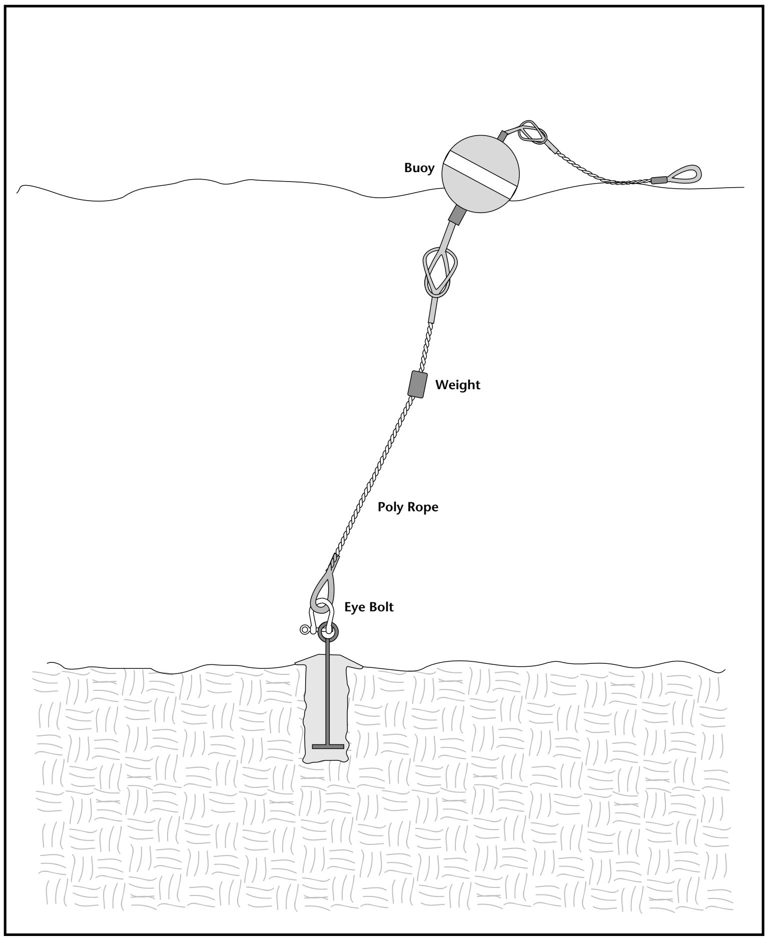
Mooring Buoy Planning Guide



PROJECT AWARE

PADI

Acknowledgments

The Project AWARE Foundation and PADI International Resort Association (PIRA) have worked to develop this booklet on mooring buoys to address some of the issues relating to the planning, installation and maintenance of a mooring buoy program.

The following pages are excerpts and/or complete documents from many sources and contributors. We wish to express gratittude to the leaders and experts in their fields, for their time and contributions to future mooring buoy programs around the world, and to all who contributed in one way or another.

A special "thanks" goes out to Athline Clark, John and Judy Halas, Center for Marine Conservation, David Merrill and Jeff Fisher for their contributions to this document. An additonal "thanks" goes out to Joy Zuehls, Jeanne Bryant, Dail Schroeder, Joe De La Torre, Greg Beatty and Kelsey of PADI Americas for their hard work on the production, designs, illustrations and typography of this document.

Mooring Buoy Planning Guide

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Introduction

It is estimated that 40 percent of the world's coral reefs are likely to seriously degrade, perhaps even beyond recovery, by the year 2015. Population increase in coastal areas adjacent to reefs, waste disposal, pollution, sedimentation, overfishing, coral mining, tourism and curio collection all damage coral reefs. These are serious problems with complex solutions. Other problems, serious but smaller in scale, also face the reefs. Anchors, for example, pose a threat that can easily be seen by recreational divers: they simply rip coral reefs apart. Determined individuals and organized local groups can help solve this and similar problems.

Since the early 1970s, pioneering members of the dive community, whose livelihoods depend on the quality of the reefs in their area, have championed the installation and use of mooring buoys to lessen the harmaful effects of anchors on coral reefs. Over the years the movement has gathered momentum and is now widely accepted as an effective solution to one aspect of coral reef degradation.

The mooring buoy concept is simple: install a mooring buoy close to or over a site where boats traditionally anchor. Instead of anchoring, boat users tie off to the mooring and this lessens damage. Mooring buoys can also be used as an ongoing aid to coral reef conservation. They may be used to zone an area for a particular activity and help avoid conflicts between, for example, fishermen and divers. If an area is being overused, moorings can easily be removed, placed elsewhere, and replaced at the original site when it has had adequate recovery time.

Installing mooring buoys requires professional expertise at all phases of project planning and implementation. Several factos must be considered and in many situations, the scope of the project will demand cooperative effort between relevant government agencies and interested parties. The anticipated use of the project site determines the number, location and type of moorings deployed. Funding for installation and ongoing maintenance, a crucial element of any mooring buoy system, must be organized. Educational programs must be undertaken to ensure that private users understand what the buoys are for and adequate arrangements for enforcement of the project or site regulations need to be in place.

Despite the effort involved in a mooring buoy planning and installation project, the benefits far outweigh the work involved. Mooring buoy projects are firmly fixed as a healthy element in the future of the world's coral reefs. This booklet can be used as a valuable tool when developing a mooring buoy program. It outlines the components that need to be considered when taking on such a project.We hope that you will use this booklet as a guideline in initiating the process of mooring installations.

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Section I

The Importance of Coral Reefs

Overview

In this section you will find an introduction to the threats facing the aquatic ecosystem, specifically the coral reefs. A brief summary of the importance of the coral reefs and the interactions between people and corals will also be covered in this section.

Contributions

Reefs at Risk, coral reefs, human use and climate change, a programme of action, Oct. 1993.

Contents

Reef at Risk

Coral reefs, human use and climate change

1. A worldwide threat of ecological collapse

For once, the popular mythology contains some truth. Coral reefs can be likened to tropical forests in certain important ways. Both reefs and jungles are biologically diverse in comparison with other ecosystems. Reefs are an essential supplier of protein to subsistence communities; a valuable currency earner for low-income countries through exploitation of their resources and through tourism; a protector of land; and a naturalist's paradise.

Unfortunately, the analogy is equally apt with respect to the dark side of the picture; though we have barely tapped coral reefs for the knowledge to be gained or the natural products of interest to society, reefs are coming under increasing threat, almost exclusively because of human activities.

Around the world coral reefs have suffered a dramatic decline in recent years. About IO% may already have been degraded beyond recovery. Another 30% are likely to decline seriously within the next 20 years. It has been predicted that more than two-thirds of the world's coral reefs may collapse ecologically within the lifetime of our grandchildren, unless we implement effective management of these resources as an urgent priority.

The reefs identified as being at greatest risk are in South and Southeast Asia, East Africa, and the Caribbean. An IUCN survey during 1984-1989 found that people had significantly damaged or destroyed reefs in 93 countries.

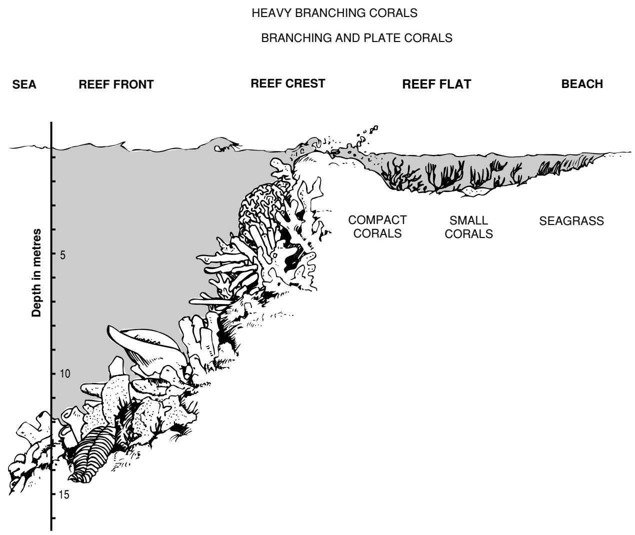


Figure 1

Coral reefs and biodiversity

Coral forms range from compact brain corals found in areas of high wave energy, through heavy branching and plate corals in deeper water, off the reef edge, to smaller finely branched corals found behind the reef crest and in the lagoon.

Coral reefs are generally divided into four main types: atolls, barrier reefs, platform reefs and fringing reefs. Atolls, where reefs form a ring around a lagoon, are mainly found in the Indian and Pacific Oceans. In the Pacific they are grouped into long island chains such as those of Micronesia and Central Polynesia. Barrier reefs are separated from the mainland by a deep channel or lagoon, in which are found platform reefs. Fringing reefs are directly attached to land or separated only by a shallow lagoon.

On an individual reef, the total count of fish species and smaller marine organisms may exceed several thousand, but the number of individual coral species is much lower.

The Indo-Pacific has some 700 reef building coral species, many times more than the tropical Atlantic (with some 35). In general, reefs in the Indo-Pacific differ from those of the Atlantic by having many more coral species, and by supporting much richer animal communities on their intertidal reef flats. The centre of coral diversity is the Southeast.

Asia region of the Indo-Pacific, and over 400 species of hard coral are believed to occur in Philippine waters.

Moving away from this region, coral diversity declines. Nevertheless, over 200 coral species are recorded from the northern and central Red Sea, about 200 from Madagascar and Chagos. The east coast of the Malaysian peninsula has 174 identified species, southeast India about 117, the Gulf of Thailand some 60, and the Persian Gulf 57.

2. The living reef

Corals are colonial animals that produce a calcium carbonate (aragonite) skeleton beneath their film of living tissue. Reef-building or hermatypic corals contain within their tissues symbiotic algae, so that the colony actually functions as a plant-animal combination. A coral reef is the physical structure created by the growth of the reef community.

When a coral colony dies through storm damage, is broken by the action of living organisms, or is eaten by a parrotfish, the skeleton becomes the basic material forming the reef structure. Dead coral branches form the substrate on which new corals grow, while the fragments are cemented together by the action of coralline algae. The fragmented skeletons form the sand which contributes to reef growth by filling in the space between the larger fragments of dead coral skeletons. Continual deposition allows a reef to keep pace with rising sea-level by upward growth.

Coral species, coral communities and the reef structure differ widely in the growth rates. Among the species, branching and staghorn corals can add more than 10 cm a year to their branches. Massive corals grow at about a tenth of that rate, or roughly 10 mm a year. As for vertical reef growth, in Mauritius it reaches as much as 10 mm a year, but no more than a few millimetres for some reefs in the Red Sea.

Coral reefs depend very much on the prevailing environmental conditions. Some reefs did not survive the rapid sea-level changes experienced during the ice ages. We find many dead reefs drowned in earlier periods, or stranded above present sea-level. But under the right conditions coral colonies can survive for centuries.

Although we think of reefs primarily in terms of corals, they are home to a myriad of other organisms, all of them important to the overall functioning of the community, and all of them sensitive to climate and environmental conditions. Coating the exposed sand grains of coral lagoon are microscopic algae and bacteria grazed by mollusks, crustaceans, sea cucumbers, sea urchins and sediment-eating fish. "Turf' algae cover all bare surfaces and are grazed by large populations of fish when the tide is rising. Many of these animals provide food for fishers and gleaners of reefs.

Other organisms play an important role in building the reef by breaking down the calcium carbonate skeletons of larger organisms to produce sediments. Some organisms, like sponges, worms and mollusks, bore into the coral skeletons so that they become fragile and fracture in strong waves. Grazing fish and sea urchins at the surface produce large quantities of sediment.

A major role in the functioning and survival of coral reefs is played by the tiny plants and animals known as plankton (from the Greek for "floating"), which provide food for sedentary reef corals and other animals. The life cycle of many corals and other species, including fish, involves a larval planktonic stage, enabling them to disperse over long distances and between different reef areas.

Limits to abundance

The living matter produced by the plants and algae in a coral reef system, its gross primary productivity, is between 30 and 250 times as great as that of the open ocean. While the productivity of tropical oceans is very low (18-50 grammes of carbon per sq. metre in a year), coral reefs produce 1500-5000g. The reason for the higher productivity of reefs is that corals and coral communities recycle nutrients such as nitrate and phosphate which are in limited supply in open-ocean surface waters.

But it would be a mistake to assume that the high productivity of a coral reef provides an automatic surplus of potential food. The primary production - the amount of energy produced by photosynthesis - is very nearly balanced by the reefs whole consumption. Net productivity is often only 2-3% of the gross, and only slightly higher than the net productivity per unit area in the surrounding ocean water. The highly productive coral communities also occupy only a fraction of the surface of a coral reef system.

So the amount of organic matter that can be taken out of the reef whether by harvesting or other means without causing damage to the community remains severely limited. One calculation puts the amount that could be extracted on a sustainable basis each year at less than 50 grammes of carbon per square metre (less that 50 tonnes per km^2), an extremely small figure by agricultural standards. Modern rice-growing techniques can produce yields of over 400 tonnes per km^2).

Reef growth and the environment

Reef corals do best in shallow, warm, clear oceanic water. Therefore reefs are most abundant away from large land masses, which produce too much freshwater runoff and sediments. Coral reefs are found in warm subtropical or tropical oceans where the annual temperature range is 20-30C. Nevertheless, reefs in the Florida Keys (USA) grow at 18C, and temperatures above 33C are tolerated by healthy coral communities in the northern Great Barrier Reef and the Persian Gulf. But when air and water temperatures in the Gulf fell to 10C in 1968, almost all the inshore coral colonies died. Even small temperature increases above the normal local maximum temperature may result in coral bleaching, which occurs when the symbiotic algae are expelled by the polyps in response to stress. (See Figure 2.)

Though corals can be found to a depth of 100m,

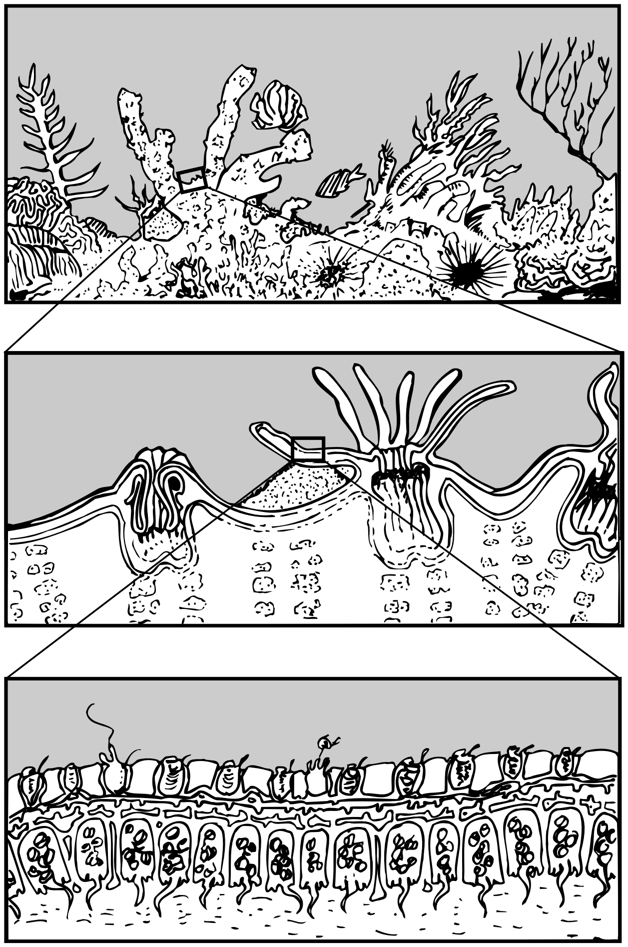


Figure 2

reef-building corals do not grow well below 20-3Om because their symbiotic algae depend on sunlight for photosynthesis.   Too much fresh water can kill corals; heavy runoff has wiped out shallow reefs off the north coast of Jamaica. So have hurricanes. But the reefs' ultimate chances of survival are determined by the fact that they often coexist with large human populations in the tropics. This could doom many to extinction.

Because coral reefs grow close to sea surface in warm waters, and often adjacent to land, changes in environmental conditions in the atmosphere, on land, or in the sea are all likely to have a marked influence on the reef ecosystem.

3. People and corals

It's hard to say precisely how large an area of the seas is covered by coral reefs. One commonly quoted estimate is 600,000 km^2 for reefs from the surface down to 30m. More important than their total area, however, is their role in global and local environmental processes and their contribution to human welfare. Millions of people in developing countries depend on reefs, at least in part, for their livelihood. Reefs provide an important source of food for the inhabitants of countries as populous as Indonesia, Jamaica, Kenya and the Philippines.

Corals reefs are not just passive parts of the environment. They form natural breakwaters, creating sheltered lagoons and protected coastlines. They protect mangroves - the nursery for many commercially important marine species - against wave damage, while the coastal mangrove systems act in turn as a barrier against sediments and nutrient loading that could create problems for the reefs.

The economy of Atoll nations such as the Maldives is based on marine resources, mainly those of coral reefs. Atoll islands account for most of Kiribati, the Marshall Islands, Tokelau, Tuvalu, and French Polynesia. The Pacific is home to some 2.5 million people living on islands that are either exclusively built by coral or surrounded by significant coral reefs. Another 300,000 people live on coral islands in the Indian Ocean, and many more in the Caribbean.

Coral reefs provide 10- 12% of the harvest of fin fish and shell fish in tropical countries. Apart from snapper and grouper, jacks, grunts, parrotfish, goatfish and siganids are favorite catches. It has been estimated that coral reefs may account for 20-25% of the fish catch of developing countries. Up to 90% of the animal protein consumed on many Pacific islands comes from marine sources. In the South Pacific, reef and lagoon fish can make up 29% of the commercialized local fishery as well as supplying subsistence food.

Tourism and recreational use of reefs on a large-scale are recent developments, but the use of coral for building has been a central part of some island cultures for nearly 2500 years.

4. The threats and the causes

The dangers facing coral reefs today have more than one cause, but they all result from global change.

One of the major factors is demographic: rapid population growth found in the tropical developing countries and migration to coastal areas where coral reefs are located, result in increasing pressure on coastal resources.

Another major factor in recent coral reef decline has been technological development. Pre-industrial peoples took material and resources from reefs with minimal impact on the environment. Mechanical dredges or hydraulic suction devices, dynamiting and large scale poisoning of reefs to collect fish, produce "the 4 Ds" of coral reef impact: damage, degradation, depletion, and destruction.

Population growth and technology: operating together these two factors account for the major causes of coral reef decline - excessive domestic and agricultural waste pouring into ocean waters, poor land-use practices that increase sedimentation of rivers and then of reefs, and over-exploitation of reef resources, often in combination with practices such as harvesting with dynamite and poison; all degrade reefs.

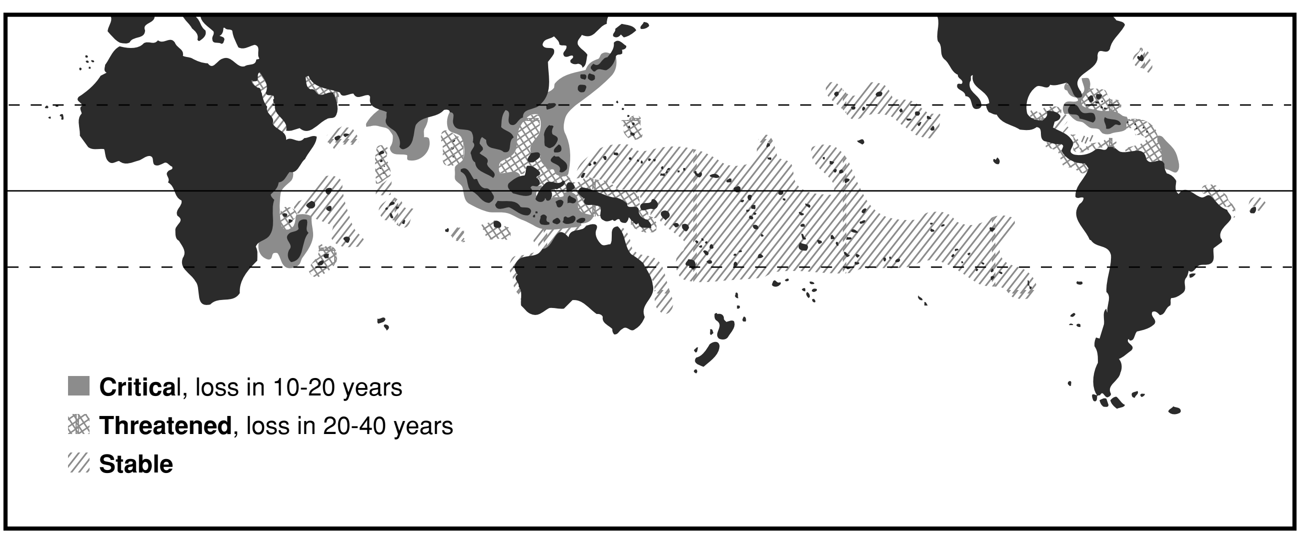
Domestic, agricultural and industrial wastes are discharged into coastal waters in many countries. Apart from the pollution and risks to human health created by such wastes, nutrient-rich waters diminish rather than increase the health of coral reefs. Deforestation, overgrazing, and poor land-use practices, often far inland, are leading to massive soil erosion and siltation of rivers - and washing large loads of sediment into coral reefs. (See Figure 3.)

Because reefs have such high species diversity, overfishing may not be noticed until depletion of resources is relatively advanced. Fish stocks have certainly declined markedly in many reef areas, particularly close to centres of human population in developing countries. Landings of any fish species are continuing to decrease and it takes much more energy and effort to catch the fish in many areas. Average and maximum sizes have diminished, and the mix of species in the catch has changed. As-early as 1959 in Jamaica, for example, fish catches in coral reefs waters contained only juvenile fish.

In some areas fishermen say they have been forced by the decline in catches to use destructive techniques to get enough fish to feed their families and make a living. These practices, which have now lasted several decades, are today considered part of the "traditional" culture. Dynamite fishing is illegal in the Philippines but is still commonly practiced in some areas.

The overfishing of some species has other effects which accelerate the degradation on coral reefs. Removing fish and other grazers of reef algae such as mollusks from the system allows the algae to compete with the corals for substrate. Jamaica provides an example of the devastating effect that can result. A hurricane hit this Caribbean island in 1980 causing severe destruction of corals. The normal recovery process was impeded by a second event. The major algal grazer on these reefs, a long-spined sea urchin, was wiped out by disease. Coral cover dropped from 50-70% to under 5%, and 10 years afterwards, there is still no sign of recovery.

Particularly in Southeast Asia, export of reef fish to Japan, Taiwan, Hong Kong and Singapore is contributing to overfishing. Taiwanese harvesting of the giant clams Tridancna spp. has led to population crashes and local extinctions on isolated reefs, Tobacco and soap may also be killing giant clams. In the Philippines many tridancnid clam species have become locally extinct. The main cause is the trade in shells, frequently sold to tourists as ashtrays and soap dishes. This country probably remains the major exporter of coral reef curios, though largely prohibited within the country and by the states where tourists



Critical and threatened coral reefs of the world

Figure 3

import them. Giant clams have recently been added to the list of species covered by the Convention on International Trade in Endangered Species (CITES) as a means of reducing the trade.

