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The Culture of Soft Corals (Order: Alcyonacea) for the Marine Aquarium Trade

Simon Ellis
Larry Sharron




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Introduction

About this Manual

There are currently many excellent books and articles about the biology and husbandry of soft corals as aquarium specimens. However, the literature on artificial propagation or culture of these animals, especially on a large scale, is scant or lacking. One report exists on large-scale farming of soft corals based on work performed at the Palau Mariculture Demonstration Center (Heslinga, 1995).

The purpose of this manual is to provide a step-by-step guide to soft coral farming for potential farmers throughout the tropical Indo-Pacific region. Biology and culture techniques are provided mainly for soft corals that have shown culture potential and therefore the text may not extensively cover all members of the soft coral group. This manual has an accompanying video titled “Farming Soft Corals for the Marine Aquarium Trade.” Additional copies of this manual or copies of the video can be obtained from:

Center for Tropical and Subtropical Aquaculture
The Oceanic Institute
41-202 Kalanianaole Highway
Waimanalo, HI 96795, USA
Tel. 808-259-7951, Fax. 808-259-8395
e-mail: clee@teligentmail.com

IMPORTANT NOTE: Before starting a coral cultivation project, it is critically important that you become familiar with local and international laws regarding the collection, cultivation and possession of live corals. Please contact your local government agencies to obtain information regarding current regulations in your area.

The Aquarium Industry

Over 1500 species of aquatic animals and plants are sold worldwide, of which approximately 80% can be farmed or cultured (Winfree, 1989). Total world retail value of the aquarium industry in 1995 was estimated at between 4 and 15 billion $U.S. (Corbin and Young, 1995) with plant and animal sales alone estimated at 900 million $U.S. (Bassleer, 1994). The United States, Japan and the member states of the European Union are currently the world’s largest importers and consumers of aquarium livestock.

Marine species make up only 9% of the volume of the aquarium pet trade but due to their high value represent 20% of livestock revenues (Bassleer, 1994). It is estimated that there are 10-20 million aquarium enthusiasts in the United States alone (Winfree, 1989). The keeping of marine aquaria, especially the so-called "**reef tanks**" which contain live corals, is a rapidly growing sector of the aquarium industry. This expansion is primarily attributed to the public's increased exposure and access to the tropical marine environment (Puterbaugh and Borneman, 1996). In addition, aquarium technology has improved greatly thereby improving the success rate for marine aquarists and allowing an increasing number of marine species to be kept in aquariums. However, while 80% of freshwater species marketed to the aquarium industry are cultured, just 1% of marine species sold are farm-raised. (Gomes, 1996).

Why culture soft corals?

Soft corals are currently cultured almost exclusively for the saltwater aquarium trade. However, the unique chemicals that are found within soft corals may prove to have medicinal value. Aquarium hobbyists have been propagating soft corals on a small-scale for some years now, but production has been limited.

The case for culturing soft corals on a large scale as opposed to collecting them from the wild is purely one of conservation versus economics. The high commercial value of marine tropical fish and invertebrates has led to a sometimes ruthless exploitation of reef animals in developed and developing countries alike. This fact, in conjunction with increasing concern over the negative effects of activities such as logging, dredging, oil drilling, human habitation and destructive fishing practices, has led to a trend of protective legislation for coral reefs worldwide. Many tropical nations with coral reefs in the Atlantic, and to an increasing extent in the Pacific, have now banned or restricted the collection of aquarium specimens from their waters (Heslinga, 1995) and are encouraging sustainable aquaculture of these animals (Young, 1997).

Aside from legislative restrictions, there has also been an increasing global awareness in recent years of the over-exploitation of coral reefs throughout the tropics. Many buyers of reef animals for aquaria are also avid divers, conservationists and naturalists who wish to protect the natural environment. This attitude of conservation has provided a market for cultured reef animals, while offering an economically viable alternative to wild specimen collection.

Classification and Biology of Soft Corals

For the purposes of this manual, soft corals will be classified as all members of the subclass Octocorallia which contains three orders: Helioporacea, Alcyonacea, and Pennatulacea. Although classified as soft corals, Helioporacea have a hard, calcareous skeleton and are not commonly cultured for the aquarium trade. Pennatulacea or sea pens are another type of soft corals that are not cultured for the aquarium trade. For these reasons, only members of the order Alcyonacea will be considered in this manual.

Classification

This section is not a full classification of the soft corals, but is designed to provide basic taxonomic details on commonly cultured Indo-Pacific species.

Phylum - Cnidaria
Class - Anthozoa
Subclass - Octocorallia
Order - Alcyonacea
Suborders - Stolonifera, Alcyoniina, Scleraxonia, Holaxonia
Commonly cultured families - Clavulariidae, Alcyoniidae, Nephtheidae, Xeniidae, Briareidae, Gorgoniidae
Commonly cultured genera
- Clavulariidae - *Clavularia*
- Alcyoniidae - *Sarcophyton*, *Lobophytum*, *Sinularia*, *Alcyonium*, *Cladiella*
- Nephtheidae - *Nephthea*, *Lemnalia*, *Lithophyton*
- Xeniidae - *Xenia*, *Cespitularia*, *Anthelia*
- Briareidae - *Briareum*
- Gorgoniidae - *Rhumphella*

** See Appendix B on keying soft corals to genera.*

Biology

Soft corals are colonies of small animals known as polypoid cnidarians (shortened to **polyps**). These polyps rarely exceed 5 mm in diameter and are arranged in soft, fleshy, irregularly shaped colonies of up to 1 meter in size (Barnes, 1980). Each polyp has 8 **tentacles** which are **pinnate** (Figure 1, page 5), an identifying feature of the subclass Octocorallia. Polyps are embedded together as a colony in a mass of tissue called the **coenenchyme** which is fed and maintained from the gut of the polyps and covered by a protective skin. The colony grows through **asexual budding** and consequent formation of coenenchyme around the new polyp. Special organs, called amebocytes, secrete **calcium carbonate spicules** (Figure 2, page 6) in the coenenchyme which give rigidity and support to the colony. Spicules differ in shape and size with each genus and are used to identify different soft coral species. A key to soft coral genera is included in this manual and can be found in Appendix B.

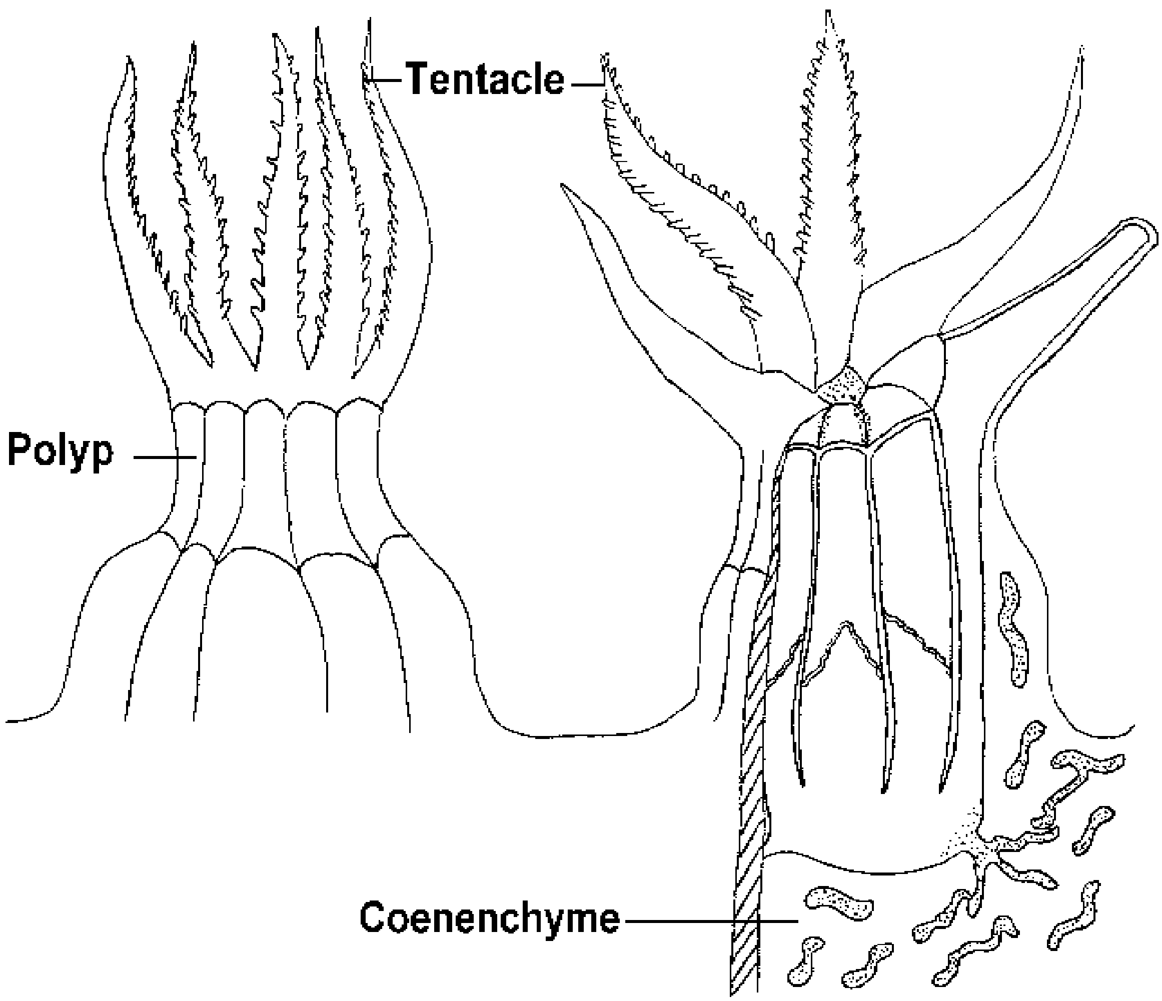

Figure 1. Schematic diagram of a soft coral polyp. (Adapted from Barnes, 1980)

Definitions

Spindle: A straight or curved elongated sclerite pointed at both ends.

Club: A sclerite that has a short stem leading to only one bulbous end.

Sclerite: A calcareous solid mineral element within the soft coral tissue.

Capstan: A sclerite like a short rod with two whorls of warts.

Dumb-bell: A sclerite with two warty heads connected by a narrow wartless bar.

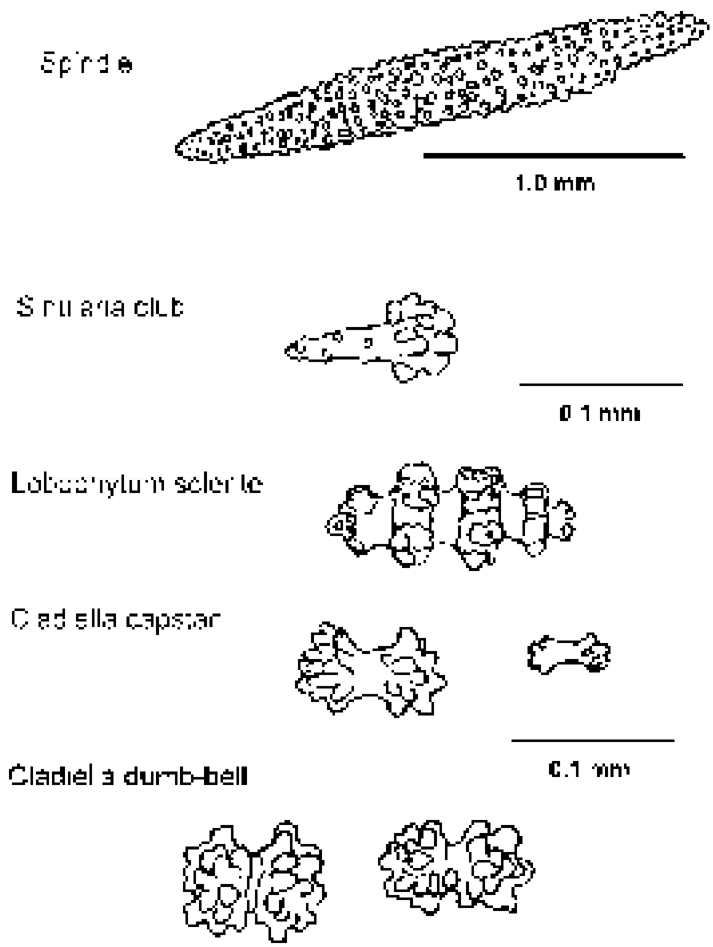

Figure 2. Various types of spicules found in soft coral. (Adapted from Gawel, 1994 Soft Coral Key)

Soft corals in the ocean feed by trapping prey with their tentacles. Stinging cells in the tentacles, called **nematocysts**, immobilize microscopic **plankton** and transfer it into the body cavity for digestion. However, many shallow water soft corals that are prominent on the reef also possess **symbiotic** algae known as zooxanthelle. These zooxanthelle live in the coenenchyme of the soft coral and use **photosynthesis** to produce sugars, **fatty acids** and **amino acids** that help to feed the colony. In return the zooxanthelle receive protection and nutrients such as nitrogen and carbon dioxide from the polyps. Soft corals with zooxanthelle tend to be a more popular choice as aquarium specimens because they generally do not require special feeding. Photosynthetic species of soft corals are characteristically yellow, brown or green in color. While not unattractive, these species pale in comparison to some of their non-photosynthetic counterparts that can be pink, orange or red but are harder to maintain in an aquarium setting.

Environmental Requirements

Many species of soft corals, especially those in the genera *Sarcophyton*, *Lobophytum*, *Sinularia*, and *Cladiella*, are very hardy and exhibit opportunistic behavior, often inhabiting marginal reef areas. They are also some of the first animals to re-colonize areas of reef affected by pollution or trauma (Wilkens and Birkholz, 1992). Environmental conditions on one reef flat inhabited by soft corals were reported by Wilkens and Birkholz (1992) to vary quite dramatically throughout the day. Temperature varied from 24.2 - 35.5 C, pH from 8.35 - 8.45, and light readings rose as high as 26,000 lux. Soft corals can protect themselves from adverse conditions by withdrawing the tentacles of the polyp into the body cavity and shrinking their body mass to one third of their extended size by expelling water. This may explain in some part their ability to withstand these fluctuating environmental conditions. The shrinking and expanding ability of soft corals coupled with their extended or retracted polyps gives these animals a constantly changing appearance and makes them dynamic additions to any marine aquarium.

Although soft corals often occur in marginal habitats it is important to have clean, unpolluted seawater at the farm site for optimum growth and survival. The water temperature should range from 25-30 C, salinity from 32-35 ppt and pH should range from 8.1 to 8.5. Because sunlight is important for sustaining zooxanthelle, water depth for the photosynthetic soft corals should not exceed 10-15 meters. Mild siltation or turbidity can be tolerated by some soft coral species but clear, tropical, oceanic water is preferable.

Factors in Favor of Soft Coral Farming

1. Soft corals occur in many different colors and shapes making them attractive additions to a marine aquarium. In addition, soft corals have an ability to constantly change form by expansion or deflation of the body and retraction or extension of their polyps. This lends a dynamic aspect to coral reef tanks.

2. Most commonly cultured soft corals are photosynthetic and do not have to be fed. They are easier to maintain in an aquarium setting than their non-photosynthetic counterparts that have to be fed. With correct lighting and minimal dissolved nutrients, soft corals can thrive for years in a home aquarium.

