

The Basic Methods of Pearl Farming: A Layman's Manual

Maria Haws



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The Basics of Pearl Farming: A Layman's Manual

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**Center for Tropical and Subtropical Aquaculture
Publication No. 127**

March 2002

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Acknowledgments

The assistance and knowledge of many pearl farmers, colleagues and fellow researchers is gratefully acknowledged. Among those who selflessly contributed to this effort to provide the basic information needed by farmers to start pearl farms and produce high quality pearls are: Jean and Estelle Tapu, Tyrone Tapu, Ron Hall, Taruia Matara, Tarani and Piltz Napa, Soa Tini, Simon Ellis, Anne Orcutt Bailey, Kevan Main, Ben Ponia, Miles Anderson, Quentin Fong, David Thompson, Joan Rolls, John Rowntree, Tap Pryor, Kennedy Paynter, Francis Thibodeau, Fred Ward, Timothy Dick, Kelvin and Anna Passfield and John Sprague. Several private companies also contributed to this effort: Tapu Perles, Nukuoro Pearl Farm, Robert Reimers Enterprises and Black Pearls of Micronesia. Special thanks go to my colleagues of the Coastal Resources Center of the University of Rhode Island, who provided the moral support and flexibility to allow this manual to be written. Dr. C.L. Cheshire of the Pacific Business Program, University of Hawaii at Manoa, kindly provided assistance with the economic aspects of this work. The support given by CTSA and its personnel, Dr. Cheng-Sheng Lee (Director), Simon Ellis (Regional Aquaculture Extension Agent) and Kai Lee Awaya is greatly appreciated.

Illustrations and photographs were prepared by Diane Nakashima, Oscar Blanco and Maria Haws. The author is particularly grateful to Diane Nakashima for her efforts with the illustrations and for preparing the cover. Cover photographs are courtesy of University of Hawaii Sea Grant.

Above all, this work was inspired by the pearl farmers of Penrhyn (Tongareva), Cook Islands, who worked to establish pearl farms while maintaining the environmental health of their lagoon.

Funding for the printing of this publication was provided by the Center for Tropical and Subtropical Aquaculture (CTSA) through a grant from the Cooperative State Research, Education, and Extension Service of the U.S. Department of Agriculture (Grant #98-39500-5947). This publication was prepared with support from a grant from the Pacific Aquaculture Development Program, University of Hawaii Sea Grant Program, under Institutional Grant No. NA86RG0041 from the National Oceanic and Atmospheric Administration (NOAA) Office of Sea Grant, Department of Commerce. UNIH-SEAGRANT-grant # GEN 103.

The views expressed herein are those of the author and do not necessarily reflect the views of the U.S. Department of Agriculture, CTSA, University of Hawaii Sea Grant, NOAA or any of their sub-agencies.

Funding and resources were also provided by the following companies: Tapu Perles and SeaPearls.



Introduction

The purpose of this manual is to provide a reliable source of basic information for beginning pearl farmers to help them successfully start farms and produce high quality pearls. The manual is formatted so that each individual section can usually stand alone and therefore if read from cover-to-cover, there will be some repetition. As this was written and published in the United States, all references to money are made in U.S. dollars.

Because most pearl farmers hope to avoid competition by keeping their methods secret, the pearl farming industry has traditionally been one of the most problematic of aquaculture businesses to start from scratch. Although the basic methods are simple, beginning pearl farmers find it difficult to obtain the technical information needed to learn how to operate a farm, thus generally spending a long period of time experimenting. This manual describes basic methods of pearl culture that are used on small- to medium-sized pearl farms throughout the Pacific. By using the proven methods described in this manual, the new farmer should be able to immediately start and operate his or her pearl farm.

A short history of pearl culture

Pearls were the first gems discovered by man thousands of years ago. Since that time, people of many cultures have recognized the beauty and value of pearls. Pearls are the only organic gems and require no processing to reveal their natural beauty. At first, people relied on the chance finding of natural pearls in a variety of species of marine bivalves and freshwater mussels. Natural pearls are rare as perhaps maybe 1 in 2,000 pearl oysters contain a natural pearl. Natural pearls are formed when the pearl oyster reacts to an irritant by coating it with nacre, the shiny iridescent material found on the inner surface of the shell. Natural pearls are usually small, of various colors and irregular in shape. The high value of natural pearls led to the creation of pearl fisheries in nearly every part of the world where pearl-producing mollusks were found. Most of these pearl fisheries were short-lived because the fishers soon over-exploited the natural stocks.

Prompted by the high value and scarcity of natural pearls, Japanese researchers developed methods that brought pearl production under the control of humans in the early twentieth century. These “cultured pearls” are generally larger and of a more consistent size and color than natural pearls. Producing cultured pearls depends on a surgical procedure called grafting, which entails surgically implanting an artificial nucleus (shell bead) into the tissue of a pearl oyster. The oyster then secretes nacre around the nucleus. After several years of caring for the oysters, the cultured pearls are harvested.



Figure 1. Black-Lip pearl oyster in its natural habitat, a coral reef of the Cook Islands.
(photograph: Maria Haws).

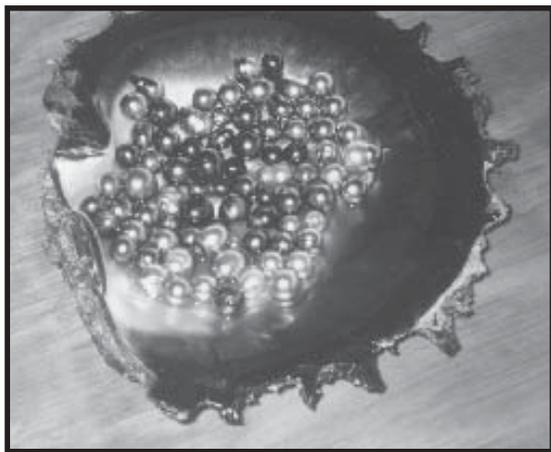


Figure 2. Black pearls resting on the shell of a Black-lip pearl oyster (*Pinctada margaritifera*).
(photograph: Maria Haws)

Several species of pearl oysters are cultivated for pearl production. This manual focuses on the Black-Lip pearl oyster (*Pinctada margaritifera*). Black-Lip pearl oysters are the most common species of pearl oyster found in the South Pacific islands (Figure 1). The Black-Lip pearl oyster is distinguished from other species by the dark, iridescent nacre found on the inner shell.

Pearls produced by Black-Lip pearl oysters are known as “black pearls” or “Tahitian black pearls” (Figure 2). Black pearls are large, usually over 7 mm (0.28 in) in diameter and may be as large as 22 mm (0.8 in). *Note: Pearls are always measured in millimeters within the*

industry. The nacre and pearls of Black-Lip pearl oysters are generally black or gray with shades of blue, green, silver and pink. Most black pearls are produced in the sheltered waters of the atolls of French Polynesia and the Cook Islands, although Australia, Indonesia, the Philippines and the Western Pacific Islands have growing black pearl industries.

Benefits of pearl culture

Pearl farming is an attractive business venture because of the high value of the final product. Although black pearls vary greatly in value depending on the size and quality, large, round pearls of high quality can sell for very high prices. For example, farm prices (2000) showed an 8-mm (0.3 in) black pearl rated “good” sells for around \$40 while a 12 mm (0.48 in) pearl of the same quality sells for up to \$120. In recent years, pearl prices have fallen significantly, especially for smaller, lower-quality pearls. The price of large and high quality pearls, however, have not declined as rapidly.

One of the principal advantages of pearl production is that the final product is lightweight and non-perishable. Pearl oysters are most commonly found in remote tropical atolls where commercial exploitation of marine resources such as fish is difficult due to the lack of refrigeration and shipping facilities. Pearls require no refrigeration and very simple processing. Pearl farming is also a compatible occupation for people who like working on the water and have boating, diving and fishing skills. With the exception of the grafting process, pearl farming is a relatively simple form of aquaculture because pearl oysters do not require artificial feeds, complicated farm structures or constant attention.

If properly managed, pearl farming will not harm the environment and can increase the wild pearl oyster population over a period of years. For these reasons, pearl culture may be the best opportunity for business development in many isolated island areas.

Three cautions

Although pearls are a high value product, many pearl farmers fail in their attempts to make a living by pearl farming. When considering pearl farming as an investment opportunity or as a small business, there are three key points to remember:

1) Successful pearl farming requires a long-term investment of time, money and hard work.

Although pearl farming is relatively simple to learn, the main reason newly established pearl farms fail is the farmer is not prepared to invest enough time and money to take the care required to produce high quality pearls. A period of 2-3 years is required before the first pearl harvest and most pearl farmers will not begin to realize a profit until the second or third harvest. As a prospective farmer, you must have enough money, time and patience to care for the farm during this time.

2) Production of high quality pearls is the key to having a profitable farm.

Only 5-10% of each crop of pearls will be of high gem quality. From these few, top quality pearls, 90% of the farm profits will come. Pearls of average quality usually sell for only enough to recover the cost of producing them, while lowest quality pearls will bring such low prices that money will be lost in their production. Producing top quality pearls is achieved by taking good care of the pearl oysters during all stages of farming and is also dependent on the skill of the grafting technician. It only takes one mistake to ruin a potentially good pearl, so attention to detail during all stages of farming is very important. Carefully following the instructions in this manual will improve chances of producing enough high quality pearls from the first harvests to begin making a profit.

3) Production of high quality pearls is only possible under certain conditions.

Before starting a farm, evaluate whether you meet the following criteria:

- A reliable source of pearl oysters
- A suitable site
- Sufficient funds to establish and operate a farm
- Access to grafting technicians
- Ability to market pearls

If you cannot meet these requirements, you should consider starting a different type of business rather than risk your money starting a pearl farm that may not be successful.

Basic biology and ecology of pearl oysters

Pearl oysters are members of the phylum Mollusca and belong to the class Bivalvia. Bivalve mollusks are distinguished by having two shells (two valves), a soft body with a small foot, a byssal gland and paired gills. Although the common name of “pearl oyster” suggests a close relationship with other types of oysters, pearl oysters are actually a distinct genus from the edible oysters, *Crassostrea* and *Ostrea* and have important anatomical and behavioral differences. The internal anatomy of a pearl oyster is shown in Figure 3.

Pearl oysters are most commonly found in tropical areas. The Black-Lip pearl oyster (*Pinctada margaritifera*) is widely distributed throughout the tropic Indo-Pacific area (Figure 4). There are several subspecies and strains of *P. margaritifera*, including the Hawaiian strain, *P. margaritifera galstofii*, and the closely related *P. mazatlanica*, which was considered a strain of the Black-Lip for many years.

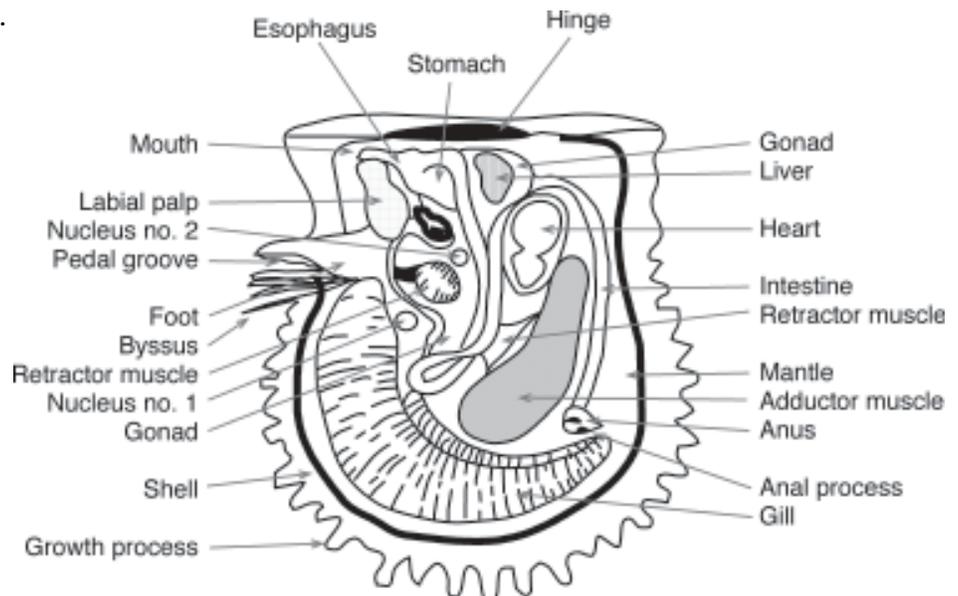


Figure 3. Internal anatomy of the pearl oyster (modified from George, 1978).

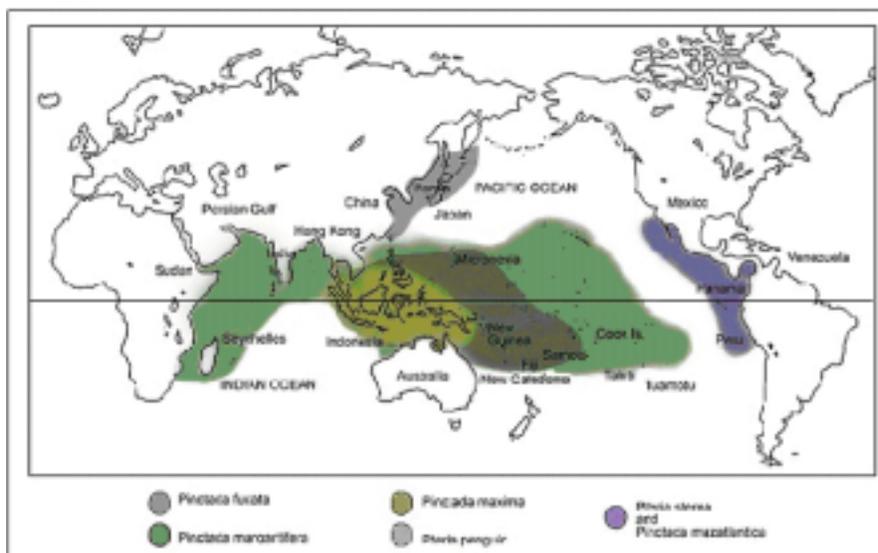


Figure 4. Distribution of the major pearl producing species (adapted from Gervis and Sims, 1992)

Black-Lip pearl oysters are generally found in areas where water temperatures range from 25 to 30°C. Below 23°C, tropical species of pearl oysters stop breeding and may die. While pearl oysters can tolerate a range of salinities, they are most common in water with high salinities (around 33 ppt). They appear to grow best in clear waters that are free of large amounts of sediment since pearl oysters may have difficulty feeding in turbid water.

Black-Lip pearl oysters spend their adult lives attached to hard substrates by the byssal threads. Before the pearling boom of the late 1800s and early 1900s, they were extremely common and are reported to have thickly covered large areas of reef, including inter-tidal areas. They are now rare in many places as a result of overfishing, and are most common at depths below 60 ft. Pearl oysters are gregarious, meaning that they tend to be found in groups, both as juveniles and adults.

Pearl oysters are protandric hermaphrodites, which means that most are first male, then female. The male phase usually occurs during the first 2-3 years of life, with the change to the female phase in later years. Pearl oysters have been reported to live as long as 25 years. Pearl oysters reproduce by releasing millions of eggs or sperm into the water column, where fertilization occurs randomly. In less than 24 hours, the fertilized egg develops into a trochophore larva, a free-swimming organism (Figure 5). The larvae remain suspended in the water column for 2-3 weeks before undergoing metamorphosis, changing into an attached juvenile “spat.” Shortly before metamorphosis, the larva develops an enlarged foot and an eye-spot. The foot remains after metamorphosis, and the young spat retains the ability to move about for several months even after it attaches itself to a hard substrate. Pearl oysters can attach and reattach themselves using the byssus.