Collecting aquarium fish and live corals for European and North American markets has developed into another lucrative but damaging industry. The techniques used in harvesting fish for this trade are often destructive, killing organisms not intended for collection. Cyanide is widely used to force fish out from the coral and stun them so that they can be easily captured. Probably more that 50% of the fish collected in this way die before reaching the retail market.

Tourism can be an environmentally friendly way of generating income from coral reefs, but only when resort development and operation are carefully controlled. Unlimited collecting, sport fishing and accidental damage by waders, swimmers and boat anchors can all degrade the reefs that earn the tourist dollars. Allowing sewage and other wastes from tourist facilities to pollute reef areas, or siting resorts so that beach erosion increase, can be even more degrading to the health of the reef than the direct damage caused by visitors.

As a result of human activities, many coral reefs suffer chronic stress. Waste disposal, pollution, sedimentation, overfishing, coral mining, tourism and curio collection: all combine to degrade and threaten the ecological collapse of an estimated 30% of the world's reefs within two decades.

Section II

Types of Mooring Buoy Systems

Overview

In this section you will find a brief description of the various types of mooring buoy systems available, the effectiveness and limitations of these various systems, materials needed for installation along with sources and price lists for these materials.

Contributions

van Breda, Anita and Gjerde, Kristina. "The Use of Mooring Buoys as a Management Tool, Types of Mooring Buoy Systems," Center for Marine Conservation

Halas, John and Judy. Environmental Moorings International

Helix Mooring Systems, Inc., Hurricane-tested Marine Embedment Anchors

Foundation Findings, "Looking Below the Bottom Line," *Boat/U.S. Reports*

Foresight Productions, "Possible Alternatives and Potential Benefits"

Contents

The Use of Mooring Buoys As a Management Tool

Types of Mooring Buoy Systems

by Anita van Breda and Kristina Gjerde

Introduction

Three mooring buoy systems are described in this chapter - the Halas, the Manta-Ray, and the traditional system. All mooring buoys systems consist of three elements: a permanent fixture on the sea bottom, a floating buoy on the water surface, and something in between to attach the two. Sea bottom characteristics usually dictate what type of system is most suitable. The Halas system is most successful in areas with flat, solid bedrock. The Manta-Ray is recommended for areas of sand, coral rubble, or a combination of bottom types. Traditional systems, limited in effectiveness, should only be used in sand or mud, if at all.

Each mooring buoy system should be designed to meet the needs of the area within the manager's technical and financial capabilities. The manager is encouraged to examine all three systems. Creativity and improvisation on all three systems can be used to design a system to meet the needs of local conditions. Whatever the technique used, the goal of a mooring buoy array is to prevent anchor damage on sensitive marine areas such as reef tracts and seagrass beds. This goal should be kept foremost in mind when planning and installing a mooring buoy system.

The Halas Mooring System

(Most of the following information is synthesized from "Mooring Buoy Installation Technique for Coral Reef Environments" by John Halas (unpublished).)

Introduction and General Description

The Halas mooring system, first developed and tested in the early 1980s by John Halas, Key Largo National Marine Sanctuary biologist, consists of a stainless steel eyebolt cemented into a hole drilled into the sea floor. A floating line shackled to the eyebolt extends to the surface and through a plastic buoy to a pickup line which attaches to the boat. (See Figure 1.) The Halas system eliminates the need for the heavy block and chain of conventional mooring systems which can often damage the surrounding sea bottom.

Materials used in the Halas system were selected to produce a strong, inexpensive, and environmentally sound unit. Although developed for the Florida Keys reef, approximately 1,000 Halas mooring buoys are now in use around the globe.

Planning for the purchase of equipment and installation of the Halas system should involve consultation with someone experienced with installation of the system. The manager should also plan to include local commercial user groups if appropriate. Professional dive operators and local community groups are often a good source for assistance in evaluating use and abuse patterns of local areas. Many marine protected area mangers rely on the professional dive community, community groups, and environmental groups for assistance in installing and maintaining mooring buoys.

Purchasing the proper equipment requires tools, mechanics, and knowledge of engineering basics for working under water. Equipment recommended for use changes over time as new materials are discovered to be beneficial and older materials are no longer available. The manager may find that components

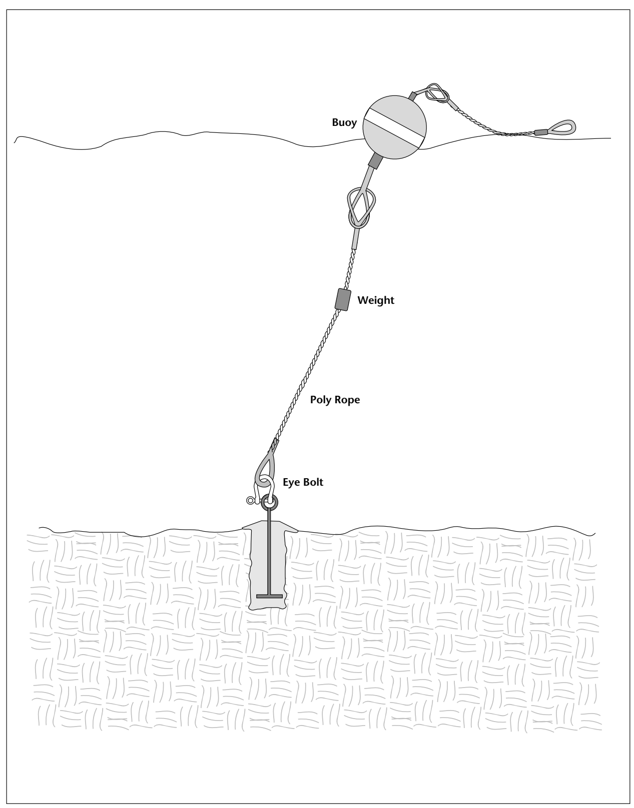


Figure 1

that work together are not always available in his or her location, and will have to improvise. Each site will have unique problems and constraints related to the bottom type, topography, sea conditions, and patterns of use that will require some adaptations to the equipment needed or the procedure for installation. For example, on Saba, a volcanic island in the Netherland Antilles, the depth of the hole drilled was decreased by six inches to reduce drilling time in deep water. A shallow hole drilled into Saba's hard volcanic basalt rock substrate provided the same holding power as a deeper hole in a softer substrate. However, modifications to the drill were required to work with the extremely hard substrate.

In the United States, the typical cost of installation and maintenance of one mooring buoy is approximately $500 for one year. Installation requires at least three people-two divers and one boat operator-but a working crew of four or five people is preferable. The time required for installation is difficult to predict but depends on how much preparation time is needed for pre-installation arrangements including: surveying mooring buoy sites; splicing lines; and preparing crew, boat and equipment.

Adaptations have been made to the Halas system to accommodate larger boats (90 feet to 100 feet) that require more holding power. In the Cayman Islands three eyebolts were installed close together in a triangle configuration connected by a large single line. The strain on the system is distributed to three anchors which serve as backups in case one pin fails (Halas, in press). In Bonaire, two pins are used in place of three to reduce the cost of the system (Hughes, peers comm. 1991).

Equipment

A) Buoys

The Halas system uses a commercial 18-inch diameter buoy constructed from polyethylene plastic filled with polyurethane foam and treated with UV inhibitors. Halas has found this material remains flexible and able to endure strain even after continual exposure to sunlight. Embedded in the buoy is a PVC pipe through which a 3/4-inch buoy through-line can pass. (See Figure 2.)

B) Ground Tackle

The Halas system is unique in that it uses a three-part rope system instead of one continuous rope. One line leads from the anchor pin at the bottom to the buoy at the surface. A second line runs though the buoy

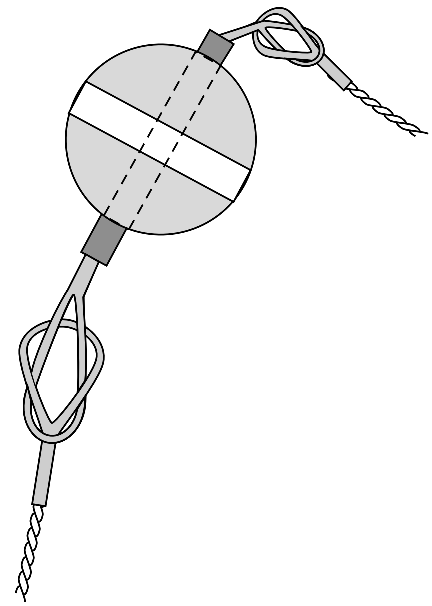


Figure 2

and is attached with a loop to the anchor line at one end, and at the other end is attached with a loop to the third pickup line.

A three-part rope system eliminates need for shackles and thus decreases maintenance time and cost of the system. Maintenance is made easier because sections of the system can be replaced or repaired as needed without detaching the entire down line. However, the manager must plan initially for more time spent splicing line. The amount of time splicing line varies with the line splicing skill of the worker. Tools needed for line splicing include a soldering gun with a cutting blade to cut the line and prevent unraveling. A marlin spike helps to make a right permanent splice.

UV-treated polypropylene rope is recommended for the three-part rope system: 3/4-inch rope for the down line and pickup line, and 7/8-inch rope for the buoy through line. The line is durable, lightweight, and strong when protected from chafing.

Down Line: 3/4-inch polypropylene line, approximately 1 0 feet longer than the depth of the water at high tide serves as the down line. The length of the down line should be adjusted for water depth and local tide conditions. At the bottom of the line a nylon reinforced hose is spliced into the loop to prevent abrasion and chafing from the bottom. The loop attaches with a shackle to the anchor pin. The pin of the shackle is softer than the eye bolt so that the shackle wears out before the anchor eye bolt. An eye splice at the upper end interlocks with the eye splice of the buoy through-line. Three feet down from the surface a lead weight is attached to the line to prevent slack from floating at the surface, causing a navigational hazard. In some places tides and currents can twist the line and cause wrapping. This can be avoided by adding swivels to the bottom of the line.

Buoy Through-Line: The buoy through-line allows the buoy to be removed for repair without removing the entire down line. Twelve feet of 7/8-inch line is passed through the one-inch PVC buoy pipe One loop is spliced into each end of the line; at the bottom end a 24-inch diameter loop large enough for the buoy to pass through, and at the top end, a small, 6-inch diameter loop for attaching the pickup line. The splices should be as tight as possible to the buoy to prevent excess movement and wear on the line. (See Figure 2.)

Pickup Line: The 3/4-inch pickup line should only be long enough for a boat to pick up and attach an additional line to it, approximately 15 feet of line for a 65-foot boat. Additional line adds scope and resiliency to the system and, therefore, direct attachment of the pickup line to the boat should be discouraged. Some managers have found that a 20-foot line provides more scope-than the 15-foot line, while preventing damage for boats running over the floating line (Bjork, VI National Park, pers. comm. 1992). Protective hosing is spliced into the end of the pickup line to prevent chafing should it be brought up on a boat deck. Some managers deliberately do not clean the eye of the pickup loop to discourage boaters from bringing it on deck. Deliberately making the loop too small to fit over a boat cleat will also encourage boaters to add their own line to the pickup line. In the Virgin Islands National Park (VINP), because boaters consistently neglect to add additional line, managers have increased the length of the pickup line. A technique to avoid loss is sinking the pickup line with a small weight to decrease the vulnerability of the line to boat props. However, it may be less costly to sacrifice the pickup line to boat props than to require a boat to come close to the buoy, possibly hitting and destroying it.

C) Hydraulic Drill

The drill used to make the mooring hole is a rotary tool powered by hydraulic fluid or compressed air, typically by the portable unit. Two high pressure hoses of adequate length for the depth of the water with quick release fittings connect the drill to the power source. A sturdy and stable workboat is needed for safe drill operation.

A drill and power unit can be rented for approximately $500 per week or $1,250 per month. Greenpeace, an international nonprofit organization, also has drilling equipment available for loan. REEF RELIEF, a Florida Keys organization, offers assistance to Caribbean nations in mooring buoy installation.

Anchoring Procedure

A) Spacing

The manager must plan the spacing of the buoys in advance of installation. Consideration should be given to the number and size of boats currently anchoring in the area and anticipated future use of the location. The manager should conduct a boat survey to evaluate the average number and length of boats found at the site. Allowance should be made for sufficient swing room between boats, a minimum distance of 130 feet, between anchor pins for boats up to 65-feet in length. In some areas spacing has been increased to 200 feet between anchor pins. Each location will require modification to allow for future development. Key Largo installs moorings in a zigzag line on the reef to allow for future placement of additional mooring (Halas, 1985).

B) Individual Site Selection

The key to success with the Halas system is locating proper substrate for drilling and cementing. The bottom substrate is what gives the system holding power. There are few known failures of individual components of the system, but have been cases of substrate failure where the entire cemented core has been pulled up and dragged across the bottom (Bjork, VI National Park, pers. comm. 1991). Therefore, once the general site selection and spacing of mooring buoys is established, based on use pattern and need for protection, the manager must do a detailed bottom inspection for suitable substrate. Flat, solid bedrock is the preferred substrate for the Halas system. Sand, coral rubble, or a combination of bottom types requires the manager to consider using alternative mooring systems, such as the Manta-Ray, in areas where the bottom will not hold a cemented eyebolt.

Site selection must consider the surrounding area in addition to the bottom substrate. The manager should avoid selecting an area where coral formations will catch and abrade the slack down line. Mooring buoys are an alternative anchoring system, therefore a buoy should not be placed in an area considered unsuitable for anchoring.

C) Drilling and Cementing the Anchor Pin

One person experienced in diving and installing moorings should be responsible for supervising the operation. Ideally, the work crew for drilling and cementing the moorings in place will consist of two teams of at least two people each. One team takes responsibility for diving and drilling underwater while a second team remains on the workboat deck. The boat team should be responsible for assisting the divers with equipment relay, operating the power unit for the drill, and mixing the cement.

Once the proper site is selected a hole is drilled into the solid substrate. An 18-inch stainless steel eye pin with a wielded crosspiece (to prevent it from pulling out of the hole) is cemented into the hole. If the outside diameter of the eye is slightly larger than the diameter or the hole, the pin will not drop down into the hole, Initial site selection and placement of the anchor pin is critical because once cemented it cannot be moved.

Drilling time depends on the working conditions, a function of water depth, hardness of the substrate, experience level of the crew, mechanical difficulties experienced, and weather conditions. Weights added to the top of the drill help stabilize the drill and decrease operator fatigue. At times it may be necessary for the operator to remove the drill bit underwater to free excess or stuck sediment, so proper tools (pipe wrenches of medium to large size) should be on hand (Bjork, VI National Park, pers. comm. 1992).

D) Cementing the Eye Pin

To prevent flexing of any exposed portion of the eye pin, the drill operator should be sure the hole is deep enough for the rim of the eye pin to rest against the rim of the hold. Once it is determined that the hole is deep enough, the drill operator signals the crew on the boat deck to begin mixing the cement. While the boat crew mixes the cement, the drill team sends the drill back up to the boat and prepares the hole for cementing by removing any loose debris by hand.

Portland Type 11 cement, manufactured to be used in salt water, sets up quickly when mixed with a catalyst. The routine mixture of cement to catalyst is 10 to 1. However, the catalyst is not absolutely necessary and Type I cement can be used if type 11 is not available (Halas, unpublished). Commercial premixed cement is also available but is costly, and does not allow the mixing crew flexibility in adjusting setup time. When working in deeper water, slower setting time is needed to get the mixture to the bottom before hardening. In shallow water surges can wash the cement out of the hole if setting time is too long. Molding plaster used as a catalyst is varied to control setup time of the cement. More critical than setting time is ensuring that the cement reaches the bottom of the hole.

The mixed cement, placed in a plastic bowl and covered with a lid, is taken down to the hole by a drill team diver. The wet cement is scooped into the hole up to the rim. The anchor pin is pushed into the hole until the eye rests on the rim. Additional cement is then packed around the eye and into the hole to make sure all void spaces are filled. A temporary string and float is attached to an adjacent structure for locating the site. Attaching the float to the anchor pin may compromise the setting and hardening process (Bjork, VI National Park, pers. comm. 1992). The cemented anchor pin should be allowed to set for at least five days prior to attaching the buoy. Detailed records, including site description, compass bearings and underwater photos and video if possible, should be made of the exact location of the anchor pin. Locating the eye can be difficult if the location marking is lost.

Maintenance

The key to success of any mooring system is regular maintenance. A proper maintenance program requires planning. The manager should assign supervision of maintenance to one individual. Consistent records of repair and maintenance should be kept on a schedule form. Each area will develop unique needs and problems dependent on environmental conditions and the type and use of the moorings. Therefore, any maintenance plan should be flexible to adapt to local conditions and patterns of use.

Almost every manager of a protected marine area using the Halas mooring system develops a different maintenance routine and schedule; however, one universal standard is regular and timely inspection of the mooring buoy system. The common and major loss to the system is damage from boats. In the Florida Keys an average of 6 to 15% loss is due to reparable boats. Inexperienced boat handlers routinely run over the moorings, severely damaging if not completely destroying the buoy and lines. Detailed records of the exact location of each anchor pin are necessary for locating a site if the entire system of lines and buoy is lost. Regular maintenance requires anticipating replacement and repair of line, hosing, and buoys. Therefore, a maintenance budget must include sufficient funds for stocking supplies and equipment for future use.

Inspection, repair, and routine maintenance of mooring buoys quickly becomes a tedious and time consuming process. Average time estimate for hands on maintenance ranges from 45 minutes to two hours per buoy per month depending on specific working conditions and total mooring area covered. Most managers have discovered that although it is often easy to find volunteers with enthusiasm to assist with installation of moorings, it is best not to rely on volunteer help for routine maintenance. In Looe Key and Key Largo Marine Sanctuaries many buoys are maintained by the volunteer dive groups and community groups that installed them. Key Largo also contracts a private dive boat operator to maintain mooring buoys.

The following is a suggested maintenance schedule adapted from Halas and maintenance programs from several organizations in the Florida Keys.

A) Monthly:

1) Inspect all buoys and pickup lines for condition.

2) Clean pickup line of growth or replace if necessary.

3) Clean buoy and check for cracks; replace as required.

4) Inspect and clean exposed portions of the buoy through-line and replace as needed.

If the buoy and lines are not cleaned on a regular basis, user may question the maintenance and integrity of the system and choose to anchor instead. The Virgin Islands National Park inspects monthly for anchor movement as well.

B Three Months:

1) Inspect down line and protective hosing for wear and damage. Replace if necessary.

2) Inspect shackle for wear or damage. Replace if needed.

3) Inspect anchor. Examine contact area between anchor and shackle for signs of wear.

4) Inspect anchor mount site and surrounding area. Look for signs of movement between anchor and cement core or between the cement core and the surrounding substrate.

C) Six Months:

1) Replace buoy through-line and pickup line after six months of use if the system is used on a regular basis.

D) Twelve Months:

1) Replace pin in down line shackle.

E) Twenty -four Months:

1) Replace down line if needed.

Modifications Unique adaptations incorporated into the mooring system include:

1) Removing and replacing on a rotating basis the entire system for cleaning and repair rather than on-site maintenance. Rough water conditions often preclude sufficient time for cleaning on-site. This practice requires building an inventory of entire mooring systems and may therefore in some cases become cost-prohibitive.

2) Using polyplus line rather than polypropylene. Many managers have found that polyplus is more durable and resistant than polypropylene.

3) Replacing shackle pins every six months to insure the pin will not break.

The Manta-Ray Buoy Anchoring System

General Description

The Manta-Ray anchor is a utility pole anchoring system adapted for underwater use. The first Manta-Ray underwater systems were installed in 1990 in Florida's Key Largo National Marine Sanctuary.

Sea bottom characteristics dictate the type of anchor system used for mooring buoys. Whereas the Halas system require a hard bottom to drill a core and cement an anchor pin, the Manta-Ray anchoring system can be used in mixed bottoms of clay, sand, gravel, broken bedrock, and coral rubble (Foresight, unpublished). In Key Largo National Marine Sanctuary, Manta-Ray anchors are used on the leeward side of reefs in mixtures of sand and coral rubble. They also work well in soft substrate. Because of sea bottom characteristics, Virgin Islands National Park plans to use Manta-Ray anchors for approximately 75% of their mooring buoys (Bjork, VI National Park, pers. comm. 1991).

The Manta-Ray system consists of a utility anchor attached to an anchor rod that is driven under the sea bottom. A thimble eye nut is screwed into the end of the anchor rod for attachment of the buoy line. (See Figure 3.) Manta-Ray anchors are now available in one-piece construction, which eliminates the problem of one piece unscrewing from another. If the anchors are purchased in sections, the sections should be arc-welded together. Installation of the Manta-Ray system does little environmental damage to the surrounding sea bed. Installation time varies with sea bottom characteristics but in most cases the Manta-Ray can be installed in less than 30 minutes, reducing time and labor costs.

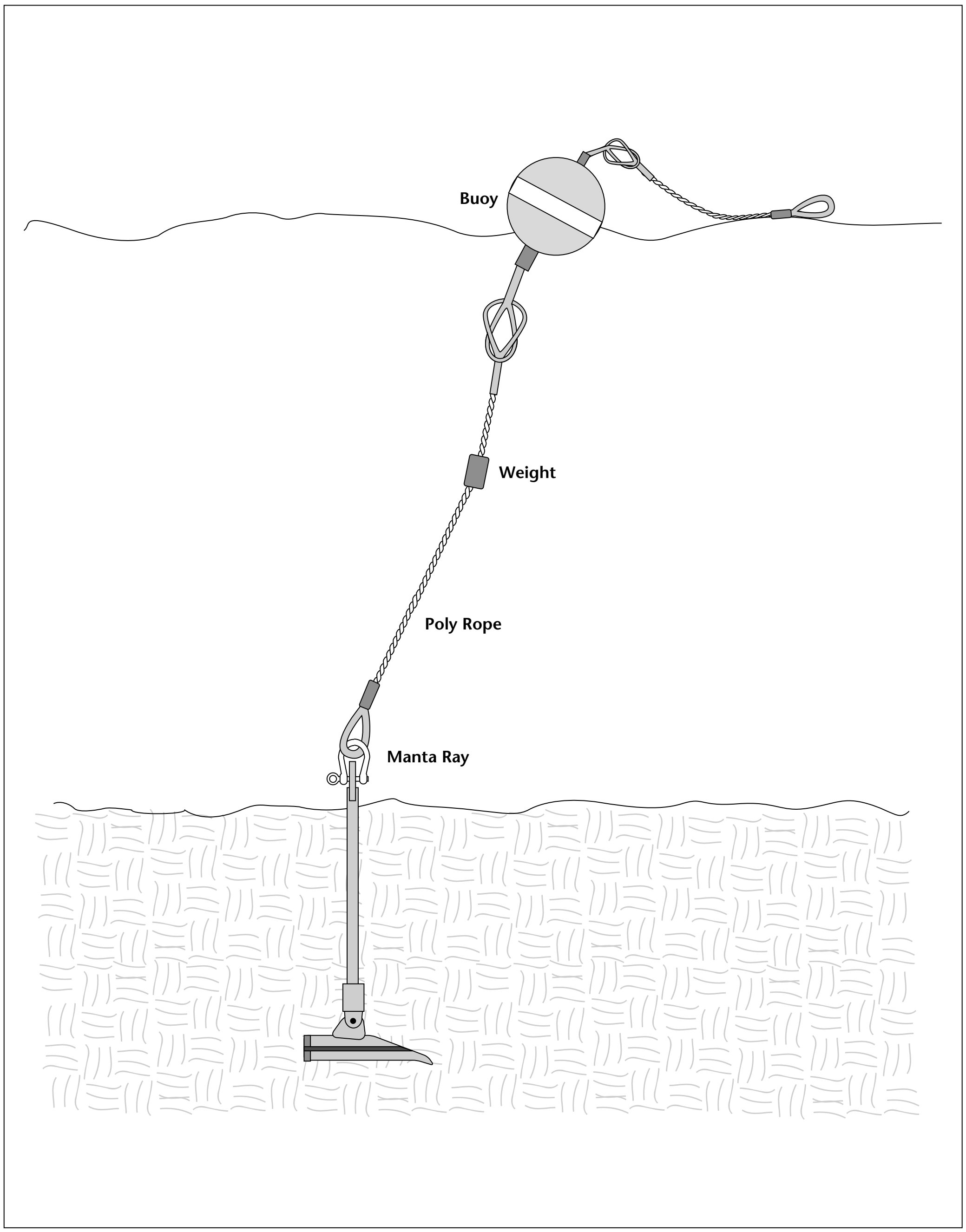


Figure 3

Procedure

Anchor style and size installed depends on the sediment characteristics of the site. Probing the bottom prior to installation will give the operator an idea of the bottom conditions. However, short of taking cored sediment samples, it is difficult to know exactly where and how deep bedrock may be. Larger and heavier Manta-Ray anchors are used in loose or wet sediments that do not have the holding power of normal sediment.