3. The hardiness displayed by many species of soft corals enhances their potential as farmed corals, because of their ability to survive handling stress during planting and shipping. In addition, these animals survive well in reef tanks making them excellent specimens for beginners and experts alike.

4. The primary form of reproduction in soft corals is cloning (asexual budding). Farmers have developed **fragmentation** techniques where a fragment of soft coral is removed from the parent colony to form a new colony.

5. Relatively fast healing times and high growth rates in cultured soft corals allow a harvest time of only 4-12 months. This can be a great benefit to farmers in allowing high inventory turnover and an early return on investments.

6. Soft corals have a high value per unit weight which makes shipping cost-effective from remote areas such as the Pacific Islands, where air freight is expensive and cargo space is often limited.

7. At the time of publication, very few of the genera in the order Alcyonacea are listed under the Convention on International Trade in Endangered Species (CITES). This eliminates the need to obtain certain permits and costly inspections involved with shipping other corals (see the section Harvesting and Shipping on page 50).

8. Soft coral farming does not need to be a full-time occupation. Once fragments are cut and successfully planted they require very little tending until harvest.

9. Capital start-up costs of soft coral farming are generally quite low (see section Marketing and Economics on page 57).

Physical Aspects of a Soft Coral Farm

The structure and organization of every soft coral farm will vary depending on factors such as location, local topography, weather and local economy. There are certain physical components common to every farm but the scale and complexity of these components will vary according to the parameters mentioned above. The three main physical components of each soft coral farm generally consist of (i) land-based holding facility, (ii) water transportation and (iii) ocean-based broodstock and grow-out sites.

Land-based Holding Facility

It should be stated from the outset that coral farming is going to be most successful if done in sheltered ocean sites. However, a land-based facility is recommended for the farm to function efficiently. It is possible to have a totally land-based facility for coral farming but this would be capital intensive and expansion would be limited to the tank capacity or land area of the farm. In addition there would be substantial extra costs associated with pumping, land leases and security measures.

A typical land-based facility is used primarily for holding corals prior to shipping. Corals should be brought into the holding facility up to one week prior to shipping. This allows animals time to recover after harvest and gives the farmer time to inspect the animals for signs of weakness or disease. While the holding period of one week is not entirely necessary it will ensure a higher survival rate during shipping and therefore should be considered a standard business practice.

In many cases a farmer can operate without a land-based facility. This is generally the case for farmers who sell their product directly to a local wholesaler for shipping (see section Harvesting and Shipping on page 50). A farm that packs and ships its own corals will need at the very least a covered area for packing and access to a clean ocean site adjacent to the packing area where harvested corals can be stockpiled prior to packing.

Site Selection for the Holding Facility

Criteria to consider for choosing a suitable land-based facility are as follows:

1. Seawater: The site should be close to clean, unpolluted seawater and away from point sources of pollution such as garbage dumps, sewage outfalls, or dredging sites. Excessive freshwater runoff, such as river mouths, should also be avoided. Filters can be used to recirculate the water but most Indo-Pacific islands have many suitable coastal areas where clean seawater is accessible.

2. Utilities: While it is convenient to be located in an area with municipal utilities such as electric power and freshwater, it is feasible to operate a holding facility in remote locations using generators or alternative energy sources, such as solar power, and to rely on rainwater catchment.

3. Transport: Situating the holding facility close to the airport is preferable but is not always possible. When choosing a site, the time taken to get from the facility to the airport must be carefully considered and included in the shipping or "box" time (see section Harvesting and Shipping on page 50).

4. Land topography: The facility should be built on land that is close to the seawater source but is high enough to withstand flooding during heavy rains.

5. Security: Soft corals themselves rarely have any local value to an intruder, but the facility may house valuable equipment such as pumps, tanks, dive equipment and shipping materials. Sites in almost all Pacific island nations will need to be properly secured with either a chain link fence, wall or security guard.

Structure of the Holding Facility

The holding facility should have a covered structure where packing materials and other items can be stored out of the rain. It is also recommended to have space in the covered area for packing to take place. A simple carport-type structure with open sides is often adequate to provide shelter from the rain (Figure 3). Other structures, such as used shipping containers, can be used as a cheap alternative to constructing a building.

Figure 3. Covered holding facility at Belau Aquaculture in Palau. (Eileen Ellis)

Corals held in the land-based facility should not be left in direct sunlight as this can overheat the water and stress the animals. Extremely bright light can also have an adverse effect on soft corals brought from the ocean (Heslinga, 1995). Tanks containing corals should be placed under the shelter of the roof structure (providing it has open sides) or under a 50% light-occluding shade cloth.

Pumps and Plumbing

Pumps

Assuming a suitable coastal site adjacent to clean seawater has been secured, pumping seawater should be relatively easy. The volume of seawater needed for a facility should be at least 3 times the total tank volume per day, though a target volume of 5 times the total facility tank volume per day is preferable. The type of pump selected will have some bearing on both peace of mind and facility operating costs. It is important to size the pump to the volume requirements of the facility. A pump that is too big for the facility's needs will simply use electricity unnecessarily and a pump that is too small will not supply the water volume required. It is important to consider site expansion when purchasing pumps as the facility volume may quickly outgrow the pump's capacity. Most catalogs publish "pump curves" which display volume of water output against head pressure, allowing selection of the most appropriate pump. Pump efficiency can also be increased in other ways. Three-phase pumps and pumps running on 220-240V tend to use less electricity than those using single phase, 120V power supply.

Note: Head pressure is the amount of pressure that a pump must work against while operating. This includes both the vertical height that the water must be lifted and the friction caused by water moving through the pipes.

Because water flow to the corals in the holding facility is important, having a reliable flow of seawater is essential. Corals placed in shaded areas are able to withstand several hours without water exchange. However, to avoid long periods without water flow, an identical "backup" pump should be on hand to quickly replace the pump currently in use should it break down. A more reliable method is to operate two pumps in parallel. In a parallel system the intake line splits and water passes through two pumps placed side-by-side before rejoining a single pipe again. Each pump should be able to supply half the required volume. In this manner, if one pump breaks, the remaining working pump will continue to supply a diminished volume of seawater. A backup pump for parallel pump arrays is still recommended.

As mentioned previously, the type of pump required will depend on many factors such as volume of water needed and head pressure. Pumps must be able to operate continuously and withstand the corrosive effects of saltwater. Farmers must choose between submersible and non-submersible pumps. Submersible pumps are placed in the water at the end of the intake line and cost less to run than non-submersible pumps. However, submersible pumps for use in seawater must be stainless steel or titanium and tend to be more expensive. They can also be difficult to service or replace.

A popular pump in many aquaculture facilities is a centrifugal, self priming swimming pool pump. These reasonably priced, non-submersible pumps are sized to accommodate many different head pressures and water volumes and are quite durable because the seawater never comes in contact with any part of the motor, except the corrosion-resistant impeller. The self-priming feature on these pumps also adds peace of mind as the pump will automatically start pumping water again after power outages. Pumps can be purchased from many vendors such as supply sources 1, 2, 3, 4, and 5 in Appendix A.

Pipe and Plumbing

Note: Schedule 40 PVC pipe and fittings are suitable for all aquaculture facilities. Assembly is easy, the pipe is nontoxic, and pipe and fittings are usually locally available*. If any other type of plastic pipe is to be used, it should be nontoxic and safe for marine life.

** Supply sources 1, 2, 3 and 4 in Appendix A.*

Water Inflow

One of the most critical parts of the land-based facility plumbing is the intake pipe. This will be subjected to any wave action or currents in the area and must therefore be secured to the ground. The method of attachment will be determined by the level of wave action or strength of current at the site. In some cases the intake pipe must be covered with concrete or weighted down to eliminate any movement due to wave action. Schedule 40 PVC pipe, or in certain circumstances, the more flexible black HDPE pipe, can be used for the intake.

The intake pipe should be fitted with a **foot valve** (also called a check-valve) which will assist with priming the pump in the event of a loss of suction. The foot valve need not be located at the end of the pipe but should be covered by seawater at low tide. An advantage to placing the foot valve at the end of the pipe is that it is easy to clean or replace if it becomes clogged or fouled.

A strainer should be placed at the end of the intake pipe. This is a box or piece of pipe that has a mesh over it to prevent small fish and debris from entering the pipe, and consequently, the foot valve and pump. Commercially available strainers can be purchased* or homemade versions can easily be constructed from available materials. The strainer should have a large enough surface area to allow for the required water flow to the tanks and should be inspected and cleaned regularly. The end of the intake pipe and strainer should be supported far enough off the bottom so that sand, mud and small rocks are not constantly being sucked into the pipe with the intake water.
* *Supply sources 1 and 2 in Appendix A.*

Water Drainage

Each tank should be equipped with a bulkhead drain* and a standpipe which leads into a drain pipe or trough. A standpipe is a short piece of pipe that slots into the bulkhead and determines the water level in the tank. Drainage from the tank can be through a drain pipe or into a drainage trough. In sandy areas water is sometimes allowed to drain away into a hole in the ground. In muddy or easily corroded areas, troughs may be more appropriate. Troughs can be made out of concrete and are often cheaper to construct than buying drainage pipe.
* *Supply sources 1, 2, 3 and 4 in Appendix A.*

Note: The point of water drainage back into the ocean should not be near the end of the intake pipe as this may lead to recycling of dirty water through the tanks.

Useful plumbing hints:

1. It is important to use the correct diameter pipe when plumbing any aquaculture facility. Using small diameter pipe increases head pressure caused by friction and increases pumping costs in the long-run. If there is any doubt about the correct pipe size, a larger diameter should be used. The life span of schedule 40 PVC in the tropics is in excess of 10 years making the long-term investment in the facility minimal. A book titled “The Aquaculture Desk Reference” (Creswell,1992) can help pinpoint pipe and pump sizes for required flow rates.

2. A union should be placed on each side of every pump in use. In the event of a failure the broken pump can be easily replaced by unscrewing the unions and installing the new pump.

3. Use of elbows and bends in the pipe should be reduced wherever possible as this increases head pressure.

4. Ball valves should be placed at the junction of every tank or row of tanks. If there is a problem with the plumbing to one set of tanks then the water flow can be turned off to that section of the facility without affecting the other areas.

5. Pipe on the suction side (between the pump and the ocean) of the pump should be regularly checked for leaks. Small holes cause air to be forced into the water under pressure, a process called super-saturation. Tiny bubbles are visible in the water entering into the tank when this is happening. Super-saturated water can be toxic to many species of fish and invertebrates.

6. Pure silicone caulk* should be applied to any threaded PVC fittings prior to threading, especially on the suction side of the pump.

** Supply sources 1 and 2 in Appendix A.*

7. Loc-Line return jets* should be used to supply water to small tanks. These versatile valves can also control flow direction.

** Supply sources 1 and 6 in Appendix A.*

Water Storage Sump

At some facilities water cannot be pumped all the time. Examples of this are areas with a high tidal variation, freshwater runoff during heavy rains, or frequent power outages. In these instances a water storage sump can be used to supply the holding tanks while the pump is off. A water storage sump is a large nontoxic tank or container that is elevated above the holding area and feeds water via gravity into the holding tanks. The water storage sump fills while the pump is running and then drains to the holding tanks while the pump is turned off. The sump should be large enough to supply water for the time the pump is off.

Example: A facility has 2000 L of holding tank capacity but can only pump water for 12 hours per day because of a high tidal variation. To obtain the minimum 3 water exchanges per day the storage sump must be able to supply 1.5 exchanges during the 12 hours that the pump is switched off. Therefore (1.5 x 2000-L) 3000 L of storage capacity are required in the sump.

There are instances where a water storage sump can also save money. Sumps can be equipped with float switches that activate the pump when water in the storage tank gets low and turn the pump off when the tank is full. With such a system, the pump operates at full flow for short periods of time rather than running continuously. As pumps are most efficient when operating at full flow this will represent a cost saving in electricity in the long-term. Even at facilities where 24-hour pumping is usually possible, having a sump can act as a backup in case of pump or power failure. This is beneficial at sites where large quantities of inventory are being held which cannot be readily returned to the ocean.

Holding Tanks

Figure 4. Coconut holding tank with vinyl liner at ICLARM's CAC in the Solomon Islands. (Simon Ellis)

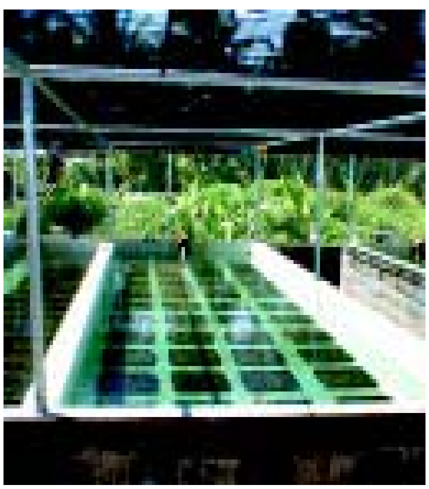

Figure 5. Rectangular concrete raceway at the RRE Wau Island mariculture farm in Majuro, RMI. (Simon Ellis)

Any tank that offers a large surface area and is made of a nontoxic material is adequate for housing soft corals in the holding facility (Figures 4 and 5). However, the preferred type of tank for holding corals is the water table style (Figure 6, page 16). Water tables are usually less than 30 cm deep and are elevated so the water surface is the height of a standard table.

Water tables can be made in a variety of ways. A popular method is to use plywood that has been coated with fiberglass or epoxy resin to prevent leakage at the seams. It is important to ensure that the coating is nontoxic and that it covers the entire surface of the plywood. Supply sources 1 and 2 in Appendix A offer nontoxic epoxy coatings that are ideal for applications such as this. Partitioning the tanks in some way makes it easy for different species or cohorts to be separated and inventoried. Water flows from the inlet to the drain through holes drilled in the partition walls. One disadvantage of large water tables is that any introduced disease may spread rapidly throughout the entire inventory in the tank.

An alternative to using plywood is placing individual plastic or fiberglass tubs or trays into a pre-made wooden frame. While this has the same effect as using partitioned wooden water tables each individual tank has its own inlet pipe and drain. While this is more costly, disease cannot spread easily between tanks.

Figure 6. Water tables at CRRF in Palau. (Eileen Ellis)

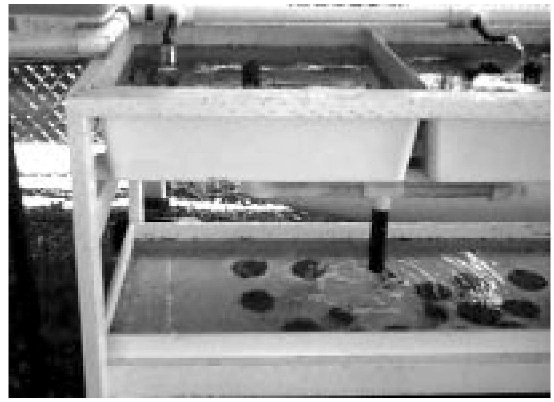

Figure 7. Bi-level water table at Belau Aquaculture in Palau. (Larry Sharron)

Advantages of using water tables for holding soft corals are as follows:

1. The shallow water provides a high surface area but low tank volume, allowing a higher water turnover per tank for the equivalent surface area.