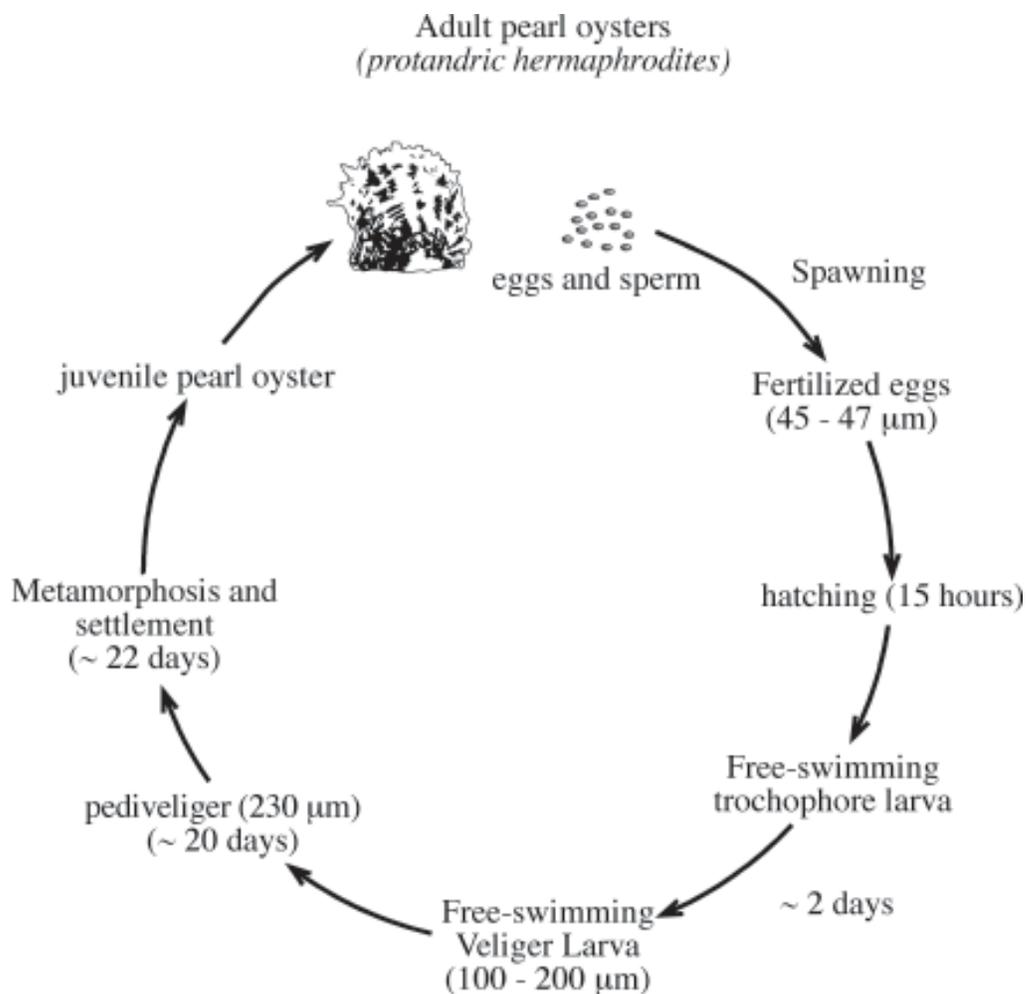


Figure 5. The life cycle of the pearl oyster.

Pearl oysters feed on small algae found in the water column. The gills in bivalves are large, and tiny hair-like cilia on the gills are used to remove small particles from the water. Both adults and larvae feed on algae and other small organisms. Clear tropical waters contain limited amounts of algae. Therefore, a large amount of water must be filtered daily in order for the pearl oyster to obtain sufficient food. This is the reason that importance is placed on not crowding pearl oysters on the farm and for keeping the shells clean of organisms that compete for food.

Overview of pearl farming

Pearl farming begins with conducting a feasibility study to determine whether the proper conditions (financial, environmental, operational and biological) that allow pearl farming to be profitable exist for the situation in which you wish to farm. If the results of the feasibility study are positive, a farm site will be selected and the farm structure established. A source of pearl oysters must then be obtained. A new stock of young pearl oysters should be added each year to the existing pearl oysters on the farm, so

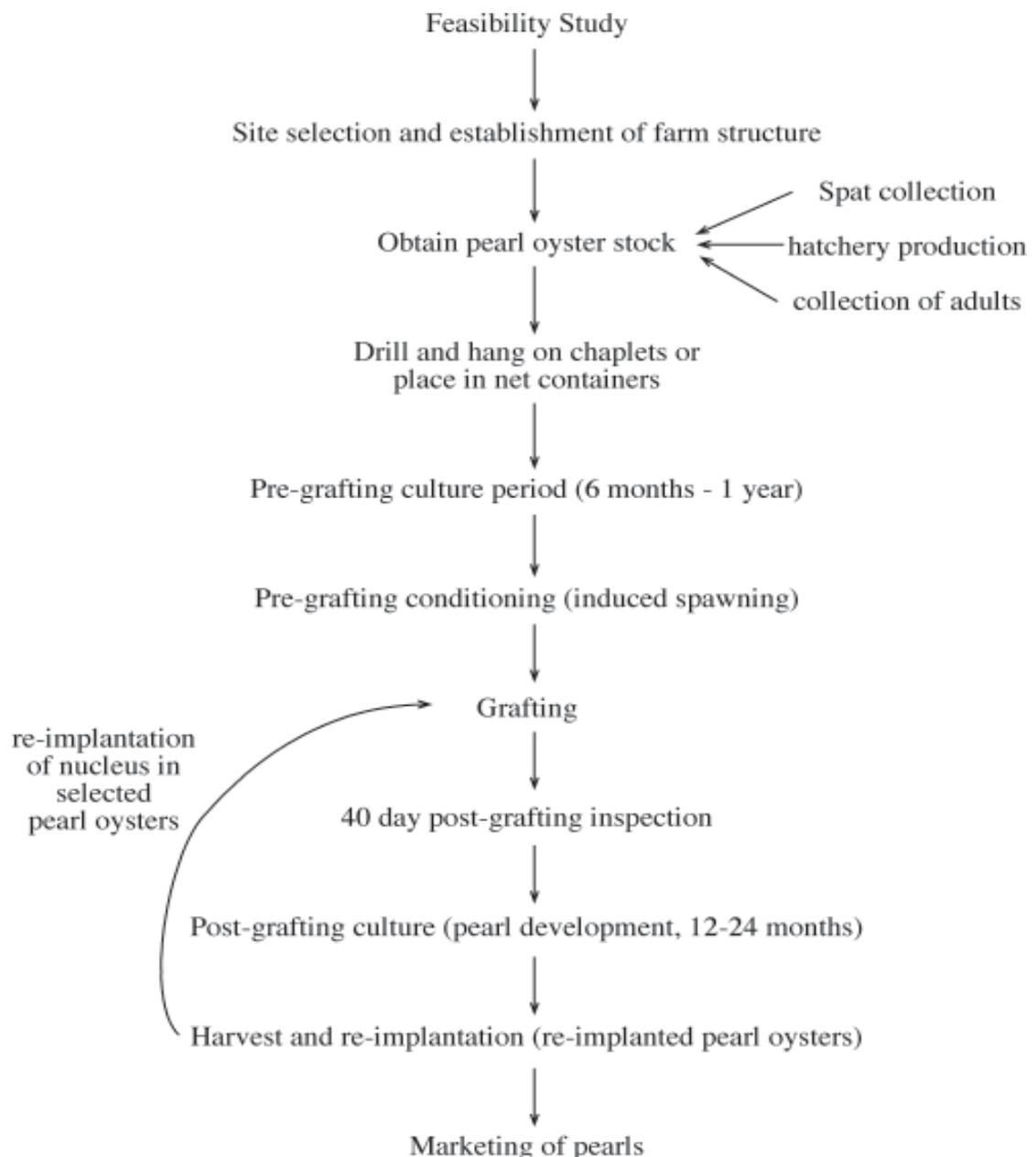


Figure 6. Steps in pearl farming

that new cycles of grafting and harvesting can take place regularly. After young pearl oysters have reached about 2 years of age, they are ready for grafting, which starts the development of a cultured pearl. After an inspection 40 days after grafting to evaluate the results, the pearl oysters are kept on the farm for a further 12-24 months. The pearls are then harvested, and the pearl oysters that produce good quality pearls are grafted a second time (Figure 6).

Determining if pearl farming is possible and will be profitable for you

Establishing and operating a pearl oyster farm requires a large investment of time and money over a period of several years. Additionally, the correct biological conditions must be present to allow pearl oysters to grow well and produce high quality pearls. By conducting a feasibility study before starting a farm, you can determine how much it will cost to operate a farm and if the right conditions for growing pearl oysters are available. You can also roughly calculate how much you can expect to earn from pearl farming. The following is a list of factors that must be contemplated before investing in a pearl farm:

Costs of starting and operating a farm

Starting a pearl farm and keeping it operating for a long enough period to obtain a steady return may take as long as 4-5 years. Obtaining spat, growing them out to grafting size, grafting and culturing until the first harvest is a lengthy process. It must also be recognized that even with a good first harvest, the original investment may not be entirely returned. This may not occur until the second or third harvest. The major types of expenses of starting and operating a farm are listed below and also in Appendix A.

Major Costs

- Cost of obtaining pearl oysters by one of three methods: Spat collection, purchase of hatchery-produced spat or collection of adults from the wild.
- Equipment and supplies (see list at the end of the manual)
- Shipping costs for equipment and supplies and import taxes
- Farm structure (lines, rafts, underwater trestles, floats)
- Farm platform
- Boats
- SCUBA gear
- Labor
- Utilities (e.g. electricity, water) and communications (e.g. telephone or radio)
- Gas and oil for boats or vehicles
- Replacement costs for equipment and supplies

- Licenses or permits
- Fees for grafting technician
- Marketing expenses
- Transportation
- Consulting fees for technical advisors

It is difficult to present information here that specifies exactly how much will be necessary to invest in a farm, since this will vary widely according to local prices and the characteristics of each farm. Some of the major factors that influence costs are discussed below. In the Appendix, simplified budgets are presented for two sizes of farm: a small farm where 3,000 pearl oysters are grafted every 18 months and a medium size farm where 6,000 pearl oysters are grafted during every production cycle. While most farms will have the same sorts of expenses, each farmer must collect information on what the real costs will be in his or her location and use these to decide whether pearl farming is feasible.

1. Farm size

In general, 3,000 pearl oysters is the minimum number needed for a profitable farm because there are certain fixed costs that will be too high if fewer pearl oysters are available for cultivation. Fixed costs are those which do not change regardless of farm size. For example, it is not profitable to hire a grafting technician unless you have at least 3,000 pearl shells of the right size and condition to graft. The major expense of hiring a grafting technician is paying for his transportation, lodging and food. These costs change little whether 3,000 or 300 pearl oysters are grafted. The cost of a boat is another fixed cost, which will vary little unless the farm is so large that two or more boats are required to service the farm. The example presented in Appendix 1 shows that with a farm of this size, about \$9,000 will be recovered over the amount of the expenses required to operate a farm for 18 months. There will be an additional start-up cost of approximately \$17,000 which means that it will take at least two production cycles to recover these expenses. Only on the third crop (after about 4 ½ years) will the farmer have recovered all costs and start to make a modest profit.

Farm size does influence certain costs. For example, in order to maintain a pool of 3,000 pearl oysters of suitable size and condition to graft every 18 months, the total farm size would typically need to have 12,000-15,000 pearl oysters in various stages of culture (spat, grafting size, grafted). The size of the farm will also determine the quantity of materials such as lines and floats needed, and the labor costs of maintaining the farm. The example in the Appendix shows that within a certain size range, larger farms are more profitable since start up costs and operation costs do not increase in proportion with farm size. That is, a farm can double in size from 3,000 to 6,000 pearl oysters grafted, thus doubling revenues, without having costs double.

One way to overcome some of the limitations and high costs of operating a small pearl farm is for neighboring farmers to cooperate on some tasks such as hiring technicians or monthly cleaning. Purchasing equipment and supplies together may also allow farmers to obtain better prices.

2. Labor

Pearl farming is fairly labor intensive and labor requirements vary depending on which tasks are being performed. As a pearl farmer with 3,000 grafting-sized pearl oysters and several spat collector lines, you will have to work about half-time on the farm yourself and also hire one or two part-time assistants. Because it takes a minimum of 2-3 years to reach the first harvest from the time the farm starts operating, you must have other means to support yourself until the first harvest, as well as sufficient funds to hire some workers. Labor costs will also depend on whether this is a part-time occupation where a family works without wages or whether laborers must be hired. Again, as can be seen from the examples in the Appendix, within a certain range of farm sizes, larger farms can be operated with little additional costs. For example, two people can tend 6,000 pearl oysters with a small amount of additional time each week so that labor costs do not double with farm size.

3. Equipment, supplies and facilities

The cost of equipment will be determined by the size of the farm and by the type of facilities already available in your location. In some cases, individuals may have most of the resources needed already, for example, a boat and outboard motors. Often farmers can benefit by sharing certain equipment or facilities such as SCUBA compressors or grafting platforms. You must plan on the expense of regularly replacing and maintaining equipment and facilities.

4. Location

The requirements for a good site are discussed later in this manual. Remember that the further the pearl farm is from your house or boat dock, the more it costs to buy gas to reach it. You may also suffer more losses due to theft if the site is far from your house. The amount of ropes, floats and anchors will vary according to the type of site chosen and the culture method. Gas to get to the farm tends to be a highly variable expense and when using the model budgets in the Appendix, you will need to carefully calculate what your particular expenses will be.

5. Spat source

Since spat collection is the main source of young pearl oysters, you must decide how many spat collectors you want to use on a regular basis and the cost for collector materials, lines and gas to service the lines. If spat are purchased from a hatchery or from someone who collects spat, this cost must be taken into consideration. Whichever method is used to obtain spat, the cost of raising them to grafting size must also be calculated. The smaller the spat collected or purchased, the higher the cost of caring for them until they reach grafting size. If adult pearl oysters are collected and used, transportation and diving costs will be incurred.

5. Grafting

Hiring a grafting technician is one of the major expenses for any farm. A technician will usually charge \$3-\$4 per pearl oyster seeded, or will take part of the harvest as a share. The additional expense of his or her transportation, lodging and meals will vary depending on where your farm is located.

6. Marketing expenses

Pearl farming does not end with the harvest. Pearls must still be sold in order to make a profit. Selling pearls can be a lengthy, complicated process requiring local and foreign travel, communications and presentation costs. Start making marketing contacts well before the harvest, and budget for the expenses incurred to find a buyer willing to purchase your pearls for a reasonable price.

7. Miscellaneous expenses

You should also account for having to pay miscellaneous expenses, such as repairs, communication costs, permit fees, taxes, etc.

How much can you expect to earn from a pearl harvest?

The Appendix contains examples of budgets for small and medium size pearl farms that will provide a beginning farmer with a model to use to estimate how much it will cost to start and operate a pearl farm and approximately how much profit he or she can expect to make. These are simplified examples and must be adapted to the specific costs and prices of each individual (see the Appendix).

The amount of money you can expect to earn depends on the number and quality of pearls harvested.

In cases where the grafting technician is good, and good farming practices are used, it is generally expected that marketable pearls will be obtained from at least 45% of the pearl oysters that have retained the nucleus 1 month after grafting has taken place. The remaining 55% may be of such poor quality that they cannot be sold. For example, if a good technician grafted 3,000 pearl oysters, about 20% would die or reject the nucleus within 30 days. Between further losses during the cultivation period and the number of poor quality pearls harvested, the resulting 45% saleable pearls would be 1,350. It is not possible to calculate exactly how much these 1,350 pearls will be worth, since pearl prices fluctuate, and because each harvest contains a widely varied assortment of pearl types, sizes and qualities. However, as a general rule, the average farm price of a pearl is around \$35. At this price, the 1,350 pearls could be sold for about \$48,000 (gross revenue). A small amount of this revenue would also be gained from the keshi pearls harvested at this time.

The profit margin on pearls is relatively low.

To estimate how much of the \$48,000 will be profit, the estimated costs are subtracted from the expected gross profit. With the exception of the very largest, highest quality pearls, you can expect that from the average pearl, which sells for \$35, the profit will be approximately \$7 per pearl since the cost to produce a pearl is about \$28 (\$38,713 costs, 1,350 pearls). Using the earlier example, 1,350 pearls bringing a profit of \$7 each would result in a total profit of \$9,000. This is relatively low for 2-3 years of hard work, particularly when considering that the startup costs must also be recovered. Note that in the model budget for a medium size pearl farm of 6,000 pearl oysters grafted, while the average price per pearl is the same, the cost to produce each pearl is lower, at about \$20 per pearl. This results in each pearl yielding a profit of \$14, about double that of the profit from pearls produced on the small farm.

This slender profit margin is the reason that great emphasis is put on producing high quality pearls, since only these pearls sell for a high profit. As can be seen, the “average” pearl brings very little profit. It is the rare, exceptionally high-quality pearls that produce most of the profit for a farmer. This example considers only the pearls produced the first time a pearl oyster is grafted. As will be discussed later, the pearls produced the second time a pearl oyster is grafted are larger and generally of higher quality and contribute significantly to farm revenues over time.

There may be more profitable ways to invest your money and time.

As demonstrated above, pearl farming can be profitable, but the profits realized are usually not as great as expected. Additionally, to reach even this level of profit requires the ability to maintain the right conditions to grow pearl oysters by using good farming practices. To decide whether pearl farming is the best way to spend your time and money, it is helpful to compare the expected return from pearl farming with that of other investments and activities.

Consider whether you would earn more money if you invested the same amount of time and labor into other activities as you will have to in order to maintain your pearl farm. This is called the opportunity cost. It is also important to compare the amount of money you would earn if you invested your money in some other type of investment (return on investment). For example, if instead of investing \$10,000 in a pearl farm, you kept this money in the bank for 5 years, with a 5% return provided by a traditional bank, this investment would then be worth approximately \$12,760. Will the pearl farm give you a higher return on your money? Will the return justify the increased risk associated with pearl farming as compared to keeping it safely in a bank? If you had to borrow the money to make the original investment, you will have to pay that back with the income generated, decreasing your net income even more.

Comparing the financial advantages and disadvantages of investing your time and money in pearl farming will help you to make an objective decision about whether pearl farming is the right choice for you.

Selecting a site for a pearl oyster farm

Selecting a good farm site is an important first step towards producing good pearls.

Where the farm is located can determine whether the operation is biologically and economically feasible. The site affects how well pearl oysters grow, the quality of the pearls, how safe the farm is from theft or vandalism and how much it costs to operate the farm. Choosing an appropriate site from the beginning is also important because it is difficult to move a farm once it is established.

