Establishing Community-based Marine Protected Areas for Cockle Fishery Management

Karen Palmigiano and Brian Crawford

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The Sustainable Coastal Communities and Ecosystems Program (SUCCESS)
A Component of the Global Program for the Integrated Management of Coastal and Freshwater Systems (IMCAFS)

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I. Introduction

Figure 1-Cockle Pickers, BBC News online. 2004.

This guide focuses on the use of small-scale no-take zones known as community-based marine protected areas (CB-MPA) for the purpose of improved management of cockle fisheries. Cockles are an important resource, especially in coastal and island populations, where they provide food, are a source of protein, and provide income for thousands of families worldwide. Cockles are mainly gathered by gleaning, which is often done by women and children without mechanical assistance (see Figure 1). In many parts of the world, expanding populations and the opening of commercial markets has led to increased collection of cockles. The increased rate of collection then leads to over-harvesting and declining stocks and catches as well as declining income for harvesters and food availability for coastal communities.

This guide will provide information on CB-MPAs that can be used to help prevent the decline of cockle populations and improve fisheries production. CB-MPAs have been used extensively in several regions of the world to help restore and protect wild shellfish for the purpose of collection. The guide will briefly explain the biology of important species of coral reef and mangrove cockles. It will then explain the function of CB-MPAs, the process of setting up, managing, monitoring, and evaluating a CB-MPA and finally some case studies from countries which have set up successful CB-MPAs.

II. Biology of Cockles

Cockles along with clams, oysters, mussels, and scallops, are members of the class Bivalva, which is one of the seven classes of the phylum Mollusca, and often referred to generally as bivalves. The word "bivalve" refers is to the structure of the organism with two shells that are hinged together. Cockles can be found all over the world and they range from about one centimeter (0.4 inch) in diameter to about 15 centimeters (about 6 inches). The two shells of the cockles are divided from front to back into left and right valves and are hinged on one end. They can be very colorful with either a surface that is quite smooth or others that have ribs radiating from the hinge area between the shells, which help in aging the organism (Figure 2). Depending on the particular species of cockle some tend to burrow deep into the sediment while others will remain partially buried. Deep burrowers often have two extremely long tube-like structures called siphons to reach the surface for breathing and streamlined or wedge shaped shells for slipping through the sediment. One siphon carries water to the mantle cavity (the inhalant siphon) and one from the mantle cavity (the exhalent siphon) (See Figure 3.). Cockles that bore into hard substrates such as wood, rock or coral have shells reduced or adapted as files or with cutting edges.

Figure 2-*Anadara granosa*, www.fishesnpets.net. 2002

Cockles live in marine, estuarine or freshwater environments. Most species live just below the low-tide line; some have been obtained from depths of more than 500 meters (1,500 feet), and a few live in the intertidal zone. Many are found in sandy or muddy areas shallowly buried to a depth of not more than three centimeters (about one inch) while others live attached to various firm surfaces. Cockles can be so prominent in some areas that they dominate entire habitats and assume important roles in the nutrient cycle.

Common cockles that are harvested for human consumption, such as *Anadara granosa,* are typically intertidal species, and naturally live in an area of silty bottom with relatively low salinity. They are widespread in the Indo-West Pacific, from East Africa to Polynesia, north to Japan and south to Australia. Other commonly harvested species in Central and South America, such as *Anadara tuberculosa* can be found in the intertidal zone among the roots of mangrove trees. *Anadara senilis*, in West Africa and the Americas, usually reside in the upper part of the

intertidal and sublittoral zones. Other species of Anadara such as *Anadara cornea* are found around the mean low water of spring tides, while *A. subcrenata* and *A. broughtoni* are found largely in muddy substrates subtidally. *A. trapezia* occurs mainly in estuarine mudflats and sometimes on rocky substrates. Other species are not present in muddy substrates. *A. antiquata* is usually located in the sublittoral area inhabiting rocky crevices and attached to rocks and stones. *A. anomala* is also situated sublittorally, but in sandy substrates. Lastly, *A. inaequivalvis* is found intertidally in sandy areas.

Most bivalves are filter feeders, which feed on a wide range of microscopic plants and animals in the ocean. The vast majority of Cockles feed on the dead plant matter, bacteria, and algae that characterize the sediment surface or that cloud coastal and fresh waters. Their gills have become adapted to filter feeding and are paired to help sift water from water particles and sediments. Other cockles and bivalves use their siphons to pull water towards them and then filter the water to separate the liquid from the tiny organisms, which they then digest.

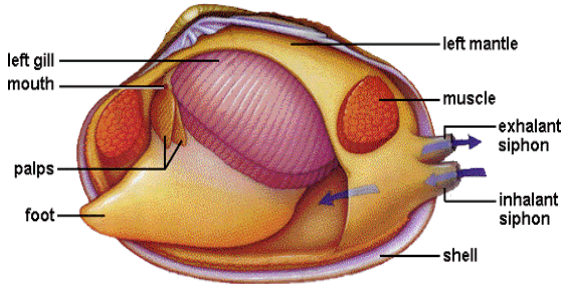


Figure 3-Clam Anatomy, Dennis Anderson, Oklahoma City Community College

Bivalves have separate sexes that are impossible to distinguish from the outside. Eggs and sperm are shed into the sea, where fertilization occurs. The young larvae swim freely for a time before settling on the bottom. In some species the eggs are retained in the mantle cavity while they develop into a tiny-shelled individual and then they are expelled. The breeding season of most species of cockles lasts several months. There is some evidence of hermaphroditism (both sexes in one individual), although it is very rare and has only been found in a small percentage of populations. The age of sexual maturity for each species of cockle varies. It is estimated that *Anadara granosa* can reach a level of maturity after one year and a length of 18-20mm. Other species' age and length at maturity can be found in table 1.

Table 1- Species, age and length at maturity.

Species Name	**Age at Maturity**	**Length at Maturity**
Anadara granosa	<1 year	18-20mm
Anadara subcrenata	-	15mm
Anadara broughtoni	-	48.3-52.5mm
Anadara tuberculosa	-	32-36mm
Anadara trapezia	-	20mm
Anadara cornea	-	20mm
Anadara senilis	5 months	18-20mm
Anadara granis	-	21mm

The spawning of cockles is a synchronized event where both the tiny sperm and small eggs are released into the water at the same time. Once the egg is fertilized by the sperm it will slowly settle to the seafloor (where it is now referred to as spat) of the intertidal zone, usually in fine, soft, blackish mud (see Figure 2.). Once the organism is settled it remains on the floor as it develops into an adult. For some species such as *A.granosa*, spawning can take place year round with one or two peak times throughout the year. Seasonal peaks are been seen in the spawning of *A. subcrenata, A. broughtoni, A. granosa,* and *A.trapezi*. The causes of seasonal variation of spawning are not very well understood but are thought to be due to changes in salinity and water temperature. In Central America, spawning of *A. tuberculosa* and *A. senilis* is thought to be triggered by a decrease in water temperature during the winter/dry season.