2. Water tables are a convenient height for working.

3. Specimens in water tables are easily observed for signs of disease or stress.

4. Putting a drainage trough under the water tables can double the facility's tank capacity (Figure 7, above). A drainage trough is nothing more than another plywood tank into which the water drains from the table above. The drainage trough can act as a holding tank for species that can handle low light intensity or for short term holding of animals prior to shipping.

Note: Water tables should be constructed from 18 mm plywood (minimum) and the sides secured using brass or stainless steel screws. Thin plywood is hard to screw together properly and steel screws will eventually rust. Using more robust materials will ensure a longer life span for the water table and help to prevent an unfortunate loss of inventory if the table sides separate unexpectedly.

Water Transportation

Regardless of the size or scale of an ocean-based farm it will almost certainly be necessary to have some form of water transportation. This may take the form of a raft, canoe or powered boat. The decision on the type of transport will be dependent on the location and size of each farm.

Figure 8. Outrigger canoe used for tending offshore farms at ICLARM CAC in the Solomon Islands. (Simon Ellis)

Raft or Canoe

These hand powered vessels should only be used for farms close to the farmer's house (Figure 8). In this case the vessel would be used for moving farm materials around and bringing harvested corals ashore. Farmers who have a small operation, such as growing 1-2 species of soft coral to sell to a locally based wholesaler, should be able to adequately run their operation in this manner.

Figure 9. Powered working boat used for collecting soft corals in Kosrae, FSM. (Eileen Ellis)

Powered Boat

Using a fiberglass or wooden boat with an engine is going to be the more common choice for most large-scale coral farmers (Figure 9). There are a number of reasons for this. Firstly, it is likely that most of the sites adjacent to a farmer's house will be unsuitable for coral farming and travel to remote sites will be necessary. Secondly, even if the farm site adjacent to the farmer's house is adequate, travel to different areas will be necessary to collect broodstock or take cuttings. Farm sites are often placed adjacent to areas of abundant, suitable broodstock as a matter of convenience. Because most areas tend to be abundant in only a few species of soft corals, a farmer who cultures more than one species of soft corals may have to travel large distances between different sites.

A work boat for coral farming should have the following attributes:

1. Large work and storage area. The boat must be capable of carrying diving equipment, buckets of gravel, basins of water, ice chests and other equipment needed for farming. In addition there must be room for to move around.

2. Cover. A cover to provide protection from rain and sun to workers, equipment and corals under transport is a useful, but nonessential, addition to the boat.

3. Storage. A lockable storage area on board the boat is useful for holding equipment that does not need to be removed daily.

4. Live well. While transport of corals can be done using ice chests or basins, a live well can be beneficial for transport over long distances.

Ocean-based Farms

Diving Equipment

It is likely that a serious coral farmer will need some form of underwater breathing equipment such as **SCUBA** or **hookah** (supply sources 8 and 9 in Appendix A). Exceptions to this may be small, 1 or 2 species farms that are located in shallow water. While the purchase of diving equipment represents a relatively high capital investment, there are many advantages to using SCUBA or hookah equipment:

1. Freedom to use sites deeper than 3 m that cannot be worked on by snorkeling.

2. The ability to dive to greater depths when collecting broodstock or taking cuttings will result in a more diverse inventory.

3. Work time is not interrupted by constantly coming to the surface for air, even in very shallow water.

Site Selection

The selection of the correct site for an ocean farm is critical. What makes a good site for a farmer will vary greatly with each location and it is usually a combination of cultural, legal, security and biological factors that determine which sites are used. This section can only give guidelines as to what a good site would be. A prospective farmer must weigh all the factors carefully before choosing.

Cultural and Legal Aspects

The cultural and legal aspects of site selection should be researched first. In some areas of the Indo-Pacific, lagoon areas are similar to land and are owned either by individuals, communities or villages. Access to that area is by permission only. In other areas the ocean is considered public domain, though a permit may still be needed to lease the sea floor. In some cases, cultural and legal issues can also play against each other. An example of this is where it may be permissible by law to place a farm close to a house located on the shore but culturally the land owner considers the water around the house to be family domain. It is therefore important to ensure the support of the local community or coastal families where the farm is to be situated as well as to apply for necessary permits or clearance to farm there.

Note: Local marine resource departments should be contacted to determine what, if any, permits are required for a sea bed lease in each individual country or state.

A second cultural factor that may influence site selection is security. Even if permits and support from local communities have been obtained there is still a risk that the farm will be disturbed. While the soft corals on the farm themselves may have no apparent value, the nursery trays or other submerged materials used to construct the farm may be of some use to passing fishermen or other water users. For this reason, or simply because the farm exists, an unguarded site may be disturbed or looted. Site security must therefore be considered as an influencing factor in the location of the soft coral farm. If security is a problem, then the only site choices available may be within view of the farmer's house or the house of a relative, employee or friend.

Biological Aspects of Site Selection

Although many species of soft corals naturally prefer areas with high water exchange, this may not be the ideal site to farm corals, especially in the early stages of attachment (see section Planting and Attachment on page 29). During attachment, corals need to be protected from turbulence. Sites should be chosen primarily for low turbulence caused either by wave action or tidal currents. Sites that have a high current flow can be used effectively for soft coral farming but care must be taken to protect the corals during the attachment phase (see section Constructing the Farm on page 21).

Depth is another important factor to consider in site selection. The shallower the site, the easier it will be to work on. However, very shallow farms run the risk of being exposed at low tide, flooded with freshwater during heavy rains or affected by wave action during windy periods. Sheltered, shallow coves with land on three sides have proven to be ideal for soft coral farming. In the absence of such sites, the alternative is to place the farm at a greater depth. Farms placed at a depth of 4-6 m generally avoid the problems stated above while allowing divers to work for long periods of time on SCUBA or hookah gear using very little air and without risk of decompression sickness. Flat areas of sand or coral rubble generally make good farm sites. Areas with high soft coral growth do not necessarily make good farm sites, but having a source of broodstock close by can be to the farmer's advantage as broodstock or cuttings do not have to be transported large distances.

Note: It is important that the farm site be chosen in an environmentally responsible manner. The entire concept behind coral farming is to help preserve natural reef habitats. Therefore, farms should be set up on barren areas such as sand or dead coral rubble, and trays or aggregate should never be placed over living reef areas.

Substrates

Soft corals are planted by burying the severed end of the fragment into a crushed rock substrate or aggregate to which the cuttings attach. The optimum size for this aggregate is 7-20 mm. What aggregate is used will depend entirely on what is readily available in each area. Many Pacific islands have large deposits of basalt which has proven to be an excellent substrate (Figure 10). The types of aggregates available in each area can be easily determined by a call to local quarries or any large construction firm. Aggregates used should be free of oils, tar or other toxic materials associated with road building or construction and should not have been used for any other purpose prior to purchase.

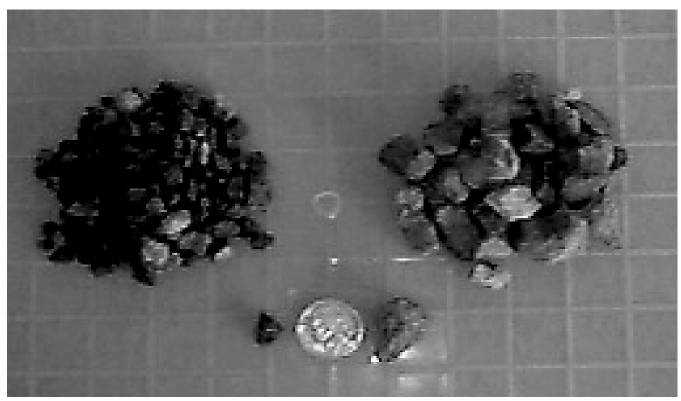

Figure 10. Basalt aggregate used for attachment. (Larry Sharron)

Note: Coral rubble is often readily available and is one of the best attachment substrates. However, it should be avoided if possible as it gives the cultured product the appearance of a wild-collected animal. This can give rise to questions from inspection authorities in countries where the corals are shipped.

In some cases soft coral fragments are glued, wedged or otherwise attached to a larger piece of rock or other material. Such materials include basalt, pumice, plastic or concrete block chips (Figure 11). The goal is to attach the coral to an object that will be aesthetically pleasing to the buyer, does not weigh too much for shipping and demonstrates that the coral was cultured rather than wild collected. Pumice is an excellent rock for this purpose. It is light, nontoxic, unobtrusive in the aquarium and does not occur widely in the marine environment.

Figure 11.Concrete, basalt and pumice recruitment substrates. (Larry Sharron)

Constructing the Farm

After the substrate is chosen it must now be placed on the sea floor in a way that minimizes disturbance to the cuttings by waves, tidal currents or fish activity (Figures 12 and 13, below). A boundary of some description is usually put down to hold the aggregate in place, although this is not always necessary. This may be nothing more than a rectangle of rocks or dead coral heads into which the aggregate is placed. Plastic trays such as horticultural nursery trays, old bakers trays or milk

Figure 12. Ocean based soft coral farm in Koror State, Palau. (Larry Sharron)

Figure 13. Ocean based soft coral farm in Koror State, Palau. (Eileen Ellis)

cartons make excellent planters for soft coral cuttings (Figures 14 and 15, below) as do old metal barrels cut into segments. Rectangular or square frames made out of 5 cm diameter PVC pipe can also be used as a boundary for the aggregate. Another alternative is to use cheap laundry baskets or to construct wire cages. As with the choice of aggregates it is important to look at what materials are cheap and available locally.

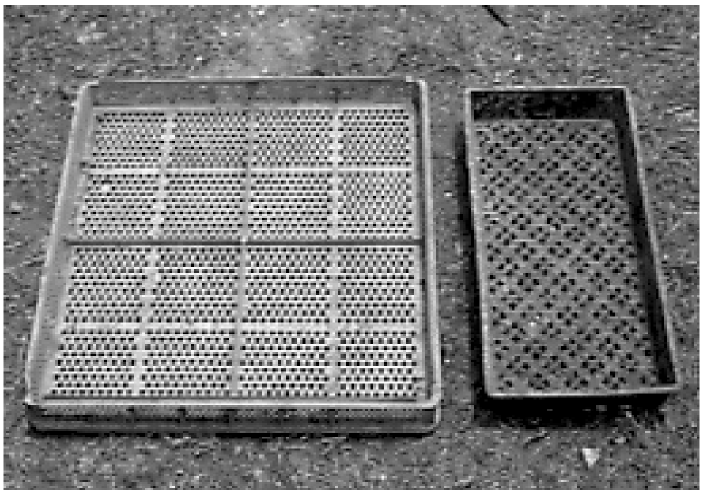

Figure 14. Nursery trays used for planting. (Larry Sharron)

Figure 15. Planting basket filled with gravel. (Simon Ellis)

Exclusion type structures such as cages can be especially useful in the early stages of planting as they can prevent unattached cuttings from being washed away and also prevent unwanted fish activity around the cuttings before they attach. Some farmers employ a two-tier culture method where exclusion structures are used until the cuttings are attached. At this point attached corals can be moved to more open farm structures such as open nursery trays. This method is particularly effective in high current areas.

Layout of trays, PVC frames or other boundaries is also an important aspect of constructing the ocean farm. Generally the trays are arranged in a square or rectangle with a space in the middle that can also be filled with aggregate (Figure 16, below). Broodstock are often planted in the middle area and cuttings are planted in the trays. The width of the middle section of the farm should not exceed 2 m because cuttings in the trays may be disrupted while the farmer is working in the central area.

Once the farm boundaries are laid out in the desired manner, they are then filled with approximately 3-5 cm of aggregate followed by a thin layer of fine sand. The sand helps to cauterize the cut part of the corals, makes planting easier and also makes the farm less visible from the surface.

Note: Farms at remote sites that use trays, baskets or PVC pipe may be looted if they are not regularly checked.

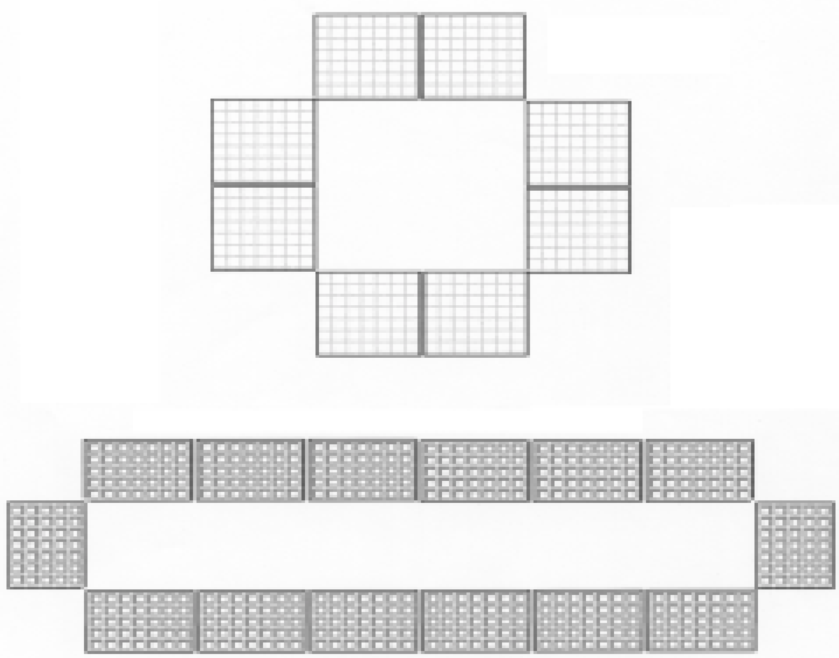

Figure 16. Schematic diagram showing possible farm configurations using trays as a boundary.

Biological Aspects of Soft Coral Farming

Listed below are general descriptions of four phases of soft coral farming: broodstock collection, fragmentation, healing, and planting and attachment. These processes vary slightly depending on the type of soft coral being cultured. Detailed descriptions of these processes are included in the section Commonly Farmed Soft Corals on page 35.

Broodstock Collection and Transportation

The term broodstock refers to the parent colony from which fragments are cut to form the new colony. In order to minimize damage to the reef ecology, cutting from broodstock should be carried out in a manner which ensures that the parent colony will survive and regenerate. In this way a farm can operate from the continued cutting of existing broodstock without having to constantly collect new specimens from the reef. Broodstock corals will heal and regenerate to their original size in 6-12 months if they are cut and treated properly.

Equipment

- Masonry chisel (local)
- Hammer (local)
- Razor knife (local)
- Collection bag or basket (1*, 4, 8 or 14)
- Boat (optional)
- Clear polyethylene bags approximately 30 x 50 cm (local or 10, 11 or 14)
- Mask, fins, snorkel (8)
- SCUBA or Hookah equipment (optional) (8 or 9)
- Large ice chests, tubs or boat live well (local)

** See Appendix A for supply sources.*

While different species and genera of soft corals have characteristics that alter their suitability for farming, there is also a certain amount of interspecific variability. For this reason, broodstock should be collected for attributes that would be desirable in the fragmented colonies. An example of this would be color. Many soft corals of the same species will have different colors depending on the strain of zooxanthelle they possess. Colonies that have attractive colors such as bright green and yellow should be chosen over brown or beige colonies. Some species also have large or brightly colored polyps which add to their marketability. Other factors to consider in broodstock selection include disease and deformity. Specimens that are free from evident disease or recent predation should be selected in preference to colonies that are showing scarring or unsightly mottling. Wherever possible, it is preferable to locate the farm in close proximity to an area of abundant broodstock. If this is not possible, the farmers will need to transport broodstock to a more convenient location such as shallower water or an area adjacent to the farm. Broodstock survival will be highest if the whole colony is transported from the reef although in some cases this may not be possible. When collecting more than one species of broodstock in the same trip the hardiest species should be collected first.