What to look for when choosing a farm site

The presence of pearl oysters

The presence of adult pearl oysters or spat indicates that the environment is a good one for pearl oysters. However, do not eliminate a location because of its lack of oysters, in some areas, no pearl oysters will be found because they have been removed, or are naturally rare, but these areas can still be good farm sites if they have the characteristics mentioned below.

Good water quality

Pearl oysters prefer clean, clear water far away from sources of contamination such as chemicals, oil, sewage or other pollution. Areas near large villages or towns will usually have some pollution, so farms should be located as far away as possible, or up-current from the source of pollution. Do not locate your farm near the mouth of a river or other sources of freshwater since sudden changes in salinity can be harmful. Areas with rough water where sand and silt are stirred up should also be avoided since pearl oysters have trouble feeding in cloudy water. A general rule is that a site with thriving corals will be a good site for pearl oysters.

A depth of 75-120 ft (22-36 m) and away from reef areas

If the farm is located in an area shallower than 75 ft (22 m), there will not be room to hang farm lines. Locating a farm within 75 ft (22 m) of reef areas may also result in predation by mollusk-eating fishes, rays and octopi that find shelter in the reef. A maximum depth of 120 ft (36 m) is suggested since diving to greater depths is dangerous. Setting secure anchor lines is easiest when the diver can tie off the anchor line to rocky areas on the bottom, which cannot be safely done in depths over 120 ft (36 m). Also, when seeded pearl oysters are dropped or fall off the line, they must be retrieved, a dangerous or impossible task in a very deep area.

A slight water current

A current is beneficial, since water exchange provides a constant supply of oxygen and nutrients to the pearl oysters. Water exchange also helps prevent a build-up of waste products beneath the farm that could cause problems with water quality. It is important to observe both surface and bottom currents at a site, since in some areas the surface current may appear to be adequate, but the bottom current may be much less. Waste products can then accumulate underneath the farm. Areas with fast currents or rough water, however, are difficult to work in and possibly harmful to the pearl oysters. Therefore, only slight currents are tolerable. Areas with stagnant water or rotting seaweed present are also not good sites.

A site that can be watched and protected

Pearl oysters are valuable and theft is common. Locating the farm within sight of your house will help prevent this. Additionally, boats or fishing activity can damage lines, so look for areas with little traffic or activity. By avoiding conflicts with other users of the area, your farm will be safer from damage and theft.

A site where the farm lines or other farm structures can be securely anchored.

There are two ways to secure the main line and anchor lines. One way is to tie them to rocks or coral heads that occur naturally on the farm site; the other is to use artificial anchors like concrete blocks or sand screws. However, tying off the lines to rocky areas is by far the easier and more secure method.

A healthy reef

It is important to maintain the condition of coral reef areas. Pearl oysters grow best when their environment is healthy. Therefore, take care not to break or damage corals when setting up the farm – the health of your farm depends on the health of the reef.

Although it is usually most convenient to tie main lines and anchor lines to rock or coral areas, avoid disturbing corals if possible. Never tie lines onto large, protruding coral heads. Coral heads make poor anchoring points since they are fragile and break easily. Pick areas where the lines can be tied to the solid base of the reef structure and where little coral will be broken. Coral will rapidly grow around the ends of the lines tied to it and over racks anchored on the bottom. Bare, rocky areas with minimal coral cover are the best spots on which to tie lines.

Also take care not to break the coral by standing on it, by allowing farm lines to drop over the reef, or anchoring boats to coral areas. Establish a mooring buoy near your farm instead of anchoring directly on the coral, or tie the boat to the farm line itself.

How to setup the farm

Pearl farms require only very simple structures, the main purpose of which is to provide some means of holding pearl oysters off the bottom. There are three basic types of farm structures: Tahitian longlines (so-called because they are the most common method used in Tahiti), rafts and underwater trestles. You can also use some combination of these, depending on your needs and location.

1. The Tahitian Longline Method

A Tahitian longline is simply a length of strong line (main line) held in place by anchor lines and kept afloat by buoys. Proper placement of the anchors and buoys keeps the longline at the correct depth (See Figure 7 - longline illustration). The longline can be used to hang chaplets, pocket panels, lantern baskets or spat collectors.

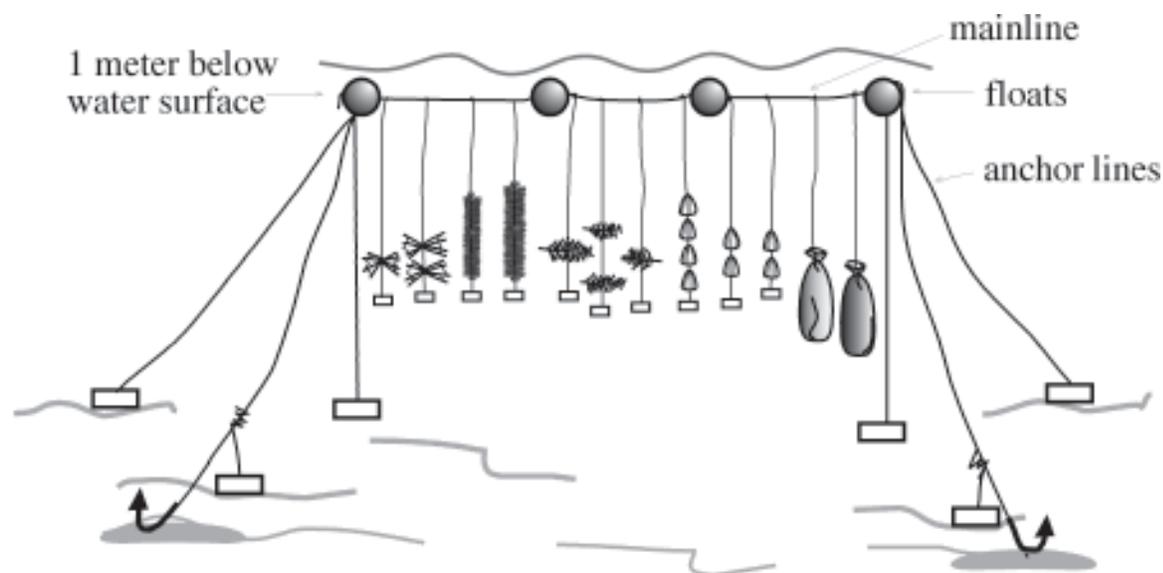


Figure 7. "Tahitian" long line. A mainline is hung from a series of anchor lines kept suspended by floats interspersed along the line. Longlines can be used to hang chaplets, spat collectors or pocket panels. Modified from Gervis and Sims (1992).

This method is favored because the entire farm structure is below water so the farm is hidden and protected from damage from rough weather and boats. Additionally, material costs are low and should the need arise, the lines can be moved more easily than with other types of farm structures. One disadvantage to the longline method is the need to dive to work on the farm.

Since the longline method is the most commonly used in the Pacific, only this method will be described in detail. It takes two people working underwater and at least one person in a boat to establish a

longline. The line used for the main line should be a minimum of 3/4-in (18-mm) polypropylene or nylon line.

To start, a diver ties one end of the main line to a coral or rock pinnacle or other anchoring point no deeper than 9 ft (3 m). Be sure the knot used to tie the main line to the anchoring point is very strong. It is wise to anchor the main line at multiple end points since occasionally the main line may fray where it is attached to the coral or rock pinnacle. Then play out the line in the direction of the next anchoring point. Continue until the end of the main line is reached. When tying the line at the last anchor point, it is important to pull the line as tightly as possible before knotting it securely around the anchor point. Usually two people are needed to do this; one person pulls the line as hard as they can and holds it, while the second person ties the knot. You can also use a boat to pull lines tight.

Once the main line is securely attached at both ends, begin to attach the anchor lines at 66-ft (20-m) intervals. Use at least 1/2-in (12-mm) polyethylene or nylon rope for the anchor lines. Loop the anchor line over the main line and secure it, using a knot that holds firmly but can be untied easily, since the final adjustments to the anchor lines will be made later. Leave plenty of extra line for making adjustments and tying knots. Tie a weight to the free end of the rope and then drop it straight down. This keeps the anchor line positioned vertically below the main line. When you feel that the weight has hit bottom, one diver follows it down and ties the end of the rope to the bottom. Be sure and tie the rope to a secure point. Divers can take turns doing the deep dives as this makes it safer because of the number of deep dives required. Depending on the current and location of the line, you may have to add some anchor lines tied at angles to the main line to keep it from drifting to one side.

In many cases, you may not be able to use coral heads or rocky pinnacles as anchor points, but will have to use weights as anchors instead. More care is needed in this case, as it is important that several sufficiently heavy weights be used at each end and for each anchor line. The end anchor point should have one anchor line tied directly under the main line, and three additional weighted lines tied at angles to the main line. When using weighted anchors, be sure that each anchor weighs at least 75 lb (34 kg). You may need to add more anchor weights, depending on how rough the water is. For several months, before adding the pearl oysters check the lines weekly to be sure that the anchors are not shifting and allowing the line to move.

Once all the anchor lines are in place, attach one float directly over each anchor line. Use a slipknot, which can be easily untied later but is strong enough to hold the float in place. Once all the floats are attached, go back along the line and begin to pull the main line down to the correct depth by pulling down the anchor lines. The main line should be about 13-16 ft (4-5 m) deep, so when the chaplets are tied on, they will hang at a depth of 19-23 ft (6-7 m). When you have finished doing this, swim back along the line and check the depth at each anchor point. You may have to adjust some of the anchor lines and floats because the line tends to stretch and the weight of the pearl oysters may cause the line to sag. Recheck the depth of the line every week or so; you may have to retie some of the anchor lines or add more floats as the lines stretch.

A word about dive safety and pearl farming

The most hazardous part of pearl farming is the frequent need to make multiple deep dives. Most of the diving done on a pearl farm, especially when setting up the farm, are bounce dives. Bounce dives are those dives where a diver descends and then immediately ascends, for example, when tying an anchor line to the bottom of the lagoon. Bounce dives can easily lead to decompression syndrome (DCS, also known as “the bends”) because the diver has a tendency to ascend rapidly and to make several of these types of dives in rapid succession without taking sufficient time at the surface (surface interval) to release nitrogen from his or her body.

Avoid DCS by following these guidelines:

- € Take a SCUBA certification course and follow all dive safety rules.
- € Use dive gear that is regularly inspected and certified as safe.
- € Avoid areas and farm set-ups that require diving to depths over 100 ft (30 m).
- € In deep areas, use weights to sink and anchor lines rather than diving to dangerous depths (over 120 ft or 36 m) to tie the ends of the anchor lines to the substrate.
- € Avoid multiple deep dives, especially to depths over 60 ft.
- € Use a dive computer or a dive table and watch to time your dives and keep within no-decompression limits.
- € Always ascend more slowly than the slowest bubble that is released when you exhale and hold on to the anchor line on the way up to slow your rate of ascent.
- € Take extra long surface intervals between bounce dives.
- € Always dive with a buddy and take turns making deep dives.
- € Alcohol or drugs, and diving are a dangerous combination. Never dive while under the influence of alcohol or drugs, or while suffering from a hangover.
- € To avoid dehydration, which may contribute to DCS, drink water regularly while working.

Maintain the main line at the correct depth.

When pearl oysters are hung on the main line, the added weight will cause the line to sag between the points where the floats are attached. The entire line may also sink. Therefore, you should be prepared to check the depth of the entire line every week or so. Add more floats to points where the lines sag, and add enough floats to keep the line at a depth of 13-16 ft (4-5 m). Keeping the pearl oysters clean will also help reduce the weight on the line. Once the pearl oysters and line become fouled, the line may sink out of sight in just a few days. And a line is very difficult to raise to the surface after it has sunk.

2. Floating rafts.

Floating rafts can be used as bases to hang pearl oysters. Rafts are commonly used in Japan and Indonesia in protected areas and bays. Usually the raft is constructed from lightweight timber or bamboo. The floats can be made from large drums sealed with fiberglass or commercial floats (Figure 8-diagram of raft).

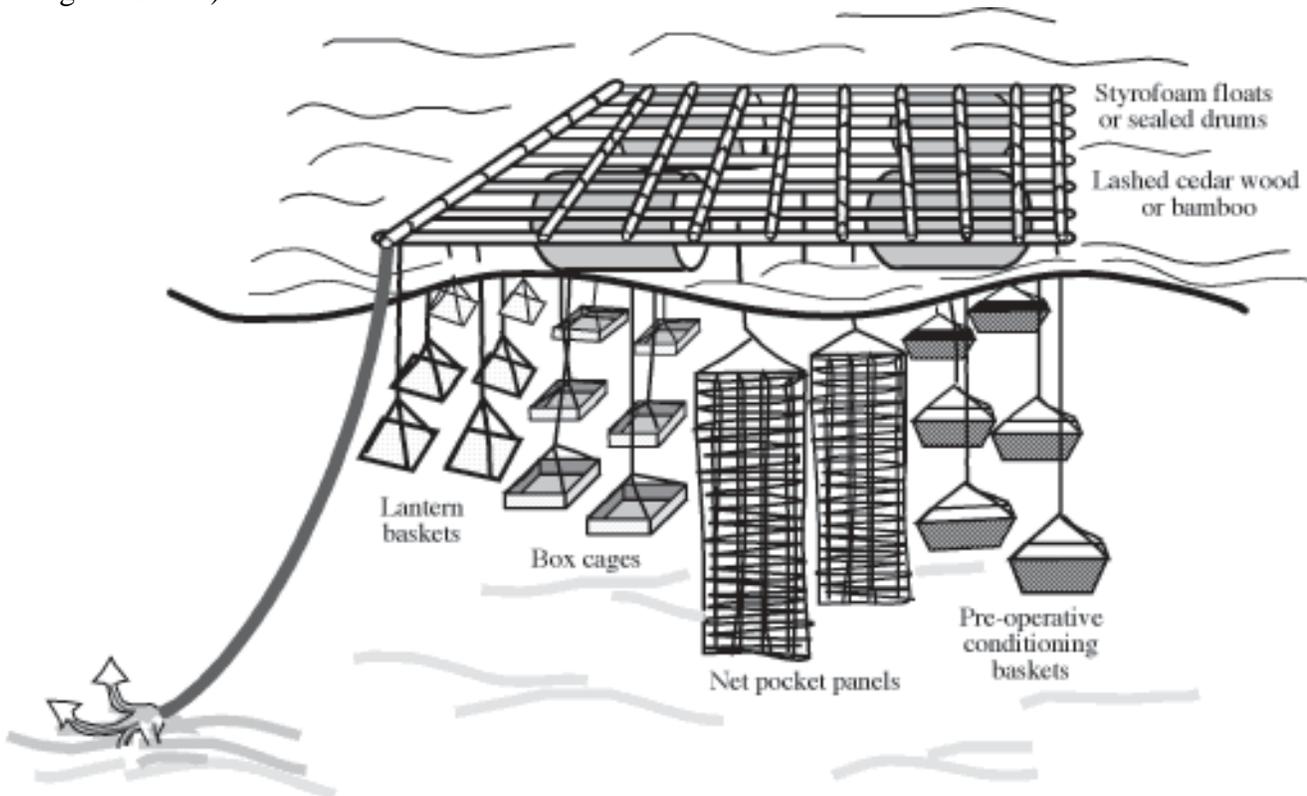


Figure 8. Rafts can be used in calm waters to hang a variety of pearl oyster containers. Modified from Gervis and Sims (1992) by Nakashima.

One advantage to this method is that it provides a stable work platform and little diving is needed to tend to the pearl oysters. Floating rafts can only be used in very calm, protected waters and in cases where theft can be prevented. The materials may be expensive, so they should be carefully chosen for the length of their lifetime in seawater. Careful attention must be given to the anchoring to ensure the raft does not break free.

3. Underwater trestles.

Underwater trestles can be built from timber, PVC pipes or steel reinforcing bar. Low trestles are used as a base for trays or cages made out of vinyl-coated wire mesh. Higher trestles can be used to hang chaplets or lantern baskets. Underwater trestles can be used to culture adult oysters or juveniles, depending on which type of container you wish to use (Figure 9-underwater trestle with hanging containers).

