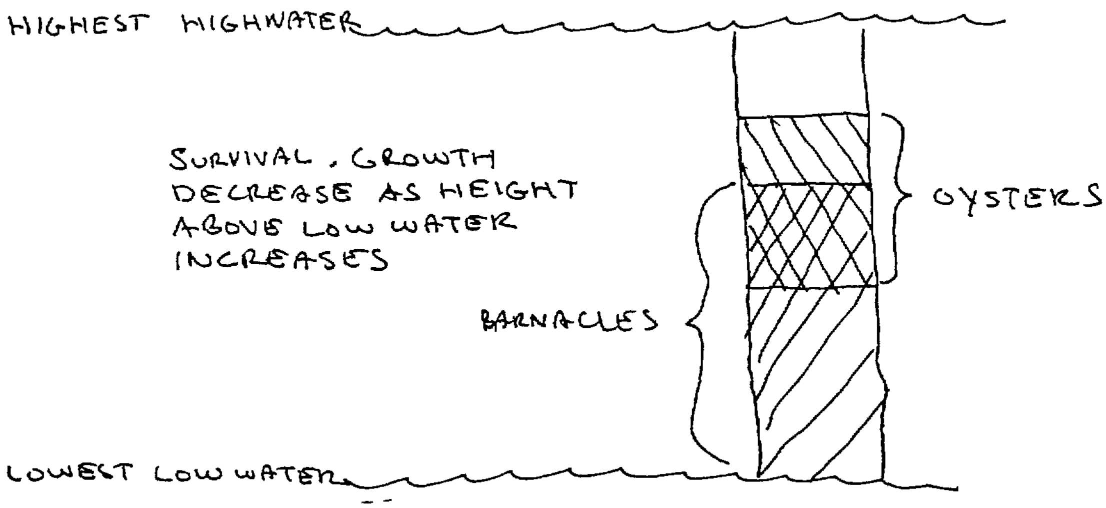

Fig 13 The relative zonation of barnacles and oysters in the estero

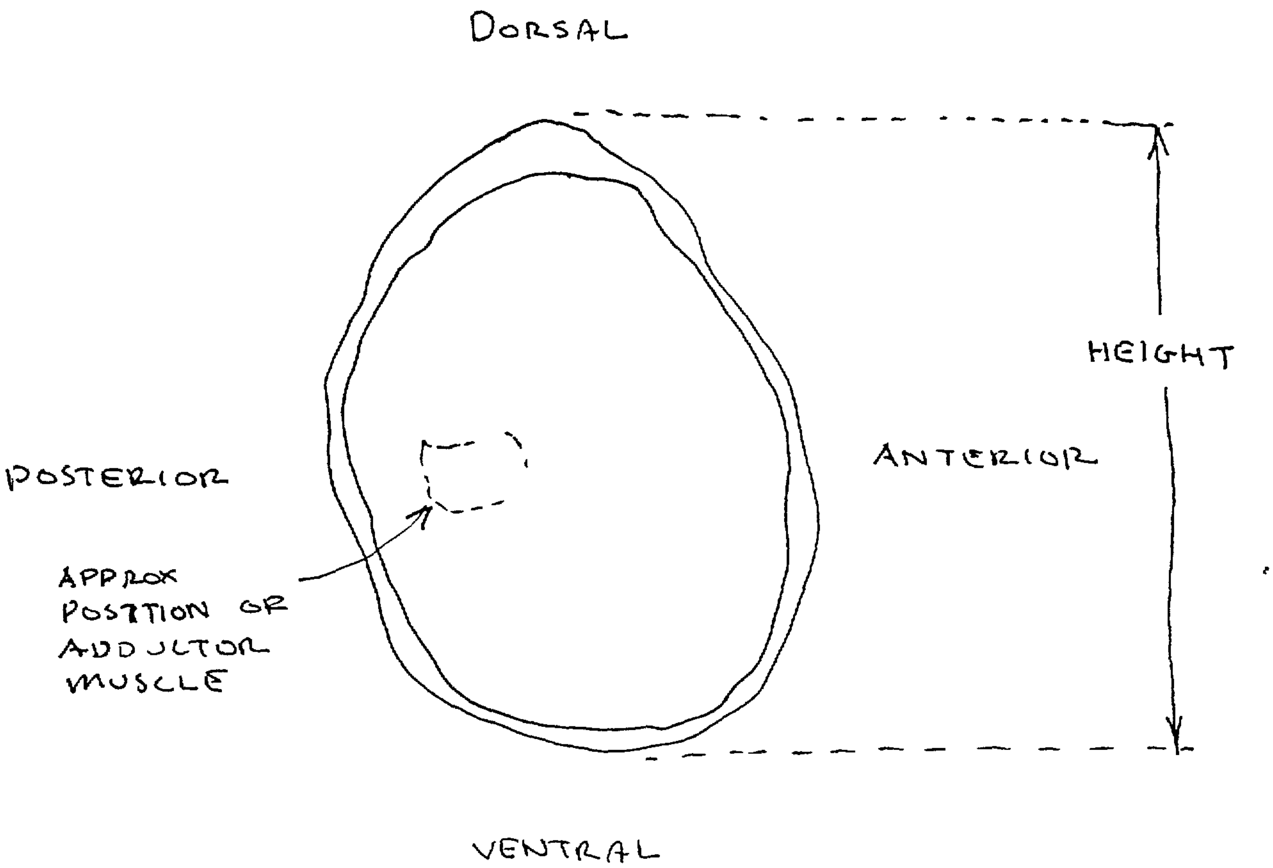

Fig 14 Shell measurement in relation to dorsal, ventral, anterior and posterior positions