Figure 17. Tools for collecting broodstock. (Eileen Ellis)

Soft corals are collected by chipping the colony from the rocky substrate using a masonry chisel and hammer (Figure 17). A piece of the rock to which the base of the colony is attached should be removed. If possible, the colony should not be cut at the base as this may cause stress to the coral and provide an area for infection. Collected colonies should be placed in polyethylene bags filled with seawater (Figure 18, page 28). The bags should be half filled with soft corals and half with seawater. Bags are then tied at the neck and placed in a collection bag or basket and left submerged in the water until all the other work is complete. Using polyethylene bags has the added advantage of providing a seawater buffer for the collected corals, thereby preventing unnecessary bruising or abrasion.

Note: It is important to collect soft corals in an environmentally responsible manner. Do not remove all of one particular type of colony from an area and minimize damage to the reef when collecting. Collecting from coral rubble areas is fast and environmentally safe. Soft coral colonies in these areas tend to be attached to small pieces of dead coral making collection swift and simple.

Once colonies are removed from the water they should be handled in one of two ways depending on the length of the journey to the farm site. For journeys of 20-30 minutes collected corals can be left in the polyethylene bags and placed in a tub, live well or ice chest filled with seawater. For trips of greater than 30 minutes corals should be removed from the bags and placed in tubs, ice chests or a live well filled with fresh seawater. Water should be changed in the transport container at least every 30 minutes during the journey. One of the greatest threats to broodstock health during transportation is rapidly elevated temperature in the transfer container. Therefore it is important to keep containers out of direct sunlight and to ensure that they are filled immediately prior to adding the collected corals. Care should be taken to ensure that colonies are not crowded on top of each other in the transport container. In addition, leaving soft corals out of the water for long periods of time may cause dehydration, sunburn and internal damage. At the transfer location environmental conditions should be similar to those of the area where the corals were collected. Corals should be placed in an open area and left to recover for at least one week before being handled again.

Fragmentation

Fragmentation is a natural process for soft corals. The often turbulent environment in which these corals live has led to an adaptation whereby dislodged or fractured corals can reattach to a new substrate. Fragmentation is considered to be an extremely important form of reproduction among major reef building corals, resulting in their domination in certain reef zones (Highsmith, 1982). Farmers exploit this natural process by fragmenting broodstock colonies and replanting them to form new colonies that are then grown and marketed to the aquarium industry. The way in which different types of corals are cut has a great effect on the survival and resulting shape of both the cutting and the parent colony.

Fragmentation or cutting techniques follow a similar format. A sharp knife or pair of scissors are used to remove a piece of the parent colony. If the cutting is properly removed it will heal and form a new colony similar to the parent.

The following rules apply to all forms of fragmentation:

1. A sharp razor knife, kitchen knife or pair of scissors should be used for cutting (Figure 19, page 28).

2. The parent colony and cuttings should be handled gently to prevent internal injury and bruising. Whenever possible parent colonies should be held by the substrate to which they are attached.

3. All cutting should be done under water.

4. The cutting or parent should not be exposed to air for long periods of time.

Note: Mucus is produced as a natural protective coating in soft corals and is produced in large amounts when corals are cut. This natural secretion can be a great advantage to the soft coral farmer, acting as a cauterizing agent and a natural glue.

Healing

Many species of soft coral need to undergo a healing phase after cutting. During this phase the cut area of the coral is left exposed to the ambient seawater to heal. Certain soft corals that are planted too soon after cutting suffer **necrosis** and bacterial infection which often results in death. The healing phase may take up to 2 weeks and is dependent on species and environmental conditions. As healing adds an additional step to the farming process, farmers should experiment with the different species they grow to determine the minimum healing time possible.

During the healing phase the open wound on the coral must be exposed to fresh seawater so that bacterial infection does not occur. Because the corals are laid on their side and are unattached during this time they must be kept in areas of low turbulence or in a cage or basket to prevent them from being washed away. Heslinga (1995) used wire cages to contain cuttings during the healing phase, but plastic baskets or even the sides of the aggregate containers can be sufficient to hold the cuttings during healing. Another alternative is to make a rock or coral rubble impoundment adjacent to the planting area in which to place the cuttings. Again, it is important that the farmer adapt these techniques to the species being cultured, the environmental conditions at the farm site and the use of locally available materials.

Figure 18. Diver collecting broodstock in Palau. (Eileen Ellis)

Figure 19. Cutting Sarcophyton *using a razor knife. (Eileen Ellis)*

Figure 20. Sarcophyton *fragments planted in basalt. (Larry Sharron)*

Figure 21. Planting Sarcophyton *fragments in nursery tray. (Larry Sharron)*

Figure 22. Lithophyton spp. *attached to basalt chips. (Larry Sharron)*

Planting and Attachment

Passive Attachment

Once cuttings have gone through the necessary healing phase, they can be planted in, or artificially attached to, the substrate. Unlike terrestrial plants the cutting often does not have to be buried in the substrate. As long as the cut section of the coral is touching the substrate, it will attach itself providing the current or turbulence is not too strong. To ensure that the coral attaches before being washed away, the cut end of the coral is usually nestled 1 to 2 cm into the aggregate (Figure 20, page 28). This provides the cutting with some stability and anchorage. In areas of high turbulence or strong current, coral cuttings can be placed in high-sided baskets, barrels or cages and covered with mesh, if necessary, to stop fragments from being washed away. Once attached, the cuttings can then be transferred to a more open farm type such as nursery trays and the baskets can be reused for further attachment.

Note: The cut area of a fragment can be dipped in fine sand immediately after cutting. This helps to seal the exposed area and also adds negative buoyancy to the cut area of fragment, causing it to sit upright in the aggregate. Cuttings should not be crowded. A standard nursery tray (36 x 72 cms) can hold around 30 cuttings (Figure 21, page 28). This equates to approximately 120 cuttings per square meter of aggregate surface area. Attachment generally takes 10 to 14 days and the coral may attach to one or more of the aggregate pieces (Figure 22, page 28).

An important aspect of the attachment aggregate relates to weight. Because the piece of rock to which the coral attaches will be shipped when the coral is sold, large pieces of gravel will add extra weight and may be bulky. Therefore, aggregate size should only be large enough to keep the base of the coral anchored to the bottom. Once the corals are attached, their growth rate will increase and the cuttings will need little attention until harvest.

Other Attachment Methods

Allowing the natural attachment of fragments to aggregates is one of the most efficient methods for farming soft corals. Using the above methods of cutting, healing and planting, a diver can process 250-300 cuttings in a two hour period (Heslinga, 1995; personal observations). However, certain methods of attachment are practiced by hobbyists that have application in mass farming of soft corals.

Using these methods, a cutting is physically attached to a new substrate using glues, netting or rubber bands. Advantages to this method are that the attachment substrate can be individually selected, attachment can be fast and loss of cuttings from currents and turbulence is reduced. Disadvantages of individual attachment methods are mainly related to time and materials. It can be very time-consuming to individually attach each cutting to its substrate and materials such as glue may be costly.

Passive attachment can be assisted by making sure the cutting remains in contact with the aggregate. A number of methods can be used to do this, the easiest of which is to use a skewer or toothpick to hold the cutting onto the aggregate. The skewer is first pushed through the cutting and then pushed into the layer of aggregate until the cutting and gravel touch. After 1-2 weeks the skewer can then be removed and the cutting will be attached to the aggregate. Skewers can be reused for further attachments.

Another variation of this technique is to use 5 or 10 mm plastic mesh (supply source 1 in Appendix A). Small V-shaped cuts are made in a sheet of the mesh and the exposed end of the cuttings are placed into the V cut. The natural elasticity of the mesh clamps the cutting down and aggregate is then placed on top of the mesh around the cuttings so that the cutting and gravel are in contact. After 1-2 weeks the cuttings will be attached to the aggregate and can be pulled free of the plastic mesh which can be reused for further attachments.

Cyanoacrylate Glues

Equipment :

- Bowl of clean seawater
- Coral fragments
- Paper towel
- Cyanoacrylate glue
- Clean, dry attachment substrate

Cyanoacrylate glues, also known as Super or Crazy glue, are characterized by the immediate and strong bond that they form between almost any two materials. While the use of glue is time consuming and more costly, the benefits can be substantial. One of the major benefits is that the cutting can be attached to virtually any surface, including smooth plastics such as acrylic. At Belau Aquaculture in Palau soft coral fragments have been successfully attached to media such as pumice rock which makes a lightweight and attractive substrate. Another advantage to gluing is that the cut area of the fragment is sealed upon contact thereby avoiding any healing process and allowing the coral to begin growth almost immediately. Headlee (1997) provides a detailed description of the use of super glues as a propagating tool in marine aquaria.

Gluing of fragments must take place out of the water, so fragments either have to be transported to shore or to a floating work platform such as a boat. This can represent a major time investment and can be considered one of the disadvantages to using this method of attachment on ocean-based farms. Fragments should be transported using methods described in the section Broodstock Collection and Transportation on page 24.

Fragments are placed into a bowl or tub of clean seawater. After putting 1-2 drops of glue on a piece of attachment substrate, a fragment of coral is removed from the bowl and dried using a paper towel. The cut end of the coral is then placed onto the glued part of the substrate and gentle pressure is applied for 3-5 seconds before returning the glued fragment to the water (Figure 23). Headlee (1997) refers to using rubber bands and bridal netting to hold species that are difficult to attach to the substrate. The cutting is first glued or simply placed on the substrate. Next a piece of fine or coarse netting is placed over the cutting to hold it snugly to the substrate and a rubber band is then used to hold the netting in place. While these methods are proven techniques and are used routinely by marine hobby aquarists, a farmer should consider very carefully the time involved and potential benefits before adapting them to a commercial-scale, ocean-based farm.

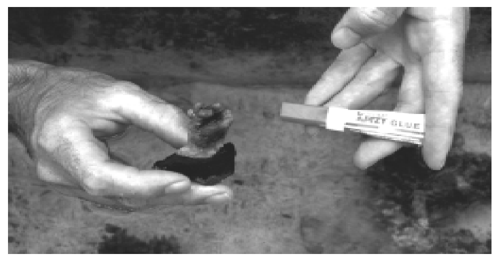

Figure 23. Soft coral fragment attached to basalt using super glue. (Eileen Ellis)

Underwater Epoxy

Equipment

Aquastik underwater epoxy (1*)
Everfix epoxy stick (7)
** See Appendix A for supply sources.*

Use of Aquastik underwater epoxy is advocated by Sprung and Delbeek (1997) for attaching corals to rocks or glass and also rocks to glass or other rocks. Aquastik is nontoxic and hardens to a smooth unobtrusive finish (if using the grey color).

Aquastik epoxy is a ready-to-use product which has a putty-like consistency. Unlike the super glues, it can be used underwater which means that corals do not have to be brought ashore for attachment. This reduces stress to the animals and also significantly reduces the time taken to attach each fragment.

Fragments can be attached in a number of ways. The easiest way is to find a piece of aggregate with a hole or crevice in it and place the stem of the coral in the hole. Epoxy can then be pushed into the hole surrounding the coral in a similar manner to placing soil around a potted plant. Pumice rock or pieces of coral rubble are most suitable for this planting method.

Everstick epoxy is a two-part putty that must be kneaded for 1-2 minutes prior to use. It sets within minutes to a rock hard finish. Aquastick epoxies take several hours to dry so it is essential to find an area where the cuttings will not be disturbed. A lidded basket placed in a calm area with no turbulence or current is ideal for this. Once the epoxy has set, then the cuttings can be removed to another area for grow-out. As with super glues the use of epoxies can be costly and time consuming and a farmer should consider very carefully the time involved and potential benefits before adapting the use of epoxies to a commercial-scale ocean-based farm.

Recruitment

Recruitment is probably one of the simplest forms of mariculture. This technique involves placing a substrate in the wild and allowing invertebrates to settle on the surface. One of the most common types of recruitment substrates are concrete disks or “cookies” which are made by pouring quick-setting concrete into a sand mold (see section Making Concrete Recruitment Substrates on page 34). Recruitment substrate can be made of many types of material providing it is nontoxic and is aesthetically acceptable for the aquarium. Other examples of recruitment materials are concrete rubble, basalt, tiles and acrylic sheeting.

There are two types of recruitment, **larval** and adult. During larval recruitment, the substrate is put in an area of high water flow. The new substrate acts as an attractant to larval invertebrates in the water column which then settle out and begin growing. Larval recruiters should be either hung on a line or placed on the ground in high current areas. Alternatively they can be placed close to the water intake of a pump. The farmer can never be certain what will settle on larval recruiters but many interesting invertebrates can be obtained in this way.

Adult recruitment is more controlled and has less of an element of chance involved. Using this method, the recruitment substrate is laid on the ground either in contact with or very close to the target species. The target coral will then migrate or grow onto the substrate and be ready to harvest usually in 6-12 months. This method is commonly used for recruiting Zooanthids and Corallimorphs, but is equally effective for *Briareum*, *Clavularia*, *Xenia* and many other soft corals.

Note: As the concept behind coral farming is one of conservation, care should be taken not to disturb other marine life when positioning recruitment substrate on the ground. For example, concrete discs should not be placed on top of other marine life in order to promote recruitment to the disc.

Husbandry

Soft corals require little attention once they are planted. Progress of cuttings should be checked once weekly until they are attached and then once monthly until harvest. Any cuttings that continually come loose from the substrate should be reburied in the gravel until they attach properly. If the corals grow so dense that branches are touching, they should be thinned out by removing some of the cuttings and replanting or harvesting them. Occasional maintenance of the farm may be required to remove algae or other fouling that encroaches on the corals.

Making Concrete Recruitment Substrates

Equipment:

- Box (approximately 1 m x 1 m) filled with fine sand (local)
- Quick-setting cement (local)
- Regular cement (local)
- Bucket (local)
- Template (local)

Concrete recruitment substrates can be made in a variety of ways. A simple method is as follows. A plywood box is filled with fine sand and smoothed flat on the surface with a flat instrument such as a piece of milled wood. The sand on the box should be 7-10 cm deep. Imprints are then made in the sand with a template (Figure 24, below). This can be a round piece of wood or a shell. The imprints should be approximately 12-15 cm in diameter and 1 cm deep. Concrete is mixed at a ratio of 1 part regular concrete, to 1 part quick-setting cement, to 6 parts sand. Water is added until the mix is fluid. A cup or ladle is then used to pour the concrete into the imprints and they are left to set for about 30 minutes (Figure 25, below). At this point the concrete discs should have set sufficiently to be popped out of the imprint. Discs should be left to fully cure for 24 hours before use. Each disc will have one side that is smooth and one side that has a coating of fine sand. When placing discs out for recruitment they should be placed with the sandy side facing upward.