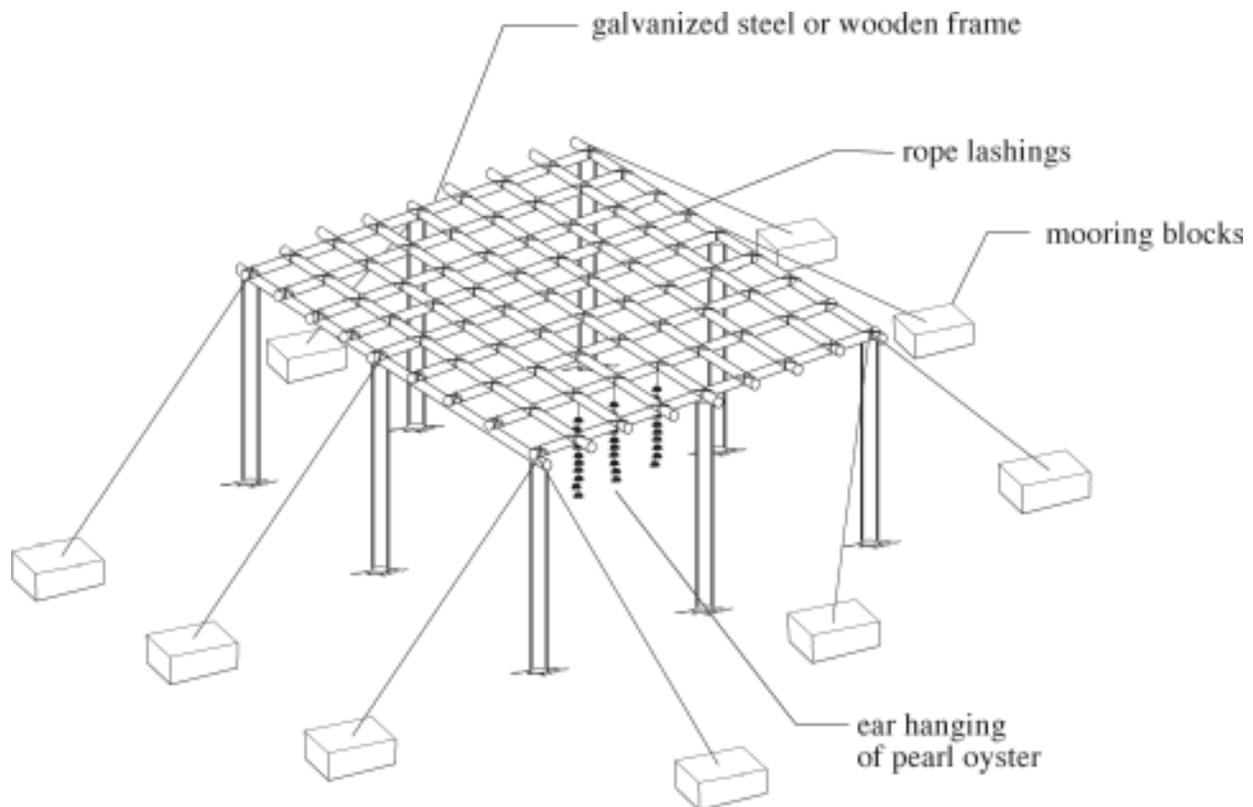


Figure 9. Underwater trestles are useful in shallow areas and may be used to support trays, chaplets and other containers. It is important to use materials that are resistant to corrosion. Modified from Gervis and Sims (1992) by Nakashima.

Trestles can be good systems for growing spat if properly constructed, but are expensive to build and maintain. They are best used in fairly shallow water, since diving will be required to tend the pearl oysters. Predation by fishes and carnivorous snails is often a problem. You should check the trays weekly for predators such as snails and crabs, which should be removed and killed.

Preparing the pearl oysters for hanging on the farm



Figure 10. Oysters hanging from chaplets.

There are many ways to hold adult pearl oysters including chaplets, lantern baskets, pocket nets and floating or submerged trays (see Figure 11 - different ways of holding pearl oysters-chaplets, lantern baskets, pocket panels). You must decide which method is best for your location and budget. Chaplets are the easiest and least expensive method, and can be made from line that is easily obtainable. The various containers (lantern baskets, pocket panels or trays) are particularly useful in protecting smaller pearl oysters or spat from predators, but are more expensive and must either be purchased or manufactured using special materials.

Whichever method you choose to use, be sure that you carefully clean the pearl oysters each time you move them or transfer them into new containers. Proper spacing of pearl oysters is important as crowding can lead to stress and disease. Pearl oysters are powerful filter feeders and will filter a large amount of water each day to obtain enough algae to keep themselves fed. If too many adult pearl oysters are crowded together, they may not be able to obtain enough food from the surrounding water to keep them healthy.

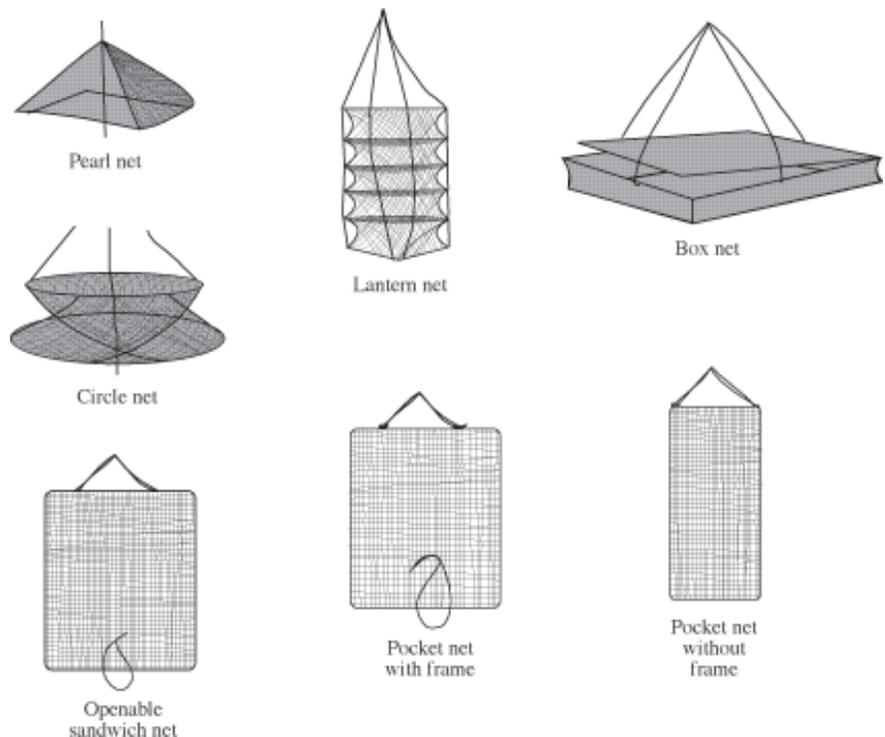


Figure 11. A variety of containers are commonly used to hold adult pearl oysters or larger spat. Gervis and Sims (1992). The most commonly used type is a pocket panel that holds 10 or 20 pearl oysters.

Guidelines for keeping pearl oysters on chaplets or in containers

For chaplets:

Hang only 10-15 pearl oysters on each chaplet, spacing them about 9 in (20 cm) apart on the chaplet. Although it is common to hang 20 or more pearl oysters on a single chaplet, this makes the chaplet longer, heavier and harder to handle. It may also lead to crowding on the farm, resulting in disease or reduced pearl quality. When tying the chaplets on the main line, leave at least 38 in (1 m) of space between the chaplets. Main lines should be spaced at least 66 ft (20 m) apart on a farm. This spacing helps to keep the chaplets and lines from getting tangled and prevents crowding.

If using chaplets, you must first clean and then drill the pearl oysters. Use a 1/8-in drill bit to drill a hole near the pointed edge of the shell (the ear) towards the back of the shell. Figure 12 shows an external view of a pearl oyster indicating the spot for drilling. Be careful not to drill into the meat of the animal. Use a length of 18-gauge stainless steel wire to attach the pearl oyster to the chaplet or 80-lb monofilament (nylon fishing line). When drilling many pearl oysters, it is easiest to mount the drill solidly on a table rather than holding it in your hand.

Farms where there is no electricity commonly use 12-volt drills powered by car batteries. Chaplets and the lengths of stainless steel wires can be reused many times.

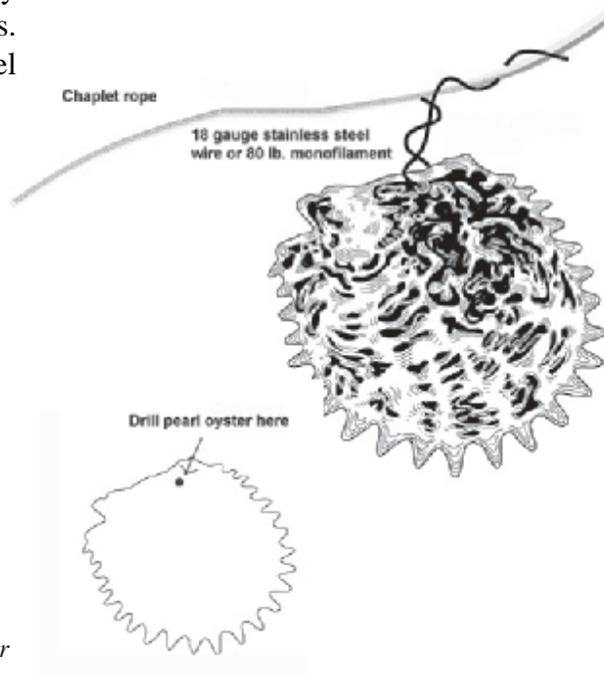


Figure 12. Pearl oysters should be drilled in the “ear”, the corner of the shell opposite the byssal notch taking care not to drill through the internal tissues. Then the pearl oyster can be attached to the chaplet line using either stainless steel wire or monofilament (fishing line).

One problem that may be encountered when using chaplets is that the monofilament line or stainless steel wire used to attach the pearl oysters to the chaplets may break. If this happens, it is usually an indication that heavier line or wire is needed. Also, it may be a sign that the lines are experiencing too much motion due to wind or rough water. Sinking the lines a bit deeper or choosing a calmer area for the farm may help solve this problem.

For panels, trays and lantern baskets:

When using containers of any type, it is important to prevent crowding. Adult oysters should not touch each other when kept in containers. Try to leave a space of at least 4 in (10 cm) around each pearl oyster. Fast-growing pearl oysters have shell edges with many small, flattened spines giving it a frilly appearance. If your pearl oysters do not look like this, they are not growing quickly and you should try giving them more space.

If using panels, trays or lantern baskets, clean the pearl oysters first. Soak the new panels, trays or lantern baskets in salt water for 1 week before using, helping to remove any possible contamination from the equipment. Pocket panels are most commonly used for adult pearl oysters and usually hold 6 to 18 animals. One difficulty with panels is that they tend to foul rapidly and frequent cleaning is needed. It is helpful to transfer pearl oysters into new panels at each periodic cleaning, then mend the old panels and let them dry until needed again. Mending and drying of the panels can then be done during leisure hours and the pearl oysters can be returned to the water immediately. A helpful hint when using pocket panels is to insert the pearl oysters into the panels with the byssal notch facing outwards (towards the frame). The pearl oysters will commonly attach themselves to the mesh of the panel and it is easiest to cut them free if the attachment is on the outer edge of the panel.

With very small pearl oysters (less than 4 in or 10 cm in length), it may be necessary to tie the opening of the pockets closed with a piece of line to keep them from being dislodged in rough weather.

Lantern baskets are best used for spat, since they are too cumbersome to work with when adult pearl oysters are kept in them. Lantern baskets must be kept clean and inspected frequently for predators. Trays can be used for either adults or spat, but offer the disadvantage of providing little protection unless covered. As with lantern baskets, they must be cleaned and inspected frequently.

General farm management

Tending the farm is an important part of producing good pearls. Growing pearl oysters is the same as growing any crop; the farm must be tended often for the pearl oysters to grow well and produce high quality pearls. The following are the most important farm management activities:

Visit the farm at least every 2 days to inspect it for any maintenance needs.

When visiting the farm, look for damaged or missing lines and floats. Be sure the depth of the line is 16-19 ft (5-6 m). If needed, adjust the depth of the line by adding floats or tightening the anchor lines. Make sure none of the pearl oysters have fallen off or been stolen. Count how many pearl oysters have died and keep a record of this. Frequent visits will also allow you to judge when the pearl oysters need to be cleaned.

Clean the pearl oysters and lines monthly.

Pearl oysters must be cleaned of the fouling organisms that grow on their shells. If left for long periods, these organisms can bore through the shell or compete with the pearl oysters for food. Some types of fouling organisms can grow between the shells and prevent the pearl oyster from closing completely. Fouling on the lines and pearl oysters can cause the line to sink under the increased weight. Frequent cleaning will make the job easier by removing the fouling organisms while they are still small and easily removed.

Cleaning can be done by gently cutting off the fouling organisms with a knife or a steel-wire brush. Mechanized cleaning machines that use high power jets to remove fouling are available. Another alternative is to use a high-pressure hydraulic sprayer designed for use with seawater.

It is important to understand that cleaning is stressful for the pearl oysters, and if done too roughly or too frequently, could lead to poor quality pearls. Pearl oysters should not be cleaned more often than once a month, because they need time to recover from the stress. It is usually not necessary to clean them more frequently than this at any rate. The farmer must strike a balance between keeping the pearl oysters sufficiently clean, not over-stressing the animal and wasting valuable time.

There may be certain areas within a lagoon where farming occurs more rapidly than in others. If you experience very heavy fouling or fouling by particularly damaging organisms such as the boring sponge, you might want to consider moving the farm.

Always handle the pearl oysters gently during cleaning.

Avoid keeping pearl oysters out of the water for more than 20 minutes or so. The oysters should always be laid on their sides so that water does not leak out of the shell. If the pearl oysters begin to open, that indicates they have been kept out of the water too long.

When cleaning by hand with knives, try to be as gentle as possible. Avoid breaking the edge of the shell. Regrowing shell takes energy and this could slow down pearl development.

Do not throw the waste from cleaning into the lagoon or farm area.

Wastes from cleaning, dead pearl oysters or other trash will pollute the water and could harm the pearl oysters. It should be buried on land or disposed of at sea outside of the lagoon area.

Keep records of the work you do.

Write down the work done each time you visit the farm; for example, how many new pearl oysters were added to the farm, how many died, how much was spent on materials for the farm and any other information. Thorough records are useful for keeping track of costs, losses and if any problem such as disease or mortality occurs, the records may provide information that may help you determine the cause.

Keep the pearl oysters healthy by collecting and handling them properly.

See the “Handling and transport” section on Page 35 for guidelines on handling pearl oysters.

Prevent predators from eating or damaging pearl oysters.

All pearl oysters are vulnerable to attack from predators, but small spat are especially likely to be eaten by predators. When using containers such as lantern baskets or trays to hold small pearl oyster spat, check regularly for predators such as crabs or snails, which easily invade and hide in these containers. Predatory snails (*Cymatium* spp.) can kill several pearl oysters once they enter a container. Snails tend to hide in crevices and under pearl oysters, so a thorough, weekly inspection is needed. The main threat to pearl oysters hanging on chaplets are predatory fishes such as triggerfish and rays, which have strong jaws capable of crushing even adult pearl oysters.

Protect the farm from vandalism and theft.

Theft and vandalism commonly cause economic losses on pearl oyster farms. Prevent this by siting the farm where you can watch it from your house. At the very least, try to keep its location a secret by submerging the entire farm. Farms have sometimes lost up to 20% of their pearls to theft. Pearls are valuable and farms are often left unattended. Anyone entering your farm should be monitored at all times.

Handling and transport

The most important thing to remember when handling or transporting pearl oysters is that they are living animals and must be treated carefully.

Rough treatment, exposure to heat or cold, and long periods out of the water can stress the pearl oyster. Stress is the primary cause of disease in aquatic animals. Even a short period of stress can weaken the pearl oyster so that it is more likely to become sick or produce a poor quality pearl.

Pearl oysters are valuable animals and are sensitive to environmental changes.

Each seeded pearl oyster is potentially worth hundreds or even thousands of dollars. Only a healthy pearl oyster can produce a high quality pearl, and it may only take a short period of stress to damage the developing pearl. It is well worth the extra time and effort required to keep the pearl oysters alive and healthy.

The basics of safe handling

Clean pearl oysters and equipment before handling and transporting.

Cleaning pearl oysters and the equipment used to clean them helps prevent infections or contamination with chemicals. It is particularly important to clean any equipment that has come into contact with oil or gas. Cleaning the pearl oysters of fouling animals and plants before transport is also especially necessary because these organisms may die during transportation, resulting in decomposing matter that consumes oxygen and produces toxins that could harm the pearl oysters. Pearl oysters should be cleaned with a wire brush or knife. This should be done very gently without breaking the shell, since this slows the growth of the pearl oyster. Always bury the waste produced by cleaning on land or dispose of it in the sea outside of the lagoon. Never put the waste in the water near the pearl oysters as it not only pollutes the water, but as it rots it will also harm the oysters.

Only clean saltwater should be allowed to contact the pearl oysters.

The only time that freshwater should contact the pearl oysters is if it is used as a quick rinse to help prevent fouling. Immersion for more than a few minutes in freshwater can kill pearl oysters. Similarly, dirty seawater or seawater that is warmer or colder than the water in which the pearl oysters were grown can also be harmful.

During transport, pearl oysters prefer to be moist rather than submerged in water without an air supply.

When pearl oysters are immersed in water, they open their shells and try to breathe. In small containers of water with no source of air, pearl oysters will suffocate quickly. If the pearl oysters are kept wrapped in materials such as burlap bags or papers that are moistened in clean seawater, they keep their shells closed and will not dry out or suffocate for long periods of time. If kept in the shade, they can survive for several hours out of the water this way.

Always keep pearl oysters lying flat on their side when out of the water.

Pearl oysters cannot close their shells tightly enough to prevent water from escaping. If they are kept out of the water in a vertical position, the water trapped inside their shells will quickly leak out. The pearl oysters will then open their shells to try to breathe and will dry out. Laying pearl oysters lying on their sides helps keep them moist.

Protect pearl oysters from exposure to heat, cold, drying out, rough handling, dirt and chemicals.

Any of these things can kill or shock pearl oysters. Avoid these by limiting how much time pearl oysters spend out of the water and follow the guidelines listed above.

Minimize the amount of time pearl oysters are kept out of the water.

If kept moist and lying on their sides and if not exposed to heat or sun, pearl oysters can generally remain out of the water for about 20-30 minutes before gaping. However, if possible, avoid exposing pearl oysters for even this length of time.