III. Human Collection of Cockles

Cockles, particularly of the species *Anadara,* are a very important resource. The average marketable cockle is about 2.5 centimeters (one inch) long and two or three years old. The meat, which is usually sold fresh or preserved in salt or vinegar, is sometimes eaten raw. When canned, the meat is commonly eaten as hors d'oeuvres. A popular way to serve cockles in Central and South America is with limejuice

over rice. The meat of the cockle is a very important part of the diet for many people in tropical countries especially for coastal communities. The cockle meat can provide a good source of protein. The sale of cockles also provides an important source of income to families that harvest cockles

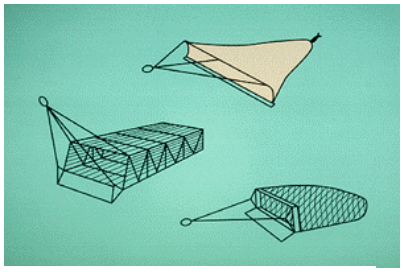


Figure 4-Dredges. FAO/FIIT Gear Sheets, 2001

Collection of cockles from mangrove forests and coral reefs relies on several gears or can be collected by hand. Local fishermen may go out in boats to the collection areas and wait for the tide to drop so that the cockles are exposed in the mudflats, mangroves or coral reef flats. Sometimes a wooden sled is brought with them to provide support for the fishermen while they maneuver through the mud as well as forming a repository for collection. In Malaysia, a hand dredge is operated from a boat and attached to a long pole, which has usually been cut from a nearby mangrove. The dredge is dragged along the surface of the substrate and collects organisms that are embedded into the seafloor. Dredges are gears, which are dragged along the bottom to catch shellfish. They consist of a mouth frame to which a holding bag constructed of metal rings or meshes is attached. Another type of a collection gear is an otter trawl (see Figure 5). A bottom otter trawl is a cone-shaped net consisting of a body normally made from two, four and sometimes more panels, closed at one end and with lateral wings extending forward from the opening. A bottom trawl is kept open horizontally by two otter boards. A boat can be rigged to tow a single or two parallel trawls from the stern or from two outriggers. Both dredge and trawl fishing techniques along with many others can disturb the cockles as well as destroy the habitat on which they depend. In many areas, cockles are typically harvested by hand, a more sustainable and manageable method of harvest.

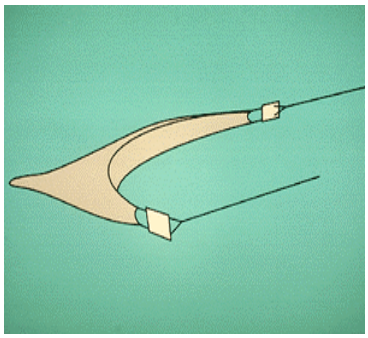


Figure 5-Trawl Net. FAO/FIIT Gear Sheets, 2001.

In South American countries, harvesting usually lasts 15-20 days per month. The fishermen harvest cockles at low tides when they can walk in the mangrove areas. Once in the mangroves, the fishermen reach down and feel in the mud. Their hands penetrate the mud to their wrists and commonly their elbows. Fishermen usually harvest barehanded, but some wear gloves, and some in Peru wear cloth tubes tied onto each finger. Net or cloth baskets or sacks or small plastic buckets are used to hold the cockles during harvesting. After collecting, the fishermen return home or to the middlemen in villages where they sell their cockles.

IV. Cockles and Human Health

The benefits of harvesting cockles for food are great but there are also some risks. Shellfish contamination can be a problem and can lead to health problems for people that consume contaminated shellfish. Contamination of shellfish meat with human pathogens, heavy metals, and toxins from red tides can all lead to serious health problems.

Human Pathogens

One problem with eating shellfish is possible contamination with human pathogens that can lead to outbreaks of gastroenteritis, typhoid, cholera, hepatitis, and salmonellosis. During feeding, cockles, like other shellfish, take in bacteria and viruses that may have been discharged into the water through fecal materials from humans and livestock. The fecal materials can be found in the water either through direct deposit or through seepage from pit toilets and leaky septic tanks. Once again the pathogens will continue to accumulate within the tissue of the cockles and then will be transferred into the human body upon consumption by people. *Escherichia coli*, a bacteria found in human feces, is used as an indicator of human pathogens. Levels of *E.coli* in water can be measured as a sign of danger for eating shellfish in that area. An indicator organism is one whose presence in an environment indicates the presence of other contaminating substances, which pose a risk to human health. The presence of *E.coli* indicates that the substance has potentially been contaminated with other harmful pathogens that can also be

transmitted through human faeces. Cooking shellfish usually kills all human pathogens. In areas suspected of contamination by human faeces, eating of raw shellfish should be discouraged.

Heavy Metals

Heavy metal contamination from pollution brought by industrial effluents along coastal waters can have a direct toxic effect on the organism or contaminate it, making cockles unsuitable for human consumption. Several types of metals found to accumulate in cockles are cadmium, mercury, copper, and lead. These heavy metals can build up in the sediment and water column from which the cockles eat. Once the organisms are harvested, the metals build in the tissues and cannot be eliminated through cooking. They are then subsequently transferred into humans once they are eaten. These metals can have damaging affects on people including digestive problems, tremors, central nervous system dysfunction, seizures, cancer, and death. Luckily for most countries, the risk of contamination from heavy metals is small or none. Metals are put in the water by pollution typically associated with large urban, commercial or industrial areas. Heavy metals can cause pollution from fertilizers that run-off into water bodies. Commercial fertilizers, which are applied to home gardens and lawns, may contain high levels of cadmium, copper, zinc, and nickel. Groundwater carries these chemicals from the lawns and gardens into water bodies and may contaminate any fish or shellfish present in the water.

Other activities, which have been known to produce heavy metals that can contaminate shellfish and harvest areas, are the production of steel, paint, magnets and batteries. All of these objects contain some type of heavy metal. Soils normally contain low levels of heavy metals. However, in areas where agricultural, industrial or municipal wastes are applied as fertilizer, concentrations of heavy metals present in the soil may be much higher. Excessive levels of heavy metals can be hazardous to man, animals and plants. Heavy metals cannot be removed from shellfish tissues, so contaminated areas generally need to be closed permanently to shellfish harvesting. Transporting infected shellfish to clear areas will not help in the cleansing process and all shellfish from a contaminated area should not be consumed.