Lighter, smaller anchors are used in average sediment. A hydraulic underwater jack hammer and gad, attached to the anchor drives the Manta-Ray anchor into the sea bottom. The anchor should be driven deep enough that the anchor rod is not exposed above the bottom. Anchor rods are made in either 3 1/2 or 7-foot lengths. If the operator believes a 3 1/2-foot anchor rod can be driven further down into the bottom, (increasing the holding capacity of the anchor) couplers and extensions can be added in order to add length to the anchor rod. Occasionally an anchor will run into a layer of bedrock and cannot be advanced any further. The anchor should then be pulled up and moved to another location.

Once the anchor and rod is in place the anchor is set and locked into a permanent position. To lock the anchor into place, an upward force must pull the anchor so that the anchor wing rotates and pivots into a locked position. An anchor setting device, known as a load locker applies a force (measured in psi, (pound per square inch)) to put the anchor into locked position. Without a load locker, the anchor can be set by tieing a line from the anchor to the workboat, driving either forward or in reverse, to pull the anchor upward, locking it in place. However, the holding capacity of the system cannot be assured when the anchor is set without a load locker. (See Figure 4.)

An advantage of using a load locker to set the anchor is that the holding capacity of the anchor is immediately determined. Documenting holding capacity may be a crucial feature of a system if the manger is concerned about legal liability (see legal liability section). The psi force of the load locker can be converted to pounds of holding capacity. Holding capacity varies with the size of anchor use and substrate characteristics, but can range from 8,000 to 14,000 pounds in medium-stiff clay or loose sand, to

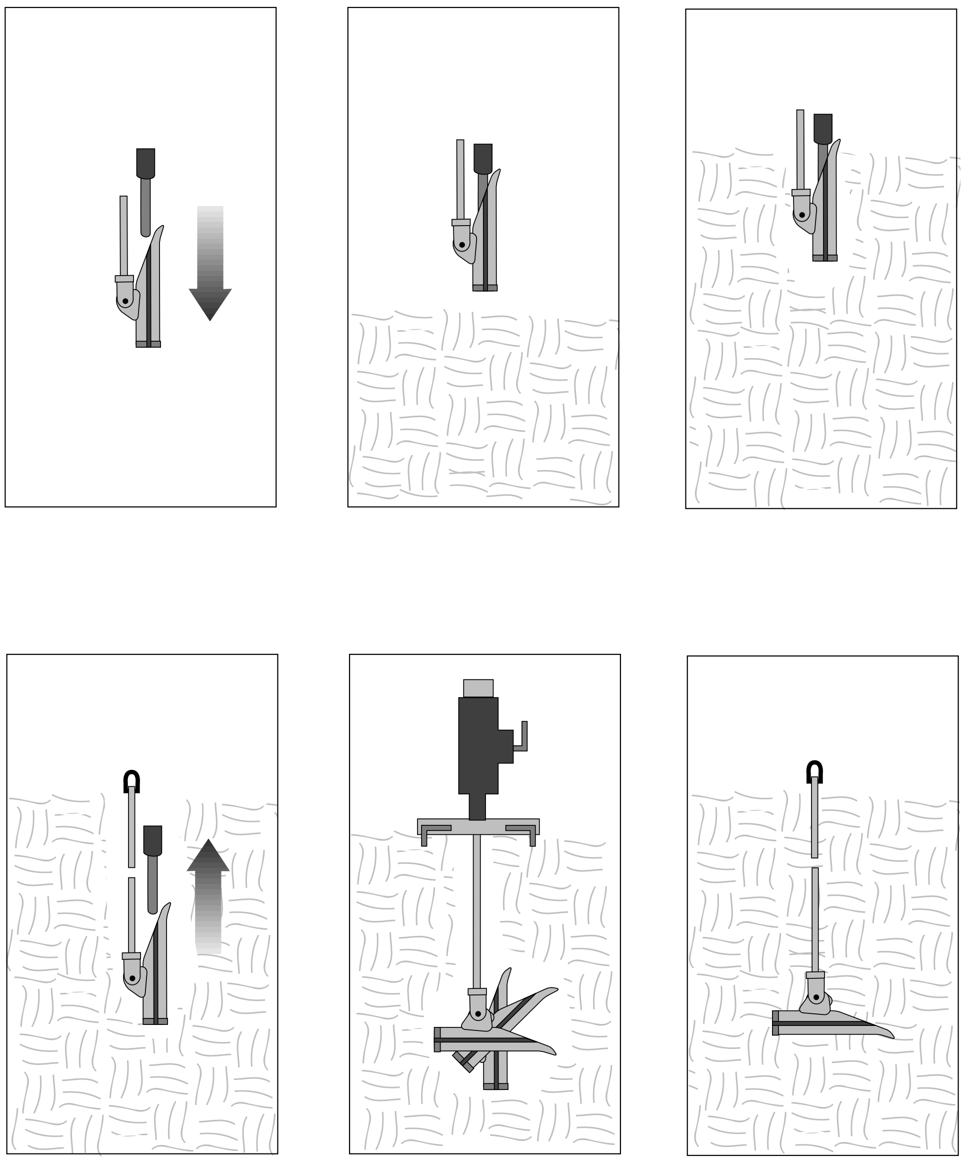


Figure 4

2,000-40,000 pounds for dense sand, compact gravel, or sandstone. Holding capacity requirements vary with the size of the boat attached to the Manta Ray system. On average, a 65-foot sailboat requires approximately 30,000 psi of holding capacity. A down line and mooring buoy can be immediately attached to the Manta-Ray anchor. Typically, the down line and mooring buoy used in the Halas system is also used with the Manta-Ray system.

Videotapes demonstrating installation of the Manta-Ray system are available free of charge from Foresight Products, Inc.

Maintenance and Budget

Once the Manta anchor is installed maintenance for the mooring system is the same as for the Halas system.

Required fixed cost equipment for installing Manta-Ray anchors, as with the Halas mooring system, includes: an underwater jack hammer, power source, hoses, drive gad, and load locker. Much of this equipment can be rented on a daily or weekly rate. However, shipment overseas may require a down payment of the full equipment purchase price. Supplies for one average-sized Manta-Ray system cost approximately $110 including anchor, rod, and eye nut.

Modification of equipment as well as development of new technology continues to improve the successful Manta-Ray anchoring system. As with the Halas system, the manager considering the use on Manta-Ray anchors should consult with current users of the system for advice in system design, equipment purchase, and installation techniques (see Appendices A and B). Unless the manager is experienced in underwater work an the engineering involved in the installation, anchoring system, hiring a consultant for assistance could be critical for success.

Traditional Mooring Buoy Systems

General description Traditional mooring systems typically consist of a floating buoy attached to a chain and heavy anchor, an engine block, for example, or a concrete block (See Figure 5.) . Although it is possible to design a mooring system with non-commercial supplies found locally, it is critical that the system used does not cause more damage to the resource than a boat anchor and chain. The Halas mooring system-a proven safe, effective and popular method-was designed to avoid the limitations of traditional mooring systems. However, a manager faced with limited budgets, equipment, materials, or expertise may find a traditional mooring buoy system necessary.

Traditional, simple systems are best suited for shallow mud, sand, or gravel bottoms and are not recommended for coral or seagrass areas. Although is it is not necessary to protect sand or mud from anchor damage, a mooring in sand may still prevent anchor damage to the reef. For example, a boater may choose to use a mooring buoy in sand located within swimming distance of the reef rather than trying to anchor on the reef. Placement in deep waters will make regular inspections and maintenance difficult. Underwater surveys are needed for proper site selection. Concrete block type anchors, not permanently attached to the bottom by some physical restraint, must be placed on level bottom to avoid shifting. Installation of heavy block (and chain if used) can be difficult and hazardous from a boat in even the best sea conditions. Therefore, a sturdy, stable workboat with adequate deck space operated by experienced personnel is necessary for installation. Assembling all materials and equipment on land prior to installation will reduce actual boat time.

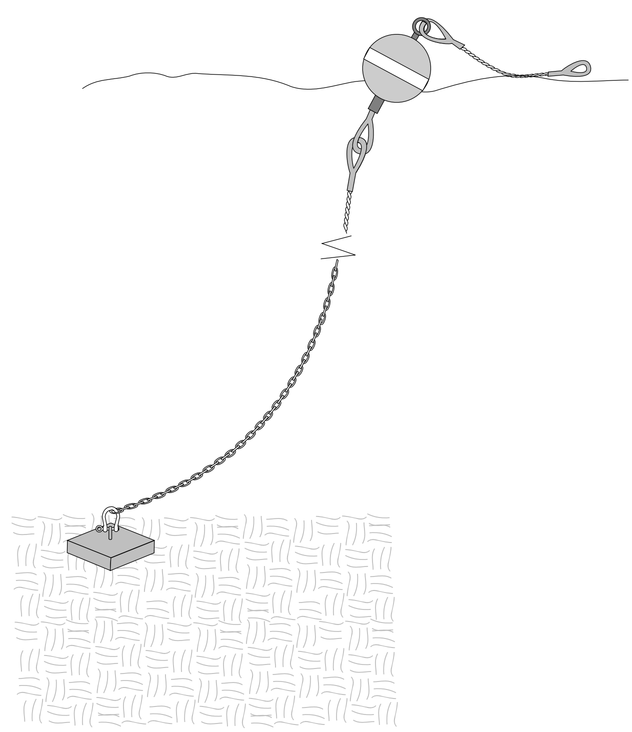


Figure 5

Materials

High quality materials, equipment, and supplies should be used whenever possible. Inexpensive local materials such as bamboo or plastic bottle for the buoy, and chain for the down line, can be used if commercial materials are not available. If the manager is concerned about theft or vandalism, these parts can be easily replaced (Salm and Robinson, 1982).

Anchor/Block

A mooring block can be used as an alternative to a cemented eyebolt. The block can be any heavy object sufficient to hold a boat. Railroad wheels (Halas, 1985) or discarded car or truck engine blocks (properly stripped and cleaned) are occasionally used as blocks.

However, most traditional mooring blocks are made from cast concrete shaped into a square pyramid, box, or drum. Metal rings are set into the concrete for attaching the anchor line. The shape of the block depends on the holding conditions of the bottom. The holding power of any block not physically attached to the sea bottom is limited however, and dragging does occur.

Screw anchors, eyebolts with a long shaft screwed into the sea bottom, have been used in soft sand or seagrass beds (Halas, 1985). These screw anchors tend to back out if not monitored, and have limited holding power. They are only recommended as marker buoys (Kelley, pers. comm. 1991).

Buoy

The buoy can be obtained commercially or constructed from plastic, tin, or a metal drum. Although not as attractive or durable as a commercial model, readily available local materials can also be used to construct a buoy. For example, a simple, inexpensive buoy can be constructed from bamboo, or any other buoyant material, lashed together with cables and clamps (Salm and Robinson, 1982).

Although somewhat unsophisticated, systems built from local materials may suffice when other options do not exist. The manager must understand that these basic systems will require added maintenance.

Anchor Line:

Chain, rope, or polypropylene line can be used as an anchor line. Chain does not usually break and is difficult to cut. However, chain is heavy, difficult to transport, and can cause considerable structural damage to the bottom and sedimentation as it swings with the current. Rope is not as destructive as chain but can rot and break easily. The preferred anchor line, therefore, is made from polypropylene, material that is light, durable, and easily replaced if cut or lost.

To protect the line from chafing, splice a thimble (small metal strip) into each end of the line, or modifications can be adapted from the Halas system by splicing protective hose into the line. Attach one end of the line with a shackle to the mooring on the bottom. Attach the other end of the line to the bottom of the buoy at the water's surface.

If rope or line is used as a down line, two rings should be set in the mooring block so that a replacement line can be attached before the other wears and breaks. Usually, a nylon line with greater flex than a polypropylene line is used as a down line (Bjork, VI National Park, pers. comm. 1992). The length of rope or chain should be twice the depth of the water, with consideration given to local tide and sea conditions. Insufficient scope in the down line will cause a boat to sit directly above the mooring, snapping the line or lifting the block in rough seas or high tides. If the Halas three part rope system is used the same instructions for ground tackle should be followed.

Pickup Line:

The pickup line runs from the buoy to the boat. UV-protected polypropylene line floats and is durable but braided nylon can be used if polypropylene is unavailable or too costly. A thimble is spliced into a loop at one end for attaching to the buoy and a loop is spliced into the other end for attaching to the boat. A plastic hose is spliced into the loop to protect the line from chafing on the boat cleat or gunwale. Users should be instructed to attach extra line to the pickup line for additional scope and resiliency.

Maintenance and Budget

Every buoy system, no matter how sophisticated or simple, requires diligent maintenance. The manger should plan a financial budget to maintain supplies and a staff to oversee the system. All components of the system must be visually inspected and worn parts replaced as soon as possible. Therefore, the manger should not install more buoys than can be properly maintained. Inspections should be done routinely. The system will require more frequent inspections if nondurable materials are used. Replacements parts, including line or chain, should be on hand and ready for installation. If replacement parts are not available, the buoy should be removed until repairs can be made.

The Helix Mooring System

Hurricane-tested Marine Embedment Anchors

The helix anchor has been used to secure:

- Single-point boat moorings
- Mediterranean-style boat moorings
- Floating docks
- Fixed walkways
- Floating breakwaters
- Bulkheads - Pipelines
- Storm moorings
- Navigation and boundary buoys
- Floating ice barriers
- Shellfish long lines
- Finfish cages

Helix Mooring Systems, Inc.
1-800-866-4775

Simple installation procedures

Square Shaft anchors are installed with a torque motor taken below and operated by a diver. These installations may be in depths exceeding 10 feet. In shallower waters, the motor can be mounted on a small barge. With the use of drive tools, the entire installation can be managed from the surface.

Round Shaft anchors can be installed by hand with the mechanical advantage of a pipe or other turning bar. Although our low-load option, these anchors can deliver significant holding capacity in competent soils as demonstrated in the example at Marshall, California. These anchors are available with a single 6-,8- or 10-inch diameter helix on a 5 1/2-foot-long shaft.

The helix-anchor concept and competitive test results

The first helical screw anchor was patented in the early 1800s and used to support lighthouses in the Chesapeake Bay. (See Figure 6.) Whether intended to resist a downward force (supporting a fixed walkway) or an upward force (securing a boat or a dock), helical embedment anchors derive their significant holding power from the soil into which they are installed.

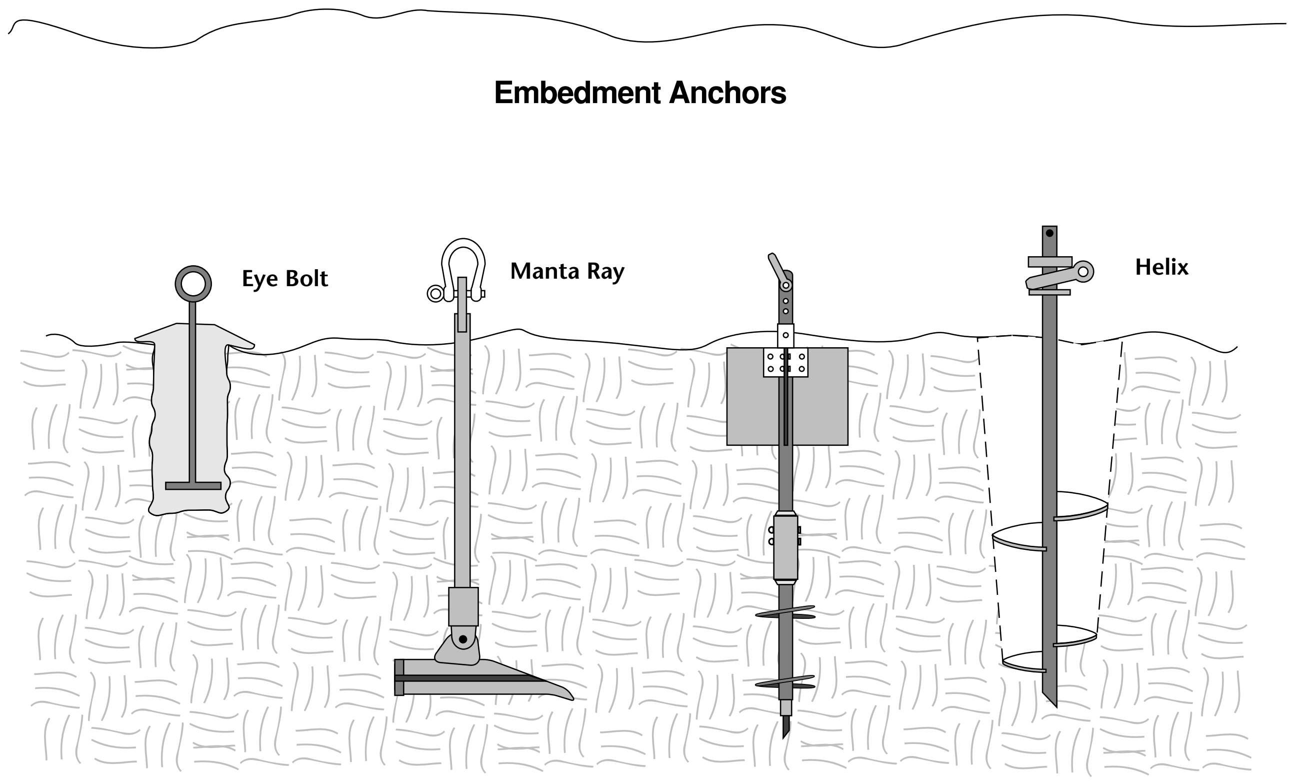


Figure 6

Vineyard Haven, Pull Test Results		
Mooring Type	Bottom Condition	Breakout Force
350-lb. Mushroom	5 ft. deep in mud	2,000 lb.
500-lb. Mushroom	in sand bottom	1,700 lb.
3,000-lb concrete block	set in mud	2,100 lb.
6,000-lb. cement blodk	on sand bottom	3,200 lb.
8/10 Helix	soft clay mud	20,800+ bl.

The soil above each helix on an anchor resists the upward tension which is exerted by a moored boat or dock. The firmer the soil and the deeper the anchor has been turned into that soil, the more resistance to the upward tension is generated. Anchors relying on this exact same concept have been used in applications which required holding capacities up to 200,000 lb. loads far greater than those we are generally considering.

The table above compares the holding power of different traditional marine mooring anchors with that of a helix anchor. The Vineyard Haven, Mass., harbormaster selected typical traditional anchors within his harbor for a comparative test. A 65-foot tug pulled laterally on each anchor until it failed and the load at failure was recorded.

The helix anchor never failed. Rather, the 1 1/2" pulling hauser parted at 20,800 lb. of load.

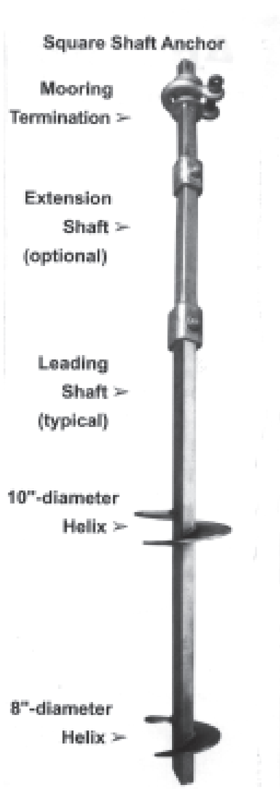
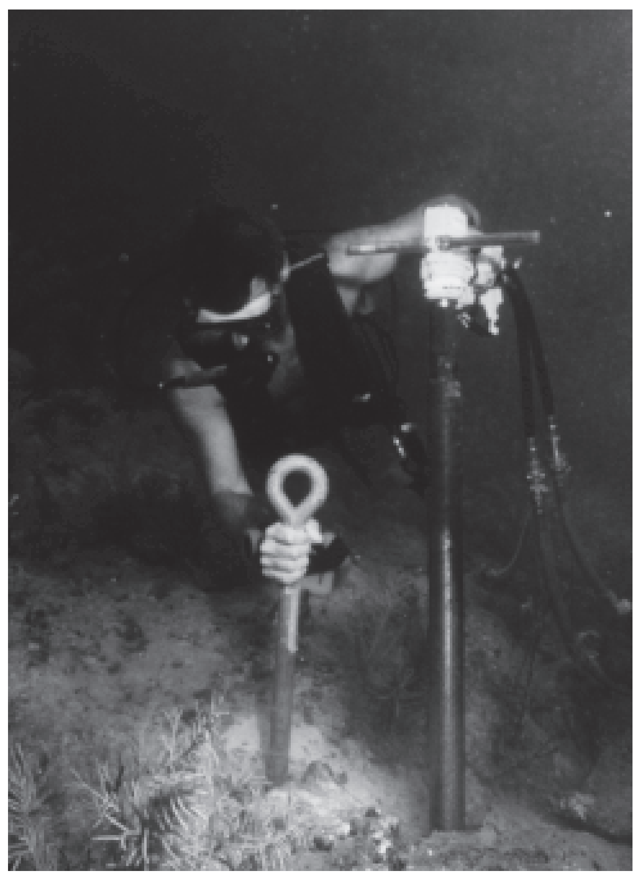


Figure 7

Figure 8



How are Helix anchors manufactured?

These anchors are manufactured in the USA by A.B. Chance Co. which has been building embedment anchors for more that 75 years. The steel, welding, couplings, and hot-dipped galvanizing meet ASTM specifications. The complete unit, including grade 7 coupling bolts, are load tested to minimum ultimate tension strengths of 70,000 lb. (l 1/2" square shaft anchors) and 100,000 lb. (1 3/4" square shaft anchors). Complete specifications available.