Handle pearl oysters gently and with care.

Rough treatment can break the pearl oyster's shell or shock the animal, either of which can slow pearl development or affect the quality.

How to collect pearl oysters

Remove pearl oysters by gently cutting the byssal threads, not by pulling it free.

Pearl oysters anchor themselves to the reef or other hard substrate by threads called "byssal threads" or "byssus." Because the byssal threads are attached to the internal organs, harvesting a pearl oyster by pulling the byssal threads free can damage the organs and kill it. This is especially important to note after the pearl oyster has been grafted. Pulling on the byssal threads can affect formation of the pearl. If the pearl oyster attaches to the chaplet or panel, cut it loose.

Transporting pearl oysters in coolers

Pearl oysters can be transported without water if kept cool and moist.

The best way to do this is by using a Styrofoam or plastic cooler (also called ice chests or chiller bins). First, scrub the cooler with clean seawater. Then put a layer of paper or cloth dampened with clean seawater in the bottom. Next put in a layer of pearl oysters. Cover the pearl oysters with more damp paper or cloth. More layers of alternating pearl oysters and wet cloth or paper are then added. Keep the cooler cool by placing it in the shade. You can add a very small amount of ice, but be careful not to let water collect at the bottom of the cooler (use a cooler with a drain if you plan to use ice). Pearl oysters will die if left soaking in accumulated water, whether freshwater or seawater. It is better to use ice packs, which can be frozen and reused. Although pearl oysters have been shipped successfully using this method for periods up to 24 hours, try and limit the time in the cooler to 5 or 6 hours. Keep the temperature inside at 26-28°C (about the same temperature as the seawater from which they came). The pearl oysters should be kept cool, but not cold, since this may weaken them. Handle the cooler gently without allowing it to get jostled in the boat.

Transporting pearl oysters on the deck of a boat

Avoid transporting pearl oysters where contaminated air or water is present.

Transporting pearl oysters on the deck of a boat is a common practice, but if the pearl oysters are exposed to oil, gas or heat in the air or in the water, they could die. The deck of a boat is often full of water that contains oil or gas from the outboard engine. Try and keep the oysters on a platform or in a container away from this oily water.

Pearl oysters should never be kept in standing water in an enclosed area like a boat deck, or in a bucket.

When pearl oysters sit in a small amount of water, they open their shells and try to breathe and feed. The oxygen in this small amount of water is used up quickly and the pearl oyster will suffocate and die. It is better to transport pearl oysters in baskets, panels or damp sacks so that any water will drain out. Pearl oysters do much better if kept just a little moist and cool, but not wet.

Pearl oysters must be protected from the heat of the sun.

Always cover pearl oysters with a moist sack or palm leaves when exposed to sun. Try to transport pearl oysters during the coolest times of day. You can also occasionally douse them with fresh seawater, as long as this water does not accumulate around them.

Limit transport on deck to 30 minutes or less.

If you have to transport pearl oysters for longer than 30 minutes, try to use coolers. At the very least, wet the pearl oysters with clean seawater, taking care that the water drains away.

Transporting pearl oysters in tanks

Pearl oysters can be transported for longer periods of time using special seawater tanks, but you must have a pump to keep water flowing in and out of the tanks at all times.

It is rarely necessary to transport pearl oysters for such long distances that tanks need to be used. Transporting pearl oysters in tanks is more expensive and complicated than other methods. In addition, transport tanks require special materials for building the tanks and pumping system. It is also possible that something will go wrong with the pump and the pearl oysters will die. If you need to use tanks to transport many pearl oysters or to transport them over long distances, you should contact your aquaculture extension agent for advice on how to properly build and operate the tank.

Spat collection

Spat collection is the best means of supplying a farm with young pearl oysters of the right age for grafting. If spat collection is biologically possible in your area, it is the preferred means of obtaining spat. Collecting adult, wild oysters can threaten the wild populations and most of these animals are too old to produce high quality pearls. Hatchery-produced spat are a good option if available and reasonably priced, but there are very few Black-Lip pearl oyster hatcheries.

What is spat collection?

The pearl oyster has several different life stages (Figure 5-life cycle). During the first 2-3 weeks of life, the pearl oyster larva can swim freely. It then begins to look for a place to which it can attach itself, such as a reef or the shell of another pearl oyster, to spend its adult life. The transition from free-swimming larva to settled juvenile is called metamorphosis. Metamorphosis lasts 2-3 days and major changes occur in the anatomy and behavior of the pearl oyster during this time. Metamorphosis is also called “setting” or “settling” because attachment of the juvenile to a substrate is one of the main changes that occurs throughout a pearl oyster’s life cycle. The small, juvenile pearl oyster that has passed through metamorphosis and attached itself is called a “spat.”

Important things to remember in spat collection

Choose materials that increase the probability of spat set.

Spat collectors are designed to offer a protected area where spat can settle and grow safely. Pearl oyster larvae generally prefer to attach to dark materials that offer shelter from predators. Many types of materials have been used with success. These include pearl oyster shells, nursery shade cloth (55% shade), black plastic strips (polyethylene sheeting), coconut husks, bundles of brushy twigs such as “mikimiki” (*Pemphis acidulus*) or commercial spat collection material. Plastic materials, especially nursery shade cloth, work best because these are lightweight and can easily be reused. Other materials will collect spat, but tend to be so heavy that extra care is needed to ensure the spat collector lines do not sink.

Correct placement of the spat collectors will improve the likelihood of good spat set.

Selecting a good area to place spat collectors can be difficult the first time spat collection is attempted. Generally, protected areas such as lagoons or bays are best since it is assumed that larvae are retained in these areas long enough to mature and set on the collectors. Lagoons with high rates of water exchange or open-ocean areas are usually less likely to produce good spat set because larvae produced in these areas may be flushed out by tides and currents. Areas within a lagoon where large numbers of pearl oysters are found are also likely to produce good spat collection. Look also for areas where there are gyres or eddies in the current, which may help retain spat in the location. Areas where there are a number of coral pinnacles near the surface may also be good, since currents may slow near the pinnacles, especially on the leeward sides.

Keep spat collectors as near the surface as possible.

Materials hung near the surface of the water appear to collect the most spat. Keep collectors within 3-5 ft (1-2 m) of the surface by hanging collectors on very shallow main lines. Do not attempt to use the farm lines to hang spat collectors since these are too deep. Add floats at frequent intervals on the line to prevent sagging. Collectors that sink below 5 ft (2 m) rarely collect Black-Lip oyster spat, although they may collect other types of animals and plants.

Locating spat collectors in calm areas prevents loss of spat.

Young spat are capable of detaching their byssal threads and moving if environmental conditions are not suitable. This may happen if the spat collectors are in rough areas. Once you have seen spat set, you can lower the lines so they experience less movement.

Making the collectors

Using shade cloth or plastic materials

The spat collectors should be about 3 ft (1 m) in length if using shade cloth or other plastic materials. The material is first cut into strips that measure 3-5 in (7-8 cm) in width. Thread these onto a length of 1/8-in (4-mm) polypropylene rope in accordion fashion (See Figure 13-shade cloth spat collector). The material should be packed onto the rope firmly, but not tightly. Snugly packing the material onto the line creates a collector with a large amount of surface area and protected areas where spat are safe from predators. Tie knots at the top and bottom of the collector to keep the material from slipping off the rope. You may wish to tie a knot in the middle of the collector line to keep the material from sliding down and bunching at the bottom once it becomes heavy with fouling.

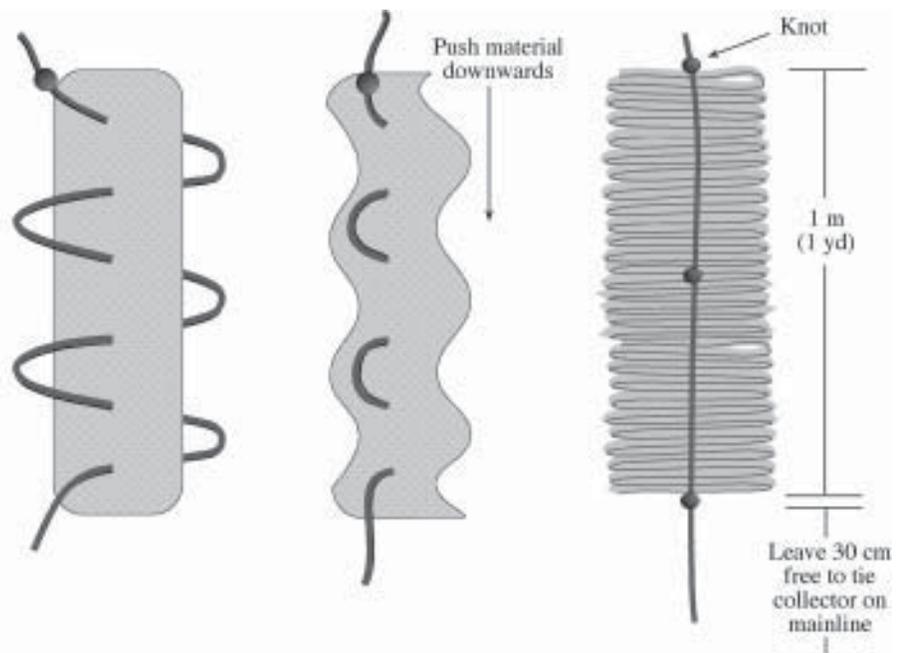


Figure 13. Making a spat collector out of shade cloth. Shade cloth is cut in strips and thread onto a line. The shade cloth is then compressed to form a bushy mass of shade cloth to provide shelter for young spat.

Leave about 13 in (30 cm) of rope free at the end of the collector so it can be tied onto the spat collector main line using a slipknot (see Figure 14-knot for tying spat collectors or chaplets onto the main line).

Using plant materials or shells:

If using mikimiki or some other brushy material, leave the small leaves and twigs in place and cut the branches in lengths of about 22 in (50 cm). Then tie them together with rope or monofilament. Leave enough extra line to tie the bundle onto the main line. If using coconut husks (the inner, brown husk), make a hole in the end of each coconut half. Shred the coconut husk so that a furry mass is created. Using a piece of 1/8-in (14-mm) polypropylene rope, tie a knot at one end, then thread on a coconut husk. Tie another knot about 8 in (20 cm) above this and add another coconut half. Repeat this until 5 or 6 coconut halves are on the collector and then hang it on the main line.

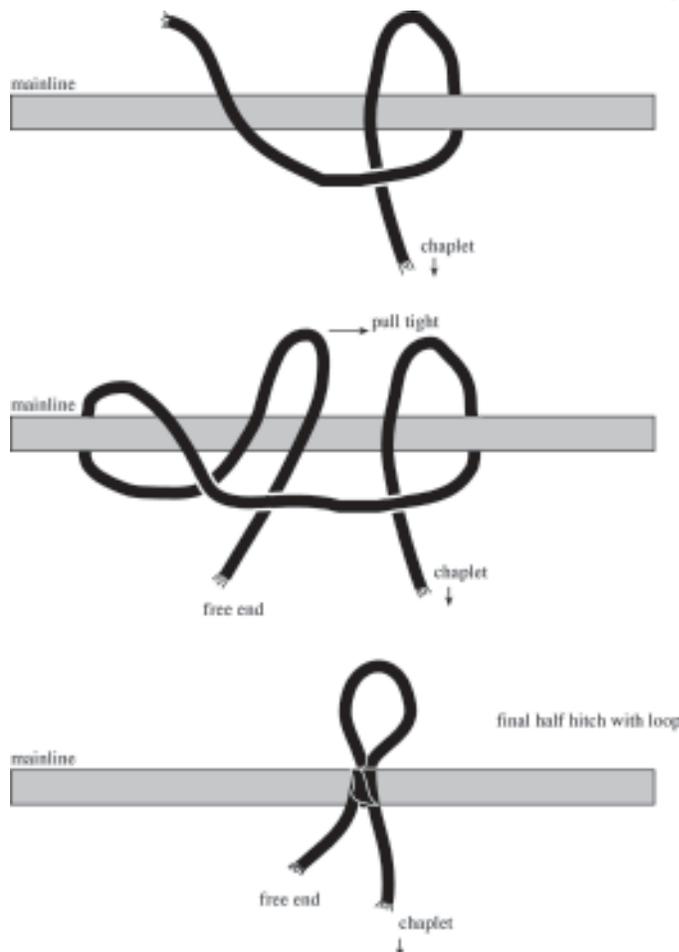


Figure 14. Collectors should be tied on to the mainline using a knot that can be easily tied and untied using one hand, such as the knot shown here. This knot can be easily broken loose even when fouling organisms have covered the line.

The same can be done using pearl oyster shells. This is a good use for old or broken shells. Drill a hole through the center of the shells and thread them on the collector line, using knots to keep the shells from touching each other. Shells that have been aged in the sun will work best.

When using any of the heavier materials, the spat collector line will need more floats and will have to be checked more often to be sure it does not sink.

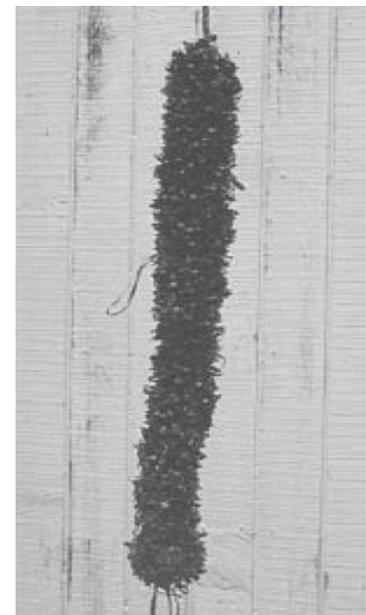


Figure 15. A spat collector

Setting the collectors in the lagoon

Collectors should be set on main lines as close to the surface as possible.

Locating and maintaining collectors within 3 ft (1 m) from the surface of the water is ideal. It may be necessary to set the collectors a bit lower if boats pass through the area, but do not set the collectors deeper than 6 ft (2 m). When tying the collectors to the main line, use a slipknot that holds firmly, but that can be tied and untied using one hand (Figure 15-slip knot for tying spat collectors onto main line). Space the collectors about 8 in (20 cm) apart to prevent them from getting tangled up with each other. If your main line sags more than 6.5 ft (2 m) between floats, try using empty plastic drink bottles to serve as “mini-floats” along the sagging part of the line to keep the collectors high in the water.

A second method for deploying spat collectors is to tie them onto a line on land, which is then attached to the main line. This method has the advantage of allowing most of the work to be done on land, rather than in the water. When the time comes to harvest the spat, the collectors and the line they are attached to are removed from the water. The main line is left in place.

Spat bags may help protect the spat from predators.

Spat bags are fine-mesh bags that are used to enclose the collectors in order to protect them from predators. These have been used with mixed results. Spat bags are best used when the main cause of predation is fish picking off the small spat. They may also be useful in areas that are often rough, since spat falling off the collectors will be retained inside the bag. However, if predation by snails or crabs is a problem, spat bags may only worsen the problem by retaining the predators near the collectors. Also, once the mesh of the spat bag is fouled, there will be little spat set. It is recommended that the effectiveness of spat bags be tested along with unenclosed collectors the first time spat collection is done in a new area.

Keep collectors at least 160 ft (50 m) from reef areas to prevent predation.

Reefs shelter fish and other animals that eat spat. Keeping the collectors as far away as possible from these areas will help prevent losses due to predation.

When to set out spat collectors

Spat set will be heaviest about 1 month after the high annual water temperatures occur.

Pearl oysters spawn (produce eggs and sperm) when water temperatures are highest, although they will usually spawn at lower levels during the entire year. Setting out collectors about 1 month before the peak spawning season will improve your chances of capturing large numbers of spat.

In the southern hemisphere, peak spawning seasons are in October and November, with a smaller peak in March and April. Pearl farmers there set out spat collectors in late September and October. In the northern hemisphere, very little spat collection has been done, so the peak spawning time is unknown. In many areas, the highest water temperatures occur in July and August, so these may be the best times to set out spat collectors. It is recommended that in areas where spat collection has not been previously done, the pearl farmer set out some collectors every month during the first year and keep a record of the times when the best settlement of spat occurs. Keeping a weekly record of water temperatures may also help provide information that suggests best times to deploy spat collectors.

Maintaining the spat collection line

The most important part of maintaining the spat collection line is keeping it high in the water.

As spat, other animals and plants begin to settle on the collectors and main line, they begin to weigh down the line. If the line sinks below 6 ft (2 m), very few spat will set on the collectors. You should check the spat collector line at least every week. Keep the main line high in the water by cleaning the line often and adding more floats as needed. Inspect the collectors to see if any spat have settled. Be sure to look at the center of the collector for small, hidden spat since they tend to seek protection there. Keep monthly records of the number of spat settling on collectors. This will allow you to determine which time of year is best for setting out spat collectors.