Red Tides

Red tides (also called harmful algal blooms) have also been a problem in some areas and are related to shellfish contamination in areas where they occur. The phrase “red tide” describes a biological event that occurs when species of phytoplankton “bloom” or grow very rapidly and accumulate into dense, visible patches near the water surface. Certain species of phytoplankton may contain a red pigment causing a coloring of the water when they bloom and giving the event its name. Some species that bloom contain neurotoxins that can contaminate shellfish. While they may not kill the shellfish, they can cause harmful and life-threatening illnesses in people who consume the shellfish. Symptoms of poisoning from eating shellfish contaminated by red tides include: tingling of the lips and tongue, tingling of fingers and toe, loss of control of arms and legs, difficulty in breathing, nausea, paralysis of muscles of the chest and abdomen, and death.

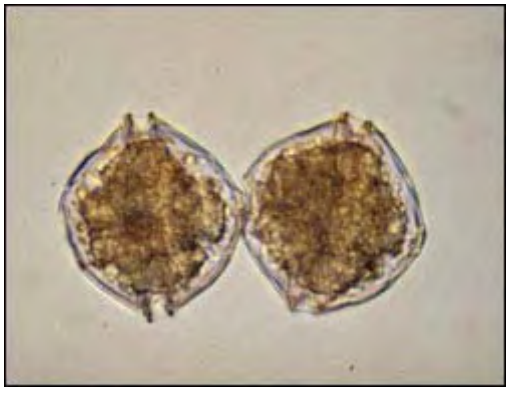


Figure 6- One species of Phytoplankton responsible for Red Tides. Don Anderson.

Best management strategies for shellfish stocks in known toxin areas are still prevention of blooms and early toxin detection measures as opposed to control methods. Plankton samples can be taken to detect whether the harmful red tide algae is at a dangerous level. Canning of shellfish meats has been shown to decrease the amount of toxins found in cockles. In the Mediterranean, cockles of the species *Acanthocardia tuberculatum* where once banned from harvesting. Now through the canning process and the process of a toxin-monitoring program, harvesting of these cockles from known bloom areas has become much safer. Household cooking, including boiling, steaming, and frying are ineffective methods for removing toxins found in cockles. Effects of red tide blooms on the environment, such as large fish kills and the reddish brown color of the water can often last for months at a time and may last up to a year

and a half. Cockle beds affected by red tides must be closed until several weeks after the red tide bloom has subsided to ensure that the toxin accumulated during the red tide blooms are cleansed naturally from the tissues of cockles.

V. What is a Marine Protected Area?

A protected area refers to portions of land and/or water designated by reason of their unique physical and biological significance and managed to enhance biological diversity. A marine protected area (MPA) is any area where the ocean meets the land including the overlying waters and plants, animals, historical and cultural features, which have been reserved by law or other binding measure to protect part or all of the enclosed environment.

Marine protected areas are called different things in different parts of the world. They can be called marine protected areas, sanctuaries, reserves, conservation areas, tabu areas, or preserves. These titles are not always good indicators of what types of activities are permitted and which are not. There are generally two types of MPAs. The first type, called a no-take MPA, is a management area that prohibits all extractive activities including fishing. The other type is known as a multiple-use MPA and allows limited extractive activities. Some multiple-use MPAs can be very large with different areas zoned for specific uses and may even have small no-take areas within them.

The use of no-take MPAs has several benefits for fishery management and is the emphasis of this guide. (For simplicity purposes in this guide no-take MPAs will be known as either MPAs or CB-MPAs.) First of all, MPAs prohibit all forms of fishing in the area. The termination of fishing helps protect target and non-target species, eliminates bycatch, and decreases habitat degradation from harmful fishing gears. MPAs can help restore those areas that were once harmed from human activities, to a more natural state thereby conserving and enhancing biodiversity. They offer complete and total protection to the area. Unlike other management approaches which might only protect a certain species or area at a specific time, MPAs protect all species within an area all the time.

Small-scale marine protected areas are useful tools in rural coastal communities because they help establish local rules and responsibilities for use of local resources and collective management of those resources. CB-MPAs are often established with the goal of restoring or repairing the fisheries and coastal resources in an area known to have important ecological functions. CB-MPAs help control fishing effort, protect breeding grounds and juvenile fishes, guard against overfishing and ensure a sustainable supply of fish stock for local populations. CB-MPAs are mainly used as a management tool for fisheries but they can also be utilized as a tool for tourism. CB-MPAs can provide revenue for local communities through snorkeling and diving operations in the area. For this guide though, we focus on the benefits of CB-MPAs for fisheries management and cockle harvesting.

VI. Function of a Marine Protected Area

A marine protected area, as defined earlier, is an area of land that has been set-aside by law or other means to conserve or protect a specific resource. MPAs can be characterized by their design and management plan. Depending on the level of protection desired and the way it is being protected will determine what kind of MPA it is and its specific function. A community based MPA (CB-MPA) is usually a small, protected area within coastal waters where the community takes leadership in establishing and has full authority for its management. These are small areas commonly 5-100 hectares in size. The reason for establishing a CB-MPA is most often for fisheries management. The level of protection for a CB-MPA is usually decided by its governing parties, whether they are local communities and/or government. CB-MPAs that are jointly managed by communities and the government are referred to as co-management. The two most common types of protection are MPAs and multiple use MPAs.

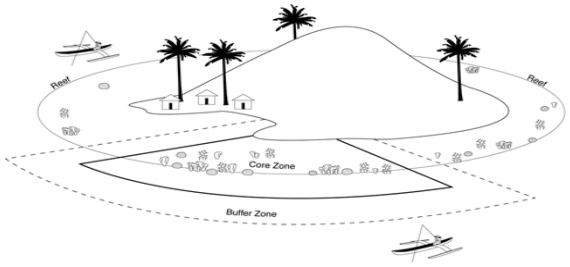


Figure 7- MPA with core and buffer zones.

The MPAs, also known as fully protected marine reserves prohibit all extraction and destruction of natural or cultural resources within the MPA boundaries. Some may also restrict access and/or other activities, which may adversely impact resources, processes and qualities, or the cultural and ecological services they provide. Less protection can be found through multiple-use MPAs which tend to be bigger than no-takes and allow different activities in different areas. They may also consist of an area, which would be considered a small no-take zone. Both types of MPAs share the opportunity to use zoning or spatial planning. Zoning involves designing a spatial system of marine areas where certain activities are allowed and others are prohibited in designated areas. Since CB-MPAs are very small they commonly employ a simple zoning scheme of a core zone surrounded by a buffer zone (see Figure 7). A "core zone" is the main zone of the MPA where no fishing or other extractive or possibly damaging activities are allowed. The "buffer zone" is an area surrounding the core zone where some activities including fishing may be allowed and others are prohibited. Buffer zones typically allow certain types of activities, which are deemed to be less damaging such as traditional fishing, scuba diving, snorkeling, or boating, and others restrict commercial fishing or use of large scale gears.