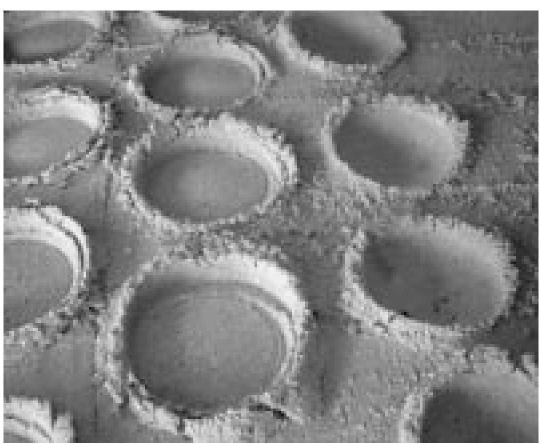

Figure 24. Recruitment substrate moulds. (Simon Ellis)

Figure 25. Pouring concrete recruitment substrates. (Simon Ellis)

Commonly Farmed Soft Corals

Many families, genera and species of soft corals are not commonly cultured. The main reason for this is that some types of soft coral do not survive well in an aquarium environment. Poor survivors are predominantly the non-photosynthetic species that require feeding of plankton or special foods. Therefore it is important to know what corals to culture and which ones to avoid. Unfortunately most of the more colorful and beautiful soft corals are non-photosynthetic, making them unsuitable for culture. While many of these animals can be easily grown in the ocean, they quickly die in the aquarium and are therefore a poor business proposition. In the Indo-Pacific region, good examples of these kinds of corals, are some members of the family Gorgoniidae and the genus *Dendronephthya*.

Note: In certain instances, soft corals may be grown not for the aquarium but because they possess chemicals with beneficial medical properties. In cases such as these it would make no difference if the animal is photosynthetic or not. However, these cases are exceptionally rare to date.

Soft corals, in general, are notoriously difficult to identify, requiring a process that involves microscopic examination of spicule shape. Sprung and Delbeek (1997) state quite correctly that seemingly different soft corals can be forms of the same species since many soft corals vary greatly as the result of environmental factors. Furthermore, seemingly identical corals may belong to different species, genera or even families. A key to soft coral genera is included in this manual and can be found in Appendix B. Because of the difficulty in identifying soft corals, they are grouped below in terms of general shape and characteristics. A generic name is given to each of these groupings but it should be kept in mind that many genera look alike and there is generally overlap in culture techniques and characteristics. To further assist in identification, color images of the corals described below are on pages 45-49.

Order: Alcyonacea - Suborder: Stolonifera - Family: Clavulariidae (waving hand or clove corals)

Stolonifera are a group of soft corals that generally have small polyps attached by a thin runner or **stolon**. There is no **coenenchyme** in this group with all polyps arising from new stolon growth.

Clavularia

General characteristics: This genus is often confused with *Xenia* as these corals put out a large, feathery polyp from a fused stolon mat (Figure 26, page 45). *Clavularia* are photosynthetic and are generally beige or light brown in color, although brighter colors are commonly found. These corals are abundant throughout the tropical Indo-Pacific region and are found typically in coral gravel and rubble areas.

Culture techniques: Because it spreads via a stolon and commonly occurs on coral gravel, *Clavularia* is an excellent culture candidate. Fragments can simply be severed across the stolon and laid on a bed of fresh aggregate. The freshly cut fragments will reattach within 1-2 weeks and begin growing. *Clavularia* generally do not like strong current, or turbulence. Culture techniques for *Clavularia* can be used on most of the other members of the family Clavulariidae. Because of their rapidly spreading nature, Stoloniferans are excellent candidates for recruitment mariculture techniques.

Order: Alcyonacea - Suborder: Alcyoniina - Family: Alcyoniidae (leather corals)

This family contains the genera *Sarcophyton*, *Lobophytum*, *Sinularia*, *Alcyonium* and *Cladiella*, which are some of the most hardy and therefore most frequently cultured species of soft corals. They are generally characterized by a soft, fleshy, smooth skin from which the polyps project. If a stalk is present, it generally does not have polyps.

Sarcophyton (mushroom corals)

General characteristics: These are the hardiest and easiest to culture of the soft corals. They are extremely abundant in the tropical Pacific Ocean, Indian Ocean and Red Sea, often occurring in high energy areas such as surge zones and tide pools but are also found in deeper water. Like nearly all cultured soft corals, *Sarcophyton* possess zooxanthelle and generally have a beige, olive, brown, green or light yellow color (Figures 27 and 28, page 45). *Sarcophyton* have a smooth base containing no polyps which is covered by a crown which houses the zooxanthelle and polyps, giving the colony the impression of a large mushroom. The crown may be **lobate** or **undulating** to increase surface area, especially in larger specimens. Polyp size, shape and color can vary quite dramatically between *Sarcophyton* species making them attractive additions to home aquaria.

Culture techniques: Species that have an attractive color and distinctive polyps (star shaped, bright color, etc.) should be selected for culture. Broodstock should be a minimum of 30 cm in diameter although smaller specimens that are particularly attractive can also be used.

Before fragmenting, the colony should be gently handled to ensure that the polyps have retracted and the body has become firm. One of two methods can then be used for fragmentation.

1. Using a sharp blade such as a razor knife or scissors, a series of incisions are made every 3 cm around the edge of the crown going 3 cm directly toward the center of the colony. After a 3-7 day healing period, fragments can be removed from the parent by slicing off every second cutting from the colony. The resulting cutting will generally not have any of the stem of the parent colony and will consist of only tissue from the crown.

2. A series of incisions 3 cm deep and 3 cm apart are made in a criss-cross manner over the entire surface of the crown. After a 3-7 day healing period, fragments can be removed from the crown by cutting horizontally through the crown or stem. The center of the crown of the parent colony should be left intact.

Sarcophyton broodstock recover and regenerate very quickly after fragmentation and can usually be used again in 12-18 months. Fragments should be planted in aggregate as outlined in the section Planting and Attachment on page 29. *Sarcophyton* produce a lot of mucus and the freshly cut edge of the fragment should be dipped in sand before planting to seal the cut and provide negative buoyancy to the cutting. Cuttings can be nestled into the substrate and attachment should occur in 10-14 days. Once attached, the cuttings will differentiate into a stem and crown, the latter of which will round out to look like a miniature version of the parent. Market size for *Sarcophyton* is generally at a crown diameter of 5-6 cm which can be obtained in as little as 4 months with some species, while in other species this can take up to 12 months.

Note: Sizes at harvest given in this section are approximate and based on current market demand. Actual size at harvest and the type of product grown will be driven by the market. Feedback from the buyer on required size is extremely important. (See section Marketing and Economics on page 57).

Lobophytum (finger coral and Devil's hand)

General characteristics: *Lobophytum* colonies tend to be encrusting with many varieties of lobed, finger shaped and occasionally bushy appendages (Wilkens and Birkholz, 1992). Unlike *Sarcophyton* they tend not to have a differentiated stem but instead have lobes originating from an encrusting body (Figure 29, page 46). They possess zooxanthelle and therefore have the characteristic brown, green, beige and olive colors of *Sarcophyton*. Certain species of *Lobophytum* can be easily mistaken as *Sarcophyton* and visa-versa although *Lobophytum* are generally more lobate. They are found in all areas of the Pacific Ocean, Indian Ocean and Red Sea, usually associated with the reef flat and slope and also on hard substrates within lagoons.

Culture techniques: *Lobophytum* are fragmented by either removing only the lobes (fingers) from the parent or by cutting an area containing one or more of the lobes. When single lobes are removed these are sometimes referred to as "finger corals". For single lobe removal, a pair of scissors or sharp razor knife can be used. If a portion of the coral containing more than one lobe is to be removed, it can be cut in much the same way as a *Sarcophyton*. This fragmentation method is common in species such as the Devil's Hand and other corals with smaller lobes.

Lobophytum cuttings must generally undergo a longer healing phase than *Sarcophyton*. After cutting, the corals should be allowed a healing phase where they are laid on their side in a tray of aggregate for 1-2 weeks. The end of the healing process will be indicated when the cut area of the fragments start to produce the new attachment cells, which appear as soft, fleshy, white tissue. The cuttings can then be nestled into the aggregate where they will attach in 14-28 days. A typical finger coral cutting is 2-3 cm in diameter and 5-7 cm long. Cuttings with one or more lobes should be about 3 cm square.

Market size for finger corals is around 10-12 cm long. Cuttings with one or more lobes should be allowed to round out and grow in size to 5-6 cm in diameter prior to marketing. Growth rates are again variable depending on the species and time from planting to harvest is approximately 6-12 months.

Sinularia

General characteristics: Like the *Sarcophyton*, the *Sinularia* have a nearly polyp-free column which differentiates into a polyp-bearing area. However, *Sinularia* have a more branch-like (**arborescent**) or bushy appearance (Figures 30, 31 and 32, page 46). They are one of the most morphologically diverse groups of leather corals and can easily be confused with other soft coral genera, especially *Cladiella* and *Lobophytum*. They are found mainly on rocky substrates and hard gravel of lagoons and reef fringes throughout the Red Sea and Indian and Pacific Oceans. All *Sinularia* studied have shown to have zooxanthelle and are therefore relatively easy to keep in the marine aquarium (Wilkens and Birkholz, 1992).

Culture techniques: *Sinularia* are fragmented by either removing branches or lobes from the parent colony. Most species of *Sinularia* have branches but some are lobate. However, because these lobes tend to be thinner than in the *Lobophytum*, it is often better to use a sharp pair of scissors for removing branches or lobes. If a portion of the coral containing more than one lobe is to be removed, it can be cut in much the same way as *Sarcophyton* and *Lobophytum* using a razor knife.

A healing period is important for *Sinularia* and after fragmentation the open wound of the cutting should be dipped in fine sand and the fragment left on its side for 7-10 days. After this healing process, the cuttings should be planted in a 75% aggregate: 25% fine sand media. This will aid the cuttings in attachment. After a further 10-14 day period the cuttings can be replanted in a bed containing only aggregate. At this point the fragments will be weighted on the bottom by sand and aggregate and stand upright.

Cuttings should be planted at 3-5 cm in length and harvested at 7-12 cm. *Sinularia* are characterized by their large robust spicules around the base of the colony (Sprung and Delbeek, 1997). They are often slow growing, taking up to 12-18 months to harvest. However, there are some extremely attractive species of *Sinularia* that are highly marketable and worth the extra time and effort.

Note: A high-quality pair of stainless steel scissors should last many months if properly cleaned with freshwater after use and stored with a thin coat of silicone gel or cooking oil on the blades.

Cladiella

General characteristics: *Cladiella*, *Alcyonium* and certain *Sinularia* often look very similar and their constantly changing morphology in different environments makes them very hard to identify using external features. Microscopic examination of *Cladiella,* however, shows them to have much smaller spicules than the *Sinularia*. *Cladiella* have a similar branching structure to *Sinularia* with the same polyp-free stem leading to polyp-bearing branches or lobes (Figures 33 and 34, page 47). The body color generally varies from creamy white to light brown with dark polyps and they are usually photosynthetic. According to Wilkens and Birkholz (1992), these corals are normally found in deeper water on the outer reefs, fore reefs and deep lagoons of the Pacific and Indian Oceans. They prefer strong currents and are often found in association with *Dendronephthya* and Gorgonians.

Culture techniques: Culture methods for *Cladiella* are the same as those for the *Sinularia*. Scissors or a sharp razor knife are the most effective tools for removing cuttings from this type of branching soft coral. Cutting, harvest size and the time to harvest are the same as for *Sinularia*.

Alcyonium (Colt or Cauliflower corals)

General characteristics: Formerly known as *Cladiella* in aquarium literature, *Alcyonium* is a separate but similar genus (Sprung and Delbeek, 1997). Many similarities remain in their appearance—a branching structure with a polyp free stem (Figure 35, page 47). Sprung and Delbeek (1997) noted that the polyps appear to be generated on the lower portion of the stalk and develop as they migrate upward. *Alcyonium* species produce large amounts of mucus and are generally slimy to the touch. They are predominantly photosynthetic and have a beige or brown color with the stalk usually light in color. *Alcyonium* are most abundant in shallow lagoons throughout the tropical Indo-Pacific.

Culture techniques: As with *Cladiella*, follow the culture methods described for *Sinularia* and use scissors to clip small cuttings from the parent colony. *Alcyonium* are fast growing and can reach a 7-12 cm harvest size in as little as 6 months.

Order: Alcyonacea - Suborder: Alcyoniina - Family: Xeniidae (waving hand corals)

General characteristics: The three main genera commonly found in the aquarium market from this family are *Anthelia*, *Xenia* and *Cespitularia*. All are characterized by large, non-retractable polyps that often pulse. *Anthelia* forms an encrusting mat while *Xenia* and *Cespitularia* form stalks. All tropical species are photosynthetic and have the characteristic beige, cream or brown color of their symbiotic zooxanthelle. All three genera are found in a variety of reef habitats but are often associated with shallow, fast moving water.

Culture techniques: *Anthelia*, *Xenia* and *Cespitularia* are quite sensitive to excessive handling and it is important, when collecting broodstock, to minimize the handling and transportation time. Always place individual colonies in a plastic bag with clean seawater and try to minimize contact between the animal and the bag wall.

Anthelia (Figure 36, page 47) and *Xenia* (Figure 37, page 48) can be fragmented by snipping away parts of the colony (as small as one polyp in some instances) and laying the cuttings on a bed of fresh aggregate. These cuttings are often light and are easily washed away. Using a high-sided basket or skewers for initial attachment can reduce the loss of cuttings due to turbulence. Both *Anthelia* and *Xenia* quickly migrate in a new setting by producing buds that migrate onto new substrate. For this reason these species are good candidates for using recruitment techniques.

Cespitularia (Figure 38, page 48) has more of a stalked and branched appearance than *Anthelia* or *Xenia* and look something like a cross between *Alcyonium* and *Xenia* (Sprung and Deelbek, 1997). Because of this, fragmentation can take place by snipping branches from the parent colony and laying them on a bed of fresh aggregate. As with *Anthelia* and *Xenia* these cuttings should be sheltered from excessive turbulence by a high-sided basket or tray until they are attached.

Anthelia, *Xenia* and *Cespitularia* generally do not ship well (see section Harvesting and Shipping on page 50) but grow very fast once established in an aquarium. For this reason it is best to target a 3-5 cm colony for market as the smaller animals seem to withstand the rigors of shipping better than larger colonies.

Order: Alcyonacea - Suborder: Alcyoniina - Family: Nephtheidae

General characteristics: The family Nephtheidae contains some of the most attractive and brightly colored of all marine invertebrates. Unfortunately, most of these animals do not possess photosynthetic algae and are therefore generally unsuitable for reef aquariums. However, there are limited markets for some of the non-photosynthetic corals, and their culture will be briefly dealt with in this section. Nephtheidae are characteristically branched and very **spiculose** resulting in a rough texture to the ends of the branches.

Photosynthetic genera from the Indo-Pacific region that are commonly found in the aquarium trade are *Nephthya* (Figure 39, page 48), *Lithophyton* (Figure 40, page 48), *Lemnalia* (Figure 41, page 49), and *Spongodes*. All these animals have a similar, arborescent appearance with spiculose polyps. Colors are generally the brown, beige and cream hues associated with photosynthetic soft corals. All are found mainly on reef slopes or coral rubble with strong illumination and regular high water flows.