Identifying Black-Lip pearl oyster spat

Generally Black-Lip pearl oyster spat can be easily identified when they reach a size of 1/2 in (1 cm). Spat reach this size about 2 months after setting. Very small spat can sometimes be confused with other species of oysters (*Pinctada radiata* or *Pinctada maculata*), which look very similar to small spat. Small Black-Lip pearl oyster spat are distinguished by being entirely or partially green, particularly in the area near the umbo. The predominant green color is most obvious when the spat are smaller than approximately 1/2 in (1 cm). As the spat grows, there may only be a hint of green near the umbo, while the rest of the spat is brown or brownish-green. Other species tend to be entirely brown, orange or yellow. Black-Lip pearl oyster spat also tend to have fewer streaks of white in their shells and when they do occur the streaks usually do not reach back to the umbo area, but are confined to the middle or edge of the shell. The smallest spat (less than approximately 1 in or 2 cm) tend to be smooth. Later small growth process (spines) appears. The small spines on Black-Lip pearl oysters are wider and flatter than the spines on similar species, and may be broader at the tips than the base. The spines on Black-Lip pearl oysters also tend to be more rounded on the ends and crowded together. If in doubt, keep the spat until they are large enough to positively identify their species. Consulting with an experienced farmer or extension agent may also be helpful.



Figure 16. Black-lip pearl oyster spat. Note the growth processes with broad tips-a distinguishing characteristic of this species. Related species usually have growth processes with more pointed ends.

When spat appear on collectors

When spat are large enough to be identified, you have two choices of what to do next.

1) Cut (never pull) the spat off the collectors and keep them in lantern baskets.

The lantern baskets have the advantage of protecting the spat from predators and fewer spat will be lost due to falling off the spat collectors. This option is more costly and requires more maintenance. The lantern baskets should be cleaned and inspected weekly for the presence of predators such as snails and crabs.

2) Leave the spat on the collectors until they are large enough to drill and hang on chaplets.

Spat are large enough to be drilled when they reach a size of 4 inches (8-10 cm), or are large enough to put in panels. If you wait to remove them from the collectors until after the spat are larger, be prepared to add more floats to the spat collector lines since they will become very heavy and sink. In addition, you may lose some spat to predators this way to predators or they may fall off the collector. However, if spat settlement is heavy, this option is less expensive and more efficient.

After removing the spat, the collectors can be dried for a few weeks, cleaned and reused.

Caring for the spat

Spat are like all young animals; they are weak and easy to damage.

Spat should be handled gently at all times, and never more than necessary. Most importantly, never pull the byssal threads out of a spat, as this will kill them. Always gently cut the byssal threads.

Spat are very sensitive to heat and drying out.

If you must handle them, do not leave them out of the water for more than a few minutes. When out of the water, keep them cool and shaded.

Give spat plenty of room to grow.

When spat are kept in lantern baskets, they tend to attach themselves to each other. You should check the lantern baskets at least once a week and gently cut the spat apart if they are attached. Make sure that each spat has at least 4 in (10 cm) between it and other spat, whether they are kept in lantern baskets or panels.

Protect the spat from predators.

Carefully inspect lantern baskets at least once a week for predators like snails and crabs and exterminate them. If spat are kept on the collectors or in some type of container that is not enclosed, be sure to keep these at least 165 ft (50 m) from reef areas to lower the risk of predation from fish and octopus.

Once spat are removed from the collectors they can be kept at a depth of 19-23 ft (6-7 m).

Hang lantern baskets or panels containing spat at a depth of 19-23 ft (6-7 m). If keeping spat on the collectors until they are large, the main line holding these collectors can be allowed to sink slightly.

What to do if the spat collectors do not collect any spat

In some areas, it may be difficult to collect many spat. You should expect to collect at least 1 or 2 spat on each collector, although more is ideal. If the collectors do not yield this number of spat after 6-8 months in the water, see if any of the following tips help:

The collectors may be too deep.

If you see spat setting on the ropes and floats, but not the collectors, this may be a sign that the collectors are too low in the water. Make sure all collectors are no deeper than 6 ft (2 m). Add more floats at any part of the line that sags below 6 ft (2 m).

The collectors may be too shallow.

In some cases, you may observe that a large number of other bivalves are settling on the collectors. If you see Black-Lip spat anywhere on the anchor lines lower than the collectors, you may need to lower the collectors to the same depth.

Be sure the water currents are not too strong near the main line.

Try to put the lines in fairly calm water or spat may fall off the line.

Try other locations in the lagoon.

Spat settlement will be uneven throughout a lagoon. The best areas are those where the water is calm or where eddies form, because spat will spend more time in these areas. Also try locations on the downcurrent side of small patch reefs, since eddies may occur here.

Try putting collectors out each month to determine which time is best.

The best times of year to collect spat are still unknown in many regions. Periodic deployments throughout the year may be necessary to detect the best times.

Collectors lose their effectiveness if fouled with other organisms.

If collectors are set out more than 2-3 months before the peak spawning season, other organisms will colonize the collectors first and possibly prevent pearl oyster spat from settling. If the collectors are becoming colonized with other animals, the collectors should be removed from the water, cleaned and deployed again.

Try different types of materials for making the collectors.

If a first attempt using materials other than shade cloth or other plastic materials specifically made for spat collection has failed, you may have to switch materials. Materials such as shells, coconut husks or mikimiki may not work if they have sunk too deep.

Disease and other causes of death

While very little is known about pearl oyster diseases or their treatment, it is known that stress can bring on disease. Disease organisms are always present in the water, but healthy pearl oysters seem to be capable of fighting off disease. When disease appears on a farm, it is almost always a sign that the pearl oysters have been subjected to some form of stress, which weakens the pearl oyster so it can no longer fight off disease organisms. New diseases can also be introduced to which pearl oysters have no resistance. In most cases where disease has been epidemic in farming areas, it appears to be related to crowding, poor farming practices or problems in transport.

The best way to prevent diseases is to keep pearl oysters in good condition so they can resist diseases. Prevention is also important because there are no known cures for pearl oyster diseases.

Causes of stress that may bring on disease include:

Polluted water from boats, villages, factories or the farm itself;

Prevent stress by locating farms in areas with clean water or upcurrent of pollution sources. Do everything possible to keep the farm area clean, including not discarding the waste material from cleaning pearl oysters in this area.

Crowded conditions with too many pearl oysters in the same area;

Prevent crowding by keeping only 10-15 pearl oysters per chaplet, not crowding pearl oysters in lantern baskets, keeping main lines at least 66 ft (20 m) apart and farms at least 1650 ft (500 m) apart.

Rough handling;

Handle pearl oysters gently and work quickly to minimize the time they are out of the water.

Exposure to heat and cold;

Keep temperatures constant during handling and transporting by shielding pearl oysters from heat and by using coolers for extended transport periods.

Nucleus implantation “grafting or seeding;”

Grafting is a very stressful process. Pearl oysters must be handled gently during and after grafting. Minimize the risks by hiring a good technician and following his or her instructions for post-grafting care of the oyster.

Transporting to other areas;

Transporting pearl oysters over long distances is not a good idea for several reasons. The trip itself is sufficiently stressful that pearl oysters may become sick and die afterwards. Transferring pearl oysters between areas may also introduce new diseases. Additionally, there is evidence that pearl oysters from different lagoons may be genetically different. This means that pearl oysters are best adapted to their native lagoon environment and may be more susceptible to diseases when transplanted to a new area.

Too many fouling organisms on the shell;

Fouling organisms can weaken pearl oysters by competing for food or by boring into the shell. Prevent this by cleaning the pearl oysters regularly.

Lack of food due to crowding or being held at the wrong depth;

Keep the pearl oysters at a depth of 19-23 ft (6-7 m) or at depths where you have seen the best growth. Follow the guidelines for proper spacing given above to ensure that pearl oysters receive enough food and oxygen through good water exchange.

Introduction of new disease from other areas.

Bringing in pearl oysters from other areas, particularly those areas where farming is intensive, may introduce new diseases and should be avoided. If you do bring pearl oysters in from areas outside the lagoon, set up a quarantine area far away from the farming area and keep pearl oysters there for a month so you can observe them before transferring them to your farm.

What to do if disease strikes

Disease can strike without warning and kill many pearl oysters in a short period of time.

Disease can spread rapidly and kill quickly. You may not notice that the pearl oysters are beginning to die until it is too late unless you visit the farm often. If you notice that more than a few pearl oysters have died recently, try to determine if some factor is stressing the animals. There should be very little mortality on a farm except during the month following grafting. Even after grafting, mortalities should not exceed 5-10% of grafted pearl oysters. Correct this if possible by following the guidelines listed above. Usually crowding, excessive fouling organisms on the shell and/or rough handling during transport are to blame. Take action immediately, so the situation will not worsen and jeopardize more of your pearl oysters

If pearl oysters begin to die, avoid moving the possibly afflicted ones to areas with healthy pearl oysters and risking spreading the disease.

Other causes of death or poor health

Pearl oysters can also suffer from predation or fouling that may ruin their commercial value, health or even kill them.

Fouling organisms such as sponges and burrowing worms (polychaetes) can damage and weaken the shell by boring into it. Other fouling organisms may not directly attack the pearl oyster, but as they accumulate and become heavy, they prevent the pearl oyster from feeding normally and thus weaken it. Prevent damage from fouling organisms by regularly cleaning the pearl oysters. Some lagoon areas may have higher fouling rates. If your farm area suffers from a heavy degree of fouling, consider moving it to another area.

Although more difficult, some animals also prey upon pearl oysters. These predators include certain kinds of snails, crabs, fish and octopus. Snails and crabs are most often a problem in lantern baskets or other containers. They must be removed by hand and killed. Fish and octopus can also attack larger pearl oysters, although small pearl oysters are still most vulnerable. Keep the spat in lantern baskets or cages if you have problems with mortality caused by these animals. Snails and crabs are most likely to attack spat because their shells are weaker.

Nucleus implantation (grafting)

Nucleus implantation, also called grafting or seeding, is the surgical implantation of a shell nucleus and tissue graft (a small piece of mantle tissue) into the pearl oyster, thus starting the development of a cultured pearl.

Natural pearls occur when a foreign body, such as a boring worm or grain of sand, irritates the pearl oyster. Nacre is secreted around the foreign body by the mantle tissue to protect the pearl oyster's tissues. Grafting is a means of imitating this natural process so that a cultured pearl can be grown. Grafting is a surgical procedure that should only be done by a qualified seeding technician. Almost anyone can learn from a technician how to perform the grafting operation, but it requires years of practice and dedication to perfect this skill and produce high quality pearls.

Guidelines for obtaining good grafting services

The skill of the grafting technician affects pearl quality and farm operating costs.

Good technicians are in high demand and prefer to work with experienced, reliable farmers. If a technician is confident of the skill of the farmer, he will work for a share of the harvest. Otherwise, a technician will demand a cash payment of \$3-\$4 for each pearl oyster he grafts. In both cases, the farmer usually pays the airfare, lodging, food and expenses of a grafting technician while he works on the farm. The farmer must negotiate the best deal he can, since the cost of hiring a technician is one of the major farm operating costs. It is preferable to have the technician work for a share of the harvest, since this motivates the technician to return and also if the technician's earnings depends on the harvest of good quality pearls, he or she will be much more motivated to graft carefully and give the farmer helpful advice.

Beware of technicians who graft too rapidly.

It is common practice for technicians working on a cash payment basis to simply graft as many pearl oysters as possible without regard for suitability of the pearl oyster to produce a good pearl. Careful grafting takes time, therefore, if a technician grafts more than 300 pearl oysters in a regular 8-hour workday, it may be an indication that he is working too fast.

Traits to look for when hiring a technician are extensive experience, skill and a good reputation.

Since grafting services are expensive, be sure and select a qualified technician. It takes several years for a grafting technician to be able to reliably produce good quality pearls. The success of a technician is measured by several factors: mortalities after grafting, the number of pearl oysters that reject the nucleus and ultimately, the number of round Grade A pearls produced. Always ask for letters of refer-

ence from farmers who have worked with the technician before and be sure and write a service contract for both you (the farmer) and technician to sign.

Technicians can be good sources of technical advice.

Each seeding technician has his own methods and it is imperative that you follow his instructions during the grafting process to guarantee success. Several months before the technician is scheduled to arrive, ask him for instructions on how to prepare the pearl oysters and farm for the grafting procedure. Try and learn as much as possible from the visiting technician about how to operate a farm. Even the best technician cannot produce good pearls if farm management is poor before or after grafting.

While many technicians also buy pearls, they may not offer the best prices.

Technicians will often make a farmer an offer to buy the pearls immediately after a harvest. In many cases, the price offered is below the market price, but you may feel pressured to accept the offer either to please the technician or because you do not feel confident that you can sell the pearls elsewhere. Resist the temptation to sell the pearls immediately. You will usually be able to obtain a better price from wholesaler pearl buyers or jewelers. If you want to sell to your technician, you should try to have the pearls graded and the price set by an impartial professional.

The grafting process

Preparation for grafting

The ideal pearl oyster size for grafting is about 4.5-6 in (12-15 cm) in length, or about the size of a woman's hand.

These animals will be 1½-2 years of age. This age is ideal because the pearl oysters are still growing quickly and will produce nacre at a more rapid speed. The nacre produced by young pearl oysters also tends to have more luster than that produced by older animals. Older and larger pearl oysters can be grafted, but are less likely to produce high-quality pearls.

Pearl oysters gathered from the reef need special preparation for grafting.

Pearl oysters collected as spat are superior to adults collected from the reef for pearl production. The reasons for this are not completely understood; it may be that animals farmed from a very young age are simply more accustomed to the sometimes stressful conditions of a farm. Also, pearl oysters collected from the reef are likely to be older. If you must use pearl oysters taken as adults from the reef, you should prepare these carefully for grafting. These animals should have been hung on lines or in baskets for at least 6 months before seeding begins.

Pearl oysters must be cleaned on a monthly basis before grafting; a final cleaning is done just before grafting.

Cleaning keeps the pearl oysters healthy and in good condition. The cleaning done just before grafting should be a light and gentle cleaning so that the animals are not shocked.

The technician may ask for you to perform pre-grafting conditioning.

Technicians have different methods of conditioning the pearl oysters, but it is common for the technician to ask the farmer to condition the pearl oysters about 6 weeks before grafting. Conditioning is a means of inducing the pearl oysters to spawn, thus ridding the gonad of most of the egg or sperm, which can interfere with grafting. If grafting takes place just after the normal annual spawning, this may not be necessary. Conditioning is done by raising the lines to the surface of the water for about 4 hours during the heat of the day. The increased temperature and reduction in water pressure makes the pearl oysters spawn. After spawning, they are returned to their usual depth. It is important that this is not done immediately before grafting since conditioning weakens the pearl oysters and they need time to recover.

A special farm platform or building where the technician can work is needed.

Grafting is usually conducted on a covered platform built over the water. This platform must be sturdily built so that it does not shake while the technician is working. It should also be built in an area that is deep enough to hang chaplets of pearl oysters. The water surrounding the platform must be calm and clear since sediment in the water can interfere with the quality of the seeding. The platform should also be spacious enough that workers can move around without disturbing the technician. Technicians usually will request that a special table and chair be provided. Seeding can also be conducted on land, but this is not as convenient.

The grafting procedure

When the pearl oysters are brought to the platform for seeding, they are opened slightly with special tools. A wooden peg is then inserted to keep the pearl oyster open until the seeding technician works on it. Care should be taken not to leave the pearl oysters open for longer than a few minutes as this can kill it.

The seeding technician will look for a donor animal from which to take the mantle tissue graft. The mantle tissue of the donor animal determines the color and quality of the cultured pearl, so care should be taken to use only pearl oysters with the most beautiful nacre for this. The donor is then killed and the mantle tissue removed. This strip of mantle tissue is trimmed and cleaned until only a thin strip containing the nacre-producing epithelial cells remains. The strip is then cut into tiny squares about 1/8 x 1/8 in (2 x 3 mm) long. These tiny pieces of mantle tissue will be inserted along with the nucleus into the tissues of the pearl oyster. The transplanted mantle “graft” will grow, covering the nucleus with a

tough tissue called the “pearl sac.” The inner lining of the pearl sac contains the epithelial cells, which continue secreting nacre onto the nucleus. As the layers of nacre accumulate, a pearl is formed (Figure 17).