The use of community-based no-take zones for cockles is important for several reasons. Since cockles are a sedentary species (non-mobile) it is easier to establish an area of protection around the cockle's habitat than it would be for a species that is more mobile and with a wider range within which they moved. Migratory species are much more difficult to protect but cockles tend to burrow into the substrate and remain there for the greater part of their lives allowing monitoring of a population to be simple and providing a good basis for setting up protection. The sedentary nature of cockles can also make them more susceptible to damage from harmful fishing techniques such as bottom trawls or dredging. No-take zones do not allow any kind of fishing within the boundaries of the protected area and therefore help protect the cockles from all types of indiscriminate and destructive gear.

There are three main functions of no-take reserves used for fisheries management. They are reserve effect, spillover and recruitment.

Reserve Effect

Providing protection to the population found inside the protected area is a positive characteristic of no-take areas as they have an advantageous effect on the growth of the stocks residing within the no-take area. Organisms, which are not harvested, are more likely to survive to reproductive age and become larger and be more abundant. Larger organisms are therefore able to produce more eggs to replenish other areas and increase the reproductive output (see Figure 8). One indicator of a successful MPA is an increase of numbers, size and diversity of individuals within the protected area. This "reserve effect" leads to two other important functions: the recruitment effect and the spillover effect. Both help increase the number of individuals outside the protected area that can become available for harvest.

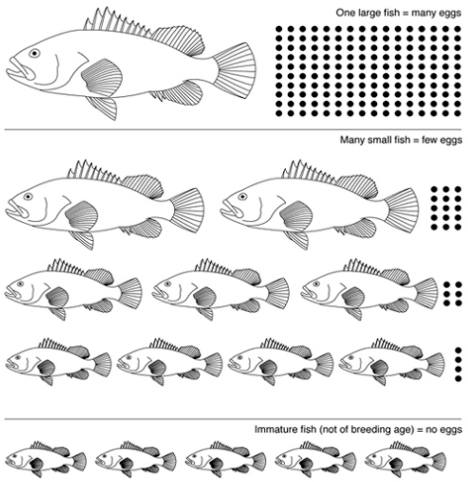
Spillover Effect

Although fishing is not allowed within the no-take area of the MPA, fishing is allowed outside and around the borders of the MPA. Species abundance tends to increase within the protected area. Due to crowding, adults will then exit into the areas adjacent to the MPA. This is called the spillover effect (see Figure 9). The mature individuals, who usually inhabit the MPA area, eventually venture out of the MPA boundary where there is more. The result is that the fish now become more plentiful outside the MPA where fishermen are able to harvest them.

For cockles and other shellfish the movement of mature individuals to areas outside of those which are protected is not likely to occur because the mature individuals are usually embedded in the substrate, connected to immobile structures, and are sedentary (non-mobile) species. In MPAs for cockle

management the spillover effect is not expected as it would be for mobile finfish. Instead of the spillover a recruitment effect is more important for cockle MPAs.

Figure 8-The Relationship of Fish Size and Egg Production. When fish are allowed to mature to a larger size they will then produce many eggs. Fish of a smaller size, even if there are more, will not be able to produce as many eggs.



Recruitment Effect

Another way for organisms to migrate outside of the protected area is through the recruitment effect. The recruitment effect occurs when organisms such as cockles release larvae into the water column. Currents then carry larvae outside the MPA boundaries. This is also called "larval export" (see Figure 10). These larvae will then settle to the ocean floor and burrow into the substrate. Once they have burrowed into the substrate these organisms are now referred to as spat, which is a newly settled or attached bivalve (also termed post larval or juveniles in bivalves). The organisms will mature in this area and then grow up to become available to fishers. The recruitment effect requires larvae from the organism in the MPA to remain suspended in the water long enough to travel outside the boundary of the protected area. Cockle larvae can stay suspended in the water for as long as 21-30 days depending on currents and wind. Other factors such as the amount of spawning cockles and the temperature of the water can also affect the movement of larvae. Cockle larvae have a higher success rate when there is a large number of individuals spawning at the same time, which is one result of the reserve effect (see Figure 8). For the stock to survive and be available for harvest the number of surviving spat that settle in the collection area is more important than the number of individual larvae that are released or settle. An increase in small cockles (recruits) down stream of a MPA will be one of the first signs that the recruitment effect is occurring.

MPAs as Source and Sink

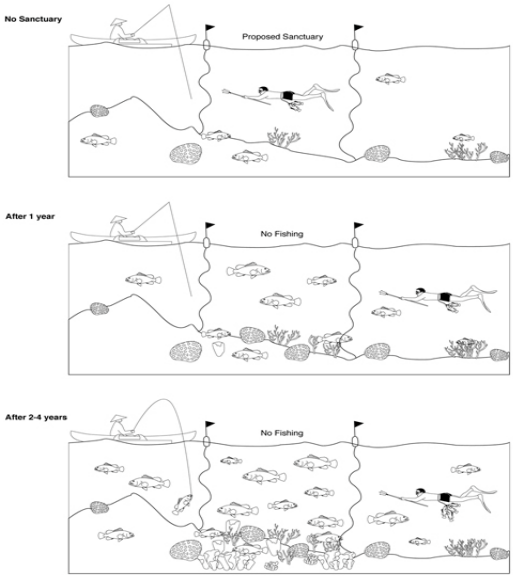


Figure 9-Improvements in Reef Condition and Fish Abundance. The Spillover effect depicted over several years to show how the fish will eventually migrate beyond the boundaries of the MPA to an area where they can be harvested.

Initially, a newly establish no-take MPA may attract fish from nearby areas that come into the area to live, feed and grow in addition to the fish that are already there. Other organisms, such as spat, may be carried into the no-take area by currents. Overtime, as the fish in the no-take area grow and additional fish settle, the area starts to become overcrowded. Crowding makes less room for more individuals to settle and forces some of these individuals outside the boundaries of the no-take area. The area outside the no-take MPA is less crowded because fishermen are constantly catching the individuals that settle there. In this manner the no-take MPA acts helps populate individuals into areas adjacent to the MPA. The over-abundance of organisms that are produced and migrate out of the no-take area can result in increasing catches for fishers in the areas adjacent to the MPA.