What does a Helix anchor cost installed?

$700 to $1,000 is a fair rule of thumb for the high load 1 3/4" Square Shaft anchors, but there are many variables. The right size of a Helix anchor varies with the harbor bottom and load requirement. The cost to install varies with local conditions and the number of anchors being installed at one time.

Chain and buoy prices are not included, but your dealer can also help with those. A Helix mooring anchor is more cost effective than traditional anchors based on cost per holding capacity.

How are Helix anchors Installed?

These anchors are installed using a hydraulic torque motor to screw the anchor into the harbor bottom. They can be installed from a surface barge using drive tools to reach to the harbor bottom or by a diver using an underwater torque motor and supported by a surface vessel. If your dealer is not a trained Helix installer, he/she will coordinate the installation with a trained installer for you.

Can a Helix be removed or repositioned?

Yes! Helix anchors can be removed by reversing the installation process, or they can be water-jetted out by blowing the subsoil off the helices.

How is holding power measured?

Holding power is based on collected engineering data. The torque (measured in PSI) required for installation is related to the harbor bottom material and the size of the torque motor used to install the anchor. Holding power can then be approximated using a chart.

Where is the dealer closest to me?

Please give us a call to find the dealer closest to you. If no dealer currently exists, we would appreciate your suggestions of local marine contractors and commercial divers who might be interested in becoming a dealer. Alternatively, we may be able to meet your needs with a mobile installation team.

Benefits of the Helix Anchor

Versatile, high-load capacity to serve any permanent anchoring need. Holding power which cannot be equaled by traditional mushroom anchors or deadweight blocks. Maintains its holding power even with the shorter scooping necessary in congested harbors. Stays where it is put and is friendlier to harbor bottom environments.

Single Point Boat Moorings

The anchor pictured in Figure 7 is our most popular anchor. Its overall length is about 7', and there are two helices welded to the central shaft. The top helix is 10" in diameter; the lower one is 8". Although this anchor weights just over 100 lb., it can deliver a holding force in excess of 20,000 lb. in good competent soils. When there is a layer of soft materials over the competent soils, an extension is added between the anchor shaft and the mooring termination by the installer. This ensures the helices are sufficiently buried into good holding soils to deliver satisfactory holding. When mud and silt are the primary subsoil, the installer will use additional extensions or our large anchor. The added installation depth and/or number and size of the helices will compensate for the weaker soils.

Standard

1 3/4" Square Shaft Anchors
- Single 10"
- Double 8/10"
- Triple 14"

Extensions are available for both the 1 3/4" Square Shaft and 1 1/2" Square Shaft Anchors. Extensions are the same as the central shaft and come in lengths from 3' to 10' long. If necessary these can be added on continuously to make an anchor as long as necessary.

Standard

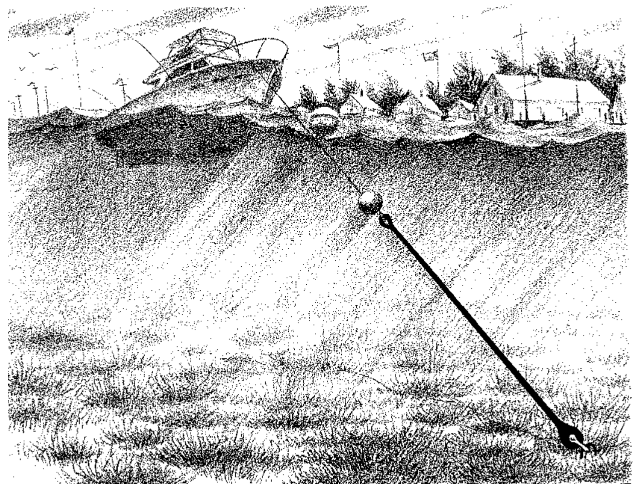
1 1/2" Square Shaft Anchors
- Single 8"
- Double 8/10"
- Double 14"
- Triple 10/12/14

"Helical Piles or sea screws (two names for Helix anchors) are not common, but are exceptionally effective . . . Recent tests have shown that holding power is vastly greater than any traditional mooring system of mushroom or deadweight anchors." –

MOORINGS: A Discussion of Problems and Solutions by Michael Taylor, CMS Marine Surveyor CIGNA (Property & Casualty) Loss Control Services January, 1994

"... Hurricane Erin's 80 MPH sustained winds and 100 MPH gusts proved no threat to the (Florida) vessels (moored on Helix anchors) . . . all five vessels equipped with the new (Helix) moorings in the immediate vicinity of Melbourne (Florida) rode out the storm without an incident, even a large, 52 foot yacht moored in open, exposed water." Cape Cod Times, August 14, 1995

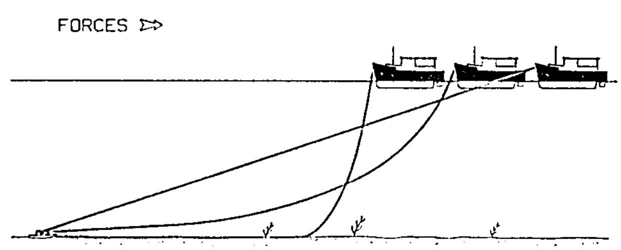
After the hurricane season of 1985, the owner of a 109' LOA privately owned motor had two Helix anchors installed in Palm Beach, Florida as the key components of an in-line storm mooring which the owner hopes will never be needed.

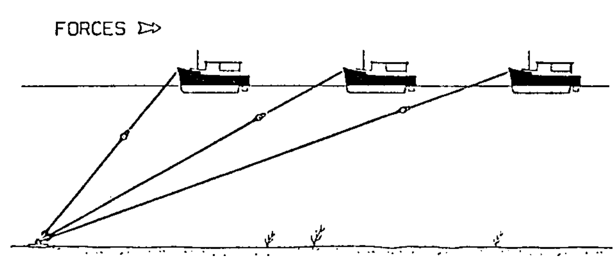


Hazelett Elastic Mooring Rode

A conventional mooring system uses a chain rode or a combination of chain and line to connect an anchor on the sea floor to a float on the surface. In moderate weather, this rode has a catenary curve between the bottom and the top. A boat pulls harder against this rode in reaction to the increasing force of wind and waves. In gale conditions, the chain extends until it is almost straight. When this happens, the elasticity provided by the curve is lost. The chain becomes a rigid steel rod between the bottom anchor and the boat. Any additional increases in the force of the wind or waves must be absorbed by a component in the anchor system. Something is bound to fail. The anchor yanks loose, the pennant breaks or a cleat pulls out.

The Hazelett Elastic Mooring Rode offers a better solution. Because of its engineered ELASTICITY, it stretches out smoothly under the load of wind and sea, thereby eliminating the peak forces of a rigid chain rode. The Hazelett rode provides a new dimension in mooring systems – the dimension of elasticity. During storm conditions, this new dimension also protects against the effects of the sudden increases in water depth caused by storm surges or the impact of a break-away boat. The Hazelett rode maintains its elasticity to absorb these forces and to preserve the integrity of the mooring system under the severest of storm conditions. The smooth extension of the Hazelett rode system also acts to keep the boat pointed into the wind instead of yawing.





Foundation Findings

Report #20 Mooring Anchors

Looking Below the Bottom Line

In the aftermath of recent devastating hurricanes, the wreckage left in numerous harbors has pointed to a "weak link" in preventing storm damage - moorings.

Pictures of boats – moorings still attached - flung up on beaches , docks and atop other boats remain vividly etched in our memories. The thousands of boat owners whose vessels were damaged or destroyed by those disasters live in fear of another destructive storm.

In an attempt to reduce the extent of storm-related damage in the future, the BOAT/U.S. Foundation for Boating Safety along with Massachusetts Institute of Technology (MIT) Sea Grant College Program, and Cruising World magazine, conducted tests earlier this year to examine relative merits of old and new anchoring technologies.

We tested five types of mooring anchors in Rhode Island's Newport and nearby Jamestown harbors by pulling on them with a 65-foot tugboat powered by two 450 horsepower engines capable of generating up to 14,000 pounds of pull.

Our team measured force exerted upon two traditional anchor types, concrete blocks and mushrooms; the pyramid-shaped Dor-Mor, and two "embedment" anchors, a helical screw and the Manta Ray. (See Figure 9.)

We will present the test outcomes and then examine some mooring anchor attributes that contributed to those results.

THE DOR-MOR

We first tested a 650-pound version of the cast iron Dor-Mor, which is available in 10 sizes from 35 pounds to 2,000 pounds. This anchor is shaped like an inverted, squat pyramid with a short, large-eyed shank extending from the center. The Dor-Mor we tested had been in place for one year and our BOAT/U.S. Foundation diver found it was completely buried in mud.

Water depth was about 18 feet, creating a scope of slightly less than 3: 1. Two strain gauges were tied into the rode package - one an analog mechanical type, and one digital, which fed data to the lap-top computer. The tugboat began to pull and according to both measuring devices, the Dor-Mor broke out at approximately 4,500 pounds of pressure. Computer data indicates the anchor may have tried to reseat itself several times as it was pulled along the bottom between breakout and shut down of the engines.

HELICAL SCREW ANCHOR

Next we tested a helical unit that had been placed in about 20 feet of water, using a special hydraulic torque motor. The anchor consisted of a 15-foot long,

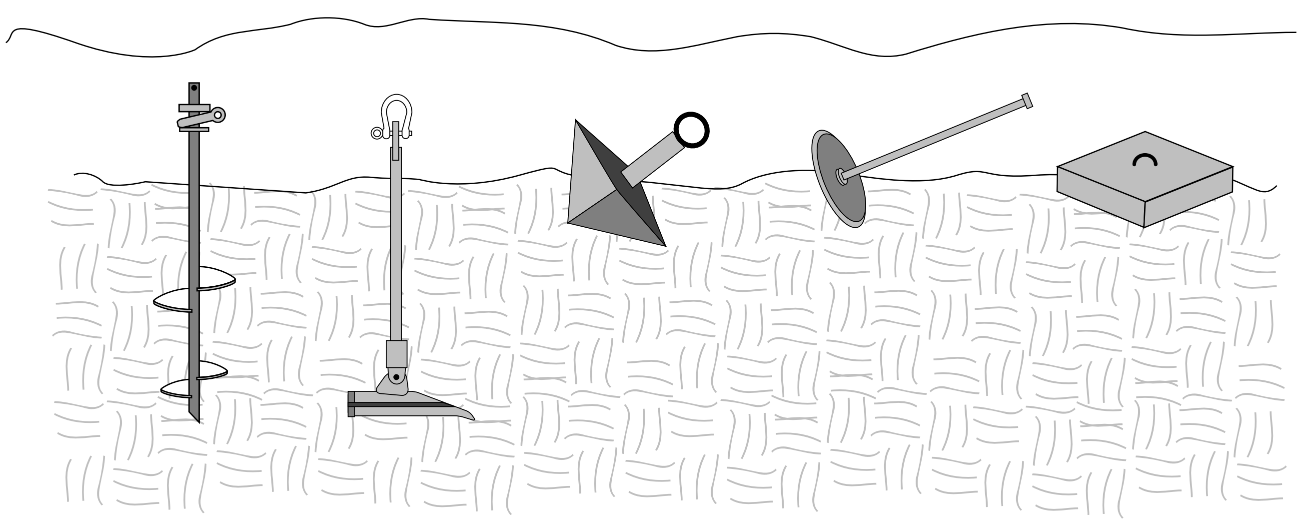


Figure 9

galvanized, steel shaft, screwed into the harbor floor with three 14-inch round helical plates in an area of very deep mud.

It was connected through the two strain gauges and attached to the tug at approximately a 4:1 scope.

The tug began its pull, increasing power until the mechanical strain gauge showed 12,000 pounds of pressure. Suddenly, the gauges hurled through the air and slammed into the transom several yards away. Some element of the system had given way, causing it to break apart.

The aftermath of the incident revealed a damaged and frayed steel cable, a warped and broken connecting shackle, and a shattered analog strain gauge, lying in pieces where it had landed on the fantail. The digital unit was beyond repair.

Fortunately, we were able to continue our tests using a backup digital gauge, brought along in anticipation on just such a failure.

THE MANTA RAY

Next, we attached the tug - digital strain gauge in line - to the galvanized cast iron Manta -Ray. It had been driven into an area of solid shale in about 19 feet of water, creating a scope of about 4: 1.

The Manta Ray's spade-shaped head is attached by a swivel joint to a shaft that varies in length according to how deeply it must be driven to hold in different soil types. It is set by a hydraulic "load locker," which toggles the manta-like projection into a position perpendicular to the shaft and locks it into place below the harbor bottom. The load locker can set an anchor with holding power up to 45,000 pounds, depending on the bottom composition.

We had the skipper increase engine revolutions per minute until the computer tallied 7,500 pounds, then backed off the throttle and removed the gauge to insure its availability for the remainder of the tests. We again increased engine power to the 1,700 rpm it had taken to break down our initial setup. As with the helical system, the Manta Ray didn't budge when the tug's twin screws reached that power level.

Conventional Mooring Anchors

The next anchor to be tested, a mushroom type lying in about 15 feet of water, was not very well dug into the mud. Optimally, the mushroom "cap" and the shank to which it is attached are fully buried. But, as so often happens, this one was only about half covered, with the shank lying in line with the area's prevailing winds.

It took a "quick tap" of the tug's throttle, generating about 1,200 pounds of pull, to break out the 500-pound mushroom, despite the normally acceptable 3-1/2:1 scope.

In our last two tests, it took only about 800 pounds of pull in 14 feet of water to pull out a 2,000 pound concrete block, and about 4,000 pounds of pull to dislodge a pair, of 4,000 pound cement blocks connected by chain in 35 feet of water. Both moorings had 3:1 -scopes.

Now we can examine how the various anchors differ and why they interact as they do with different marine environments.

Weight-Dependent Anchors

The first deadweight mooring used by a man was probably a submerged rock with a length of vine tied around it to keep a dugout canoe or raft from drifting away. Today, many types of mooring systems are available, meeting boat owners' needs as dictated by bottom conditions, weather patterns, and wallets.

Concrete blocks, chunks of granite, railroad wheels or engine blocks make up the simplest category of anchor, and all have one thing in common - their holding power comes mostly from dead weight, with some help from suction, especially in soft mud and silt.

Dead weights weigh less when underwater than on land. Cement blocks lose 45%, while granite loses 36%, iron loses 14%, and steel 13% when submerged.

Mushroom anchors also, are best suited for use in muddy or silty environments, but not in coarse sand, hard mud or clay, or rocky conditions. The mushroom's upended "cap" works into the underwater subsoil and the "stem" - to which ground tackle is attached protrudes from the bottom. When all but the tip of the shaft is buried, mushrooms are said to have holding power 10 times their weight. But partially buried mushrooms may hold only at a rate double to their weight. When hurricane-force winds blow a mushroom anchored mooring from a direction opposite that of the prevailing winds, the force of the storm can uproot the shaft by flipping it over, neutralizing most of the anchor's holding power.

To ensure that mushrooms are properly seated, compressed air is sometimes "jetted" downward into the bottom, creating a hole that later fills in around and above the anchor. But generally a boat is used to circle the newly placed mushroom, keeping the rode taut so that it works the anchor partially into the bottom.

The Dor-Mor because it offers less leverage when the-prevailing wind reverses its direction, is probably less likely to be uprooted-than the mushroom. And, as our test seemed to indicate, it may have better gripping power after being dislodged because of its sharp edges and pointed construction. It is best suited to muddy or silty bottom environments like the mushroom. Also, the Dor-Mor's thicker eyelet may not rust out as quickly as those on the mushroom or block.

Embedment Anchors

Helical Screw Anchors were introduced as screw pilings for lighthouses in 1838. The technology has been used continuously since, most recently in the construction industry for retaining walls, offshore pipelines, and pole guy wires.

Holding power for helical anchors, just as with the Manta Ray, is dependent oh the composition of the harbor bottom where they are placed. They don't do well in rock bottoms, and the number of helixes employed differs with soil type - from loose silt to highly cohesive clay -just as wood screws with different threads are used to achieve optimum results in different woods like pine or oak. One underwater helical anchor installer claims the mooring will withstand "more that 25,000 pounds of straight upward pull" when properly set into the bottom.

Manta Ray, like the helix, has been used in traditional construction applications and to anchor embankments, sea walls, and artificial reefs. Its holding capacity varies from 8,000 pound to 25,000-plus pounds in soil ranging from loose sand and silt to very dense sand and hardpan, according to the manufacturer. Manta Ray can be used in harbor bottoms ranging from solid bedrock, which has to be predrilled, to very loose sand, saturated silt, and swamp, where two or three anchors are tied together.

Unlike weight-dependent anchors, embedment types' holding power appears not to be affected by the angle from which they are pulled. Therefore, the strength of other mooring system components, like the hardware, rode, and pennant, dictate the amount of scope required.

But we should not overlook the beneficial effects of scope, with its uniform curve, or catenary, to absorb storm surge or other sudden stress.

Costs

The manufacturers of both helical and Manta Ray mooring anchors say their products offer greater holding power than is offered by conventional moorings. And some insurance companies offer lower rates for approved mooring systems.

A helical mooring anchor with double helixes and mooring adapter is about $550. Installation runs about $250, with a $60 per hour surcharge for any installation taking more than an hour. Total cost, installed, would probably run $800 to $860 for a single unit, with prices for multiple installations being negotiable.

Manta Ray anchor and seven-foot-long rod combination, adequate for recreational boats in most soil types, costs $130. Typically, a professional diver with the proper gear would charge a minimum of about $1,000 per day, during which time he could put eight to 12 Manta Ray units into place. A single anchor, including placement, should run about $1,150 to $1,200, with a sharp decrease in per unit price for the multiple installations.

Equipment, installation, and maintenance costs would be virtually the same for any recreational boat, ranging from a 19-foot sloop to a 50-foot power cruiser with a tuna tower.

The cost of inspections to check for deterioration of underwater anchor sections protruding from the bottom should also be figured into overall expense of a system. Visual inspections, much like those made on conventional mooring systems, may be necessary. And, since both types require professional installation, they might also require specialized personnel with torque motors or load lockers to "proof load" and perhaps reset them if they should loosen.

A 300-pound mushroom anchor retails for about $500; a 500 pounder costs about $800. Transport and placement of a mushroom within a harbor would probably run about $150 to $200, according to one New England harbor master. And installation at a location remote from a commercial harbor or boat yard, for instance near a private waterfront property, could become quite expensive, based on time and transportation costs, he said.

A 500-pound Dor-Mor sells for $600 and would be subject to the same transportation charges as a large mushroom.

Concrete blocks, though cheaper, could be subject to higher transportation and installation costs because of their weight.

Some Conclusions

Our tests seem to indicate both the helical and Manta Ray mooring anchors may offer at least a partial solution to one of the most basic mooring problems -

preventing storm damage to recreational boats.

When viewing the test results, bear in mind that a mooring system is made of four interdependent and equally important parts: lines (See BOAT/U.S. Reports, March, 1994, p.6), chains and shackles, deck hardware (See BOAT/U.S. Reports, July, 1993, p. 6), and the anchor. Our test covered just one of those elements.

Pulling on the mooring anchors in a steadily increasing manner permitted us a sound evaluation of the comparative merits of various anchor types, but that is quite unlike the yanking about that occurs when storm winds blow through an anchorage and sharp gusts pick up the waves.

Sometimes it is difficult to figure what is best in terms of safety, costs and benefits. And in areas where the chance of hurricanes or violent storms is slim the old technology still may suffice.

But investigators from BOAT/U.S. Marine Insurance and others in the wake of hurricanes Bob (1991) and Gloria (1985) identified traditional moorings with inadequate scope as a major cause of boat damage. in the final analysis, perhaps the only true measure of a mooring's value is how secure we eel when a big blow is headed for our boat and whether - after the storm - it still sits at its mooring.

ENVIRONMENTAL MOORINGS INTERNATIONAL

172 Lorelane Place
Key Largo, Florida 33037-4235 U.S.A.
Fax/Phone: (305) 451-5984

1996 Price List

(all prices in U.S. Dollars; does not include inland shipping or freight charges)

MOORING ARRAYS:

8-inch polyethelene MOORING BUOY (Standard) $58/ea
Foam filled, true white, one-inch pipe, blue reflective stripe, bushings attached. (Colors available add $2).

30-inch polyethelene MOORING BUOY $145/ea
Foam-filled, true white, 1 1/2 inch pipe (adjustable), blue reflective stripe, bushings attached. (Colors available, add $3).

22-inch polyethelene MOORING BUOY $90/ea
Foam-filled, true white, 1-1/2 inch pipe (adjustable), blue reflective stripe, bushings attached. (Colors available, add $2).

13-inch polyethelene MOORING BUOY $35/ea
Foarn-filled, true white, one-inch pipe, blue reflective stripe, bushings attached. (Colors available, add $1).

DEMARCATION BUOY. 9-inch diam., 62-in. ht., lettering, stainless eye. $105/ea

7/8 inch POLY P LUS BUOY LINE $365/roll
600 ft. roll, treated, heavy duty.

7/8-inch POLYPROPYLENE BUOY LINE $215/roll
600 ft. roll, UV treated, heavy duty.

3/4-inch POLYPROPYLENE BUOY LINE $156/roll
600 ft. roll, UV treated.

SHACKLE, stainless steel, 1/2-inch, with cable tie locks. $12.50/ea

Galvanized SHACKLE, 5/8-inch. $ 8/ea

CHAFING HOSE, I -inch ID, nylon reinforced, (100 ft. minimum). $1.10/ft

CHAFING HOSE (FIRE HOSE)
I- 1/2 inch, single jacket, 250 psi $1.60/ft

2-inch, single jacket, 250 psi $2.10/ft

2-1/2 inch, single jacket, 250 psi $2.60/ft

Soft LEAD SHEET, 4" x 3" x 1/8", 1/4 lb. $1.35/ea

Heavy duty CABLE TIE $.70/ea

MOORING ANCHORING SYSTEMS (FOR SOLID SUBSTRATE)

Mooring Anchor Eye, Standard, 5/8-inch ‘)
16 stainless steel, $38/ea
18-inch depth.(Use with cement in limestone.)

Mooring Anchor Eye, 5/8-inch 316 stainless steel $48/ea
24-inch depth, knurled or threaded. (Use with epoxy in hard rock),

“U” ANCHOR HEAVY DUTY MOORING, 3/4-inch $90/ea
stainless steel, 24-inch depth, 12-inch interior width.

Portland Type II CEMENT, 90-lb bag $15/bag

UNDERWATER ADHESIVE, 2-part epoxy, dual tube, I I oz., with/Nozzle (extra nozzles @ $3/each) $26/appl.

UNDERWATER ADHESIVE dual tube applicator, I I oz. size $72/ea

MOORING ANCHORING SYSTEMS (FOR SOFT SUBSTRATE - SAND/RUBBLE): MANTA RAY MARINE MOORING ANCHORS
Heavy duty, includes custom one piece 7-foot x 1 -inch anchor rod with forged eye-nut.