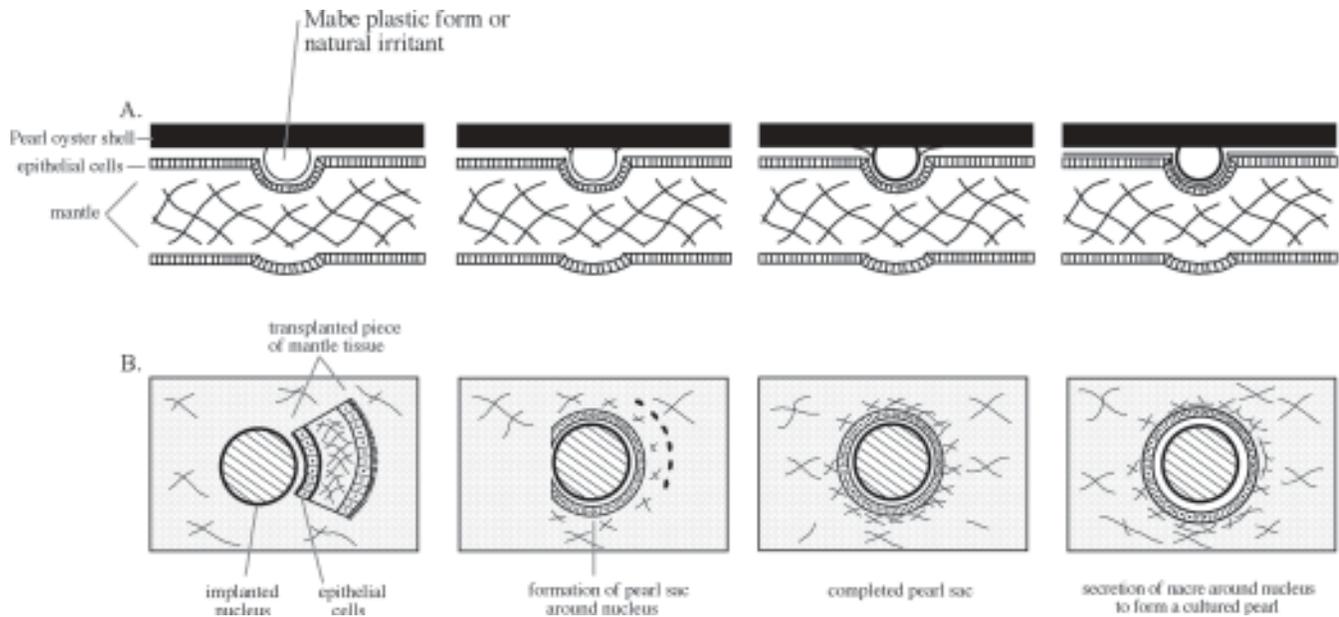


Figure 17. Nacre is formed by the epithelial cells of the mantle tissue. The upper diagram shows a natural irritant or a plastic mabe form being covered progressively with layers of nacre deposited by these cells. In the case of a cultured pearl, this process is imitated. The transplanted piece of mantle tissue contains the nacre-producing epithelial cells. The small piece of tissue grows around the nucleus with the epithelial cells forming the inner layer of the pearl sac (from Wada 1973).

The seeding technician will then take the pearl oysters selected for grafting and open them slightly wider. These are placed in a special clamp. After examination, some of these will be rejected as too old, too small or simply unsuitable for seeding. In most cases, the size and shape of the gonad will determine whether the pearl oyster is grafted or not. This is based on the judgment of the grafting technician and is learned after years of practice.

The technician makes a small cut in the gonad of the pearl oyster. The mantle graft is inserted into the gonad first, followed by the nucleus. The size of the nucleus used depends on the size of the pearl oyster and the condition of the gonad. Generally nuclei range in size from 0.3 in (7 mm) to 1.56 in (14 mm), with the smaller sizes being most commonly used the first time an animal is grafted. A small piece of the donor mantle tissue is inserted last. The pearl oyster is then allowed to close, placed on a chaplet or in a tray and returned to the water.

Post-grafting care

The first 30 days after grafting are a critical period during which the pearl sac forms.

The first 30-40 days after grafting are critical because that is when most deaths or nucleus rejections occur. During the recuperation period after grafting, the piece of mantle tissue that was implanted along with the nucleus will slowly grow around the nucleus creating the “pearl sac.” Layers of nacre are slowly secreted around the nucleus by cells contained within the pearl sac. It usually takes about 1½-2 years to form a pearl with sufficiently thick nacre 0.8-0.12 in or (2-3 mm) to harvest.

To monitor the grafted pearl oysters, use catch bags.

It is common to enclose the newly seeded pearl oyster in a fine-meshed bag called a “catch bag”. Using the catch bag allows you to see if the nucleus is rejected. Catch bags can be used with either chaplets or panels. Some technicians may object to using catch bags, you can and should insist on this, as it is the only way to determine how well the technician is doing. Be sure to include this condition in the contract with the technician. The catch bags should not be left on for longer than 40 days after grafting because it may interfere with the pearl oysters’ ability to feed.

The pearl oysters should be allowed to rest in very calm waters for about 40 days after grafting.

You may need to have a special line for this if your other farm lines are in an area that experiences swift currents. As always, handle the grafted animals gently when moving them to the line and do not expose them to heat or dryness.

After 40 days, the pearl oysters can be removed from the catch bags and inspected.

Some pearl oysters will die and others will reject the nucleus during the first 40 days. The pearl oysters can be cleaned for the first time after grafting at this point. Remove the pearl oysters from the catch bags and carefully inspect the bag for a rejected nucleus. Keeping a record of how many died and how many rejected the nucleus helps you evaluate the performance of the technician. Return the pearl oysters that have kept the nucleus to the farm lines. It may be helpful to make a map of your farm or to place plastic tags on the chaplets to help you remember which pearl oysters are grafted.

Separate the pearl oysters that have rejected the nucleus and keep these to produce keshi pearls.

Even though the nucleus is rejected, some of the mantle tissue may remain inside the gonad. The pieces of tissue often form baroque pearls without a nucleus called “keshi.” Farmers usually leave these pearl oysters in the water for 2 years before harvesting. Keshis can be large and attractive and may produce a high proportion of your farm’s revenue.

Harvest

Harvest pearls when the nacre layer is 0.08-0.12 in (2-3 mm) thick.

A good quality black pearl has a nacre layer at least 0.08-0.12 in (2-3 mm) thick, which takes a minimum of 18 months in most areas. Do not risk producing pearls with thin nacre by trying to harvest early. If you are not sure if your pearls have a thick enough layer of nacre to be harvested, harvest a few and have them drilled. Examination of the drilled hole with a magnifying glass or jeweler's loupe will reveal whether the nacre is thick enough. Pearls with thin nacre have poorer luster and buyers will soon discover that these pearls are of inferior quality when they are drilled because they crack around the drill holes. Selling poor quality pearls can ruin your reputation as a pearl farmer and make future sales more difficult.

The technician who grafted the pearl oysters will likely want to return for the harvest.

In most cases, technicians will want to harvest the pearls they grafted, especially when working for a share of the harvest. This is advantageous for the farmer because the technician will be especially motivated to work carefully.

Supervise all workers and technicians during the harvest.

Although most people are honest, it is not unusual for a pearl farmer to lose a high percentage of his harvest through theft. Some technicians may try and insist that the farmer not watch them harvest the pearls because of the supposed danger of revealing secret methods. This should not be allowed. The farmer has the right to supervise all phases of the harvest. Additionally, pearls can easily be dropped and lost by careless workers. Having you there will make workers more careful because they may be held accountable for their actions. After harvest, pearls should be stored in a secure place.

A second or third graft may be performed on some pearl oysters.

Second grafts can be an important part of operating a profitable farm. A skilled technician can graft a pearl oyster a second time if the first pearl produced is a high-quality, round pearl. Second grafts are only performed on pearl oysters that produce good pearls because the price of the larger nucleus used in the second graft is high. The second pearl will be larger and has a higher probability that it will be of good quality. Conversely, a pearl oyster that produces a poor quality first pearl will most likely produce a poor quality second pearl.

Wash pearls after harvesting.

Pearls will have a thin mucus coating when harvested, so it is best to keep them in freshwater until they can be cleaned using a salt bath. Special tumblers can be purchased for this purpose or a cloth bag can be used. Add approximately twice as much rock salt to the tumbler or bag as the volume of the pearls to be cleaned. Then add just enough freshwater to make a slushy mixture. Tumble or gently shake the bag for about 5 minutes. Next, rinse in freshwater and dry on a soft cloth. The pearls will be much more lustrous after cleaning. This is all the processing necessary for black pearls. Do not risk your reputation as a producer by attempting other forms of processing designed to cover flaws or poor luster.

An important part of grafting and harvesting is keeping thorough records.

Keep records throughout the entire production process. Record the number of pearl oysters that were taken to be seeded, rejected, died and/or rejected the nucleus. The number of second or third grafts that were performed and how many pearls were harvested should also be recorded. Tracking the performance of individual technicians is also a good practice.

Half-pearl (mabe) implantation

Half-pearls, also called “mabe,” can be a good way to make money from pearl oysters.

Mabe are dome-shaped pearls formed on the surface of the pearl oyster shell. Although the term “half-pearl” is also used to describe mabe, this may be confusing since the term “half-pearl” is also used to describe other types of pearls. Although not as valuable as a round pearl, it is easier to reliably produce mabe. If for some reason you cannot or do not wish to hire a grafting technician, you can implant half-pearl nuclei yourself. Even if you are producing round pearls, you can use defective or old pearl oysters that the grafting technician rejects to produce mabe.

Half-pearl nuclei are made from plastic and are most commonly round, oval or teardrop-shaped. One side is flat and the other rounded. These range in size from 0.3 in (8 mm) to 0.6 in (15 mm) in diameter and cost \$0.50-\$1. The best size to implant is the 0.3–0.4 in (8-10 mm) size. Half-pearl nuclei made specifically for half-pearl production can be ordered and come in a variety of shapes: round, oval, teardrop or heart-shaped. However, just about any small plastic object with one flat side can be used.

Producing mabe

Carefully open the pearl oyster so you can see inside and select a good spot to glue the nucleus.

Open the pearl oysters by allowing the shell to open naturally; then insert a wedge of wood to keep it open. Otherwise open the shell using the flat-edge opening tool and speculum as you would for normal grafting (no more than 0.3 in or 8 mm or you risk injuring it). Place the pearl oyster in a clamp to hold it securely.



Figure 18. Typical grafting tools. Left to right: Two sizes of speculum for opening shells; spatula and hook for positioning tissues; two knives for making incisions in the gonad prior to insertion of the nucleus; mantle tissue lifter; forceps; knife for trimming mantle tissue; scissors for cutting byssus; and scissors for trimming mantle tissue. The photograph on the right demonstrates the positioning of the open pearl oyster in the clamp relative to the grafting tissue. (photographs: Fareka, Farell).

Look for areas on the inside of the shell where the nacre is lustrous and of the desired color.

The half-pearl will have the same color as the area on the shell where it is glued. If it is placed near the colored area, which is close to the edge of the shell, it will have a dark, iridescent quality. If placed further inside, it will be white or silvery. It helps to have a lamp or flashlight to be able to see inside the shell. You can also use a small dental mirror to examine the inside of the shell for a spot with good nacre to glue the nucleus.

Use only a small amount of glue to attach the nucleus to the selected spot.

Dry the part of the shell where you want to place the plastic nuclei using a cotton swab or small sponge. Pick up the nucleus on the lifter (Figure 19-how to graft mabe) with the flat side up. Put a drop of polycyanoacrylate glue (also known as Super Glue™) on the flat side of the nucleus. Press the nucleus firmly against the top shell and hold for 10 seconds. The nucleus should stick. Take care not to leave the pearl oyster open for more than a few minutes.

Some cautions:

- © Do not use nuclei so large that the pearl oyster cannot close its shell afterwards.
- © You can implant up to 5 nuclei in a large pearl oyster or 3 in a medium-sized one.
- © Nuclei can be attached to the upper and lower shells, but stagger their locations so that the pearl oyster can close its shell afterwards (Figure 18-how to place mabe nucleus).
- © Place the nucleus as close as possible to the front of the shell so that it is located on the most colorful section of the nacre, unless you want white or silver mabe.
- © Use fresh glue because old glue will not hold firmly.
- © Keep the glue in the refrigerator, but let it come to room temperature before using it.
- © Use only a small drop of glue – it should not ooze out around the edge of the nucleus.
- © Take care not to get any of the glue on the tissue of the pearl oyster.

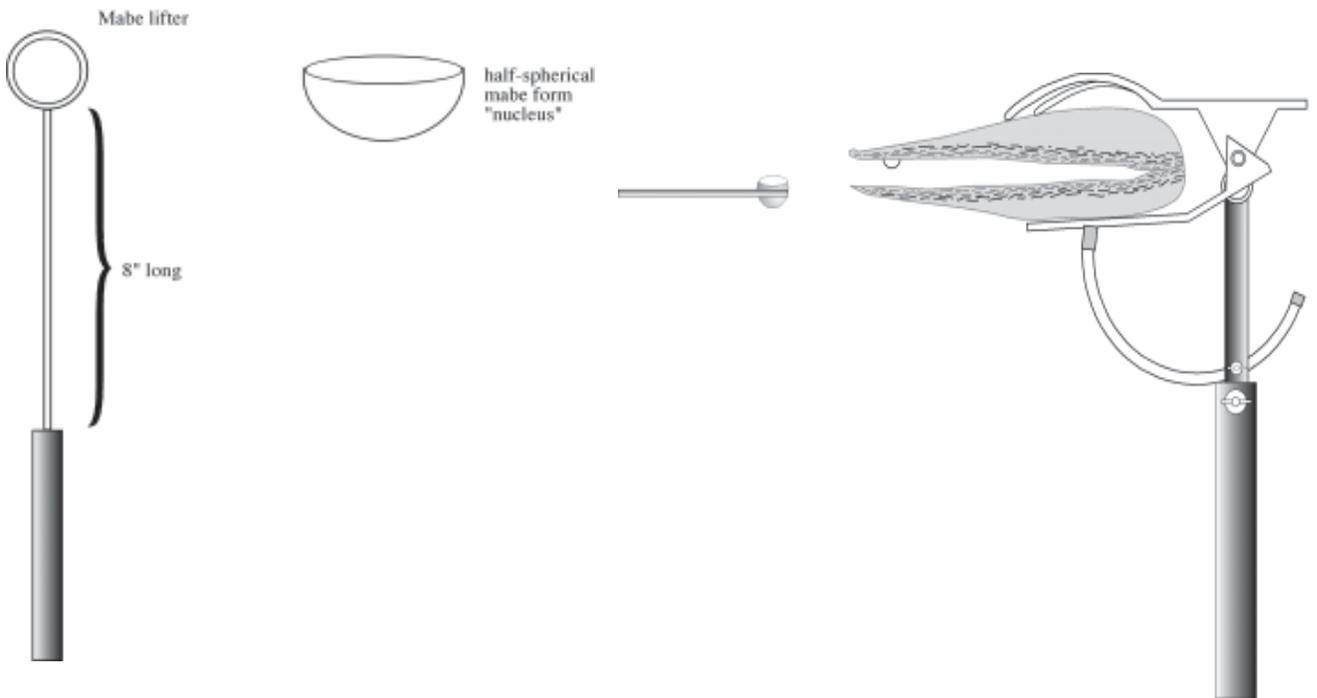
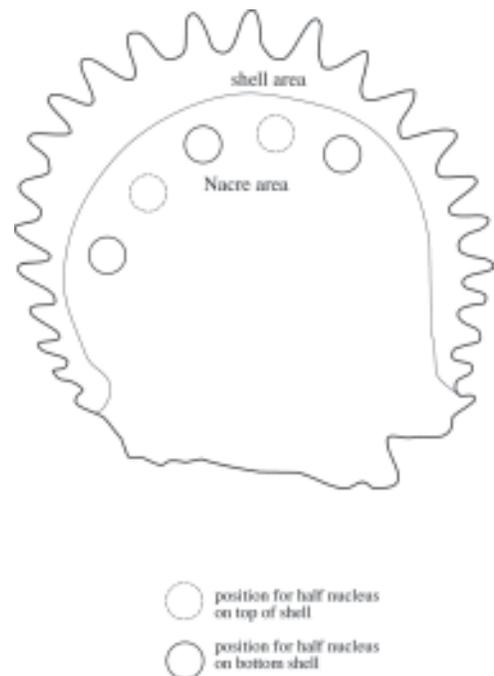


Figure 19. Tools for grafting mabe. A lifter is used to pick up and position the plastic mabe forms on the interior pearl oyster shell.

Figure 20. Mabe forms can be attached to the upper and lower shell as long as the forms are alternated between top and bottom so that two forms do not come into contact with each other and prevent the pearl oyster from closing its shell. Note that you should place the mabe forms in the most highly colored area of the shell since this will produce the best quality mabe.



Good quality mabe can be harvested after 9-12 months.

A few mabe can be checked 6 months after implantation to determine if the nacre is thick enough to allow harvest. It should be at least 0.12 in (3 mm) thick. If not, the mabe may break during processing.

Before starting mabe culture, look for a buyer.

The buyer can tell you how to prepare the mabe for harvest. In some cases, they may want you to send the entire shell without cutting out the half-pearl. However, if you can cut them out yourself it is more profitable to you because you can use the remaining parts of the shell for production of handicrafts. However, if you do not have the proper tools or sufficient skill to cut out the mabe, then do not risk ruining the mabe and just sell the entire shell.

Mabe require processing before they can be made into jewelry.

The mabe that are embedded in the shell will be cut out of the shell leaving about 0.5 in (1 cm) between the edge of the mabe and the cut. The plastic form will either be popped out or drilled out, leaving only the nacre covering. The resulting hole will be filled with epoxy, then glue on a mother-of-pearl backing. It takes some skill to do this well, so normally farmers will simply sell the unprocessed mabe.

Selling pearls and pearl products

Most farmers sell pearls directly to buyers, who will often attend the harvest, particularly if the harvest is a large one or many farmers are participating. The buyer will want to grade the pearls, meaning evaluate the quality of each pearl. The farmer can also market his pearls directly to jewelers or wholesalers, but this requires travel and a good knowledge of pearl grading and pricing.

Pearls are usually sold as lots, although individual pearls may also be sold.

A harvest will usually be divided into lots of pearls of similar size and quality. The buyer will then pay a set price for the entire lot. Some buyers will want to buy only individual pearls that are large or of particularly high quality. If the best pearls are removed from the lot, it may be difficult to sell the remaining pearls since there will be fewer choice pearls to tempt the buyer. Until a farmer has a good knowledge of pearl grading and marketing, it will generally be advantageous to sell the pearls in lots.