Scientists refer to some MPAs as "sink" or "source" locations. In the context of a coral reef environment, a "sink" reef is where many larvae from other reefs are transported and settle. These reefs typically have a high diversity of marine organisms. A "source" reef is the location where the larvae come from. Not all larvae from a source reef will settle on other coral reefs. Some drift into the open ocean and die while small fish and other small

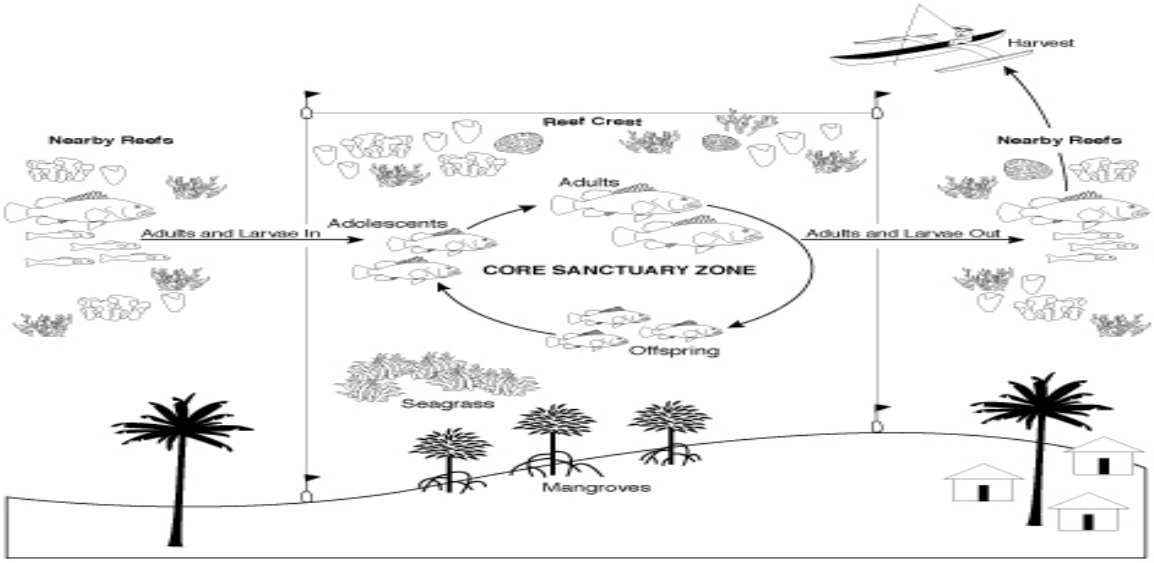


Figure 10- The Recruitment effect illustrated as the large fish swim into the protected area they produce offspring. The adults and larvae eventually migrate beyond the boundaries of the MPA. Here the adult fish will be available for harvesting and the larvae will settle to the substrate and become spat.

marine organisms eat others. Community-based MPAs are better located if they are on a "sink" reef. The larvae that settle there will be protected and can then grow larger and produce more offspring that will become available to the fishermen as they migrate out of the MPA.

VII. Socioeconomic Benefits of Marine Protected Areas

Marine protected areas provide benefits to people on a local, regional, and national level. Not all MPAs are established for the same reason but the benefits of establishing an MPA can be clustered together into three categories: ecological benefits, social benefits and economic benefits.

The ecological benefits of the reserve, which have been mentioned in previous sections, include increased fish size, number, and diversity inside and outside the MPA. Larger fish produce more offspring which can cause a spillover effect of adult and juvenile fish into areas outside the protected area. The MPA provides increased protection to vulnerable species, as well as preventing habitat loss and damage from overfishing, destructive fishing, tourism, and other recreational activities. The MPA will also help accelerate the process of recovery for an already damaged habitat.

Social and economic benefits are equally important and MPAs provide an abundance of both. Local communities will benefit from the establishment of a MPA due to the increases in fish production and improved ecosystem health. Both of these factors can bring increased revenue to the families in the form of sales of better catches of fish and shellfish in adjacent areas. The pristine ecosystems will provide opportunities for tourism which local communities can participate in either directly by providing snorkeling or scuba diving trips, or indirectly by working in hotels and restaurants or selling curios to the tourists as an alternative source of income. Some benefits of the MPA may be noticeable in the short-term, within a year, such as increased resource abundance within the MPA, while other benefits such as activities for increased revenues from improved harvests may take longer to be felt but will have a lasting impact on the community. Social benefits of the MPA include an increased local role in governance, as well as community capacity and empowerment in decision making. All of these benefits will help empower the community and allow them to take control of their resources.

VIII. Establishing a Marine Protected Area

Marine protected areas are often established because a problem has been identified, usually some evidence of overfishing. No-take MPAs can then help to solve this problem. Cockles, because they are sedentary, are very susceptible to overfishing and their habitats are susceptible to degradation from modern fishing gear or too many individual harvesters. To prevent the decline of cockle populations and to help rebuild sustainable fisheries small no-take marine protected areas are often recommended.

Participation

A participatory approach to MPA establishment and management is recommended for a MPA to be successful. Community based marine protected areas are much smaller than other MPAs, and are developed and managed by local coastal communities. Successful community-based MPAs in other countries are those which have been established by communities in villages with specific characteristics. Some of these characteristics include communities with relatively small populations, a large percentage of individuals involved in coastal activities, a perceived resource management problem, and a high level of participation by the community in planning, decision-making, and enforcement. The most effective approaches to MPA design and implementation are those which had the involvement of the local community, stakeholders, and government from the beginning of the planning process and in each subsequent step. Including all interested parties in this process can also benefit the MPA in the long-term. Communities can provide local knowledge to the planning and design of a MPA. Stakeholders and governments can provide financial and political support. Education, compliance, and harmony are also more likely to persist if local communities are involved in all aspects of the MPA.

Steps

The phases and activities for MPA establishment can be identified as the following steps:

- Issue identification
- Plan preparation (defining goals and objectives; stakeholder participation; site selection, zoning, deciding penalties for violations, drafting of a management plan)
- Adoption (formal approval of MPA site, rules and plan)
- Implementation (installation of marker buoys, enforcement)
- Monitoring and evaluation/refinement of a management plan

Issue Identification

The first step, issue identification is very important since most MPAs are not established unless an issue has already been identified. To identify an issue, extension agents or community facilitators should work with stakeholders and user groups to understand the existing concerns regarding the marine environment trends in resource condition and use, causes and consequences, and identify the priority issues. Once baseline information has been collected on resource trends, the next step is to define goals and objectives of the MPA. The goals and objectives must be clearly understood if management is to be successful and achievements measured. This means that they should be defined and worded in such a way that they can be monitored. The goals should define desired outcomes, be broad and general statements, and be short so that they can be easily remembered and understood. The objectives of the MPA should describe how the goals will be reached, be related to the key issues of the MPA, be achievable within a reasonable specified time period, and be measurable and realistic. Two or more objectives are usually required to reach a goal. The objectives should be specific and easily understood, written in terms of what needs to be accomplished, and be realistic within the local context. After appropriate goals and objectives have been identified, MPA location and design will take place, followed by the drafting of a management plan.