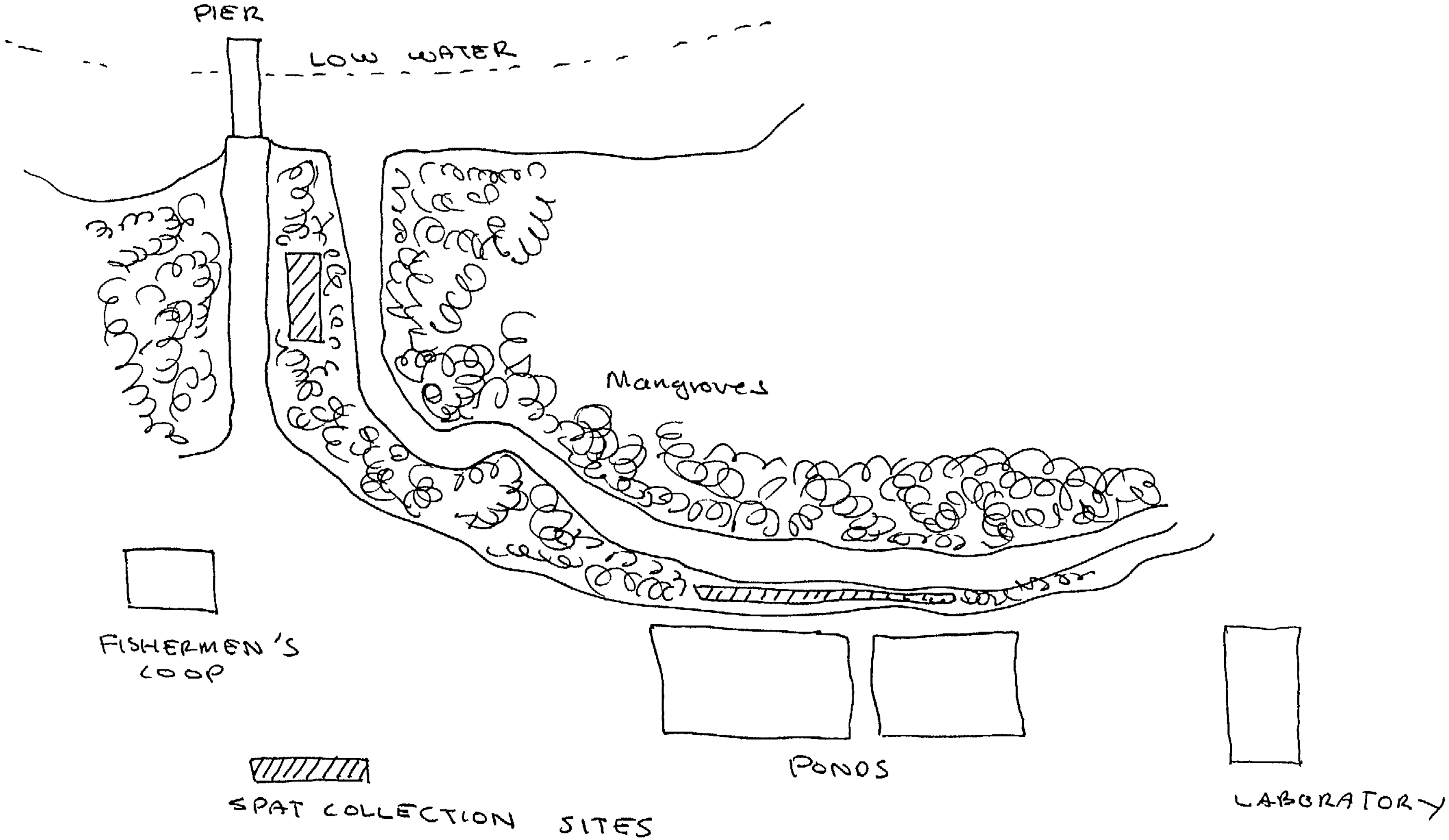

Fig 15 Possible spat collection sites at El Triunfo

APPENDIX 2a

EXAMPLE 17.5.3—A simple random sample of size 100 is taken in order to estimate some proportion (e.g., the proportion of males) whose value in the population is close to ½. Work out the standard error of the sample proportion p when the size of the population is (i) 200, (ii) 500, (iii) 1,000, (iv) 10,000, (v) 100,000. Note how little the standard error changes for N greater than 1,000.

EXAMPLE 17.5.4—Show that the coefficient of variation of the sample mean is the same as that of the estimated population total.

EXAMPLE 17.5.5—In simple random sampling for attributes, show that the standard error of p, for given N and n, is greatest when p is 50%, but that the coefficient of variation of p is largest when p is very small.

17.6—Size of sample. At an early stage in the design of a sample the question "How large a sample do I need?" must be considered. Although a precise answer may not be easy to find, for reasons that will appear, there is a rational method of attack on the problem.

Clearly, we want to avoid making the sample so small that the estimate is too inaccurate to be useful. Equally, we want to avoid taking a sample that is too large, in that the estimate is more accurate than we require. Consequently, the first step is to decide how large an error we can tolerate in the estimate. This demands careful thinking about the use to be made of the estimate and about the consequences of a sizeable error. The figure finally reached may be to some extent arbitrary, yet after some thought samplers often find themselves less hesitant about naming a figure than they expected to be.