Non-photosynthetic genera commonly found in the aquarium trade are *Dendronephthya* (Figure 42, page 49) and *Scleronephthya*. These species are hard to keep in marine aquaria and have a limited market. They are characterized by very bright colors such as red, orange, yellow and blue and have very spiculose branch tips that may vary in color from the stem. *Dendronephthya* and *Scleronephthya* tend to occur in deeper water in areas of strong current flow and abundant plankton. They are often found on vertical walls, under ledges or on pinnacles in tidal channels.

Culture techniques: A general rule of thumb for collecting Nephtheidae broodstock is to avoid the very brightly colored specimens as these are most likely non-photosynthetic. Certain photosynthetic species will have a light green, blue or red color but it will generally not be as bright as the non-photosynthetic species. If there is any doubt, then the specimen may be worth collecting or fragmenting as it may be a highly valuable photosynthetic type. Nephtheidae are generally quite sensitive to excessive handling despite their spiculose nature. Collected broodstock should be placed into plastic bags full of seawater to minimize abrasion.

Fragmentation techniques for Nephtheidae are essentially the same as for other branched or arborescent species such as *Sinularia*. Branches can be snipped from the parent using a pair of scissors and planted in a bed of fresh aggregate. One interesting aspect of many Nephtheidae is their ability to produce a bud from the branch tip or from the stalk. Budding from the stalk can be stimulated by making a small horizontal incision in the stem with a razor knife. In about 7 days a bud will appear where the nick was made and this will grow into a branch with polyps in a further 2-3 weeks. Eventually this bud will be a fully formed tree coral that can be stripped from the parent and planted for further grow-out. By stimulating budding in this manner, a large stand of broodstock can be harvested indefinitely without having to remove branches from the parent colonies. This method has the added advantage of producing clones that are less stressed and therefore less susceptible to disease and infection.

Order: Alcyonacea - Suborder: Scleraxonia - Family: Briareidae (Briareums or star polyps)

General characteristics: The principle genus found in the marine aquarium trade is *Briareum*. These species are prolific in many areas of the Indo-Pacific and form a mat or mass of fingerlike projections from which the polyps project. The mat or fingers tend to be brown or purple but other color morphs are also common

(Figure 43, page 49). *Briareum* are photosynthetic and often have brightly colored polyps in hues of green or yellow, or the more characteristic brown, beige or white. Because they are encrusting species they are often found associated with areas of dead coral in upper reef zones with moderate to heavy turbulence.

Note: There is currently a general feeling among taxonomists that members of the genus *Briareum* may belong in the family Tubiporidae, suborder Stolonifera.

Culture techniques: Members of the genus *Briareum* are quite sensitive to handling, so it is best to locate the farm close to the broodstock beds if possible. For finger-like *Briareum*, large pieces of broodstock should be laid onto trays of large aggregate. In 10-14 days the *Briareum* will have made several points of attachment to the aggregate. Cuts can then be made in the stolon approximately 3-5 cm on either side of the point of attachment. The attached cutting can then be removed to another area for grow-out.

Briareum that form mats are excellent candidates for recruitment mariculture. Concrete discs or other substrates can be placed close to the parent colony, allowing migration of the animal onto the substrate. Harvest of a marketable product should be possible in 6-12 months.

Order: Alcyonacea - Suborder: Halaxonia - Family: Gorgoniidae (Gorgonians or sea whips)

General characteristics: Gorgonians are treelike members of the soft corals that build their polyps around a rigid but flexible material called **gorgonin**. Gorgonin allows the animal to remain erect while capturing plankton but to bend under wave action or high currents. Gorgonians from the Indo-Pacific region are mainly non-photosynthetic, and while they often have beautiful colors, are hard to maintain in home aquariums. There are a few photosynthetic Indo-Pacific gorgonian genera. A widespread genera found mainly in lagoon environments and commonly found in the marine aquarium trade is *Rumphella* (Figure 44, page 49). The body of *Rumphella* is generally bushy with the characteristic brown, beige or cream color of photosynthetic soft corals and brown polyps.

Culture techniques: Cuttings taken from gorgonians with a pair of scissors will quickly reattach to any substrate they come in contact with. However, because gorgonians are tall corals with a rigid skeleton, simply burying the stem in gravel and waiting for reattachment to occur is rarely successful. Firstly, it is likely that the gorgonian will fall over or be toppled by fish before it has time to attach. Secondly, even if it does attach, the gravel cannot provide the animal with the flat base needed to support its height. For these reasons the animal needs to be attached quickly to a substantial base which can support its height.

The use of underwater epoxy (see section Underwater Epoxy on Page 31) is a good way to attach gorgonian fragments. The best substrates for attaching gorgonians are large (5-7 cm diameter) pieces of aggregate. Examples of suitable substrates are pieces of pumice rock or coral rubble which have holes or crevices in them. An excellent alternative to this is to use molded concrete discs similar to those used for recruitment but with a hole or depression in the center. The flesh from the bottom of the fragment should be cut away to expose the gorgonin skeleton. This is then pushed into the hole in the substrate and epoxy is packed around the stem, supporting the upright gorgonian. The glued fragments should then be left in a calm area away from fish activity for at least 12 hours. In time, the gorgonian will grow its own attachment structure over the epoxy and the bond to the substrate will become strong.

Figure 26. Clavularia spp. *(CRRF, Palau)*

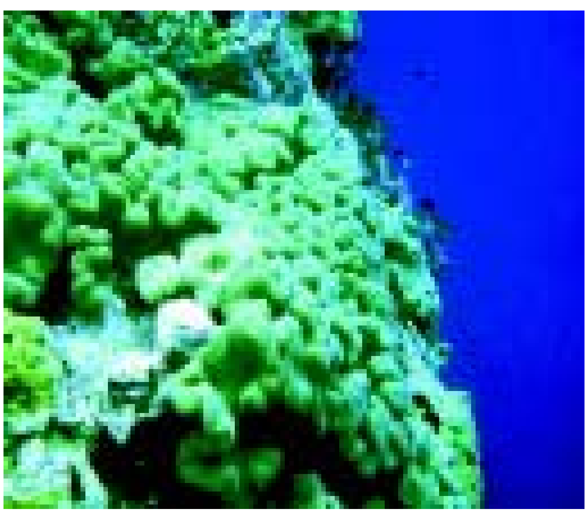

Figure 27. Sarcophyton spp. *on reef in Pohnpei, FSM (Eileen Ellis)*

Figure 28. Sarcophyton spp. *(CRRF, Palau)*

Figure 29. Lobophytum spp. *(Larry Sharron)*

Figure 30. Sinularia spp. *(Larry Sharron)*

Figure 31. Sinularia spp. *(Larry Sharron)*

Figure 32. Sinularia spp. *(CRRF, Palau)*

Figure 33. Cladiella spp. *(Larry Sharron)*

Figure 34. Cladiella spp. *(CRRF, Palau)*

Figure 35. Alcyonium spp. *(CRRF, Palau)*

Figure 36. Anthelia spp. *(CRRF, Palau)*

Figure 37. Xenia spp. *(CRRF, Palau)*

Figure 38. Cespitularia spp. *(CRRF, Palau)*

Figure 39. Nephthya spp. *(CRRF, Palau)*

Figure 40. Lithophyton spp. *(CRRF, Palau)*

Figure 41. Lemnalia spp. *(CRRF, Palau)*

Figure 42. Dendronephthya spp. *(CRRF, Palau)*

Figure 43. Briareum spp. *(CRRF, Palau)*

Figure 44. Rumphella spp. *(CRRF, Palau)*

Harvesting and Shipping

Harvest

Harvest of soft corals from the ocean farm is a relatively straightforward procedure. Animals are collected from the farm and brought into the land-based holding facility for at least a week prior to shipping. This helps corals to get over the initial stress of handling and transportation from the ocean site before undergoing the rigors of air freight. Overall survival of product for the buyer may be significantly improved by doing this.

Transportation techniques for harvested corals are similar to those for transportation of broodstock (see section Broodstock Collection and Transportation on page 24). For short journeys of up to 30 minutes, the corals can be kept in plastic bags placed in coolers or tubs of water. For longer journeys the corals should be removed from the bags and placed in coolers or tubs of water and water changes done every 20-30 minutes. Upon arrival at the land-based facility, corals should be quickly transferred to tanks with ambient, flowing seawater. Exposure time to air should be minimized with most soft corals, especially members of the Xeniidae and Nephtheidae.

Shipping

Permits, CITES and Shipping Documents

Many marine species have been assigned legal protection, both in the countries of origin and destination, that are designed to protect them from over-exploitation. The most wide-reaching of these conservation measures exists in the form of the Convention on International Trade in Endangered Species (CITES). While CITES is not a law in itself, any country that is a member of CITES must comply with standardized import and export documentation in order to monitor the trade in endangered species.

CITES has three appendices that provide varying degrees of protection to the species listed in each appendix. Member countries of CITES are expected to comply with those levels of protection and ensure that nonmember countries comply in regard to any product imported or transshipped through a CITES member country. Most countries where corals are shipped to, including the USA, Japan and member countries of the European Union, are CITES member countries. At the time of writing this manual, the only soft corals listed in Appendix II of CITES are the Helioporacea (the blue corals) and the family Tubiporidae (organ pipe corals). Neither of these corals are covered by this manual.

One technical aspect that often causes problems for exporters is the use of coral rubble as an attachment substrate. Most reef-building hard corals such as *Acropora*, *Pocillopora* and *Pavona*, that form the basis of coral rubble, are protected under Appendix II of CITES. If a farmer uses coral rubble as an attachment substrate, a CITES permit will technically be needed to import the product, not for the living soft coral but for the dead piece of coral rubble to which it is attached. For this reason, use of attachment substrates other than coral rubble such as basalt or pumice are recommended.

Nonmember countries of CITES (which includes many Pacific Island and Pacific rim nations) must provide an ‘in lieu of CITES’ document to go with any export of a listed species to a CITES member country. This document is produced by the appropriate marine resource and management authority in the nonmember country. It must contain the following statement:

> *I _____, (signing official) hereby certify that the shipment of wildlife or plants covered by this document is in accordance with the laws of ____ (country), will not be detrimental to the survival of the species in the wild, and, if living, will be transported in a manner which will minimize the risk of injury, damage to health, or cruel treatment.*

While CITES regulations rarely apply to soft coral exports, further information can be obtained from:

The Office for Management Authority
U. S. Fish and Wildlife Service
4401 N. Fairfax Drive, Room 432
Arlington, Virginia 22203, USA

or

CITES Secretariat
6, Rue du Maupas
Casse Postale 78
CH-1000 Lausanne
Switzerland

It is extremely important that before any species is chosen for farming, thorough research should be conducted into the local and international laws protecting that species. This applies not only in the country of origin but also in the target country for export. The local marine resources division of the country of origin should be able to supply the necessary information on what permits are required for exporting soft coral products.

Laws and regulations sometimes may only apply to the wild collection of marine organisms. It is important to form a close relationship with local marine resource and management personnel so they are aware that the corals are farmed. Inviting marine resource personnel to periodically visit the farm is a good way to develop a cooperative and working relationship between the regulating agency and the farmer.

The following documents may need to accompany any export shipment of corals:

1. Original invoice listing the genus, number of animals in each genus, and the value of each animal. A sample invoice is included in Appendix C.

2. Export permit.

3. Quarantine or veterinary inspection permit.

4. CITES or 'in lieu of CITES' permit.

5. Airway bill.

Packing and Shipping Soft Corals

Equipment

- Shipping bags (1*, 10, 11 and 14)
- Shipping boxes (1 and 12)
- Insulating, polystyrene sheet or boxes (1 and 13)
- Oxygen cylinder (local rental from welding or medical supply company)
- Oxygen regulator (1, 2 and 3)
- "Special Formula" shipping compound (16)
- 12 mm ID polyethylene tubing (local and 1, 2, 3 or 4)
- Rubber bands (local)
- Tubing clamp or air nozzle (1, 2, 3, 4 or 19)

* *See Appendix A for supply sources.*

General Packing Procedures

Packing soft corals for shipping follows the same general rules for each type of coral. However, there are often subtle differences in packing procedures that will be mentioned later in this section.

Each coral is packed individually in a plastic bag filled partially with clean seawater and pure oxygen. A general rule of thumb is to use a bag at least twice the size of the cultured coral. For example, when shipping a coral 5 cm high and 5 cm wide the sealed bag should be at least 10 cm x 10 cm. Two bags are used for each coral with a double folded sheet of newspaper inserted between each bag (Figure 45). The newspaper helps to prevent tearing of the outer bag if the inner bag is punctured by a sharp piece of aggregate or a spine. Amount of aggregate attached to each coral should be minimized by removing large or sharp pieces that are not well attached to the base. This will reduce shipping weight and the chances of a puncture in the inner shipping bag.

Figure 45. Shipping box with packed corals. (Simon Ellis)

Note: Some shippers will place more than one specimen of the same species in a bag. This method reduces bag use and packing time but increases the risk of death by **asphyxiation** during shipping. However, different species are rarely shipped in the same bag.

Shipped corals are often stressed by handling, and the use of shipping compounds helps to reduce the onset of disease and improve survival. A commonly used, broad-spectrum compound with antibiotic and anti-fungal properties called “Special Formula” contains the antibiotic Nitrofurazone and is manufactured by Chemaqua (see Appendix A for details). This is added to the shipping water at a concentration of 250 mg per 40 liters of water. Other broad-spectrum antibiotics such as Penicillin and Oxytetracycline can also be used effectively.

The amount of water used in the shipping bag varies between species (see the latter part of this section). Water should be kept to a minimum because it increases shipping costs. However, too little water can lead to exposure of the corals to the air, resulting in increased shipping mortality. If there is any doubt about the animals’ resilience to shipping they should be packed in a larger bag with more water and oxygen. Having a large number of animals dead on arrival at their destination may lose repeat business. Generally, only enough water to cover the animal is needed. The bag should first be filled halfway with water and the coral placed into the bag. Excess water in the bag can then be poured out.

Once the coral is added, the bag is deflated and the end of the oxygen hose or nozzle is inserted into the neck. The opening of the bag is twisted around the tube or nozzle (Figure 46) and a jet of oxygen is squirted into the bag until an airspace has been created equivalent to the water volume (Figure 47). The oxygen hose or nozzle is quickly removed and the top of the bag is twisted to keep the oxygen inside the bag. The neck is then secured with 2 to 3 rubber bands and the bag is placed in a cool place or directly into the shipping box.

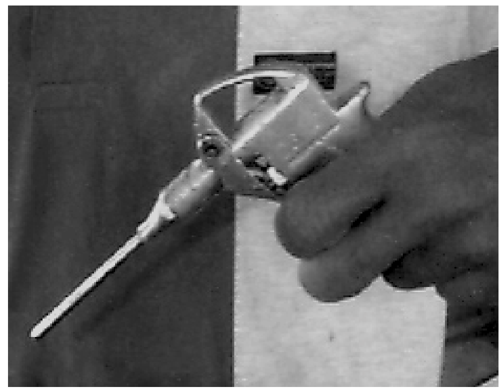

Figure 46. Oxygen nozzle used for inflating shipping bags. (Larry Sharron)

Figure 47. Inflating shipping bag with oxygen. (Simon Ellis)

Note: When shipping large numbers of animals a production line approach should be taken to packing. For example, with a crew of three people, one person should add water to the bags, the second person should bag the corals and adjust the water volume and the third person should inflate the bags with oxygen and seal them.