The quality and price of a pearl depends on several factors: size, shape, luster, color, orient and texture.

A “good” or “high” quality pearl is large, round, lustrous, smooth without flaws and possesses an iridescent quality.

Size is one of the main determinants of price.

Pearl sizes are measured by the diameter in millimeters. They may also be weighed in mommes (3.75 grams) or grams. Large pearls (over 12 mm) are much higher-priced than the smaller ones. For example, in 1992 the average price of a black pearl rated as fine, measuring 8 mm (0.32 in), was \$285; while a 9-mm (0.36 in) pearl of the same quality was worth \$385 – a difference of \$100 for a 1-mm (0.6 in) increase in size. The next size pearl (10 mm or 0.4 in) was worth \$560, an increase of \$175 for a 1-mm (0.6 in) increase in size. This progressively greater difference in price continues as pearls get larger, explaining the reasons an experienced technician will be careful to use the largest size nucleus possible. Every millimeter difference in size can mean a substantial increase in price.

Pearls harvested so early that the nacre layer is very thin, are not only smaller, but are also considered to be of lower quality because a thin nacre layer can easily crack. The luster and orient of thin nacre may also be of lesser quality. Your reputation as a pearl producer can suffer by attempting to sell pearls with thin nacre. A proper nacre layer should be at least 0.08-0.12 in (2-3 mm) thick, which takes approximately 18-24 months. Therefore, it is wise not to harvest too early.

“Black” pearls vary considerably in color.

Most pearls produced by Black-Lip pearl oysters will be dark gray or black with an iridescent quality. It is the iridescent colors of the pearl that increases its value. There should be undertones of blue, green, purple (eggplant) or silver. Predominantly blue-green colors with hints of other colors (the term “peacock” refers to having all colors present) are considered most valuable. Pearls are always examined and graded in natural sunlight so that the subtle colors can best be seen.

The color of the pearls grafted by a technician can tell you a lot about his or her skill. If a high percentage of the pearls are silver-white, yellow or orange, it may mean that the technician was not careful in selecting mantle tissue that produced the best nacre quality. Pearls of these colors have a much lower value than darker colors. However, even the best technicians will produce pearls with a wide variety of colors.

Pearl shapes are generally classified as round, semi-round, circlé, or baroque.

Round pearls are completely round on all sides, while semi-rounds may have slightly flattened or bulging surfaces. Round pearls will sell for the highest price and the number of round pearls produced by a technician is a sign of his or her skill. Baroque pearls are pearls with any shape other than round and although not considered as high quality can still be valuable if of otherwise good quality. Circlés are the baroque pearls that have circular grooves running around the outside of the pearl.

The luster and orient of a pearl are classified by the way in which the surface of a pearl reflects light.

A high quality pearl with good luster reflects light well, while a poor quality pearl is dull or chalky. The most lustrous pearls have a finish that is mirror-like. The orient refers to the way the light enters the semi-transparent nacre and is refracted outwards. This gives an appearance of depth to the pearl. Pearls with thin nacre will usually be betrayed by poor luster and orient.

The surface of a pearl should be smooth and without flaws.

Pearls are often flawed with a variety of bumps, pits and spots that reduce its value. If there are only one or two small flaws that can be hidden when the pearl is made into jewelry, it still may be rated as a Grade A pearl, but more flaws will definitely reduce its grade.

The most important thing to understand about selling your pearls is that not all pearls can or will be sold.

While a rating of “commercial” or “C+” is awarded to the lowest quality marketable pearl, often the majority of a farmer’s production cannot even meet this standard and thus cannot be sold. Therefore, since it takes only one mistake to ruin an otherwise perfect pearl, doing even the smallest tasks correctly is extremely important to the success of your business.

On average, the top 5% percent of pearls will earn 95% of a farmer's income.

Only 5-10% of pearls produced are considered high quality. This means that if you harvest 1,000 pearls, only 50-100 of those will fetch the highest prices. The rest may not sell for enough to produce a profit.

Pearl grading is a fine art, but obtaining a high price for your pearls depends on your knowledge of the basics.

Do not depend on the pearl buyer to accurately grade your pearls, since this affects the price he will pay you. If possible, have an impartial, qualified person grade your pearls. You should also try to learn as much as possible about pearl grading and the ever-changing international market to ensure the accuracy of the grader.

You can also sell other pearl products such as mabe and various shell products.

These might include jewelry made from polished shell, fishing lures, and other handicrafts that incorporate pieces of polished shell. Face cream made with scraps of nacre from pearl oyster shells can also be sold for a good price.

Appendix

Budgets for small and medium pearl farms

This example assumes that 3,000 pearl oysters are implanted (grafted) on the small farm and that 6,000 are grafted on the medium size farm. It is assumed that of the grafted pearl oysters, 45% will eventually yield a pearl that is of sufficient quality to be sold. The small farm will thus yield 1,350 pearls and the medium size farm will produce 2,700 pearls. Pearl prices are average prices for single pearls in 2001. Costs are based on typical costs in the Western Pacific, although the reader is warned that in order to use this budget to calculate returns for his or her farm, some research will need to be done to collect information on current costs and that these should be used formulating the budget for his or her farm.

The pearl oysters are cultured for 18 months before harvest, so this budget covers a period of 18 months. In most cases, a farmer will have enough pearl oysters held on the farm so that grafting and harvesting can be timed so that harvesting occurs yearly. This budget also does not consider income from second or third grafts, nor sales of other possible products like handicrafts or shells.

The budget for the small pearl farm demonstrates that at the end of an 18-month culture period, the farmer will make \$8,932 over the amount spent to operate the farm during that period. The farm-start up budget shows that an additional \$17,000 will have been needed to start farm operations. It will take the farmer slightly more than two culture cycles to recoup these start-up costs based on the return of \$8,932 per culture cycle.

In comparing the budgets for a small and medium pearl oyster farm, it can be seen that by scaling up to the medium size farm, a farmer can make higher returns. Essentially, the returns double, but the costs increase only slightly since many of the costs are similar for small and medium size farms (e.g. communications, marketing). Startup costs are slightly higher for the medium farm, but since this increase in scale is modest, the farm can be started with almost the same amount of equipment and supplies. In this case, the start-up costs are recouped by the returns from the first harvest. It is therefore advisable to try and establish a larger farm when possible. Some caution should be used since this scaling-up with minimal additional costs is only applicable to a certain point. Very much larger farms will entail much higher startup costs and operational costs. The farmer is thus advised to use accurate information to calculate costs and returns when deciding whether to farm, and for what size of farm to aim.

Small Pearl Farm Budget (3,000 pearl oysters grafted every 18 months)

3,000 grafted with final harvest of which 45% are saleable (1,350)

Table 1. Gross Returns (returns from pearl sales)

Item	Description	Unit	Quantity	Price/Unit (\$)	Total Cost (\$)
Pearls	Size 9-10 mm Grade A	pearl	110	45.00	4950
	Size 9-10 mm Grade B	pearl	160	30.00	4800
	Size 9-10 mm Grade C	pearl	190	20.00	3800
	Size 11-12 mm Grade A	pearl	143	55.00	7865
	Size 11-12 mm Grade B	pearl	219	35.00	7665
	Size 11-12 mm Grade C	pearl	250	25.00	6250
	Size 13-14 mm Grade A	pearl	22	100.00	2200
	Size 13-14 mm Grade B	pearl	25	80.00	2000
	Size 13-14 mm Grade C	pearl	31	65.00	2015
	Circles and baroque	pearl	200	30.00	6000
	Keshi	pearl	300	2.00	600
Gross Returns					\$48,145

Table 2. Costs (for operating farm for 18 months)

Item	Item Description	Unit	Quantity	Price/Unit (\$)	Total Cost (\$)
Spat (20'-30')	grafting size spat	spat	5000	1.25	6125
two outboard motors	rafting fees and	trip	4000	13,000.00	13,000
Grafting services	travel/lodging expenses		500		
miscellaneous boat gear			500		
Labor	2 persons/3 days per week/18 months	hour	1000	2.00	7488
Seeding platform			3744		
small generator	for the generator (to	gallon	500	0.50	100
Diesel gas	supply electricity)		500		
basic office equipment	(telephone, fax, etc.)		500		
Gas compressor	for the outboard motor	gallon	1000	2.00	400
Equipment repairs	repairs to boats,		1500		
2 sets SCUBA gear	engines, generator, etc.				
miscellaneous			700		
machines and other work tools	tools, knives, gloves,				
materials and ropes, floats, anchors	ropes or supplies		2300		1000
Supplies					
TOTAL			\$17,000		
Communications	phone/fax/email				500
Marketing	1 overseas trip for marketing	trip	1	4000.00	4000
Depreciation	assumes \$15,000 in assets depreciated at 10% for 10 years				3400
Insurance	worker and vehicle insurance				2000
Concession	permit fee	permit	1	200.00	200
Total Costs					\$38,713
Net Profit					(\$48,145 - \$38,713)

Table 3. Startup costs for small farms

Medium Pearl Farm Budget (6,000 pearl oysters grafted every 18 months)

6,000 grafted with final harvest of which 45% are saleable (2,700)

Table 4. Gross Returns (returns from pearl sales)

Table 5. Costs (for operating farm for 18 months)

Item	Description	Cost Unit	Quantity	Price/Unit (\$)	Total Cost (\$)
Spat (20'-30')	grafting size spat	5000	7000	1.75	12,250
two outboard motors (35 hp)	grafting fees and travel/lodging expenses	4000	1	22,000.00	22,000
Grafting services					
miscellaneous boat gear		500			
Labor	2 persons/4 days per week/1.5 years	1000	4992	2.00	9984
seeding platform					
small generator	for the generator (to supply electricity)	500	200	0.50	100
Diesel gas					
basic office equipment (telephone, fax, etc.)		500			
Gas	for the outboard motor	gallon	200	2.00	400
compressor		1000			
Equipment repairs	repairs to boats, engines, generator, etc.	1500			
2 sets SCUBA gear					
Miscellaneous materials and supplies	tools, knives, gloves, compressor supplies	700			
ropes, floats, anchors for 3 lines		4000			
Communications	phone/fax/email				500
TOTAL		\$19,300			
Marketing	1 overseas trip for marketing	trip	1	4000.00	4000
Depreciation	assumes \$15,000 in assets depreciated at 10% for 10 years				3400
Insurance	worker and vehicle insurance				2000
Concession	permit fee	permit	1	200.00	200
Total Costs					\$56,334
Net Returns					(\$96,290 - \$56,334) = \$39,956

Table 6. Startup costs for medium farms

Glossary

Baroque: irregularly shaped pearls.

Circlé: pearls which have concentric grooves around the perimeter.

Fouling, biofouling: small plants and animals that colonize the shell of the pearl oyster thereby becoming a nuisance.

Gape: involuntary relaxation of a pearl oyster's shell, often as a result of spending too much time out of the water or a weakening of the adductor muscle.

Gonad: reproductive organ, produces either sperm or eggs..

Grafting: also known as seeding or nucleus implantation; a surgical procedure in which the nucleus and a small piece of mantle tissue are inserted into the gonad thus starting development of a cultured pearl.

Half-pearl: a pearl of a half-spherical or semi-spherical shape attached to the shell, forming naturally when an irritant is covered with nacre.

Larva, larvae: early developmental stage of the pearl oyster life cycle when the pearl oyster is a microscopic and free-swimming organism. This period lasts 2-3 weeks.

Keshi: means "poppy" in Japanese, a by-product of the grafting process, produced when the implanted piece of mantle tissue secretes nacre around itself, resulting in small, irregularly shaped pearls without a nucleus.

Mabe: dome-shaped secretions of nacre developed over an artificial form attached to the shell. Sometimes also called half-pearls (see half-pearls).

Metamorphosis: developmental stage involving anatomical and behavioral changes transforming the free-swimming larvae to a settled adult.

Nacre: also called mother-of-pearl; the iridescent material lining the inside of mollusk shells, composed of calcium carbonate crystals (aragonite) deposited between layers of organic material; one of the types of shell material formed by the epithelial cells in the mantle tissue.

Pearl sac: the tissue containing the nacre-producing epithelial cells that enclose the developing pearl. The pearl sac develops out of the transplanted piece of mantle tissue (the graft) inserted into the gonad during grafting. This term may also be used to refer to the extreme end of the gonad where the nucleus is inserted.

Speculum: the tool used to open the pearl oyster shell.

Spat: juvenile pearl oyster.

Spawn, spawning: release of eggs or sperm by the pearl oyster into the water.

Suppliers of aquaculture and pearl farming supplies

The following vendors supply general aquaculture equipment and some sources of specialize pearl production items are also listed. This listing does not constitute an endorsement of these vendors, but is merely provided for purposes of information.

Pacific Aqua Products Inc

2767 Muir Road

Courtenay, B.C.

V9N 9A1

Canada

Tel 250-338-7572

Fax 250-338-7579

E-mail: inertia@island.net

Website: www.pacificaquaproducts.com

Products: Spat bags, lantern baskets, pocket panels and other pearling equipment.

Fukui North American

P.O. Box 119, Islandview Drive

Golden Lake, Ontario K0J 1X0

Canada

Tel 613-625-2544

Fax 613-625-2688

E-mail: bishopd@renc.igs.net

Website: www.fukuina.com

Products: Spat bags, lantern baskets, pocket panels and other pearling equipment.

Australian Netmaker

P.O. Box 291, Hamilton Hill

6163 Western Australia

Australia

Tel (08) 9331 1955

Fax (08) 9337 6582

E-mail: george@atticamarine.com

Website: www.attica.iinet.net.au

Products: complete line of pearl farming equipment including pocket panels, longline systems, floats, spat collectors, seeding tools and accessories.

Earth Corporation
4-3 Nihonbashi Bakuro-cho
I-chome, Chuo-ku, Tokyo 103
Japan
Tel (03) 3664 5216
Fax (03) 3666 3885
E-mail: saitou-hiro@earth-j.com
Website: www.earth-j.com/suisou/
Products: pocket panels, lantern baskets and floats.

Mori Shell Button
401-37-15- 8 Chome, Koyame
Fujiidera City, Osaka 583-0033
Japan
Tel (81) 729-55-9175
Fax (81) 729-55-0869
Email: msbshell@nifty.com or nishijima@morishellbutton.com
Products: complete line of pearl farming equipment including pocket panels, longline systems, floats, spat collectors, seeding tools, nuclei and accessories.

Mea Pacific Inc.
41-894 Kakaina St.
Waimanalo, HI 96795 USA
Tel: 808-259-8755
Fax: 808-259-8750
email: equator@lava.net
Product: nucleus

J&L Supply
2939 Old Delhi Rd.
Pioneer, LA 71266 USA
Tel: 318-926-5269
Fax: 318-926-4275

Aquila International, Inc.
2036 Larkspur Dr.
Lexington, KY, 40504 USA
Tel: 606-276-4566
email: aquila@city-online.com
Product: nucleus

Aquatic Ecosystems Inc.
1767 Benbow Court,
Apopka, FL 32703, USA
Tel 407-886-3939 or 1-877-347-4788
Fax 407-886-4884
Email: aes@aquaticesco.com
Website: www.aquaticesco.com

Products: One of the most extensive collections of aquaculture products in one catalog in the world.
Includes ropes, floats, spat bags and lantern nets.

Area
Aquaculture Research/Environmental Associates, Inc.
P.O. Box 901303
1088 West Mowry Drive
Homestead, FL 33090-1303, USA
Tel. 305-248-4205
Fax 305-248-1756
E-mail: areainc@aol.com
Products: General aquaculture supplies, shellfish production containers.

Aquaculture Supply
33418 Old Saint Joe Roa
Dade City, FL 33526, USA
Tel. 352-567-8540
Fax 352-567-3742
e-mail: ASUSA@Aquaculture-Supply.com
Website: <http://www.Aquaculture-Supply.com>
Products: General aquaculture supplies, shellfish production containers.

Memphis Net and Twine Co., Inc.
2481 Matthews Avenue
P.O.Box 8331, Memphis
Tennessee 38108, USA
Tel. 901-458-2656 or 1-800-238-6380
Fax 901-458-1601
Email: memnet@memphisnet.net
Website: www.memphisnet.net
Products: Ropes, spat bags and floats.

Nylon Net Company
845 N. Main Street
P.O.Box 592, Memphis
Tennessee 38101, USA
Tel. 901-526-6500 or 1-800-238-7529

Fax 901-526-6538
Email: nylonnet@nylonnet.com
Website: www.nylonnet.com

Pacific Seafood Industries, Inc.
P.O. Box 2544
Santa Barbara, CA, 93120, USA
Tel: 805-687-8282
Fax 805-687-2024

Suppliers of shellfish farming equipment including ropes, floats, lantern baskets, pocket panels, spat collection materials, etc.

Urban Marine Co., Ltd.
Nishi P.O. Box No. 185
Osaka, Japan
Tel. 6-543-0371
Fax 6-543-0373
Telex: 525-4557URBANMJ

Fire Mountain Gems
28195 Redwood Highway
Cave Junction, OR 97523-9304 USA
Tel: 800-423-2319
Fax: 800-292-3473
Products: jewelery making supplies

Kassoy
16 Midland Avenue
Hicksville, NY 11801, USA
Tel. 516-942-0560
Products: jewelery making supplies, pearl drills

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Wada, K. 1973. Modern and Traditional methods of pearl culture. *Underwater Journal* 4: 28-33.