Plan Preparation

Every MPA should have a management plan that is designed to ensure that the objectives are effectively achieved. The way in which the plan is prepared, its content, and its presentation all affect the extent to which it is useful. The management plan is the main tool with which to guide the development and management of a protected area. Management agencies should work together to promote collaboration between user groups and stakeholders to facilitate the drafting of the plan. Once the plan and any supporting documents are produced they should be used to guide the implementation of the MPA, and

monitoring programs should be designed to assess their effectiveness. Management plans should be revised and adjusted to reflect new issues, lessons learnt, or changes in management objectives.

MPAs are managed under a variety of arrangements. The drafting of a management plan is the key component to designing a successful MPA. Managers are tasked with having to deal with a multitude of different situations, issues, and problems. A formal management plan, written prior to the formal establishment of the MPA, helps increase the ease at which a manager is able deal with these challenges. Several key components of a management plan will be discussed below. These components should be specified within the management plan and must be practiced and enforced from the beginning of formal establishment of the protected area. There are several specific issues that need to be addressed in MPA preparation. These issues include MPA size, location and rules including penalties and user fees, as well as designating a management authority. The management authority should involve a community made up of individuals from the community. It may also include subgroups that work under the committee and have may have a special function or purpose.

Size

The size of a no-take MPA can vary considerably and still function effectively. Determining the size of the MPA depends on the species that is to be protected and the objectives of the management. In small rural coastal communities the use of several small reserves may be easier to manage than a few larger reserves. The shape of the protected area should be simple and easily defined either with permanent markers placed into the substrate, floating buoys or with natural markers such as shore based physical structures or coastline features. CB-MPAs can be anywhere from 5-100 hectares in size. As mentioned earlier, the larvae, which are released from the mature cockles, remain in the water for a short period of time before they settle to the ground. This should be taken into account when determining the boundaries of the protected area used for fisheries management. In a large MPA the larvae would be released, travel and then settle within the limits of the MPA and therefore not be available for collection by harvesters. The ideal situation for fishing for would be for some of the larvae to settle inside the protected area and some to settle outside the protected area. The larvae settling inside the area would help increase the number of individuals within the MPA, which would later produce even more larvae as they mature. Larvae outside the MPA would grow and be available for capture. Therefore CB-MPAs tend to be smaller in size than MPAs geared more towards biodiversity conservation. Many small MPAs is preferred to one large MPA if fisheries management is the primary goal.

Location

Defining the location of a MPA is an important step and complicated challenge in the initial planning process. The habitat of a marine species is often times difficult to define. The purpose of the marine protected area is to protect not only the species within the protected area, but it is also important to protect critical habitats. Defining what are critical habitats and how much should be protected should be done with local community stakeholders. In this situation, stakeholders are any organization, government entity, or individual, which has an interest or may be impacted by regulations used in establishing a MPA. Managers and planners should work with stakeholders to understand the existing impacts on the marine environment. For cockles, typical stakeholders are fishers, reef managers, cockle gleaners, local/village governments and fisheries departments. Once the resource management issues have been defined an appropriate location can be mapped out. Location of the MPA should be determined with the help of technical and environmental experts, non-governmental organizations (NGOs), marine biologists or ecologists.

A successful CB-MPA would need to be set up in an area that is in good health and not too damaged from destructive fishing practices and pollution. A high abundance of cockles are needed in the area to produce the recruitment effect to make cockles available for collection in the areas outside the boundaries of the MPA. Areas that are vitally important to other fishing industries are also not ideal areas for setting up a CB-MPA as it may lead to economic hardship. The area set aside for cockles must be a strict no-take area. Establishing a protected area in a zone that is a prime fishing area is not recommended. CB-MPAs should be established with the community, where a large percentage of residents are engaged in coastal fishing activities. The MPA should be close to a fishing community so that the area can be observed to ensure no-take rules are followed. If many people are present, live in an area from which the

MPA can be seen, and have an interest in the success of the protected area, there is less of a risk that non-compliance will occur. The ocean currents in the area will also factor into where the MPA should be located. Cockles are sedentary, but as mentioned earlier their larvae will be transported by the currents. The MPA should be established where the larvae will not be lost offshore and should be located just upcurrent from areas designated as open harvest areas.

Rules

The definition of a no-take marine protected area permanently prohibits the extraction of resources from within the protected area. No fishing can ever be allowed in this area. There is no negotiating this essential rule. To be a no-take area, this rule has to be followed explicitly otherwise the area will not succeed in achieving its goal. Other extractive activities such as harvesting coral and other living organisms are also prohibited. There are no seasonal openings within no-take areas because this would undermine the function of the MPA. Only those activities which do not remove resources from the protected area may be allowed within the boundaries of the protected area such as boat passage, snorkeling and scuba diving. Regulations regarding these activities and their presence in the protected area have to be stipulated in the management plan and usually are embedded in local ordinances that establish the MPA.

Fines and Penalties

Fines are financial penalties that are charged or imposed on violators of the MPA regulations and rules. Fines are not an essential part of management but if they are not present some other form of punishment for violators must be present. In some countries fines are not practical so other punishments including public shaming, community service, confiscation of fishing gear (temporarily or permanently) are used. The fine or alternative punishment must be suitable for the violation. Monetary fines should be for amounts that the average resident can pay. Punishments for violations should not greater than punishments for more severe crimes. The objective of a fine or punishment is to deter individuals from breaking the no-take rules, or deter a person who committed the offense from committing it again. Penalties can also be graded so that if the same individual commits the same offense again, the second violation is more severe than the first and subsequent penalties become increasingly harsh with each violation. Punishments and fines need to be explained in the management plan and agreed upon by the community.

Fees

Fees are financial charges imposed for certain allowed uses of the MPA. CB-MPAs should have use fees for sites where tourism exists. The fees, along with their collection methods, should be decided by stakeholders. Fees for non-extractive use practices should be set in collaboration with dive operators, boat operators, and tour companies. If a fee system is established, a portion of the fee should be retained by the community for management of the MPA, and some of the fee may be passed on to the government for community development. Higher use fees may be applicable in areas where foreign tourists frequent. Different rates for local residents versus foreign tourists should be established where both groups use the area.

Communities can also recommend “voluntary donations” from visitors, divers and snorkelers rather than a formal fee system. Local coastal community members can also benefit from providing services to tourists, especially divers and snorkelers, such as boat rental and operation, selling refreshments and food, or providing souvenirs or curios. Some MPAs started for fishery management may evolve into tourism sites as coral grow and fish increase in size and abundance the area may become a preferred dive/snorkel site.

When fees and fines are collected there needs to be a record keeping system of money received and how it was spent. Receipts should be provided upon payment and logged in a logbook. Stakeholders that are expected to comply with and participate in the collection of fees need to understand how they were set and where the money is going. Along with providing funding resources for management of an MPA or development project in local communities, fines and fees are also helpful in deterring over-usage of the MPA. Setting fees high in places where the ecosystem is more fragile and when the number of

visitors is high can reduce rates of tourists visiting, while keeping total revenues generated more or less the same.