MR-SRM (Wt. 42.5. lbs.) $135/ea + $15.00 ship FOB MIA $150/ea

MR-1M (Wt. 33.5 lbs.) $109./ea + $14.00 ship FOB MIA $123/ea

MR-2M (Wt. 31.5 lbs.) $101/ea + $14.00 ship FOB MIA $115/ea

MR-3M (Wt. 12.5 lbs.) $ 98/ea + $ 1 0.00 ship FOB MIA $108/ea

“FISH PLATE” for double anchor mooring (14.3lb. steel plate)$25/ea

MANTA RAY INSTALLTION EQUIPMENT

SGC- 1 8 “Stinger” dive gad set, 1-1/8 shank, 3 couplers, $ 899/ea
2 extensions, I radiused drive tip, gad extractor bar.

LL-IM Load locker ram assembly (used to “toggle or “load” test MANTA RAY Anchors) $1,886/ea

HYDRAULIC INSTALLATION EQUIPMENT
AVAILABLE, PRICED INDIVIDUALLY PER UNIT.

HYDRAULIC POWER UNIT, Marinized with aluminum frame, 16 hp $3,800/unit
Briggs & Stratton engine, gasoline, portable, runs installation equipment.

HYDRAULIC HOSES, dual 125 ft. power and return with stainless steel fittings. $950/set

HYDRAULIC COUPLERS, Stainless steel, 1/2-inch male/female. $ 78/set

DL-09 STANLEY HYDRAULIC DRILL
w/hose whips, fittings $1,795/ea

BR-67 STANLEY HYDRAULIC HAMMER
(for Manta Ray inst.) $2,200/ea

2-CB 2-inch Carbide tipped coring barrel- 24" length $ 275/ea

3/4 DB 3/4-inch Carbide drill bit (5/8-11) - 27" length $ 115/ea

ADAPTO@gr fit 5/8"x 1 6 male thread on drill to drill bit or core barrel. $64/ea

INSTALLATION TOOL KIT: Two 100 lb Lift bags,
uw tool bag, pipe wrenches, hammer, rod, lines w/snaps, $200
mixing bowls w/lids, marking tape, etc. $ 350/kit
(price depends on content/needs of project)

All specified components of the Coral Reef Environmental Mooring System make up a unique combination of materials that are necessary for the mooring buoys to function safely with a minimum amount of maintenance in the coral reef environment. With ten years experience and modifications to bring the system to the present state of the art, the materials have been selected with safety, strength, and economy in mind. Environmental Moorings International is the only vendor that can easily consolidate all of the correct components, including the anchor eye and mooring buoy specialty items, into one complete order. Environmental Moorings International constitutes a sole source for this mooring buoy system.

MANTA RAY

Marine Mooring Anchors &
Marine Installation Equipment

Domestic User Price List Manta Ray Marine Mooring Anchors
(includes custom one piece anchor rod with forged eye-nut.)

MR-SRM Holding Capacity up to 20,000 lbs (88kn)
Used with 7f (2. 1 M) x 1 “ (25mm) anchor rods
42.5 lbs 19.3 kg $135

MR-IM Holding Capacity = up to 2O,OOOlbs.
(88kn) Used with 71 (2. 1 m) x I” (25mm) anchor rods
33.5 lbs. 15.2 kg $109

MR-2M Holding Capacity = 15,000-20,000 lbs.
(66-88kn) Used with 71 (2.1 m) x 1" (25mm) anchor rods
31.5lbs. 14.3kg $101

MR-3M Holding Capacity = up to .10,000 lbs.
(44kn) Used with 6' (1. 8 m) x 5/8 “ (I 6mm) anchor rods
11.8 lbs. 5.3 kg $88

“Fish Plate” for double anchor mooring (steel plate)
14.3 lbs. 6.5 kg $20.
*Holding capacities are dependent on soil and moisture content

MANTA RAY Installation Equipment
SCG-18 “Stinger” drive gad set, 1 1/8"(29mm) x (152mm) shank,
3 couplers, 2 extensions, 1 radiused drive tip, I gad extractor bar.
64lbs. 29.1 kg $899

LL-IM Hydraulic load locker ram assembly (used to”toggle” or
“load” [test] the MANTA RAY anchors). 180 lbs. 81.lkg $1,886

LL-2M Manual load locker for MR-3M, MR-4M and
MR-88M series anchors. 72 lbs. 3 2.7kg $749

Hydraulic Installation Equipment
Stanley BR-87 Underwater Jackhammer $2,050
(shipping weight 87 lbs./39.2kg)

GPU 18-8 - Hydraulic Power Unit (portable) -18 horsepower,
5-8 GPM (20-35 Ipm), 2,009,PSI (13, 790 kPa) $4,300
Recommended to power all MANTA RAWe quipment
and processes (Shipping weight 220 lbs./99kg)

Hydraulic Hose 4.95/ft
Price per ft./ ft.=.305m

Stainless Steel Hydraulic Couplers $125/set
Minimum order of 5 sets

Light Duty Marine Anchors
MR-4M Includes custom one piece 7' (2.14m) x 5/8 (16mm) $76/ea
anchor rod with forged eye nut. Holding capacity 5,0000 lbs.
(22kn) 10.7 lbs 4.9 kg

MR-88M Includes custom one piece $26/ea
1/2" (13mm) x 30" (67mm)anchor rod with forged eye-nut.
Holding capacity 4,000 lbs. (I 8kn) 3.5 lbs. 1.6 kg

8 8-DB1-SS Anchor Cabled with 3 -1/2" (I. 07m) of 1/4"(64mm)
Stainless Steel Wire Rope, Copper Sleeves
*holding Capacity 3,000 lbs. (13kn) 1.2 lbs. .5 kg $16.99

68-DB1-SS Anchor Cabled with 2-1/2' (0.76 m) of 1/8”
(32 mm) stainless steel wire rope, copper sleeves. *Holding capacity
1100 lbs. (4.9kn) .5 lbs. .23 kg $9.99

LL-2 Manual load locker can be used to load lock the DUCKBILLC
anchors and MR—3M, MR-4M, MR-68M. Maximum Capacity =
8,000 lbs. (35kn)

*Holding capacities are dependent on soil and moisture content

Drive Steel for Light Duty marine Anchors
Note: MR-4M uses standard “stinger” drive gad set for larger
anchors.

For 68-DB Anchor
DS68HD (hand drive gad) - 4 ft. (1.2m)
long large striking head $24.99
PDS68* (power drive gad) - 4 ft.(I.2m) long.
Specify hammer chuck size w/order $130

For 88-DB Anchor
DS88 (hand drive gad) - 4ft. (1.2m) $24.99
long with large striking head
PDS88 (power drive gad) - 4’6" (1.4m) long.
Specify hammer chuck

*Standard Chuck Sizes — 7/8 (2.2cm) x 3 1/4 (8.3 cm) - 7/8 (2.2) x
4 1/4 (10.8cm) - 1 (2.5cm) x 4 1/4 (10.8cm) - 1 1/8 (2.9cm) x 6
(1.83cm) - 1 1/4 (3.2cm) x 6 (1.83m)

TERMS: $200 minimum order - Orders are F.O.B. Colorado 20%
restocking fee for all returned goods LOC may be requested - Net 30
days

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FORESIGHT PRODUCTS INC.
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Patent number 4,044,513, 4,096,673, 4,802,317, 5,031,370 and
other international patents. Additional patents pending.

HELIX MOORING SYSTEMS INC.
1 (800) 866-4775

Embediment Anchors

Retail Prices

Square Shaft Anchors

Standard 1 3/4" Shaft		Standard 1 1/2" Shaft	
Single 10"	$460 $330	Single	8"
Double 8/1 0"	$495 $355	Double	8/10"
Triple 14"	$615	Double	14"
	$435 $470.	Triple	10/12/14
3' Extension	$130 $ 80	3.5' Extension	
5' Extension	$175 $105.	5' Extension	
7' Extension	$200. $135	7' Extension	

Max Installation Torque:10.,000 ft. lbs
Max Installation Torque: 5,000 ft. lbs

Round Shaft Anchors

Single 6"	5.5' x 3/4" Dia.	$ 55
Single 8"	5.5' x I" Dia.	$ 75
Single 10"	5.5' x I 1/4Dia.	$105
Single 14"	8' x I 1/4Dia.	$160
Extension	6' x I 1/4Dia.	$100

Max. installation Torque, 3/4" dia. - 400 ft. lbs, I" dia. - 1,000 ft. lbs., 1 1/4" dia.-2,300 ft. lbs

Rock Coral Anchors

Rock Anchor 27" x 1 1/4 Dia. $ 55.

Epoxy Installation Gun, Mixing Nozzles are available upon request
EQUIPMENT All the necessary HELIX ANCHOR installation equipment is available to lease or purchase.

SEACURE RESOLUTIONS

David Merrill
Manufacturer's Representative
P.O. Box 119 Milford, NH 03055
Phone (603) 672-7260 Fax (60')) 672-1855

Nominal Boat Size	Rode Diameter
Up to 27'	1.38"
Up to 35'	1.75"
Two in Parallel	

Component Prices

1.375 inch diameter elastic rode

Length (ft)	Item #	Price
14	287285	$300
9	287287	$290
4	287289	$250

1.750 Iinch diameter elastic rode

Length (ft)	Item #	Price
14	287284	$350
9	287286	$300
4	287288	$275

Length is nominal and denotes the distance between the center of the eye at each end.

Price includes a circular thimble in the eye at each end. The thimble is available in two styles. Pin style is intended to accept a shackle pin. ROPE style functions as a rope thimble.

Additional Elastic Rode Components

Item	Item #	Price
Anchor Shackle	283585	$29
Rode Float		
8 in. dia. 7 lbs. floatation	283484	$12
11 in. dia. 22 lbs. floatation	283485	$36

GUARANTEE Manufacturer provides a one-year guarantee against manufacturing defects. Seller's liability for breach of such guarantee shall be limited to product replacement. Seller disclaims all other express and any implied warranties except the warranty of mechantability provided under Section 2-314 of the Uniform Commercial code. Seller's liability for breach of such implied warranty shall be limited to product replacement.

Purchaser acknowledges that the product is in development and that it is being distributed to a limited number of distributors in order for Manufacturer to obtain field experience. Purchaser agrees to communicate this to its customers and to clearly limit Manufacturer's liability for breach to product replacement.

Section III

The Benefits of Mooring Buoys

Overview

In this section you will find articles and studies that describe the effectiveness of mooring buoys in reducing coral damage. This section will also cover many additonal benefits to using moorings such as the ease of operation, the safety, the practicality and the affordability.

Contributions

Hocevar, John D. "A Survey of the Stoney Coral Community Composition of Pompano Ledge, Broward County, Florida with a Presliminary Evaluation of the Effectiveness of Mooring Buoys in Reducing Coral Damage." NOVA University, 1003.

Segre, Liz. "Oh, What a Beautiful Mooring." *Power and Motoryacht,* January 1993

Murphy, Tim, "Staying Power." *Cruising World,* September 1994.

Contents:

A Survey of the Stoney Coral Community Composition of Pompano Ledge, Broward Co. , Florida with a Preliminary Evaluation of the Effectiveness of Morring Buoys in Reducing Coral Damage

by John D. Hocevar
Nova University 1993

Abstract

Stony coral of Pompano Ledge, First Reef, Broward County, Florida were sampled in situ using a new reef assessment method. The circular-radial method was used to assess the effectiveness of mooring buoys in reducing damage to reefs. Data will be part of a long-term monitoring study of buoy impacts. The parameter of recent injury was used to provide preliminary information on buoy effectiveness.

Results were as follows: approximately 6% of the study area was covered by stony corals, with an average of 3 colonies per square meter. Diversity based on abundance (H'n) was 1.7, and diversity based on relative coverage (H'c) was 1.1. Evenness based on abundance (J'n) was nearly .8, and evenness based on relative coverage (J'c) was .5. Approximately 6% of all colonies surveyed were observed under the shelter of ledges or overhangs. An average of 2% of colonies were observed to be recently injured in the Winter, compared with 6% in the Summer. Twenty-nine species of scleractinian corals were observed, 26 of which were present in sample areas. Montastrea cavernosa dominated stony coral coverage, and Siderastrea spp. and M. cavernosa were the most abundant.

Mooring buoys appear to be an effective management tool for minimizing damage to corals on Pompano Ledge. The percentage of corals that had been recently injured was lower in the buoyed site ($p = .082$) even though the buoyed site was more heavily visited by both boats and divers. Future studies will be able to further assess buoy impacts by noting any changes in coral population parameters. The buoys have only been in place two years, so it will be interesting to see if the coral communities of the two sites begin to diverge in the future.

Buoy Effectiveness

Boats that tie up to mooring buoys are not anchoring, and anchoring in coral causes damage. Therefore, use of mooring buoys will reduce that type of damage to reefs. This is the basic premise behind mooring buoy use. As long as damage prevented by anchors is greater than possible diver damage caused by a resulting increased usage of the site, buoys are extremely useful management tools. Anchor damage can be minimized or even prevented from occurring by use of mooring buoys. The total amount of overall diver damage, however, is not likely to be reduced or increased by buoy usage; divers not using the buoyed site would probably be diving somewhere else. A potential scenario where mooring buoy usage would be detrimental includes the following. 1. Diver damage was more significant than anchor damage. 2. Diver damage was concentrated in the area of the buoys as a result of the buoys being there. 3. The concentrated diver damage was elevated to a level beyond that of the reef to repair itself by recruitment and regrowth.

There is no evidence to indicate that buoys are causing concentrated diver induced reef damage on Pompano Ledge. In fact, the mooring buoys on Pompano Ledge seem to be a useful tool to reduce human impacts to fragile reef organisms. The buoyed site was visited 22% more than the control site during the winter sampling period, and 116% more in the summer. Dive charters full of inexperienced student divers frequently use the buoyed site. In spite of these factors, % recent injury was lower in the buoyed site than in the control site ($p = .082$). The value of the mooring buoys is demonstrated even if injury is equal in both sites, because visitation is much higher at the buoyed site.

Pompano Ledge is an example of an area where buoys were installed on a popular reef with a preexisting condition of heavy diver pressure. Before installation of mooring buoys, it is likely that dive pressure was uniformly distributed along Pompano Ledge. Buoyed and control sites are very similar in coverage and composition of the stony coral community as well as in overall appeal to divers. A notable exception is the wreck of the Copenhagen at the southern end of the buoyed site. The spectacular pillar coral Dendrogyra cylindrus is also unique to the buoyed site, but this is not likely to greatly influence dive pressure to the site. Buoy installation appears to have concentrated dive pressure to some degree. However, there is no evidence to indicate that diver-caused damage is greater in magnitude than anchor damage. Concentration of diver effects is minimized by use of a large number of buoys spread out over a large area. Drift diving is popular in the area, particularly among dive charters, and this would further contribute to minimizing concentration of divers.

Management Considerations

Mooring buoys are an excellent tool to reduce anchor damage to heavily used reefs, and can be an important part of a comprehensive reef management plan (see van Breda and Gjerde 1992). Introducing buoys to popular reefs will reduce anchor damage with maximum efficiency. Greater care needs to be taken in locations where dive pressure is relatively low. In these situations, mooring buoys may serve to attract divers to the sites. This may be useful to mangers attempting to more evenly distribute dive pressure. In general, however, it is probably more desirable to retain some areas in relatively pristine conditions where possible. These areas can serve as sources of larval recruitment and provide "natural" comparisons that will be useful for assessing impacted reefs.

Education is a vital component of a successful mooring buoy plan. Installation of mooring buoys is a waste of time and money if the public is unaware of what to do with them. Education is an ongoing process, as new divers are constantly moving to or visiting the area. Ocean Watch Foundation educates the dive community through pamphlets available at area dive shops, booths at topical expositions and fairs, a quarterly newsletter, and numerous activities such as parties, meetings, and beach cleanups. Dive charter operators can and do play an important leadership role in educating divers on their boats. During the course of this study, several dive boat captains were witnessed using loudspeakers or radios to lecture private boat operators that had anchored near mooring buoys.

A good maintenance program is another essential part of a mooring buoy plan. A good mooring buoy system, such as the Halas-type system, must be designed for simple and inexpensive maintenance. Buoys, lines, shackles, eyebolts, and pins must be regularly inspected, cleaned and/or replaced as necessary. Reef Relief (1992) outlines a thorough maintenance and inspection plan patterned after the National Marine Sanctuaries Program. Reef Relief and Ocean Watch Foundation both utilize area dive captains to assist in this task. However, it is important to have one individual or committee to oversee maintenance and inspection to make sure parts are available and that missing buoys are promptly replaced. Numerous buoys are frequently missing from Pompano Ledge for long periods of time, during which bouyless downlines are allowed to lie on the bottom. This can result in injury to gorgonians, sponges, and other high relief organisms, which can be uprooted by the line when it is swept around by the current.

Summary and Conclusions

The stony coral community structure of Pompano Ledge, part of the first reef of Broward County, Florida, was described using a new reef assessment method developed for this study. Organisms within a circular sample area were identified and measured in situ. This was well-suited for monitoring buoy effectiveness because stations could be centered around buoy eyebolts. Use of a weighted line allowed the method to be adapted to use in the non-buoyed control site as well. This method may be useful for future monitoring studies because it allows for precise reoccupation of sites while requiring only one permanent marker. An additional advantage is that a circular sample area had the smallest boundary distance for a given area.

Coral abundance, % cover, and diversity were higher than reports for the First Reef in other parts of Broward County. A total of 29 species of scleractinian corals were observed, 26 of which were present in sample areas. Siderastrea was the most abundant genus, while Montastrea cavernosa dominated coverage. The dominance of these species and relative paucity of acroporids and Montastrea annularis that are common to shallow Caribbean reefs suggests that Pompano Ledge coral species composition may be affected by low temperatures and high turbidity.

Mooring buoys were demonstrated to be an effective management tool for minimizing injury to corals of Pompano Ledge. In general, the percentage of recently injured colonies was greater in the control site, even though the buoyed site was more heavily visited. Future studies will be able to further assess buoy impacts by comparing any changes in coral population parameters. The buoys have only been in place for two years, so it will be interesting to see if the coral communities of the two sites begin to diverge in the future.

Power and Motoryacht

Oh, What a Beautiful Mooring

by Liz Segre

John Halas is giving coral reefs a chance with permanent moorings. You're hovering peacefully in a silent blue wilderness, slowly viewing, slowly gesturing as you turn from right to left in a place where right and left dissolve into the shapeless three-dimensional, and points of reference give way to points of filtered light. You're surrounded by an octopus's garden of white elkhorn and bright brain corals. Yellowtail snapper socialize, parrotfish sing their piscine songs, and a self-effacing leopard ray hides its spots in a patch of mottled sponge. Nature smiles and you smile back (or as well as you're able to with an airhose in your mouth).

But what's this? Your partner signals and points to a bed of branch coral a few feet away. The twigs are broken, grotesquely amputated. Further on, wide scars mark the brain and star corals, monstrous wounds in the ocean floor. Little piles of coral rubble dot sterile expanses of exposed sand. You look around, and the dead scrapes seem to go on forever. You search your memory— were these marks here the last time you dived this reef? And didn't there used to be a lot more fish and plant life here just a few short years ago?

Caution: Fragile Reefs

What you've experienced has happened to lots of divers in the past 20 years, including Dr. John Halas. When he discussed the growing phenomenon of coral reef damage with fellow sport divers, he began to realize that the biggest cause of it was boat anchors. And after he began work as Sanctuary Biologist at the Key Largo National Maine Sanctuary in 1980, Halas found a way to lessen anchor damage: permanent moorings.

These devices consist of a mooring buoy spliced to sturdy line that is in turn attached to the eye of an 18-inch long stainless steel rod embedded in the ocean floor. Dive or fishing boats simply tie up to the buoy instead of anchoring on the fragile bottom.

"The problem was how to make this idea workable and not too expensive," says Dr. Halas. "The U.S. Geological Survey Field Station that used to be on Fisher Island had a drill they used to get core samples from the bottom. We tried it out to drill holes in which we could install our steel rods and it worked very well. The first six moorings were placed in 1981 off French Reef in Key Largo. Of those original six, only one had to be reinstalled later, because it had been put too close to a ledge. Now there are 400-odd buoys overall in the Florida Keys."

"So far, maintenance has not been a problem. Lines have been cut by boats running over them, but amazingly enough, Hurricane Andrew had almost no effect on the moorings in the Keys," adds Halas.

Dr. Halas also experimented with different materials, settling on corrosion-resistant stainless steel for the eyes, UV-resistant polypropylene for the lines, and foam-filled polyethylene buoys (colored white with a blue stripe in South Florida, though the colors differ from country to country). "We tried using cable and chain for the lines, but often they would rotate around the eye and cause reef damage themselves. Plus, if a boat ran over a buoy, the cable or chain could damage the boat and props, while the polypropylene lines are less likely to do so. There is no hardware on the upper end of the moorings—the lines are spliced—which further reduces the chance of damaging a boat. And the lines float, making installation and usage easier."

In Search of Funding

The idea of permanent moorings over dive sites has traveled like a hurricane throughout the Keys, all over the Caribbean, and even to the South Pacific. In most of these places, divers and snorkelers noticed the reef damage and brought it to the attention of dive shops and governments. When reefs became more barren each year, divers abandoned traditional sites in search of virgin territory elsewhere, and dive operators felt the pinch. In some areas, moorings were purchased by the government. In others, such as the Bahamas, the dive operators and shops paid for them, since the government couldn't afford to.

Some programs are funded by environmental groups, such as Reef Relief in Florida, and the Nature

Conservancy in Palau. Hawaii has been moving towards a mooring project, but while the dive shops are all for it, the citizens and the government have dragged their feet. Not so in the British Virgin Islands, where officials recognized early on the need to protect their natural resources for touristic if not altruistic reasons. At least 120 moorages are installed now in the BVI, with a total of 250 planned. Dive site visitors must use the moorings or risk fines, confiscation, and/or imprisonment. They also must pay mooring fees, but these are reasonable.

Dr. Halas has given a lot of his time and brainpower to helping these projects get off the ground. "Someone will call up and say, I need 50 units,' and that's all they have to say," says Halas. "I can call a freight forwarder and have them shipped the next day."

The cost of the moorages varies, depending on how many will be installed, where the materials are obtained, and the difficulty of installation in a particular area. Reef Relief asks for a donation of $500, which it estimates is sufficient to cover materials, boat and equipment time, installation, and maintenance for about two years. Some Florida contractors can do the job for less; and of course, in most Caribbean nations lower labor costs can bring the price down considerably.

To Dr. Halas, the money and effort to install permanent moorings and keep them going are well spent. And while boat anchors are not the only threat to coral, these moorings will help heal the wounds in the reefs and restore the beauty of your favorite dive spot in the blue wilderness.

CRUISING WORLD,

Staying Power

by Tim Murphy

Old-school mooring dogma is facing strong challenges from recent entries into the permanent-anchor marketplace. Pitting the claims of these new anchors against those of the old standbys, CRUISING WORLD teamed up with the BOAT/U.S. Foundation to stage a pull test. Here's what we discovered.