When enough bags have been packed they are placed into the shipping box. These are made of corrugated cardboard and are generally cube shaped with 40-60 cm sides. The box is lined either with 19 mm sheet polystyrene or individual polystyrene shipping boxes. In each case, a double tier of bags are packed in each cardboard box. If sheet polystyrene is used for insulation a median sheet is placed on top of the first layer of bags and the next tier of bags is added. If polystyrene boxes are used, two boxes, half the height of the cardboard box are inserted into the shipping box. An outer polyethylene bag is placed either inside the polystyrene sheeting or around the polystyrene shipping boxes before they are placed into the shipping box. This is simply an extra precaution against leakage and is often required by the airlines. Depending on the size of the corals, each shipping box should hold between 30 and 50 bags.

Specific Shipping Instructions

Members of the families Stolonifera, Alcyoniidae, Gorgoniidae and Briareidae can generally be shipped with the water to oxygen ratios stated above. Some of the more arborescent Nephtheidae (e.g. *Lithophyton*) are sensitive to air exposure and will become infected or die if exposed for even a few minutes to the oxygen in the bag during shipping. When shipping these species the oxygen space in the bag should be reduced to 25% of the bag volume and the shipping water increased to 75% of bag space.

Xeniidae are quite fragile and often do not fare well during shipping. To overcome this problem use a rubber band to attach a small piece of polystyrene to the attachment substrate (Delbeek and Sprung, 1994). The rubber band should not be placed directly on the living coral. The animal will float upside down in the bag, protected from contacting both the sides of the bag and the oxygen space. Like the tree corals, Xeniidae should also be shipped with only a 25% oxygen space in the bag.

Note: If a buyer keeps complaining of excessive mortalities in any one type of coral, some shipping trials should be conducted on that animal. During a shipping trial, the corals are packed as if for export but remain at the packing facility. Different packing methods such as use of chemicals, oxygen:water ratios and hours in transit can then be tested to determine the best shipping method for the species in question.

The Buyer's Role in Shipping

Large coral farms will generally sell to an aquarium wholesaler, who buys large amounts of each coral and resells them to retailers and sometimes other wholesalers. The buyer always pays the shipping costs on an order and therefore it is important to ensure that costs for transport are kept as low as possible. Shipping per animal usually costs about the same amount as the animal itself so helping the buyer to get the cheapest shipping cost will help to ensure repeat business.

The first place to save money is on weight, which comes mainly from water and aggregate attached to the corals. Keeping shipping water to a minimum while ensuring enough depth for healthy transit is therefore important. Excess aggregate should be removed wherever possible.

Note: If there is any doubt as to how well a particular coral will ship, then pack conservatively in a larger bag. A dead animal that was shipped cheaply is no good to anyone.

The second place to save money for the buyer is in the size of the shipment. Most carriers give reduced freight rates for cargo shipments of greater than 250 kg. This will equate to 12-15 boxes or 500-700 pieces of coral in each order. It is important that the buyers know where the cutoff points for freight cost reductions are so that they can place a large enough order to save money. Helping buyers to save money in this way helps to ensure future purchases from the farm.

Marketing and Economics

In many respects marketing is the most important aspect of a successful coral farm. Without a market for the product, there is no reason for the farm to exist. For this reason, it is very important to listen to the buyers as they are driving the market for soft corals.

Product Variety and Color

In order to fill a minimum order (500-700 pieces), many buyers will require the farmer to offer a range of different products. For instance, it is much harder for a wholesaler to resell 500 pieces of *Sarcophyton* than 100 pieces each of 5 different corals. A farm that wants to sell directly to a wholesaler should have at least 5 different varieties of coral to offer on the product list. Even if a farm has a number of attractive and hardy corals on the product list, it is good policy to constantly try to grow new species that are encountered in the wild.

Note: Small farmers who only grow perhaps 1 or even 2 types of coral may be more successful in their marketing efforts if they sell their product directly to a local wholesaler who can consolidate different products for export such as tropical fish, giant clams and corals. This takes away the work and risk involved with finding a buyer and exporting the product. However, a farmer who sells to a local wholesaler should expect to receive less for their product because the wholesaler takes on the risk and work involved with shipping and marketing.

Wholesalers want to buy products that are hardy, colorful and cheap. A product like this is unfortunately quite rare. Most of the very colorful soft corals are either slow growing or unsuitable for aquariums. However, it is important to select corals for the farm that fit the wholesaler's requirements as closely as possible. Cultured coral products are sold in direct competition with wild collected animals from around the Indo-Pacific. These are generally collected cheaply and have a wide variety of colors and shapes. Some conservation-minded home aquarists will search out a cultured product and pay a premium for it. However, they are still a minority. A benefit to cultured corals is that they are often better cared for than the wild collected animals, which are usually taken from the environment and exported almost immediately. Cultured corals are more easily moved and generally suffer less stress during harvest and shipping. This is of great benefit to the buyer who loses less animals before reselling. Another benefit of cultured corals is the consistency of the product. A wholesaler can order a certain amount of product from a farm and know what to expect in the aspects of shape, color, size and health. This may not always be the case with wild collected animals.

The "Hook"

If a farm has 1 or even 2 products that are highly sought after, it is easier to sell other less attractive products. If a particular coral is found in the area of the farm that is rare or exceptionally attractive, then this should be the focus of the farm activities. This is known as the "hook" because wholesalers who want to buy this rare or colorful coral from the farm will often be willing to accept other, less attractive products to fill the minimum order.

Price Structure

As mentioned previously, cultured corals are sold in direct competition with wild collected specimens, so pricing must be attractive to the buyer. A general rule of thumb is to sell the product for 25% of the wholesaler's reselling price. Wholesalers will generally make their price lists available or post them on the internet. Selling a product for only 25% of the wholesalers list price may seem low but factors such as cost of shipping, losses due to mortalities and profit to the wholesaler must be considered.

The Buyer

Most buyers will be wholesalers based close to major metropolitan areas around the world. Wholesalers are like any other business people, in that they want the best product for the least amount of money. Therefore it is important to reduce the cost to the buyer wherever possible. This is possible not only by watching shipping costs (see section Shipping on page 50) and keeping product prices competitive, but also by making the farm known to the buyer. (See Appendix D for a list of wholesalers of marine aquarium products.)

One of the best ways to publicize a farm is to post a stock list on the internet. A simple web site will not only make the company visible to most buyers but will allow them to make purchases via e-mail, a substantial cost savings over using the phone in most Indo-Pacific nations. However, the internet is still not widely available in many places so marketing efforts can be made in more traditional ways. The best traditional method for advertising the farm's products is a simple brochure with a few color pictures of the product, a product list and accompanying price list which can be mailed to prospective buyers. The price list should not be put directly on the brochure because the brochure may last for many years but prices constantly change.

Building a trusting relationship with a buyer is an important aspect of marketing. The farmer and the buyer are usually separated by huge distances and there is often a certain amount of initial distrust between the two parties. This mistrust is often well earned by both sides. A farmer should insist on prepayment on all shipments until there is a bond of trust with the buyer. Nurturing a long-term relationship with a buyer is beneficial for a number of reasons. Communication allows the farmer to receive feedback from the buyer on what products are selling, how the animals are doing after shipping and allows the farmer to structure farm inventory to future demand. At the same time, a reliable farmer should produce a consistently high-quality product, listen to the buyer’s needs and promptly replace or give credit for an excessive amount of dead animals. Other good ways to nurture the relationship between buyer and farmer is for the farmer to occasionally send free samples of new products or to offer discounts on certain items.

Note: Dead on arrivals (DOAs) are the animals that were shipped but arrived dead. These should generally be a small percentage (less than 5%) of the total number shipped. If a buyer receives a shipment with an unusually high proportion of DOAs then they may ask for replacement of the animals or credit on the next shipment. Occasionally an unscrupulous buyer will use the excuse of a large number of DOAs to boost profits. If the farmer suspects this is the case, then photographic or other evidence can be requested to verify the damage. A buyer who constantly uses large DOAs claims against the farmer should be dropped from the customer list.

Economics

The economics of soft coral farming is affected by many variables depending on the region. The simple example that follows is based on an existing farm, Belau Aquaculture in Palau.

This model assumes the following:

1. The facility is located in a rural or low-cost area of Micronesia.
2. Land area is coastal and is approximately 300 m in length.

3. There is a production goal of 2,000 pieces per month requiring a production rate of 125 cuttings planted per dive hour (Heslinga, 1995). Accounting for mortality, this would require 5 diving days per month for 2 divers.
4. The farmer conducts 2 broodstock collection dives per month.
5. The average sale price of each piece is $2.
6. All prices are in U.S. dollars.
7. The farm is operated by a single owner who takes salary from the profits.

The company's costs on a yearly basis are as follows:

Land lease ($300 per month)	$ 3,600
Land-based holding facility ($10,000 @ 5 year depreciation)	$ 2,000
Electricity	$ 1,200
SCUBA gear for 2 people ($1,000 @ 5 year depreciation)	$ 200
Tank fills (14 fills per month @ $5 per fill)	$ 840
Used pick-up truck ($4,000 @ 5 year depreciation)	$ 800
Boat and motor ($10,000 @ 5 year depreciation)	$ 2,000
Fuel (6 gallons per day, 7 days per month)	$ 1,008
Staff member (quarter time at $3 per hour)	$ 1,440
Miscellaneous expenses	$ 1,000
Computer ($2,000 @ 5 year depreciation)	$ 400
Marketing materials and communications	$ 800
TOTAL	$ 15,288

With sales of 2,000 pieces per month @ $2 per piece
Gross revenue = $48,000
Profit before taxes = $48,000 - $15,288 = $32,712.
Break-even point for this model = 637 pieces per month.

Although costs such as labor, tank fills and fuel increase with the amount of corals exported, the fixed costs such as depreciation, land leases and electricity remain the same. Therefore, profit increases greatly with increased production. For example, taking into account the increased costs of fuel, tank fills and labor, increasing production from 2,000 pieces per month to 2,500 pieces per month would increase profit before taxes to $43,608. Increase in total operating costs is only $1,104 to produce the additional 6,000 cuttings.

Eventually the land-based facility, near-shore farm sites, and boat will reach a carrying capacity and fixed operating costs will increase at that point. Time spent packing and shipping will also increase substantially, even though the buyer covers these costs.

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Glossary

Amino acids: the basic components of protein.

Arborescent: branched or treelike in appearance.

Asexual budding: a form of reproduction where a soft coral polyp forms an exact replica of itself without releasing gametes.

Asphyxiation: death induced by lack of oxygen.

Calcium carbonate: the chemical from which hard corals and shells are made.

Coenenchyme: material secreted by soft corals as they grow which houses and is fed by the polyps.

Fatty acids: one of the basic components in fats or lipids.

Foot valve: also called a check-valve, a spring loaded valve placed in an intake pipe that closes when suction is lost and traps the remaining water in the pipe. This is used to assist in priming pumps after power outages and pump maintenance.

Fragmentation: the process by which small pieces are taken from a parent soft coral to form a new colony.

Gorgonin: a protein based substance which is a specialized part of the coenenchyme, forming the rigid but flexible skeleton of gorgonians.

Hookah: a diving apparatus where the diver is supplied with air through a hose from a surface based compressor.

Larval: referring to the earliest stages of an animal's development.

Lobate: a body part having rounded projections or divisions.

Mucus: a slippery chemical produced by the soft corals as natural protection. Mucus is often produced in response to handling and cutting and can contribute to bacterial infection if not removed.

Necrosis: localized death of living tissue, in the case of soft corals around the cut after fragmentation.

Nematocyst: stinging cell used by the polyp to capture planktonic prey.

Photosynthesis: the ability to convert sunlight into energy.

Pinnate: having featherlike side branches.

Pinnules: the lateral processes or projections of a tentacle.

Plankton: microscopic animals and plants that occur naturally in the ocean and freshwater.

Polyp: any individual animal of the soft coral colony.

Reef tank: a home or commercial closed system tank display, designed to replicate life on coral reefs. These generally contain soft and hard corals, fish, live rock and other invertebrates.

SCUBA (Self Contained Underwater Breathing Apparatus): a diving apparatus where all the equipment needed for breathing underwater is attached to the diver, including a tank containing pressurized air.

Spicules: calcium carbonate structures which help support soft coral colonies. Occurring in different shapes and sizes, spicules are used to speciate soft corals.

Spiculose: having spicules.

Stolon: An elongated ribbonlike part of a soft coral colony which lies flat on the substrate and links polyps

Symbiotic: a biological relationship between two organisms that is mutually beneficial.

Tentacle: one of the eight armlike projections surrounding the mouth of a polyp. Tentacles are generally used for gathering food.

Undulating: having a wavy surface or edge.

Appendix A. Suppliers of Equipment Listed in this Manual

1. Aquatic Eco-systems Inc.
   1767 Benbow Court
   Apopka, FL 32703-7730, USA
   Tel. 407-886-3939 or 1-800-422-3939
   Fax. 407-886-6787
   e-mail: aes@aquatic-eco.com
   web site: http://www.aquatic-eco.com
   Comments: Suppliers of a large range of aquaculture and laboratory products.

2. Aquaculture Supply
   33418 Old Saint Joe Road
   Dade City, FL 33525, USA
   Tel. 352-567-8540
   Fax. 352-567-3742
   e-mail: ASUSA@Aquaculture-Supply.com
   web site: http://www.Aquaculture-Supply.com
   Comments: Suppliers of a large range of aquaculture and laboratory products.

3. AREA
   P.O. Box 901303
   Homestead, FL 33090-1303, USA
   Tel. 305-248-4205
   Fax. 305-248-1756
   e-mail: areainc@aol.com
   Comments: Suppliers of a large range of aquaculture products.

4. Southern Aquaculture Supply
   P.O. Box 326
   931 Saint Marys Street
   Lake Village, AR 71653 , USA
   Tel. 1-800-850-7274
   e-mail: saqua@iamerica.com
   web site: http://www.saqua.com
   Comments: Suppliers of a large range of aquaculture and laboratory products.

5. Pacer Pumps
   41 Industrial Circle
   Lancaster, PA 17601-5927, USA
   Tel. 1-800-233-2861 or 717-656-2161
   Fax. 717-656-0477
   e-mail: pacer@success.net
   web site: http://www.saqua.com
   Comments: Suppliers of a broad range of high quality pumps.

6. Advanced Aquatanks
   525 West 130th Street
   Los Angeles, CA 90061, USA
   Tel. 310-538-4282
   Fax. 310-538-9249
   Comments: Suppliers of aquarium supplies.

7. E and B Discount Marine
   201-Meadow Road
   Edison, NJ 08818, USA
   Tel. 1-800-BOATING
   Fax. 1-408-761-4421
   web site: www.ebmarine.com
   Comments: Suppliers of a full line of fiberglass and marine products.

8. Performance Diver
   One Performance Way
   Chapel Hill, NC 27514, USA
   Tel. 1-800-933-2299
   e-mail: service@performancediver.com
   web site: www.performancediver.com
   Comments: Suppliers of a full range of dive equipment.