Management Authority

Once the objectives of the MPA have been established, an organizing or steering committee should be formed to allow for the input of major stakeholders in the development of management plans. This organizational structure, or management authority, often varies from place to place and is dependent upon what is being protected. The role of the management authority is the same in most areas and consists of the responsible for coordinating activities between different interest groups. The possibility for conflict may arise if all groups are not represented in interest groups. In community-based MPAs the local government is responsible for the establishment of the MPA and their continued participation in the management is essential. Once the MPA has been established advisory groups made up of stakeholder groups, including local communities, scientists and academic institutions, the private sector, and governments, may be established to assist in decision-making and implementation. Advisory groups must be established early in the planning process to be effective, and members are usually selected by the management authority. The management authority in CB-MPAs should be made up of local community members that are interested and committed to planning, implementation and management of the MPA. These groups will provide a comfortable environment for community members to make decisions and provide input.

IV. Formal Adoption of the MPA

Once stakeholders agree on a MPA size, location, rules, penalties, fees and develop a management plan, the MPA needs to be formally adopted usually by local government through municipal or village ordinances. In some cases the Department of Fisheries may need to approve the CB-MPA. An MPA ordinance is important and must be known and understood by all those involved in the planning, establishment, and implementation of a protected area. National legislation may exist that helps provide backing to many CB-MPAs. Although MPAs can be established without a legal foundation thus informal adoption, there will be no legitimate legal procedures for court proceedings if illegal activities take place.

The use of an ordinance helps support the marine protected area, but only if the community understand it and it is described within the management plan. Visitors must also know rules, fines and fees, which can be done by disseminating information to them. A good understanding of the rules by visitors and stakeholders may help decrease the amount of violations occurring within the protected area. The final ordinance should contain sections detailing the following:

- Legal basis of a community-based MPA and the goals.
- Location of the MPA.
- Responsibilities of the management group and community for the management of the MPA.
- Allowable activities in the MPA and buffer zone.
- Prohibited activities in the MPA and buffer zone.
- Penalties and violations.
- Attached map of the MPA location.

V. Management and Implementation

The management of a MPA is totally dependent on the design. A poorly located MPA with an inappropriate shape or size will most likely not be able to meet its management objectives. The design of a MPA must take in account size and shape, position of boundaries, zoning, ecosystems, and other MPAs. A well designed MPA will make managing it easier.

The boundaries of a MPA should be simple and easily recognized. Stakeholders must decide where boundaries should be. Local knowledge is often helpful in determining where boundaries should be set. Clearly marking and maintaining the boundaries is essential to help prevent conflict and confusion. Marker buoys are a useful resource to specify the boundaries of the MPA. Other geographic features can

also be used such as a river mouth, church, large building, or water tower. Along with marker buoys, signboards listing activities allowed and prohibited within the protected area should be posted in the no-take area and in the community. The buoys and sign boards as well as educating the stakeholders and user groups on the use of the MPA and rules and penalties will help increase the likelihood that stakeholders will understand and comply with regulations, and the MPA will be able to meet management objectives.

Compliance and Enforcement

For marine protected areas to be successful a high-level of compliance with rules and regulations by stakeholders and user groups needs to be achieved. The use of community based marine protected areas puts most of the power and responsibility and rule enforcement into the hands of the community in the hope that this will increase the level of compliance with rules by community members. High levels of compliance with established rules are needed if management is to be effective. Compliance is greatly improved if stakeholders are involved in planning and agree with rules established.

Patrolling and surveillance refers to physical observation of the MPA to determine whether rules are followed or violated. Designating a CB-MPA close to communities allows community members to easily observe activities taking place in the area and adds an element of enforcement to the MPA. Community members must have clearly defined roles and responsibilities for enforcement. Identifying uniforms and/or identification can be worn so that other MPA users can identify those community members that are responsible for enforcement.

The benefits from MPAs depend ultimately on the ability of the MPA to reach its goals. When rules and regulations are not enforced the positive effects of the MPA will not be achieved. To help improve the likelihood of MPA success and compliance, regulations and legislation have to be known, understood, and respected by the community. At sea patrolling is often times very expensive and therefore not possible in many communities. In such instances, surveillance from the shore is effective only if the no-take area is located within 2 km of the community.

VI. Monitoring and Evaluation

Monitoring and evaluation is an essential component of any successful management activity. Monitoring is the continuous process of collecting and analyzing information, through the use of indicators. Ecosystem health, biodiversity, and local community well being are all dependent on the MPA and should all be monitored along with the management process. Evaluation is an activity that assesses how well the objectives of the MPA are being met. The principle reasons for developing a monitoring and evaluation program are to assess whether the goals and objectives (e.g. fisheries benefit) of the MPA. The second reason is to determine whether management actions are having their intended impact and are effective.

Management effectiveness is the degree to which management plan and management actions are achieving the goals and objectives of the marine protected area. By measuring management effectiveness, improvements can be made through learning, adaptation, and the diagnosis of specific issues influencing whether goals and objectives have been achieved. Management effectiveness can also provide some accountability to the community and managers of the MPA. Those members involved in the management are responsible for reaching the goals and providing guidance on MPA issues. If the management is not doing this then they would be deemed to be ineffective and changes would have to be made to reverse this situation.

Types of Monitoring

There are two types of monitoring, ecological and socio-economic. Ecological monitoring usually collects information on the abundance of biological organisms. Socio-economic monitoring attempts to understand how people use the resources and benefits they receive (i.e. improve catch). Both types of monitoring need to be integrated into a single monitoring strategy. While the community should be primarily responsible for monitoring, they are often unable to conduct both types of monitoring themselves. Therefore, it's best if an outside organization periodically helps the community with

monitoring and data interpretation. However, monitoring strategies should be simple enough so that communities can collect the information themselves and interpret data collected.

Ecological monitoring can be either watching or observing and counting a specific variable for a specific purpose or reason. There are several advantages to ecological monitoring such as:

a. allows people to know what is in the fishing grounds (types of fish or plants and how many)
b. allows people to know what is being taken from the area
c. allows people to know what is being overfished or what seems threatened
d. measures and allows for decisions on how management actions result in increasing or decreasing catches
e. and helps to determine if the community need for more and bigger fish is being met.

Ecological monitoring can be done through sampling. It should be a comparison of what is found inside the MPA boundaries to what is found outside the MPA boundaries (see Box 1 below). This can help explain if the MPA is helping to produce more fish for harvesting in the adjacent areas. Other methods

Box 1- Data Collected on Clam Harvests in Fiji. The number of clams increased in the protected area and in the area beyond the boundaries of the MPA. The photograph was taken of a clam collecting method. Not only did the number of clams increase but the size of the clams increased as well.