In the wake of the last decade's headline-grabbing storms, mariners all along the coastline have been reevaluating traditional mooring systems. And with good reason: Grotesque images of beaches littered with broken hulls have flashed across our screens all too often. In New England, the name Padanarum sill evokes visions of GRP carnage three years after Hurricane Bob left 100 boats mangled and stranded along the shores of the Acushnet River in Massachusetts; throughout the region a total of 3,000 boats were said to have broken free from moorings in that storm.

And even if you didn't lose a boat to Bob or Andrew or Iniki, with each payment of your rising insurance premiums you are affected by a mooring that failed.

In response to these lessons, some innovative mooring alternatives have appeared in the last few years. To better understand today's field of permanent moorings, our editors joined forces with the BOAT/U.S. Foundation to stage a pull test that compared some newer mooring systems with more traditional mushrooms and blocks. We hired an 800-horsepower tug to pull on a variety of moorings in Newport, Rhode Island — some of which had been set long before we arrived, and others that were installed just prior to our test. With a strain gauge we measured the force it took to dislodge each mooring. But before we consider test results, let's examine the different kinds of available moorings and the conditions to which they're best suited.

Traditional Mooring Approaches

Any discussion of mooring systems begins with mud. A permanent mooring needs to be paired carefully with a single seabed (unlike a ship's anchor, which is typically chosen to hold in a wide range of bottom conditions). Ledge, boulder, gravel, coarse sand, fine sand, clay, silt, ooze: The gradation of bottom conditions is infinite, and each sediment poses its own anchoring problems. To simplify matters, engineers speak in terms of the particle size and the "cohesiveness" of a sediment — the degree to which it clings together. Clay is extremely cohesive, sand and silt are not. In the context of buried anchors, greater cohesion means better holding. Because several different bottom conditions exist within the confines of one cove, it's worth collecting a sediment sample at your particular site before selecting a mooring.

Permanent moorings fall into two categories: deadweight moorings and anchor moorings. Deadweight granite or concrete blocks (as well as old engines, railroad wheels and concrete-filled bathtubs), dominate in locales where ledge prevails and nothing short of underwater drilling will penetrate the bottom; here, it's simply a matter of pitting the mass and surface friction of the dead weight against the dynamic forces of wind and chop on the boat's profile. In choosing a mooring block, the material's density is critical because porous materials lose much of their weight under water. Concrete is popular because it is inexpensive, but it becomes 45 percent lighter under water, so an extremely large block is required to do the job. A general guideline for sizing concrete blocks is to allow between 100 and 200 pounds of block for every foot of boat length, depending on how high and beamy the boat is. Along the Maine coast, where ledge bottoms and cut granite are ubiquitous, denser granite blocks can be found at the ends of most mooring rodes. These lose 36 percent of their weight under water, but probably have the longest life span of any mooring. Steel and iron is denser still, losing 13 and 14 percent respectively. Some harbormasters use industrial-size counterweights as moorings. Any dead weight set in a soft bottom will create suction, adding to its holding capacity. If it's truly buried, so much the better.

In the second category, anchor moorings are meant to penetrate a bottom and hold through resistance. Traditionally, the most popular of these is the mushroom anchor. Typically comprised of a long steel shank joined to a broad iron bowl, mushrooms function best in soils that are soft enough to allow penetration, yet cohesive enough to prevent slippage. They do not work well in rock, gravel or coarse sand. When fully buried in a cohesive soil, a mushroom's holding capacity is estimated at 10 times its weight. Where conditions are ideal, mushrooms can be set simply by dropping them over the side and pulling on them in different directions with lots of power until they no longer move. Theoretically once they're in, mushrooms will continue to bury themselves. A more positive approach is to jet them in by blowing a hole in the bottom with forced water, but jetting is an expensive, time-consuming project. Also, jetting is not environmentally friendly, because it stirs up contaminants that have settled in the upper layers of sediment.

If a mushroom is not properly set, its estimated holding capacity drops to about twice its weight. Without inspecting the anchor visually there is no good way to know how well it is set. A further shortcoming of the mushroom is revealed when its long shank orients itself in line with prevailing winds. When storm winds change direction, as occurs when the eye of a hurricane passes overhead, the long lever arm of the shank tends to pull the mushroom out of the bottom. Also, the corrosive underwater environment eats away at a mushroom's narrow shank. Once it deteriorates the shank bends and the anchor becomes useless, as the bowl simply skips across the bottom without digging in. A 300-pound mushroom anchor retails for about $500; a 500-pounder, for about $800.

New Thinking In The Mooring Field

Two things have induced harbormasters and boat owners to rethink mooring systems in recent years. The first we've already alluded to: repeated instances of boats dragged up a beach by storms. The second is a growing awareness of the biological damage that anchors and chain inflict on delicate sea grasses, coral and other organisms in popular cruising destinations. A host of permanent, low-profile solutions have stepped up to greet these challenges.

At the more flexible end of the mooring spectrum is the Dor-Mor, a pyramid-shaped mooring of solid cast iron. A distant cousin of the mushroom in design, the Dor-Mor does not require professional installation or hydraulic tools to put it in place. The advantages of the pyramid are in its construction: For one thing, there are no dissimilar metals such as the mushroom's steel shank and iron bowl to cause galvanic corrosion. Furthermore, the large-diameter eye is built to withstand years of corrosion from immersion in salt water and acidic sediment. In terms of design, the advantages are debatable. Some experts feel that pound for pound the point loading of mushroom bowl's rim as the anchor lies on its side may offer a better grip than the Dor-Mor's linear edge, others feel the pyramid's downward-facing apex and linear edge offer an improvement over the mushroom. Like a mushroom, the Dor-Mor's optimum holding capacity is rated at 10 times its own weight; some towns such as Portsmouth, New Hampshire, and Newport, Rhode Island, that require mushroom anchors in local mooring fields make special allowances for the Dor-Mor. It is available in 10 sizes from 35 pounds to 2,000 pounds; a 500-pound Dor-Mor retails for $600, and the per-pound price decreases as the size increases.

The rest of the newer moorings we reviewed are called embedment anchors. In terms of initial holding power, each of these moorings outclasses the aforementioned systems by far. Furthermore, they each exert a very low-profile impact on the bottom environment. Two limitations of these systems, though, are that they have virtually no reset capability if they ever do break out of the bottom and they are very difficult to inspect one they've been installed. All of them require professional installation.

One of these is a helical mooring. Used successfully for decades in the construction industry to anchor retaining walls, telephone-pole guy wires and underwater pipelines, the helix only recently made its appearance on the boat-mooring scene. It is comprised of one or more steel helices of varying sizes welded to a shaft, then hot-dip galvanized. The size and number of helices for any given application is a function of bottom conditions rather than of the size of the boat that will hang on it after installation. The mooring is installed from a workboat using a torque motor with a capacity of at least 3,500 foot-pounds to screw the helix into the bottom. A gauge on the torque motor shows the installer how much power is required to drive in the helix into the earth. The manufacturers claim that holding capacity is directly proportional to the torque reading, but the degree to which the sediment is disturbed during installation would lower those projected numbers accordingly — at least until the soil settles again. One drawback of the helix system, as with those that follow, is that they require an almost absolute faith in the installer. If this kind of anchor works itself free due to poor installation, the design grants no holding power to fall back on. Also, over time it is necessary to check any mooring system for corrosion, whether from salt water near the mudline or from acids deeper down. On the helix it would be desirable, yet difficult, to inspect the weld between the disc and the shaft every couple of years.

One of the biggest advantages of this kind of system is that holding power is not a function of scope; the helix holds against extraordinary loads, even when those loads are exerted in a direct line with the anchor. Manufacturers rate the direct upward lifting capacity at "up to 25,000 pounds." It is still necessary to maintain ample scope to account for storm surges and to keep the loads on deck hardware and rodes at a reasonable level.

These moorings have been installed on a large scale in recent years in Rockland, Maine; Marion and Mattapoisett, Massachusetts; Atlantic Highlands near New York Harbor; and the Florida Keys. The harbormaster in Falmouth, Massachusetts, has gridded the entire harbor and installed 150 helix moorings. Helix moorings can be removed if necessary, but it is a difficult job and requires a diver.

The retail price for a double helix plus a mooring adapter is about $550. To get an idea of installation prices, the Mattapoisett Boatyard charges $250, plus $60 per hour for any installation exceeding one hour.

Another boat-mooring system that recently crossed over from the construction industry is the Manta Ray. (See Figure 1.) Originally based on a design to anchor

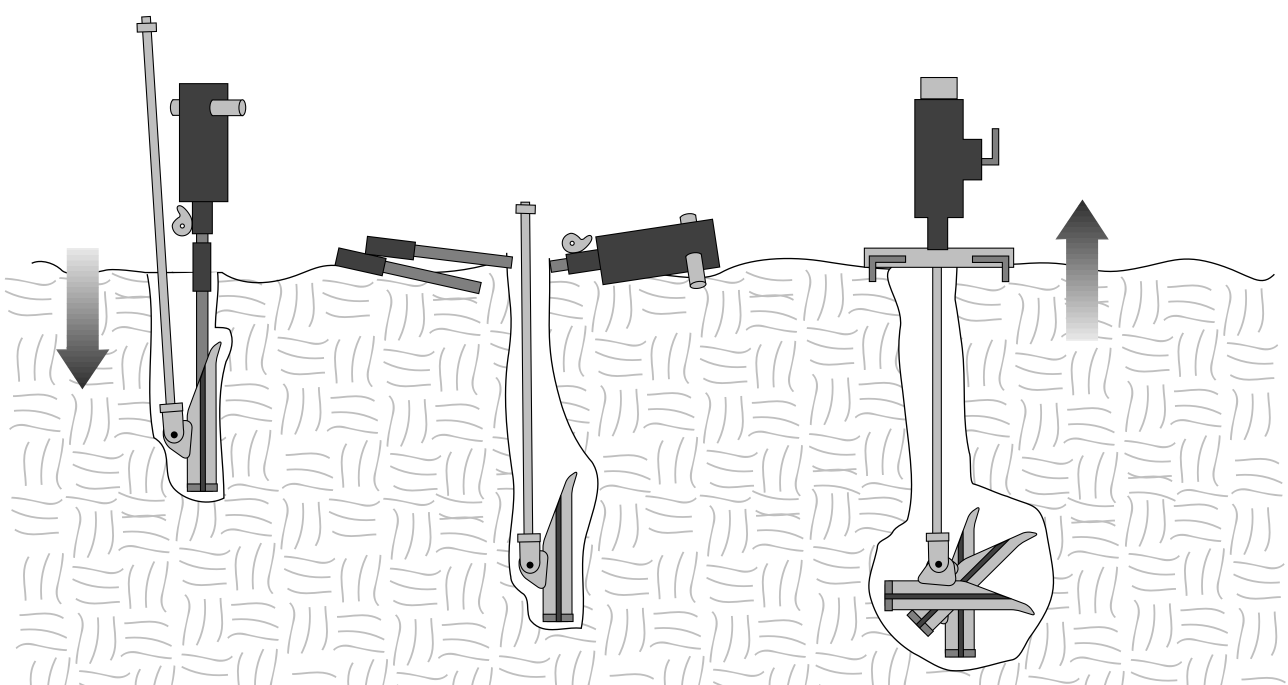

Figure 1

tower guy wires for the U.S. military, Foresight Products Inc. developed the Manta Ray to excel in difficult substrates such as sand and coral rubble. They are made of cast galvanized iron. Installation requires a diver with a 70- to 90-pound underwater jackhammer, plus a purpose-built device called a Load Locker. Once the diver has hammered the Manta Ray deep enough into the bottom, the hydraulic Load Locker exerts a high upward force on the mooring, which causes the anchor to pivot until it lies perpendicular to the rod. The force measured on the Load Locker is the actual upward force the anchor is holding, not a computed projection as with the helix. Like the helix, the Manta comes in different sizes to accommodate different bottom conditions. According to manufacturers' specs, the holding capacity of the largest Manta Ray anchor (called MR-SR) is "up to 30,000 pounds"; the MR-1 is rated at 20,000 pounds, but the manufacturers classify bottom conditions into eight distinct categories from solid bedrock to silt, and they rate holding power separately for each category. Those figures are available upon request from Foresight.

In order to protect reefs against the constant onslaught of anchors from transient boats, the Virgin Islands National Park in St. John has installed Manta Ray anchors where the bottom is coarse sand. To prevent single Mantas from lifting out of St. John's non-cohesive sand, the park installed mooring "triads," with each mooring comprised of three Mantas set 120 degrees apart. According to park officials, this has provided a "heavy-duty" result.

Critics cite the difficulty of removing the Manta Ray as a disadvantage of the system. One would want to inspect the joint where the shaft joins the anchor plate periodically for corrosion, but that's nearly impossible. The manufacturers suggest proof loading it periodically with the Load Locker to ensure that no components have rusted out.

The Manta Ray MR-SM anchor with a seven-foot anchor rod costs $130; the smaller MR-1 costs just over $100. Installation costs depend on the substrate. One diving firm in Michigan charges between $1,000 and $1,100 a day, and according to Foresight's Jeff Fisher they typically install between eight and 12 Mantas per day where conditions are satisfactory.

Another mooring system inspired by a wish to cut down on anchor damage to reefs was developed by a biologist named John Halas in association with the Florida Keys National Maine Sanctuary in Florida. The Halas system, as it has come to be known, is designed for solid ledge bottoms and is essentially comprised of an eyebolt cemented into the rock. Halas's plan calls for a diver to drill a hole into the bottom, four inches in diameter by 18 inches deep, with the aid of a hydraulic rotary wrench. In coral, which is relatively soft, this part of the job takes about a half hour; in granite, roughly three hours. The diver then places an 18-inch eyebolt with backing plate into the hole and cements it into place with underwater concrete. Recent modifications of the plan include using a smaller-diameter hole and U-bolts in lieu of eyebolts. To avoid the additional scourge of heavy chain on the bottom, polypropylene line runs directly from the eyebolt to the mooring buoy at the surface. The rode needs to be inspected often to make certain that it has not been damaged from ultraviolet light and errant propellers.

Since the system was pioneered in the mid 1980s, Halas moorings have been installed widely in the

Permanent Mooring Design Loads

LOA (feet)	Beam (feet)	Windspeed: 64 knots load in lbs.	Windspeed: 100 knots load in lbs.
10	4	720	1,500
15	5	1,130	2,500
20	7	1,630	3,600
25	8	2,220	5,000
30	9	3,170	7,000
35	10	4,080	9,000
40	11	5,440	12,000
50	13	7,250	16,000
60	15	9,060	20,000
70	17	10,000	24,000

To estimate the load that wind places on your boat, choose either the length or beam that corresponds to your boat, whichever renders the ligher load value.

Mushroom Anchor Sizes for Single-point Moorings

LOA – feet	Mushroom anchor weight – lbs. Racing sailboat and multihulls	Crusing sailboats
up to 15	100	100
20	100	150
25	150	200
35	200	250
45	300	400
55	400	600

Source: Sea Spike

Some harbor masters recommend larger mushrooms, using the formula boat length x beam x 1.5 = mushroom weight. By this standard a 30-foot boat with a 10-foot beam should have a 450-pound mushroom.

Florida Keys, Tortola, Jamaica and Hawaii. According to Phil Elliot, who has overseen the installation of 200 Halas moorings for the National Parks Trust in Tortola since 1989, only about a dozen moorings there have needed replacing. Most problems occurred where sailors did not use sufficient scope, allowing wave action to work the eyes out of their beds.

Because of bottom conditions and local regulations in Newport Harbor, we were not able to include the Halas mooring in our tests. Halas's own tests in Key Largo limestone have shown the system to withstand more than 20,000 pounds of strain without pulling out. Those loads did, however, begin to distort the eyebolts.

The Pull Test

In order to rate the manufacturers' claims, we felt that it was important to observe these newer designs in the real world and under strain. On hand for the test were representatives from Helix Mooring Systems, Foresight Products, Dor-Mor and the Hazelett Corporation (whose elastic mooring rode is described below), as well as two scientists from MIT and a marine surveyor for CIGNA Insurance. We leased a mechanical strain gauge that had up to 20,000 pounds so that we could measure the loads placed on each of the moorings by an 800-horsepower tug. In addition to our mechanical strain gauge, MIT's Norm Doelling recorded loads via an electronic gauge wired to a laptop computer. A diver observed each mooring before each test to ensure that it was suitably buried.

Theoretical test procedures called for all the moorings to be installed according to manufacturers' recommendations or local custom, to be set in similar soil and depth, using rodes of similar length and material. In reality, our conformance to these guidelines was less than perfect, due to the wide range of bottom conditions within Newport Harbor and gear breakage throughout the day. Still, the results were telling.

The first anchor we tested was a 650-pound Dor-Mor buried completely in soft ooze under 18 feet of water using 50 feet of steel cable (just under 3:1 scope). Dor-Mor literature claims a holding power of 10 times its weight with a scope of 3.5:1. The Dor-Mor initially pulled out under a load of 4,500 pounds. Norm Doelling's computer graphic shows that after the initial pullout, the Dor-Mor caught two more times, breaking out at 2,800 pounds, sliding for 20 seconds under 2,000 pounds of load then catching again at 2,200 pound. The tug's jerking motion on the inflexible cable probably caused the Dor-Mor to dislodge earlier than it would have with more scope and greater elasticity.

Next, we pulled on a helix that was installed four days before our test. Because the bottom in that part of the harbor was so soft, a 12-foot shaft with three disks, each 14 inches in diameter, was installed. The lower disks penetrated a denser layer of crushed shale. The installers hoped to achieve a torque of 1,000 foot-pounds for optimum holding, but the bottom was so soft that they reached only about 650 foot-pound. In the end, that was a moot point. The greatest drama of the day occurred as we watched the load on the mechanical strain gauge climb to 12,000 pounds. Suddenly, the entire gauge disappeared from view. A heavy shackle on one end of the gauge had let go; the equipment lay in countless bits and pieces at the tug's transom. The tug's engines were turning at 1,700 rpm when the gauge let go. We did not dislodge the helix.

We still had the Manta Ray, mushroom and concrete blocks to test, and without heavy-duty equipment, we were unable to measure extremely high loads. For the Manta Ray, we used Doelling's electronic equipment to measure loads up to about 7,500 pound. After that we disconnected the measuring equipment and ran the tug up to a sustained load at 1,700 rpm, the same that had been applied to the helix. The Manta was installed about five feet below the mudline in a bottom comprised of a foot of ooze over solid shale ledge. Installation required drilling into the shale. We did not dislodge it.

As for the mushroom, we pulled on a 500-pounder under 15 feet of water. Our diver reported that all the mushrooms in the vicinity of our test were half buried with the shank lying on the bottom in line with the prevailing southwesterlies. Clearly, this is not the ideal disposition of a mushroom, but it is in accordance with customary usage. According to the electronic gauge, the mushroom began sliding at about 1,200 pounds of strain and never caught again once it started moving.

Finally, we pulled on two different concrete blocks near Jamestown, Rhode Island, where the bottom is solid ledge. The first block weighted 2,000 pounds dry, or about 1,100 pound under water. With a 3:1 scope in 18 feet of water, the block moved at about 800 pound of strain. The other deadweight mooring was comprised of two 4,000-pound concrete blocks wired together. These moved when the strain reached 3,500 pounds.

Clearly, the embedment anchors are in a class of their own when it comes to holding power. One item

Suggested Sizes of Permanent Mooring Rode Components

Pennant size – inches Mushroom anchor weight – lbs	Light chain size – inches	Heavy chain size – inches	Rope diameter	Stainless cable diameter
200	1/4	1/2	5/8	7/32
300	5/16	5/8	3/4	1/4
400	3/8	3/4	7/8	5/16
600	7/16	7/8	1 1/16	3/8
800	1/2	1	1 1/4	7/16
1000	5/8	1 3/4	1 1/2	1/2
1200	5/8	1 1/4	1 5/8	9/16

From *Complete Book of Anchoring and Mooring,* second edition, by Earl R. Hinz. Copyright 1986, 1994 by Cornell Maritime Press, Inc. Used by permission.

Using adequate-sized components is only the first step; it is also imperative that chocks be oriented for mooring angles and that chafe gear be used and checked often.

our testing could not provide, though, was information about the life-span of the newer embedment anchors. The helix and the Manta Ray were introduced decades ago in shoreside construction applications, but only four or five years ago in a saltwater environment. Despite installers' claims of 25-year life-span, we simply will not know how these stand up to the marine environment without the passage of time.

Don't Overlook The Rode

Even with a mooring that will hold many times the strain a severe storm could put on your boat, it is critical to consider all the other parts of the system: chain, pennant, swivel, shackles, and deck hardware. The preponderance of moorings that failed in recent storms were due to parted rodes and broken deck hardware — with the final result just as disastrous as a dislodged anchor.

The question of rode begins with how much scope to put out. Of course, five to seven times the water's depth is ideal from the standpoint of holding capacity, but in popular harbors where hundreds of boats are crowded into a limited space, 7:1 just isn't practical. A traditional mooring arrangement, as recommended in Chapman's, calls for a scope of about 4:1, beginning with a length of heavy chain 1.5 times the maximum depth of water shackled to the anchor. A swivel at the other end connects the heavy chain to a light chain whose length equals the maximum depth of the water. At the surface, a buoy holds the light chain off the bottom. From the buoy to the boat's foredeck cleat runs a nylon line whose length is 2.5 times greater than the height from the water's surface to the boat's sheer line. If we take a 35-foot cruising sailboat for our example, the heavy chain should be one inch in diameter; the light chain, 3/8 inch; the nylon line, 1 1/2-inches. These are minimum recommendations; as such, they do not take into account the inevitable loss of mass after a few seasons in a corrosive environment.

The crucial design element in this system is the length of heavy chain, whose catenary provides the first defensive line of shock absorption in a blow.

This "traditional" arrangement has been challenged recently on a number of grounds. Take the nylon rode, for example. Experts agree on the desire for added elasticity in the mooring system to absorb the shock of a surging boat in stormy weather. Often this shock dislodges an otherwise adequately set anchor. But after a surprisingly high rate of parted nylon lines were found following Hurricane Gloria, the Sea Grant College Program at MIT embarked upon a study of different fiber-based ropes under strain. While the final paper was not yet published when this article went to press (it is due this month), the study found that many of the parted nylon lines failed not because of chafe against an external object, but because of internal abrasion among the individual fibers as the line stretched. For this reason, the study calls nylon "the worst material for mooring pennants."

Another problem with traditional mooring systems is the inevitable mixing of dissimilar metals. Anchors, chain, swivels, cotter pins — all these are likely to differ galvanically, and linking them together is a saltwater bath means that corrosion will be hard at work while your boat bobs peacefully on the surface. At the very least, this situation calls for a diligent eye and frequent inspections. Avoid using shackles whose pins do not thread securely into place; relying solely on a cotter pin that spends its whole life under water is a recipe for disaster.

One response to these drawbacks is truly postmodern: a bungee-cord rode. But don't laugh. Called the Hazelett elastic rode, it has been tested extensively on Lake Champlain, and many of the mooring experts who have witnessed it endorse the rode strongly. Mike Taylor, a surveyor for CIGNA Insurance who joined us for the pull test, said its biggest advantage is that it holds boats head to wind better than nylon, thereby alleviating some of the massive loads of a yawing boat as it swings beam to the wind in gusty storm conditions.