The next step is to express the allowable error in terms of confidence limits. Suppose that L is the allowable error in the sample mean, and that we are willing to take a 5% chance that the error will exceed L. In other words, we want to be reasonably certain that the error will not exceed L. Remembering that the 95% confidence limits computed from a sample mean are

$$\bar{y} \pm \frac{2\sigma}{\sqrt{n}}$$

we may put

$$L = \frac{2\sigma}{\sqrt{n}}$$

This gives, for the required sample size,

$$n = \frac{4\sigma^2}{L^2}$$

In order to use this relation, we must have an estimate of the population standard deviation, σ. Often a good guess can be made from the results of previous samplings of this population or of other similar populations. For example, an experimental sample was taken in 1938 to estimate the yield per acre of wheat in certain districts of North Dakota (7). For a sample of 222 fields, the variance of the yield per acre from field to field was $s^2 = 90.3$ (in bushels²). How many fields are indicated if we

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APPENDIX 2b

wish to estimate the true mean yield within ± 1 bushel with a 5% risk that the error will exceed 1 bushel? Then

$$n = \frac{4\sigma^2}{L^2} = \frac{4(90.3)}{(1)} = 361 \text{ fields}$$

If this estimate were being used to plan a sample in some later year it would be regarded as tentative since the variance between fields might change from year to year.