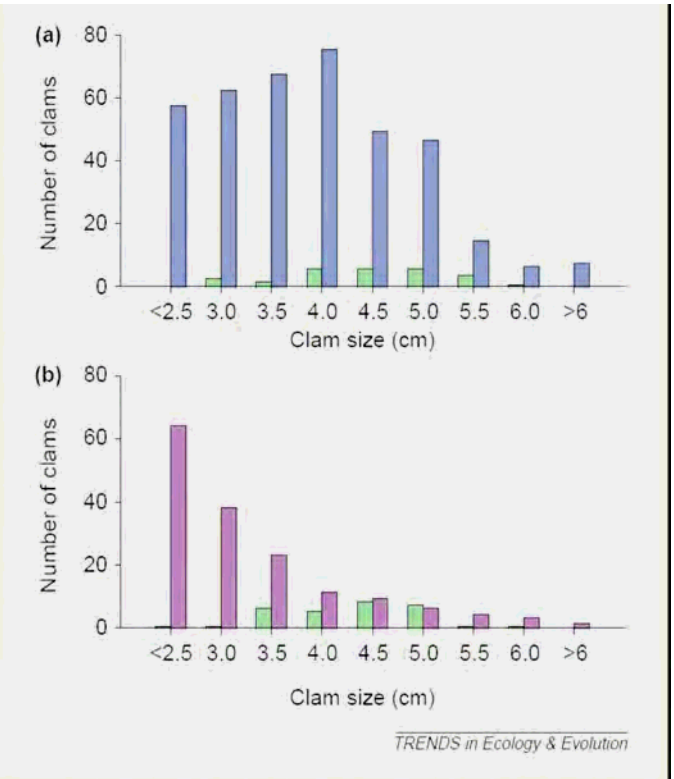
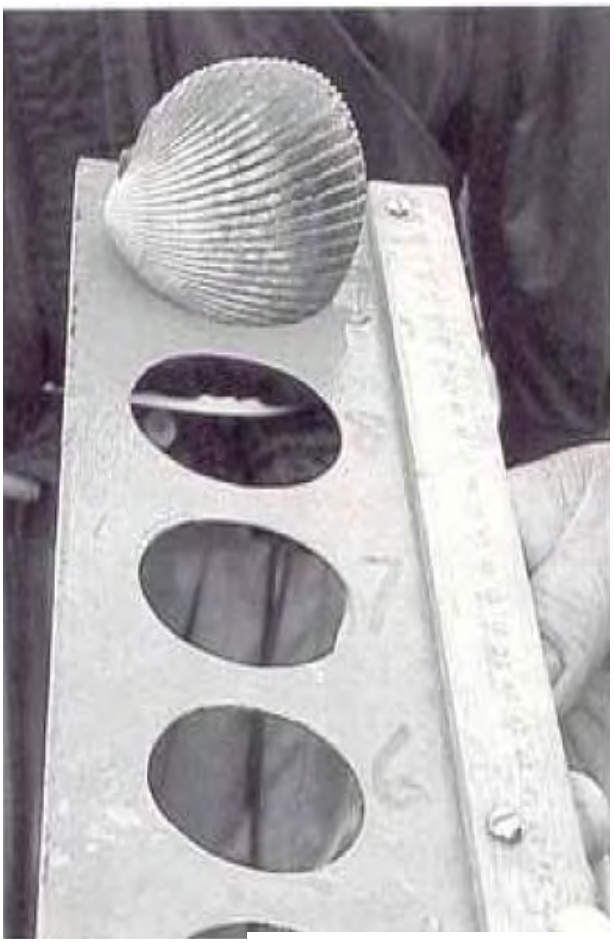


Fig. I. The number of clams counted in 50 1-m^2quadrats in each size class in the closed area (a) and in the adjacent fished area (b) in April 1997 (green bars) when the closed area was established and in 2000 (August 2000, blue bars; September 2000, purple bars) after 3.3 years of protection, in Ucunivanua, Fiji. Data collected by the Ucanivanua community monitoring team [20]. Reproduced, with permission, from [20].



Source: Gell, F.R. and C.M. Roberts. 2002.

include belt transects (used if only one species is chosen as an indicator), line transect with quadrat (used with slow moving burrowing species), line transect with point intercept (used to determine distribution of live or dead coral and coral cover, or time count or catch per unit effort (used when doing

transects but can be difficult). All of these methods depend on the indicator species being looked at or a target species for management. This activity should be practiced on land before it is done in the water. Cockles are sedentary organisms so the use of line transects with quadrats is ideal for measuring the amount of cockles in an area. To do this you would need the following materials:

- 100m measuring tape/100m rope with knots every 5m
- compass
- waterproof paper and recording clipboard
- pencil
- quadrat with 100 equal squares divided by string
- snorkeling gear
- 4-5 monitors

To perform a line-transect lay out 100m of rope over the desired area. The starting point should be recorded using a compass. The quadrat should then be laid down every 10m starting from 0m. The species found within the quadrat should be counted and the size of the species should be measured. The process of laying out a 100m transect and quadrat sampling should be repeated at least fives times. Information should then be recorded in a data table (see Appendix 1) and converted to length frequency charts (see box 1) for interpretation. Along with the information from the transects the location, date, time, and coordinates should also be recorded, as well as the distance from the high tide mark on shore. Each transect should be taken parallel to the shore therefore giving a good measure of how far offshore each transect was done.

The data should be reviewed at least once per year to see if there has been an increase in the number and/or size of the individuals found within the protected area. If the number of individuals inside the reserve is greater than the individuals outside the reserve (inside to outside ratio is greater than one) then the reserve effect is occurring—an important sign that fisheries benefits are likely to occur (see Figure 1a in Box 1). If the abundance in the areas outside the MPA start to increase, especially of smaller size cockles (see Figure 1b in Box 1), than this is an indication that the recruitment effect or larval export is occurring—essential for achieving fisheries benefits.

If the comparisons of the data from inside the MPA to outside the MPA show that there does not seem to be an improvement in the number of individuals in the areas outside the MPA this could be due to the number of fishers in those areas and the amount of effort of each fisher. As an MPA is marked off the fishermen that used to fish in that area are now forced to move to a new location, which could result in increased competition with other fishers. To determine if there has been an increase in the number of fishers and their effort in the area outside the MPA, data on catch per unit effort (CPUE) should be kept. The collection of this data should be very simple and needs to be done monthly and then plotted over time. To collect the data weights for collected cockles need to be recorded along with the amount of time that an individual fishermen has spent collecting those cockles. The total weight can be divided by the total time for a day to obtain a kilogram/hour catch rate. These rates should then be plotted over time to see if there have been any changes in the weights or the catch effort. An increase in weight and decrease in time is proof of the recruitment effect, while a decrease in weight and/or an increase in effort proves that there is a problem. This problem most likely is the result of a catch rate increase, which has caused a lower amount of cockle availability.

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