The elastic rode is made of a cast polyurethane blend, and comes in lengths from 15 feet up, in 10-foot increments. Bill Hazelett's eventual goal is to introduce a rode that eliminates all the metal links from the system — along with the attendant worries about galvanic corrosion. While the Hazelett elastic rode is not yet on the market, you can expect to see more of it in the coming seasons.

Mushroom and Block Moorings Have Been Used for Generations with Relative Success, So Why Rethink Moorings Now?

One answer is population growth. In storms a crowded harbor presents a much different scenario than does a secluded cove with a gently sloping shoreline. In a lonely cove, a mooring that becomes dislodged in high winds may dig in again as the boat drifts toward shore and scope increases; in a harbor full of boats, though, a little slippage means a lot of damage. Also, population growth has a high environmental impact.

Biologists and other careful observers have witnessed the beating that delicate bottom-dwelling organisms have already taken from the growing barrage of anchors and chain that are dropped on and dragged across them day after day.

Perhaps permanent, low-profile embedment anchors that remain right where you put them will have the best staying power in the end. But the real-world testing phase for them is not yet over. Lest we prematurely discard the old standbys on the basis of faults we know so intimately in favor of promising newcomers whose underwater life-span have not yet been measured. Keep a wary eye on new mooring possibilities.

Section IV

Management and Liability Considerations

Overview

In this section you will find detailed information regarding the management of mooring buoy systems in addition to information on legal responsibilities and liabilities of mooring buoys.

Contributions

van Breda, Anita and Gjerde, Kristina. "The Use of Mooring Buoys as a Management Tool, Management of Mooring Buoy Systems." Center for Marine Conservation.

Gjerde, Kristina M. "Mooring Buoys Legal Liability." Center for Marine Conservation, December 1991.

Contents

The Use of Mooring Buoys As A Management Tool

Management of Mooring Buoy Systems

by Anita van Breda and Kristina Gjerde

Introduction

Mooring buoys immediately benefit marine resource protection by reducing damage to the sea bottom caused by anchors and associated chain sweep. However, the effective use of mooring buoys as a resource protection tool involves more than installing as many moorings as possible in high use areas. The manager must develop and implement a comprehensive plan for long term mooring buoy management in order to meet the objective of resource protection. In developing a mooring buoy management plan, the manager should:

a) evaluate the current state of the resources, including use patterns and potential resource damage,

b) consider alternative resource protection options,

c) determine acceptable numbers and concentration of mooring buoys,

d) develop an education and outreach program,

e) establish enforcement, and

f) manage fund raising.

Resource Evaluation

The manager needs to consider all ecosystem components in planning for resource protection. Seagrass beds are an important component of reef ecology, and in many areas are an important food source for endangered sea turtles. Many seagrass beds surrounding coral areas are used as anchoring areas for visits to the reef or for protected overnight anchorage. Our anchor can damage an extensive area of seagrass beds by ripping large divots out of the bottom and scouring the bottom with chain as the boat swings. These sensitive sites should not be ignored when planning mooring buoy and anchoring guidelines.

The manager can use large-scale and small-scale surveying to determine boat traffic and potential resource damage. For example, aerial flights over a reef and associated seagrass beds can efficiently survey large areas to determine where boats typically concentrate. Aerial photos can be taken so that actual number and location of boats can be determined, which can isolate areas of concern. Aerial photographs taken on a periodic basis can serve as a permanent record of resource use.

Once a localized area of concern is identified, small-scale, individual boat surveys can determine the average number and size of boats anchored within the area. In order to plan the proper mooring system, the manager can design a simple boat survey to determine the average size and number of anchored boats typically found in a given location. Information from consistent and long term boat surveys can help the manager evaluate changes in visitation patterns and are therefore critical in the planning process.

Evaluating and measuring physical damage to coral reefs and seagrass beds is a difficult and inexact science. However, the manager can survey specific areas for an estimation of structural damage. In 1987, biologists at the Virgin Islands National Park surveyed park waters for anchor damage to coral reefs and seagrass beds; they determined that 46% of the 186 boats surveyed were damaging seagrass or coral (Rogers, 1988). Their report gives specific recommendations for monitoring and management of marine recreation areas.

Mapping the reef area can be of great assistance to the manager in planning resource protection. All information obtained from aerial or visual surveys should be recorded, and, if possible, maps of the marine communities should be generated. The manager can use a map as a guideline when planning mooring buoy installation. Maps can also be used for future comparison when evaluating resource protection needs.

Local commercial dive operators, tour group leaders, fishermen, and local conservation organizations can be helpful in assisting the manager with identifying areas in need of protection. These groups often have considerable experience on and in the water and can be a valuable source of local knowledge and expertise. In addition, local users are more likely to comply with mooring buoy regulations if they are included in the planning from the start.

Resource Protection Options

Once the patterns of actual and potential anchor damage are determined, the manager has a range of resource protection options to consider in deciding the proper level of protection and the proper number of buoys to be placed in order to reduce anchor damage. Management actions are not always implemented individually but often are sequential, building up the level of protection offered. These include:

1) Continue to document use patterns and associated damage to justify and support resource protection actions in the future if prevented from taking any manipulative action by limited funds, expertise, or ability to install a mooring buoy system.

2) Penalize boats causing anchor damage to coral or seagrass. In U.S. marine sanctuaries federal regulations penalize even minor damage to coral and seagrass. Adequate funding is required for enforcement.

3) Prohibit anchoring in coral and seagrass, permit anchoring to sand and mud areas only.

4) Develop a zoning plan. Zoning places minimal restrictions on visitors, but provides the manager options for protecting resources.

5) Rotate available mooring buoys. Although mooring buoys may eliminate anchor damage from boats, they do not eliminate damage caused by careless or inexperienced snorkelers and divers who routinely stand on, bump into, touch or break off coral.

Although cemented eyebolts are permanent fixtures, mooring lines and buoys can be removed and mooring buoy sites can be rotated. Therefore, if an area is suffering from overuse, a manager may decide to limit visitation for a period of recovery by removing the available mooring buoys, but only if enforcement is sufficient to prevent continued anchoring at the site. In U.S. marine protected areas, most boaters follow navigational aids and seem to prefer to use a mooring buoy rather than drop an anchor (boaters have been seen racing each other to get to a mooring) (Halas, 1985). In other countries however, mooring buoys are an unfamiliar concept and boaters avoid using them.

6) Enforce “no anchoring” regulations in mooring buoy areas.

7) Install marker buoys around reefs to warn boaters of navigation hazard.

Number and Concentration of Mooring Buoys

Visual Impact

A manger of shoreline bays will be faced with the visual impact of plastic floating buoys lining the horizon. Many tourists visit marine protected areas not for boating but for the scenic bays and beaches. Concentration of buoys in shoreline areas therefore can become an aesthetic problem the manager may need to consider.

Environmental Effects

In addition to aesthetics, the manager must consider the environmental effects of boat concentration in shallow shoreline areas that do not have good water circulation. Concentration of chemicals and pollutants in areas of poor flushing can affect local water quality and in turn damage shellfish and other marine life. Mooring buoys may also increase the use of an area, with associated impacts. The manager may want to describe the optimum ecological system and establish limits of acceptable change (Bjork, VI National Park, pers. Come. 1992). If those limits are exceeded, use must be decreased. Demand for moorings buoys is likely to increase with supply. Therefore, the manager will need to limit the number of mooring buoys installed in areas with a limited capacity for accommodating boats. If the manager needs to offer an area of safe anchorage to boaters but is limited in space, the use of bow and stern anchors can extend the capacity for the number of boats in a confined area (Gaythwaite, 1989).

Mooring Buoy Conflict of Use

Once mooring buoys are made available to the public, potential for conflicting uses develops. In small isolated areas with one or two commercial dive or tour operators and only an occasional boater or fisherman, conflicts will be minimal. However, in high-use, high-traffic areas conflicts may arise that the manager should anticipate. For example, in the Florida Keys mooring buoy users include: commercial dive operators, charter boats, private boats, commercial and recreational fishing boats, and glass bottom tour boats. Down lines often develop growth of marine life and build a small ecosystem which attracts fish. Many fisherman like to use these mooring buoys to catch bait fish. Commercial operators resent the removal of the very fish their customers pay to see. A serious problem arises when shark fisherman use moorings in close proximity to divers and snorkelers. To alleviate potential conflict, proposals have been made to install mooring buoys in deeper water specifically for fishing boasts, an example of how mooring buoys can be used to accommodate various needs.

Education and Communication

Objectives

Mooring buoy education programs should communicate two basic concepts: a) boaters should use mooring buoys to reduce anchor damage to sensitive and fragile marine resources b) moorings are used properly by following established guidelines.

a) Many boaters, unaware that coral is a living animal or that seagrass beds are an important component of reef ecology that deserve protection, will not know why they should use mooring buoys. Mooring buoy education programs, therefore, should include basic marine ecology. The education program should explain that anchor damage is an additional stress to a fragile marine ecosystem. Many coral reefs and seagrass beds are already threatened from natural causes such as hurricanes and other insults, including increased sedimentation from land-based development and pollution. The boater should understand that direct participation in protecting the reef is as simple as using a mooring buoy instead of anchoring.

b) Anchoring is a skill learned with experience, but even the experienced boater can save time and aggravation by the proper use of a mooring buoy. Although buoys are simple to use, boaters need to be informed of basic information, including:

1) Attach additional line to the pickup line, increasing scope and resiliency of the system.

2) Inspect the integrity of the system; do not use if the mooring does not appear secure.

3) Report any damaged buoys to authorities,

4) Contact local harbor masters or marine patrols (via radio if possible) if difficulties in using buoys arise.

Local Community Education

The education program should be directed not only at visitors to the park, but also at the local community. For example, many members of island communities do not swim, snorkel, or scuba dive, and as a result are not familiar with the underwater environment. Therefore, the manager should not be surprised that local politicians or decision makers are not aware of the vulnerability of the marine environment and the need for resource protection. Education programs should begin with informing the local community of the need for marine resource protection and the objectives of a mooring system. The education program should also provide for local community participation in planning the mooring buoy system. Mooring buoys can be an excellent way to involve communities and users in resource protection.

To insure communication of comprehensive and accurate information, the manger should consult a professional environmental educator when possible. However, simple guidelines can be followed when developing an education program for the mooring buoy system.

1) Present complete, concise, and simple information.

2) Include illustrations in any written communication.

3) Emphasize positive actions that can be taken rather than produce a long list of "do nots."

Communication Techniques

Written

A universal problem with education in marine protected areas is the visitor out on the water. Recreational trips that originate close to park facilities can be targets for educational programs. Local charter boat companies can be supplied with a one-page brochure for mooring buoy instruction to be distributed to their customers. Most charter companies are enthusiastic about encouraging their customers to use moorings as it offers better protection to their rental boats than relying on the anchoring skills of the captain.

Written material can range from a simple one page instruction handout to a full size color, water resistant, mooring and anchoring guide. Information should include:

1) how anchors cause damage and why use mooring buoys,

2) labeled diagram of the buoy system

3) instructions for proper use of mooring buoys,

4) instructions for safe and proper anchoring,

5) a map of buoy location and a description of the underwater features and available boater facilities if applicable,

6) rules and regulations for the conservation of marine communities, and

7) a list of user rights and responsibilities.

Boat Patrols

Written materials will not be effective if the information cannot be distributed to boaters. However, even if distribution is not a problem, it cannot be assumed that everyone will read the brochures. Therefore, a boat ranger patrolling the protected area for compliance with park resource protection regulations may be the best tool for educating visitors. For example, in the Florida Keys, marine sanctuary ranger duties include patrolling popular reefs for damage to coral and seagrass from anchoring. Every boat on a mooring saves the ranger time in checking for anchor damage. As a result, more of the rangers time is available for positive education rather than the negative enforcement associated with regulation violations (Causey, Florida Keys National Marine Sanctuary, pers. comm. 1991)."

Permanent Buoy Marking

A successful method of permanently attaching information and instructions directly to buoys has yet to be perfected. Although mooring buoys can be identified with spray paint or adhesive lettering, most marking will come off with wear or cleaning. Therefore, regular inspection and replacement of the marking system should be part of the scheduled maintenance program.

The Media

The manager should inform the media of mooring buoy development and planning. Many local newspapers, radio, and television stations will publish and air public service announcements free of charge. In addition, cruising and yachting guides are updated periodically. The manager should be sure to inform guide publishers of any changes to park features and regulations, including the addition of mooring buoys.

Videos shown on dive boats, charter planes, and at visitor centers and marinas are used to illustrate proper reef etiquette. Videos can also be used to illustrate proper use of mooring buoys.

The manger should review any videos, public service announcements, or press releases prior to distribution to insure the proper message is conveyed with accurate information.

Enforcement

Education and enforcement programs should develop together. The critical link for successful compliance with mooring buoy regulations is adequate funding, for regular boat patrols. Regulations should be clear and consistent and the enforcement officer should be prepared to serve as an extension of the education program. An effective education program will aid enforcement by encouraging proper use of mooring buoys and compliance with resource protection regulations.

Funding and User Fees

Several private, nonprofit, volunteer organizations have in consultation with a marine biologist, installed and maintained mooring buoys in marine protected areas. Mooring buoys can serve as a focus for fund-raising. Oceanwatch, a conservation group in south Florida, has an "adopt-a-mooring buoy" program to which individuals of businesses can donate funds for the purchase and installation of a mooring buoy. A piece of the drilled core sample is given to the sponsor, or the donor is acknowledged with a special marking on the buoy itself (Rubin, pers. comm. 1991).

The manager limited by funding and/or staff can collaborate with local and international nonprofit organizations to purchase and install mooring buoys for marine resource protection. For example, the Canadian government recently donated mooring buoy material and equipment to Hol Chan Marine Reserve in Belize. The moorings will be installed by reserve staff with assistance from volunteer divers (Azueta, 1990).

Fee/Donation Collection

Collecting fees and/or donations for the use of mooring buoys can be included in the management plan. Collection usually becomes a responsibility of the boat ranger or collection can be contracted to a concessionaire. The amount of the fee will depend on the type of use of the mooring. In some areas an overnight mooring requires a $10 fee. In areas where daily mooring buoy use is more common, boats are asked to donate $1 per person for each dive or snorkel. Collection of fees can be another opportunity for education and additional donation collection. Often, when visitors realize the nominal fee is applied to the maintenance of the buoys they will donate additional amounts to the program. Some dive operators may also be willing to solicit donations from their customers for installation and maintenance of mooring buoys.

Monitoring Mooring Buoy Systems

Every management action should be monitored for effectiveness. In addition for regular checks for buoy integrity the manager should also be concerned with the effect of the mooring buoy system to the protected area. A monitoring program can be designed to measure limits of acceptable change. Although it can be assumed that mooring buoys reduce anchor damage to an area, coral breakage may be increase by a change in the number of divers and snorkelers to the area. Efficient means of large area monitoring comparable to aerial photography in terrestrial ecosystems have not been developed yet (Kenchington, 1980). Nevertheless, the manger has several options for judging the effect over time of mooring buoys on the protected resource.

Although long term coral reef monitoring now occurs at several sites including the Dry Tortugas, United States Virgin Islands, and the British Virgin Islands, the concept of habitat monitoring is association with a mooring buoy system is in its infancy. Therefore, there is no preexisting formula or set of guidelines for biological monitoring areas. However, there are several monitoring methods that vary in comprehensiveness and cost that could be adapted for mooring areas. The manager can modify these methods to create a monitoring program which fulfills management needs within a limited budget.

Long-term monitoring of coral reef ecosystems requires expertise in marine biology. A monitoring system for mooring buoys, however, should be a relatively simple recording of the physical changes that occur in areas where mooring buoys are located. A mooring buoy system installed without a strategy for long-term monitoring, while better than nothing, has a limited role in an overall resource protection plan. A monitoring program requires a long-term commitment of personnel time and some financial expense. Therefore, managers should choose monitoring techniques that are appropriate and feasible within the resource protection plan. The manager should seek the assistance of a marine biologist or resource protection consultant for advice in establishing an initial monitoring program.

Management Approach

Crucial monitoring factors are comparison and replication. The manager should be able to compare changes in a system that has mooring buoys to a similar area that does not have mooring buoys. Change can be both positive (e.g., showing reef recovery post-mooring buoy) or negative (e.g., showing continuing or worsening decline). Therefore, the monitoring program should be initiated at both an equally used site and a site slated for use in the future but presently experiences little or no use. Unfortunately, many marine areas experience moderate or high levels of recreational or commercial use prior to designation of protected status and active management. Therefore, the possibility of beginning a monitoring program in a pristine area is not a reality for most managers. The manager may want to consider the use of a zoning scheme in order to maintain a relatively pristine section of the protected area as a control site.

Monitoring should begin as soon as possible. A period of baseline data collection is necessary to characterize each site prior to mooring buoy installation.

Site Selection

Since the monitoring is relative to mooring buoy use, site selection will be influenced by patterns of use. For example, dive operators often send their clients down the mooring line and gather them at the mooring anchor before beginning the tour. It follows that the mooring anchor becomes the area of most intense use, and that impact will decrease as the distance from the anchor increases. Saba Marine Park has taken that idea one step further. Specific high use reefs have been mapped out including the paths that dive tours generally follow; attention is then focused on the habitat along the path.

The manager may also choose to measure the recovery rate of an area that has received anchor damage in the past, but is now closed to visitation. A representative sample of the damaged area can be marked with permanent markers so that changes over time are measured consistently. Alternatively, an area now buoyed can be compared to an anchor zone.

Permanent Markers

Establishing permanent markers for the monitoring site is a common practice. The mooring buoy anchor pin can be used as one fixed point. Installation of additional permanent sites requires the drilling and/or hammering of either a reinforcement bar (´-inch) or survey stakes into the reef pavement. If drilling is required, two options exist. An individual may either use a hydraulic drill or a pneumatic drill attached to a scuba tank. Hydraulic drills provide far more power, and more options for bit or core size, but are not as portable. Pneumatic drills provide less power, are limited in bit size (´-inch chuck drill accommodates no larger than 5/8-inch bit), but are more portable and less costly then a hydraulic drill. However, if a hydraulic unit has been purchased to install moorings it can be easily adapted to install permanent pins. After the pins have been pounded into the reef it is may be necessary to epoxy or cement the pins in place. The pins should be numbered and a bearing/distance map constructed so that they are referenced to each other and the mooring anchors.

Specific techniques

Photographic

Video Photographs: Managers may discover that reproducible qualitative data may be suitable for mooring buoy monitoring programs. Qualitative information is primarily derived from videotape or photographs. Video transects are an attractive monitoring option because they can cover a sizable area at one time. Therefore, video can work well in creating a visual inventory of the state of mooring buoy habitats. For comparison purposes, the area should be videotaped prior to installing the mooring buoys; the same area should be periodically videotaped afterward.

Effective visual analysis requires that comparisons be made from replicate images of the same area. Reproducing the exact path, speed, and distance from the sea bottom of a video transect is difficult. Exact replication is not critical so long as the operator is consistent and covers the same relative area for each survey.

Still photographs: Still photographs can provide a much less expensive and more reproducible alternative to video monitoring and analysis. Still photos provide a basis for qualitative monitoring, and as with the video technique, still photography can be used to asses the relative changes to mooring buoy area. Photographs should be taken of the same area on a consistent basis. Individual coral heads can be tagged as a reference point for monitoring changes to the area.

Nonphotographic

Circular-radial Method: The Circular-radial method is adapted from a technique used to observe the presence of coral pathogens. It is a visual survey of a circular area searching for the presence or absence of a particular feature. For assessing the habitat surrounding a mooring area, instances of coral death, physical breakage, and damage would be of interest. The survey is conducted within a circle of fixed radius and center. A mooring could act as the fixed center for replication purposes. A diver ties on end of a line to the center and swims in any direction until the line is tight. The diver then moves the line clockwise, surveying the bottom which the line passes over for coral breaks, scars, or death. The survey is conducted one "pie wedge" at a time for a fixed interval. The number and types of damage encountered are tabulated and the manager can determine acceptable levels of impact. A damage magnitude scale can also be created by assigning a number representing degrees of impact (weighting), for example 1 through 5, for each observed disturbance. These figures can then be entered into a computer program suitable for resource evaluation. Although this method is more subjective, it may benefit management in the long term. A large area can be monitored effectively depending on the length of the radius (5-7 meters is reasonable). The cost of the method is minimal; equipment costs are limited to materials and personnel time.

Conclusion

Most marine park managers do not have unlimited budgets. Therefore, with assistance from a marine biologist, the manager should plan a system that is feasible given financial and time constraints. If a manager determines that a habitat which a mooring buoy serves is suffering unacceptable damage, then he or she should have the option of removing those moorings and deeming the area closed for a period of recovery. Again, this should be considered only if enforcement is sufficient to prevent anchor damage to the area.

Who does the monitoring should also be carefully considered. It may be useful to coordinate routine mooring buoy maintenance with an evaluation of the site, although many managers contract commercial dive operators to perform routine maintenance.

The Use of Mooring Buoys As A Management Tool

Legal Liabilities of Mooring Buoys

by Anita van Breda and Kristina Gjerde

Introduction

The goal of this section is to educate private organizations and government agencies about how to minimize their potential exposure to legal liability (responsibility) for claims for damages arising from use of mooring buoys.

There is no magic solution that can immunize an organization or a person from liability for irresponsible or unsafe actions. However, an organization can virtually eliminate its chances of unfairly being held responsible for injuries or property damage by using reasonable care and good judgment. Proper installation of mooring buoys and a well designed, implemented, and documented program of inspection and maintenance will go a long way toward establishing the use of "reasonable care" in mooring buoy projects. In short, if "reasonable care," good judgment, and several other steps are followed, all of which are described in fuller detail below, then it is quite likely that an organization will be able to avoid being held responsible for damages arising from use of such buoys.

Warning: This section is for your guidance only, and should not be relied on in any way to determine your course of action. Requirements vary with location and over time. You should always check with local counsel prior to any mooring buoy project.

Definitions

For the convenience of the nonlegal reader, some basic definitions of common legal terms are provided below. Other terms will be defined as the discussion proceeds.

Tort: from the Latin for "twisted", a tort is a private or civil wrong or injury, as opposed to a criminal wrong. All torts involve four elements: existence of a legal duty, breach of the duty, causation, and injury.

Legal liability refers to the responsibilities and duties between persons. When one becomes liable to another in tort, one becomes obligated to compensate that person for the loss or injury suffered.

Legal Duty: a legal duty can arise through a variety of means, indirectly as well as through an express agreement. When a person undertakes an activity, the person assumes the duty of assuring that such activity does not expose others to an unreasonable risk of harm.

Negligence occurs when a person's thoughtless or inattentive conduct injures another by creating unreasonable risks of harm. Negligent conduct may arise from active misconduct or passive inaction. A determination of negligent conduct is made by comparing the actor's actions against the conduct of a hypothetical ordinary, reasonable, and prudent person under like or similar circumstances.

Gross negligence borders on intentional conduct: it occurs when a person fails to use even slight care or omits to use ordinary care to avoid a discovered or apparent danger.