9. Brownies Third Lung
   940 N.W. 1st St.
   Fort Lauderdale, FL 33311, US.A
   Tel. 954-462-5570
   Fax. 954-462-6115
   Comments: Suppliers of hookah rigs

10. Koolau Distributors
    1344 Mookaula St.
    Honolulu, HI 96817, USA
    Tel. 808-842-3701
    Comments: Suppliers of plastic transport bags.

11. U.S. Plastic Corporation
1390 Neubrecht Rd.
Lima, Ohio 45801, USA
Tel. 419-228-2242
Fax. 419-228-5034
Comments: Suppliers of plastic transport bags and a full range of plastic products.

12. Pacific Allied Products
91-110 Koami Loop
Ewa Beach, HI 96782, USA
Tel. 808-682-2038
Comments: Suppliers of transport boxes.

13. Marnika's Packaging Company
2370 Research Drive
Livermore, CA 94550, USA
Tel. 510-373-0283
Fax. 510-449-9146
Comments: Suppliers of insulation foam sheeting for shipping.

14. Memphis Net and Twine Company
2481 Matthews Ave.
P.O. Box 8331
Memphis, Tennessee 38108, USA
Tel. 901-458-2656
Fax. 901-458-1601
e-mail: memnet@netten.net.
Comments: Suppliers of plastic mesh, heavy duty fish baskets and polyethylene shipping bags.

15. Carolina Biological Supply Company
2700 York Road
Burlington, NC 27215, USA
Tel. 1-800-334-5551
Fax. 1-800-222-7112
Comments: Suppliers of basic laboratory equipment and animal specimens.

16. Chemaqua
P.O.Box 2457
Oxnard, CA 93033, USA
Tel. 805-486-5319
Fax. 805-486-2491
Comments: Suppliers of chemicals for laboratory and technical use.

17. E and B Discount Marine
201-Meadow Road
Edison, NJ 08818, USA
Tel. 1-800-BOATING
Fax. 1-408-761-4421
web site: www.ebmarine.com
Comments: Suppliers of a full line of fiberglass and marine products.

18. Quill Corporation
P.O. Box 94081
Palatine, IL 60094-4081, USA
Tel. 1-800-789-1331
Fax. 1-800-789-8955
web site: http://www.quillcorp.com
Comments: Suppliers of a wide range of office equipment.

Appendix B. Soft Coral Key

KEY TO THE GENERA OF COMMON SOFT CORALS OF THE SHALLOW TROPICAL WATERS OF THE INDO-PACIFIC (SUBORDER ALCYONIINA)

from Gawel, Mike. 1994. (Unpublished)

Genera included: *Sympodium*, *Fungulus*, *Efflatounaria*, *Anthelia*, *Cespitularia*, *Xenia*, *Heteroxenia*, *Asterospicularia*, *Bellonella*, *Minabea*, *Siphonogorgia*, *Chironephthea*, *Capnella*, *Lithophyton*, *Lemnalia*, *Paralemnalia*, *Nephthea*, *Dendronephthea* (*Morchellana*, *Roxasia*, and *Spongodes*), *Stereonephthea*, *Alcyonium*, *Cladiella*, *Sinularia*, *Sarcophyton*, *Lobophytum*.

1A Tentacles with one or more rows of **pinnules** on each side. Sclerites absent or only very small (0.02 to 0.05 mm.) flat biscuits or ovate rods or disks. ....Family Xeniidae...2.

1B Tentacles with pinnules in a single row on each side. Sclerites larger than 0.2 mm are usually present, as rods, spindles, clubs, needles, dumb-bells, capstans or spiny spheres. ....8.

2A Polyps retractable. ....3.

2B Polyps not retractable. ....5.

3A Dimorphism occurs (polyps of two types). ....*Fungulus*.

3B Monomorphism occurs (polyps of one type only). ....4.

4A Colonies form thin, delicate, encrusting mats, with small polyps (<2.0 mm tall). ....*Sympodium*.

4B Colonies have finger-shaped branches. Always one row of pinnules on each side of the tentacles . ...*Efflatounaria*.

5A Colonies form encrusting mats with large polyps (greater than 2.0 mm tall) which are non-retractile. ....*Anthelia*.

5B Colonies have projecting lobes bearing the polyps. ....6.

6A Lobes fingerlike with polyps evenly distributed along all parts. ...*Cespitularia*.

6B Colonies mushroom-shaped, with polyps concentrated on enlarged tips of lobes or stalks. ....7.

7A Polyps always monomorphic (one kind). ....*Xenia*.

7B Polyps dimorphic (two distinct types) . ...*Heteroxenia*.

8A Polyps connected only at their bases, usually joined by a planar membrane or stolons; not born on fleshy masses of tissue nor connected side to side. ....Suborder Stolonifera.

8B Polyps surrounded by or supported on top of fleshy massive tissue. ....9.

9A Colonies upright and often treelike in shape. Polyps on branches or lobed or fingerlike bases but not on massive fleshy bases (the dominant part of the colony is the polyp-bearing branches, not the fleshy polyp-less base). ....10.

9B Polyps born above massive fleshy bases which may also bear branches and lobes with polyps on them. Polyps occur close together on upper surfaces which are supported below by a sterile base with no polyps. The polyps can fully retract into the massive tissue around them. ....Family Alcyoniidae...21.

10A Polyps clustered on top of short lobes or stalks less than 10 cm tall, which may be branched. Sclerites distinctive spiny, starlike balls less than 0.1 mm in diameter. ....Family Asterospiculariidae..*Asterospicularia*.

10B Colonies fingerlike or branched. Sclerites not starlike balls. ....11.

11A Colonies fingerlike, typically not branched and with polyps scattered over all. Polyps are retractile or capable of withdrawing into the surface of the colony. ....12.

11B Colonies tall and repeatedly branched. Polyps all of one kind (monomorphic) and not able to be completely withdrawn into branch surface. ....Family Nephtheidae...13.

12A Fingerlike colonies usually are separate, single-lobed. Colonies often are bright colored, such as orange or red, and grow in dark caves and crevices, away from light. Colonies monomorphic. ....*Bellonella.*

12B Same as 12A, but colonies dimorphic. ....*Minabea*.

13A Fingerlike lobes are normally joined at their bases and grow in lighted areas exposed to sunlight. ....*Paralemnalia*.

13B Colonies branching and treelike, usually not joined at their bases. ....14.

14A Polyps are without large (greater than 1.0 mm long) supporting and protecting spicules (sharp-pointed, needle-like sclerites). ....15.

14B Each polyp is protected by large projecting warty spicules over 1.0 mm long, which are located on the outer side of the polyp stalk, away from the polyp-bearing branch axis. ....17.

15A The interior of the basal stalk is not heavily filled with sclerites. The stalk and branches are soft and flexible. ....*Lithophyton*.

15B The interior of the stalk is heavily filled with sclerites. Stalk and branches are hard and stiff. ....16.

16A Polyps are crowded on small terminal branch tips (“catkins”). ....*Capnella*.

16B Main stalks are very much branched, with polyps scattered over tertiary branches...*Lemnalia*.

17A Colonies with secondary and tertiary or more branching. Polyps retractile. Stalk and branches do not expand or contract greatly. ....Family Nidaliidae...18.

17B Colonies with thicker, tapering branches which may enlarge greatly with intake of water or may shrink with expulsion of water. ...Family Nephtheidae...19.

18A Colonies tall and highly branched, with relatively slender branches, similar to gorgonians, but lacking a horny skeleton. Polyps scattered over branches. Stalk and branches do not expand or contract greatly. ....*Siphonogorgia*.

18B Colonies with slender branches, not gorgonian-like (more “Dendronephthea”-like). Polyps scattered on the trunk and main branches as well as on the ends of terminal branchlets. ....*Chironephthya*.

19A Polyps scattered individually over the branches of the colony. ....*Stereonephthea*.

19B Polyps clustered in groups or bundles or on terminal lobes. ....20.

20A Polyps located only on small terminal lobes and arranged closely and orderly on the lobes, usually in clusters of many more than ten polyps. ....*Nephthea*.

20B Polyps clustered in small groups or bundles, usually of two to ten polyps, on the branches as well as the terminal lobes. Not photosynthetic. ....(formerly Morchellana, Roxasia, and Spongodes)...*Dendronephthea*.

21A Polyps are clearly of two distinct types consisting of: 1) large extendable main polyps (autozoids) bearing eight movable tentacles and 2) more numerous, pore-like polyps (siphonozoids) which are embedded in the fleshy mass between the autozoids, are not extendable above the surface of the colony and appear to lack tentacles. ....22.

21B All polyps are of one kind. ....23.

22A The colony has fingerlike lobes. The autozoids are relatively small, never over 10 mm tall. Basal interior sclerites are mostly cylinders less than 0.5 mm long with several encircling whorls of large warts. ....*Lobophytum*.

22B The edge of the upper, polyp-bearing surface may be smooth or folded, but no lobes occur in its middle. The autozoids are usually large, even taller than 10 mm when expanded. Basal interior sclerites are usually spindles (thickened needles) under 1 mm long, but in some species up to 2 mm, and bearing warts which are not arranged in a few whorls. ....*Sarcophyton*.

23A Colonies low (normally under 10 cm tall) and often encrusting with limited, if any, branching and only low lobes. Living polyps are often a darker color than surrounding fleshy tissue and their darkness disappears when retracted. Sclerites are very regular with capstans or dumb-bells less than 0.2 mm long found throughout the colony. The only other sclerites which may occur are fingerbiscuit-like ones smaller than 0.1 mm long on the polyps of some species. ....*Cladiella*.

23B Polyps cover lobes and branches. Sclerites are not capstans nor dumb-bells. Some sclerites in the interior of the colony are over 0.2 mm long. Fingerbiscuit-like sclerites are not present. ....24.

24A Sclerites are predominantly spindles, less than 1 mm long in most species. No small club-shaped sclerites occur in the surface of the colony. ....*Alcyonium*.

24B Warty spindle-shaped sclerites over 1 mm long always occur in the interior of the colony's base. Small club-shaped sclerites under 0.3 mm long are abundant in the surface tissue of the base and lobes of the colony. Large species may be over a meter in diameter. ....*Sinularia.*

Types of Spicules

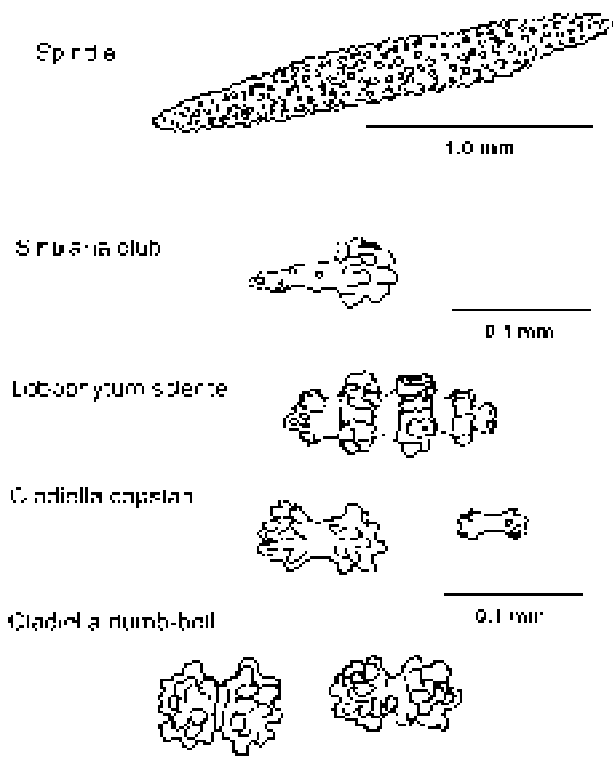
Spindle: A straight or curved elongated sclerite pointed at both ends.

Club: A sclerite that has a short stem leading to only one bulbous end.

Sclerite: A calcareous solid mineral element within the soft coral tissue.

Capstan: A sclerite like a short rod with two whorls of warts.

Dumb-bell: A sclerite with two warty heads connected by a narrow wartless bar.



Appendix C.
Generic Example of a Shipping Invoice

From:	**Address of shipper**
e.g.	Pleasant Coral Farm
	Tropical Paradise Way
	Pohnpei
	Federated States of Micronesia
	Tel. 691-555-4329
	Fax. 691-555-2657

To:	**Address of buyer**
e.g.	Contented Coral Buyer
	110 Main Street
	Anytown
	USA
	Tel. 987-320-FISH
	Fax. 987-320-CORAL
	Attention: John Doe

Quantity	Common name	Scientific name	Price (US$)	Total (US$)
130	Green leather	*Sarcophyton spp.*	3.00	390.00
210	Devil's hand	*Lobophyton spp.*	2.50	320.00
80	Tree Coral	*Lithophyton spp.*	4.00	320.00
105	Green sinularia	*Sinularia spp.*	5.00	525.00
52	Star polyp	*Briareum spp.*	4.50	234.00

Total livestock		$1994.00
Box charge[a]	12 boxes @10.00 per box	$ 120.00
Handling[b]		$ 50.00
Freight[c]	273 kg @ $4.00/kg	$1092.00

[a] Box charge includes the cost of the box, polystyrene insulation, bags, shipping, chemicals and oxygen.
[b] Handling charge includes cost of labor for extra packers.
[c] Note how much the shipping costs are relative to the livestock. This cost must be included in the buyer’s reselling price.

Appendix D. Buyers of Invertebrates for the Marine Aquarium Trade

Black Coral Hawaii, 2941 W. Central Ave., Bldg A and B, Santa Ana, CA 92704
Tel. 714-754-6368, Fax. 714-754-5432, e-mail coralfish@aol.com

Caribbean Creatures, 112 Peace Ave., Tavernier, FL 33070
Tel. 305-852-3991, Fax. 305-852-3149, e-mail drfish@bridge.net
website: caribbeancreatures.com

Dynasty Marine Associates, 10602 7th Ave. Gulf, Marathon, FL 33050
Tel. 305-743-7666, Fax. 305-743-9063

Fish Collection, Miami, USA. Tel. 305-944-3416, e-mail fishguys2@aol.com

Global Fish Net
Tel. 714-229-9910, Fax. 714-229-9919, e-mail gfn@earthlink.net

Golden Generation Inc., 13033 Yukon Ave., Hawthorne, CA 90250
Tel. 310-219-0215, Fax. 310-219-0401, e-mail saltfish1@aol.com

Harbor Aquatics, 927 N. 200 W, Valparaiso, IN 46385, USA
Tel. 219-764-4404, Fax. 219-763-4866, website: www.harboraquatics.com

Holiday Coral and Fish, 334 Fir Rd., Niles, MI 49120, USA
Tel. 616-684-3380, Fax 616-684-3244

Living Seas Wholesale, 2081 S.W. 70th Ave., H20-21, Davie, FL 33317
Tel. 954-452-2977, Fax. 954-452-5977

Reef Sciences International, 3494 Camino, Tassajara Rd., Suite 322, Danville, CA 94506, USA. Tel. 510-735-3258, Fax 510-735-6289, website: www.reefscience.com,
e-mail feedback@reefscience.com.

Sea Dwelling Creatures, 12583 Crenshaw Blvd., Hawthorne, CA 90250, USA
Tel. 310-676-9697, Fax. 310-676-9699, e-mail: sdcinc@earthlink.net

Total Marine Aquarium, 615-A North Avenue, New Rochelle, NY 10801
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