In the absence of data from an earlier sample we can sometimes estimate σ from a knowledge of the range of variation in the population using the relation between the range and σ as described in section 2.2. If the range is known in a population of size greater than 500 we may take (range)/6 as a crude estimate of σ.

If the quantity to be estimated is a binomial proportion the allowable error L for 95% confidence probability is

$$L = 2\sqrt{\frac{pq}{n}}$$

The sample size required to attain a given limit of error L is therefore

$$n = \frac{4pq}{L^2}$$

In this formula p, q and L may be expressed either as proportions or as percentages provided that they are all expressed in the same units. The result necessitates an advance estimate of p. If p is likely to lie between 35% and 65%, the advance estimate can be quite rough since the product pq varies little for p lying between these limits. If however p is near zero or 100%, accurate determination of n requires a close guess about the value of p.

We have ignored the finite population correction in the formulas presented in this section. This is satisfactory for the majority of applications. If the computed value of n is found to be more than 10% of the population size N, a revised value n' which takes proper account of the correction is obtained from the relation

$$n' = \frac{n}{1 + \phi}$$

For example casual inspection of a batch of 480 seedlings indicates that about 15% are diseased. Suppose we wish to know the size of sample needed to determine p, the per cent diseased, to within ± 5% apart from a 1 in 20 chance. The formula gives

$$n = \frac{4(15)(85)}{(25)} = 204 \text{ seedlings}$$

At this point we might decide that it would be as quick to classify every

APPENDIX 2 C

A

seedling as to plan a sample that is a substantial part of the whole batch If we decide on sampling we make a revised estimate n, as

$$n = \frac{n}{1+\phi} = \frac{204}{1+\frac{204}{480}} = 143$$

The formulas presented in this section are appropriate to simple random sampling If some other sampling method is to be used, the general principles for the determination of n remain the same, but the formula for the confidence limits and hence the formula connecting L with n will change Formulas applicable to more complex methods of sampling can be obtained in books devoted to the subject, e g (2 4, 11) In practice, the formulas in this section are frequently used to provide a preliminary notion of the value of n even if simple random sampling is not intended to be used The values of n may be revised later if the proposed method of sampling is markedly different in precision from simple random sampling

When more than one variable is to be studied the value of n is first estimated separately for each of the most important variables If these values do not differ by much it may be feasible to use the largest of the n s If the n s differ greatly one method is to use the largest n, but to measure certain items on only a sub-sample of the original sample, e g on 200 sampling units out of 1 000 In other situations great disparity in the n s is an indication that the investigation must be split into two or more separate surveys

EXAMPLE 17 6 1—A simple random sample of houses is to be taken to estimate the percentage of houses that are unoccupied The estimate is desired to be correct to within ± 1%, with 95% confidence One advance estimate is that the percentage of unoccupied houses will be about 6% another is that it will be about 4% What sizes of sample are required on these two forecasts? What size would you recommend?

EXAMPLE 17 6 2—The total number of rats in the residential part of a large city is to be estimated with an error of not more than 20%, apart from a 1 in 20 chance In a previous survey the mean number of rats per city block was 9 and the sample standard deviation was 19 (the distribution is extremely skew) Show that a simple random sample of around 450 blocks should suffice

EXAMPLE 17 6 3—West (12) quotes the following data for 556 full time farms in Seneca County New York

	Mean	Standard Deviation Per Farm
Acres in corn	8 8	9 0
Acres in small grains	42 0	39 5
Acres in hay	27 9	26 9

If a coefficient of variation of up to 5% can be tolerated show that a random sample of about 240 farms is required to estimate the total acreage of each crop in the 556 farms with this degree of precision (Note that the finite population correction must be used) This example illustrates a result that has been reached by several different investigators with small farm populations such as counties a substantial part of the whole population must be sampled in order to obtain accurate estimates

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