Reasonable care is generally defined as the conduct of an ordinary prudent person of like skill and experience under similar circumstances.

Proximate cause: to be held liable, it must be found that one's act or failure to act produced the injury, and that but for such action or inaction, the result would not have occurred.

Maritime law: Maritime or admiralty law is a body of law which particularly relates to ocean-going commerce and navigation, but also applies to other activities or events on navigable waters. Because mooring buoys are deployed in navigable waters, certain principles of maritime law may apply.

Legal Liability Under U.S. Law

Possible liability of providers

A legal duty of care (i.e., an obligation) to users of mooring buoys arises when providers of mooring buoys invite boaters to use them. To meet this legal duty, the party responsible for installing and maintaining mooring buoys (the "provider") must generally use that degree of care which a reasonable person would exercise under the circumstances to prevent unreasonable risks.

Although no cases in the United States have yet ruled on the standard of care required by providers of mooring buoys, a number of cases have discussed the standard of care applicable to those who install and maintain docks. The functional similarity between docks and mooring buoys (i.e., providing a vessel with a safe berth) suggests that the reasonable care standard for dock owners would probably apply to other mooring systems.

One who either installs or maintains a dock has to exercise reasonable care to ensure a safe berth to vessels. Dock owners have been held liable for failing to ensure that their facilities are properly constructed and maintained. Failure to provide evidence that the dock and its fittings were properly installed and its structural integrity regularly inspected led one court to declare that the dock owner had not established that it had exercised reasonable care. Similarly, failure to use accepted and proven designs in dock fittings has been held to indicate a failure to exercise reasonable care. Consequently, a private organization involved in a mooring buoy project would probably be liable for damage caused by a failure to exercise reasonable care to ensure that the system was properly constructed and maintained. As with private organizations, state and federal agencies involved in efforts to establish mooring systems are also required to exercise reasonable care and are exposed to the same risk of liability for engaging in these activities. This exposure results because under applicable federal laws, the federal government waives sovereign immunity if an agency's actions would give rise to liability in a private context. Many states have similar laws. Accordingly, if a private organization could be held liable for failing to exercise reasonable care in connection with installing or maintaining a mooring buoy, a federal agency involved in the identical activity would also be exposed to liability.

Possible means to avoid liability

Several possibilities exist to reduce the risk of liability for private organizations and government agencies involved in mooring system projects. It should be noted that none of the methods mentioned below, other than prevention through the exercise of reasonable care, are probably sufficient by themselves to eliminate all risks of liability. Instead, the methods are most effective when used in combination with one another.

A) Prevention

Prevention remains the best protection: conformity with widely-practiced (professional) standards of conduct and accepted standards of maintenance will help establish the conduct as that of a reasonable and prudent person.

To help establish that one's conduct is that of a reasonable and prudent person and thus reduce exposure to liability, a management program for the installation and maintenance of mooring buoys should make provision for the fulfillment of the following activities:

1) keeping the buoys, chains, ropes, and bottom fixtures in safe repair;

2) inspecting the buoys, chains, ropes, and bottom fixtures to discover hidden hazards;

3) removing hazards or warning of their presence;

4) anticipating foreseeable uses and activities by users and taking reasonable precautions to protect the user from foreseeable dangers; and

5) conducting operations on the water with reasonable care for the safety of all users and persons one can reasonably expect to be within the vicinity of a mooring buoy (e.g., other boaters, divers, snorkelers, and swimmers).

B) Warnings

Warnings may be necessary to ensure use of mooring buoys. Warnings may also be useful in establishing the standard of care expected of mooring buoy users. If adequate warnings are given, it can then be argued that the user failed to act as a reasonable prudent person if he or she failed to check the integrity of the buoy, its ropes, and bottom fittings soon after the vessel tied up.

The more knowledge the potential user of the buoy has, the more capable he or she is of taking the appropriate precautions. A user should be informed that moorings may work themselves loose from the bottom or ropes may break loose or become frayed for a number of reasons over which the provider has no control. For example, an extremely large or heavy vessel may decide to tie up to a buoy, causing excessive strain to be put on the buoy or its bottom fittings. Or vessels may decide to use the mooring buoys to wait out a severe storm, and the wind and waves similarly put excessive strain on the buoy fittings. A user should also be instructed as to the type and magnitude of harm that may befall both person and property from failure to inspect the buoy.

Historically, failure of the injured party to take reasonable care to prevent the accident was enough, if proven, to completely bar the injured party's claim for relief. However, most states, and all admiralty (maritime) proceedings, now favor an approach that weighs the negligence of both sides, and reduces the injured party's recovery proportionately to his or her fault. As a result, if a person is 50% at fault and has suffered $500,000 in damages, his or her recovery would be reduced by 50%, to $250,000.

Adequacy of warnings is generally an issue when warnings are relied upon to ensure safe use. They should be clearly visible, and convey sufficient information to ensure safe use of the buoy.

C) Disclaimers of liability

Disclaimers of responsibility for damage to vessels or persons caused by negligence of the installer or maintainer of the buoys may possibly reduce the risk of liability. Any disclaimer must provide notice to vessels using the mooring systems. For instance, a "use at your own risk; provider assumes no responsibility (even for negligence) for injuries or property damage resulting from use of the buoys" statement directly on a mooring buoy could be satisfactory. Statements to the same effect in pamphlets or on charts may also be helpful.

Courts, however, are generally hostile to disclaimers in contracts, especially where the activity or subject of disclaimer impacts on a public interest or policy. For example, courts have held invalid clauses disclaiming liability for injuries caused by negligence in leases for residential property and in contracts for the sale of used cars. On the other hand, courts have not found a public interest in protecting those who go to go-cart races or private swimming pools, and thus have enforced disclaimers of liability. A court's decision often hinges on whether the party seeking to disclaim liability provides an indispensable service that is not readily available elsewhere.

Whether the use of mooring buoys is an activity which impacts on a public interest or policy is unclear and has not yet been addressed by any courts. Where use of mooring buoys is mandatory, and not discretionary, a court will more likely find that the activity is in the public interest and hence declare disclaimers to be invalid (see Section D). But given that disclaimers might be effective, they should definitely be utilized though not relied on exclusively for eliminating the risk of liability.

It should also be noted that disclaimers will not relieve the responsible party for injuries caused by grossly negligent behavior.

D) Non-mandatory

Use Another method of reducing the risk of liability is to give vessel owners discretion over whether to use mooring systems. If a vessel owner "assumes the risk" of using a mooring buoy, then he or she may be barred from claiming that the supplier of the mooring buoy is responsible for his or her injuries.

Assumption of risk occurs when a party is aware of a danger and voluntary acquiesces to it. To constitute to a legally sufficient defense to a lawsuit, the defendant must establish that a party knew that the risk was present, understood the risk, and was given a choice to incur the risk or not. Posted notices or warnings my help establish the user's knowledge and understanding of the risk involved.

Assumption of risk may be complete defense to claim for damages, but is very difficult to prove. The defendant must establish that the plaintiff consented to the specific risk that caused the injury. Moreover, if the injured party acted unreasonably in assuming the risk, the defense fails and the injured party's behavior is viewed as negligent. Her or his damages may be reduced in proportion to their fault, but recovery will not be denied. Furthermore, if the injury is due to a grossly negligent act by the installer or maintainer, then the defense is invalid.

Where mooring buoy use is mandatory, as regulations within the Looe Key and Key Largo National Marine Sanctuaries currently require, it cannot be argued that a vessel owner "assumed the risk" of using a mooring buoy. A disclaimer of liability would similarly be declared invalid. A person cannot be said to have assumed the risk of injury when he or she had no alternative but to use the mooring system.

Because assumption of risk is a question of fact that the jury will decide based on the particular facts of each case, it cannot be relied upon as a sure defense. Nonetheless, so long as the use of the buoy is voluntary and not mandatory, it can at least be argued that the uninjured party "assumed the risk," and the liability of the installer or maintainer may possibly be reduced if not eliminated.

E) Statutory

Protection In some states, recreational land-use immunity statutes provide immunity from liability for injuries to the public when landowners open their property for public use (gross negligence or reckless are not, however, excused). The policy behind these statutes is to encourage private landowners to provide recreational areas to the public that the state would otherwise have to purchase and maintain.

It is unclear whether these statutes would apply to mooring system projects. It could be argued that the policy prompting immunity on land should apply in the case of a mooring buoy at sea. Mooring buoy projects also encourage safe public use of scarce recreational areas to at the same time as preventing damage to coral. Where a private group is involved in installing and maintaining buoys it is also saving scarce public revenues while promoting a public good, which also coincides with the policy of the state recreational land-use immunity statutes. Such a strategy, however, should not be relied upon to prevent liability as the question of the statute's applicability can only be decided after a lengthy court battle.

In states where mooring buoys are commonly used, private organizations may be advised to seek to have state legislatures enact a similar law directly applicable to mooring buoy systems. Even this measure, however, may not suffice, for maritime law in the United States is based on federal common law, and state law is only applicable to the extent it fills gaps left in federal maritime law. It may also be necessary to enact a similar law at the federal level. Safety considerations, and the protection of coral reefs from groundings that might occur if boats break loose from poorly installed or maintained buoys, may dictate against the adoption of a lower standard of care as a federal policy.

Legal Liability under English Law

Possible liability of providers

A person who undertakes to perform a task, even gratuitously, assumes a duty to act carefully in carrying it out. Consequently, when a party undertakes to supply buoys to the public they are placed under a duty to act carefully. If they do not act as reasonably competent providers and maintainers of mooring buoys they will be in breach of this duty.

The applicable standard of care is based according to the conduct of a reasonably competent person exercising and professing to have a particular skill. Again using the analogy of dock owners, but this time under English law, providers of mooring buoys must use reasonable care to ensure that the buoys are properly installed and maintained and safe for their intended use. Providers should be experts with knowledge as to both the nature of the buoy system (their necessary strength and durability and resistance to strong winds, storms and large waves) and to the maintenance required (the required amount of attention and frequency of inspection).

If a private organization fails to act as reasonably competent professionals and this causes boat owners and users to suffer injury or loss due to their use of mooring buoys, then the injured part will most likely be entitled to compensation through an award for damages.

Where a government body decides to make buoys available to the public, its officers and servants are placed under similar rules regarding liability. Thus servants and officers of a government body are placed under a duty to act carefully in carrying out its task. Where a public body employs an independent contractor to carry out the task of providing and maintaining the buoys, the public body must provide adequate oversight and funding to make sure the job is being carried out in a satisfactory manner. For example, the government body will still be under a duty to select a competent independent contractor, to provide adequate resources for installation and for continued inspection and maintenance, and to periodically inspect work records and evaluate performance.

Possible means to avoid liability

A) Prevention

As previously noted, that best way to avoid liability is for a person to take reasonable care to avoid acts or omissions which she or he can reasonably foresee would be likely to injure another.

When considering whether to take precautions, in the form of, for example, more thorough checks of buoys or providing components made out of stronger, more durable material, consideration should be taken of the magnitude of the risk of damage through not taking these precautions. This involves consideration and balancing of three factors: 1) the likelihood of the risk materializing; 2) the potential severity of the damage should it occur; and 3) the practicality of precautions. Practicality will inevitably be a powerful factor in determining which risks should be protected against and which should not.

If providers of mooring buoys fail to balance these considerations to the same extent as a reasonably competent professional in their position would do, they may be guilty of negligence. For example, providers of mooring buoys might be excused for not taking precautions which would involve enormous expense against an unlikely tidal wave even though the potential consequences of the damage caused by such a wave would be extremely serious. On the other hand, where the cost of eliminating a risk would be small and the likelihood of damage would be great, for example, where a frequent checking of the chains attaching the buoys to the seabed would prevent them from becoming loose and drifting away in everyday storms and winds, mooring buoy providers would be liable if they did not take such precautions.

Whether the mooring buoy provider acted reasonably in taking or not taking certain precautions in a given situation will be decided by the court based on the facts of each case. This balancing act is just another way to determine whether the defendant acted reasonably under the circumstances and did not subject the plaintiff to an unreasonable risk of harm.

B) Warnings

It may be necessary to give all potential mooring buoy users warnings of the steps necessary to ensure safe use of the buoys. Where unseen hazards exist that prevent safe use and notice of such hazard would enable a person to protect herself or himself against it, a duty to warn arises. Thus, if tieing up to mooring buoys is dangerous under any or all circumstances, and the user is theoretically able to take actions to avoid the danger, the provider of mooring buoys may have a legal duty to provide a adequate warning to all mooring buoy users.

The question most often debated in courts is whether the warning was sufficient to enable the injured party to be reasonably safe and thereby avoid the danger. The warning must at a minimum give an indication of the nature and location of the danger. It should further indicate a practical measure whereby a person can make himself or herself safe. For example, a notice warning that motor racing is dangerous but does not tell an observer that he or she can reduce his or her chances of injury by standing behind a barricade is insufficient. It fails to inform the observer to take measures to make himself or herself reasonably safe. Nevertheless, if an observer were injured while standing behind the barricade, the warning would have no effect at all.

A warning notice posted on a buoy might state, at a minimum, "Danger make sure that your boats are securely attached to buoys and inspect buoys for damage before use." If the boat owner or user or a reasonable person in their situation would possess the skill to undertake such an inspection, and to detect and amend any defect caused by storm damage to the buoy, then the notice provided would be sufficient to exclude liability, at least for the specific matter to which the notice relates. A court will take into account the practicalities of making such an inspection and might hold that due to the difficulty of making a thorough check while at sea a warning of this kind would not be enough to enable the boat owners to be reasonably safe.

C) Disclaimers of Liability

Notices on mooring buoys excluding liability for all accidents howsoever caused may be effective under certain circumstances. Except in instances of personal injury or death, English law allows a person to exclude or restrict liability for negligence, provided the term or notice satisfies the requirement of reasonableness. Liability for personal injury or death caused by negligence is expressly preserved by the Unfair Contract Terms Act of 1977, and thus may not be avoided.

Courts will closely scrutinize the disclaimer to determine whether it is fair and reasonable to allow reliance on it under the circumstances. Various factors are weighed in determining reasonableness:

1) the relative strength of the bargaining positions of the parties;

2) whether the customer received an "inducement" to agree to the terms or had an opportunity to enter into similar contracts with other people without accepting the term; and

3) whether the customer knew or ought to have known of the existence and extent of the term.

In the context of mooring buoys, a disclaimer of liability has more chance of being considered fair and reasonable under the following circumstances:

1) the boat owners or users have a choice as to whether or not to use the buoy; and

2) the mooring buoy provider takes reasonable steps to bring the disclaimer to the attention of buoy users through a warning written on the buoy, itself, by a written license or permit distributed to all buoy users, and by public announcement on the radio or in a newspaper.

If use of the buoys is compulsory, a court may be less willing to conclude that a disclaimer is reasonable since the injured party had no choice as to whether or not to use the buoy.

If these conditions are satisfied, mooring buoy providers may be able to exclude liability for physical damage to property and possibly pure economic loss by virtue of a disclaimer. Once again, such matters are decided based on the particular facts of each case, so it is not advisable to rely exclusively on disclaimers. They may, however, be useful in preventing minor incidents involving only property damage from turning into lawsuits. Such a notice might state that "all liability for negligence howsoever caused is excluded."

D) Non-mandatory

Use As under American law, if a vessel owner has discretion over whether to use mooring buoys, it may be possible to assert later that the injured party "assumed the risk" of using the buoy, and therefore should be denied compensation for resultant injuries.

Under English law, assumption of risk is referred to as "volenti non fit injuria", which means "that to which a person assents is not regarded in law as an injury." To establish that the injured party assumed the risk, two facts must be established:

1) the injured party willingly accepted the risks, and

2) the injured party had full knowledge of the nature and extent of those risks.

Where the injured party did not know of the risks, the defense is not available. Thus, prominently posted warnings and notices are key in establishing the injured party's level of knowledge. Boat owners and users should be made fully aware of the nature and extent of any risk they might incur when they attach their vessels to the buoys. A mere notice that "buoys are used at own risk" is probably not sufficient to impart this knowledge.

However, boat owners and user might well possess knowledge as to the dangers associated with buoys, the possibility of buoy deterioration arising from corrosion and damage from other boats and storms, and the consequent damage which could be incurred by boats that are attached to them. It is therefore possible that the boat owner may be held to have voluntarily assumed the risk that some damage might be caused to their vessel while attached to the buoys through some defect in the latter.

Where the injured party ought reasonably to have known of the risk, but did not, the defendant may nevertheless argue that the injured party was contributorily negligent, and therefore claim for damages should be reduced proportionately to the injured party's own fault.

An important exception is made under English law that is not made under U.S. law. Under English law, the assumption of risk defense is not available if the defendant has been negligent. Courts reason that one may take on the risks inherent in a dangerous activity but one does not willingly assume the risk of another person's negligence. For example, in a case dealing with car racing, the court stated that " if the organizers do everything that is reasonable, they are not liable if a racing car leaps the barriers and crashes into the crowd. But if the organizers fail to take reasonable precautions, they cannot exclude themselves from liability by invoking the doctrine of volenti non fit injuria for the simple reason that the person injured or killed does not willingly accept the risks arising from their want of reasonable care." Therefore, it is important for the mooring buoy provider to use reasonable care in the selection and maintenance of mooring buoys. It must be emphasized that the defense of volenti rarely succeeds. Courts are reluctant to deny the plaintiff any redress and may find contributory negligence a fairer way of resolving the situation.

Exercising Reasonable Care: A Three-part Duty

Based on the discussion of United States and English law regarding the responsibility of mooring buoy providers, a general principle becomes clear that is broadly applicable: the best method of reducing the risk of liability is for a private organization or government body involved in a mooring project to take precautions by exercising reasonable care and good judgment in their activities.

Parties involved in mooring systems will have exercised reasonable care when mooring buoys are properly installed and maintained, and the users adequately informed. Consequently, parties engaged in a mooring system project should exercise a three-part duty in order to provide the greatest protection against the risk of liability.

First, parties must be able to prove that their mooring buoys have been properly installed. Consequently, the installation of mooring buoys must be well documented. This should probably include, among other items, the type of buoy, the manufacturer, the serial number, who installed a given mooring buoy, and when and how it was emplaced. In addition, proven mooring designs should be used for these projects.

Second, parties must be able to show that their moorings are properly inspected and maintained. Therefore, parties involved in mooring buoy projects should design and implement programs to regularly inspect and maintain moorings which they have installed. These programs should also be well documented with information about who inspected the mooring buoys; when the inspection took place; notations on the condition of the mooring; recording of repairs; and taking the preventative steps of regularly changing the mooring chain, mooring line, and other hardware subject to corrosion.

Third, reasonable care should include the provision of warnings that are clear and detailed enough to allow boat owners and their users to use buoys in reasonable safety or at minimum, be made aware of the extent and nature of the risk involved. They should refer to the need for the user to inspect the integrity of buoy, its attachments, and bottom fittings whenever possible.

Although these efforts may place a burden on private organizations and government agencies involved in mooring projects, actions as outlined above would go far in proving that reasonable care had been exercised. Using due care is also the best way to avoid accidents and prevent injury. Creating confidence in the security of mooring buoys is an important element in encouraging boaters to use them, and this confidence is an essential element to achieve the ultimate goal of mooring buoy systems preventing damage to coral reefs and seagrass beds.

Section V

Case Studies of Mooring Buoy Programs

Overview

In this section you will find actual case studies of mooring programs. These studies will demonstrate the different techniques that are being used to install and manage moorings in various locations.

Contributions

Clark, Athline. “A Statewide Partnership for Reef Protection: Hawai’i’s Day-Use Mooring Program.”

Halas, John. “Advances in Environmental Mooring Technology.”

Ebanks, G.C. and Bush, P.G. “The Cayman Islands: A Case Study for the Establishment of Marine Conservation Legislation in Small Island Countries.” Center for Marine Conservation.

Showker, Kay. “Save Our Sea, The Cayman Islands Lead the Caribbean into an Era of Region-wide Marine Preservation.” *Caribbean Travel and Life,* November-December 1993.

Bryant, Marci. “Reefs at Risk: A Programme of Action.”

Danyliw, Norie Quintos. “Take Back the Reef.” *Caribbean Travel and Life.*

De Meyer, Kalli. “Channeling Revenues to Resource Protection”

Contents

A Statewide Partnership for Reef Protection: Hawai'i's Day-Use Mooring Program

Athline M. Clark
Coordinator of Volunteer Programs Hawai'i Department of Land and Natural Resources

Introduction

The following is a case study in a long-term commitment and critical partnership for ocean resource protection, which was initiated in Hawai'i by the dive operators. Using a technology developed elsewhere and modifying it to meet Hawai'i's unique environment conditions, a type of mooring was designed to eliminate anchor damage on Hawai'i's reefs. A partnership between researchers, federal and state regulatory agencies, and dive operators resulted in the establishment of a statewide day-use mooring program.

The mooring consists of a 5/8 inch stainless steel eye bolt about 18 inches long that is cemented into the reef substrate in a approximately one inch drilled hole. A mooring buoy and the associated tackle is attached to this eye bolt or pin once the cement has hardened and the buoy is placed about 10 feet below the surface. (See Figure 1.) The moorings are called day-use moorings because a 2.5 hour time limit is placed on their use and they are not designed for an overnight stay.

Background

Beginning in 1985, dive operators along the Kona coast on the island of Hawai'i, began to recognize that anchors being dropped continuously at favorite dive sites was beginning to have a detrimental effect on the coral. They went to the University of Hawai'i seeking answers on types of low impact mooring options that might exist to stop the anchor damage on the reefs. Dr. George Wilkinson from the Hawai'i Institute of Geophysics had just recently learned of a new type of eye bolt or pin technology that they had begun using on the reefs in the Florida Keys. This technology was designed by John Halas, Harold Hutson and Eugene Sinn and had been used successfully in the Keys since the early 1970s.

In Hawai'i, the process was initiated by the University of Hawai'i (UH) Sea Grant Extension Service, Hawai'i Institute of Geophysics and dive operators, to obtain the necessary permits to test the pin technology in volcanic substrate to determine holding power and feasibility of employing the system on the reefs. Initial testing was done on land and holding power was measured through several devices. The pin technology proved to be quite successful. In early 1987, the pins were placed experimentally in the reef substrate off Kailua-Kona pier to mark a swim lane, separating swimmers and boat traffic. Members of a newly formed ocean recreation organization, The Ocean Recreation Council of Hawai'i (TORCH) began lobbying the regulatory agencies to have these moorings installed statewide. The technology had proven to be successful both in Hawai'i and elsewhere and continued anchor damage was occurring on many of the reefs in heavily used dive locations.

Resource Degradation Example

Between 1981 and 1986 the tourism industry in Hawai'i grew at an astonishing rate. The commercial ocean recreation industry followed suit and grew at over 13% annually in gross revenues from $128 million in 1981 to about $270 million in 1986 (MacDonald and Markrich, 1992). In the early 1980s, Molokini Marine Life Conservation District (MLCD) at Molokini Shoal, located three miles off the coast of Maui, had no more than one or two boats visiting the reef daily. By 1987, over 35 boats, some with capacities for over 100 passengers, were visiting the Molokini MLCD daily. Anchor damage on the reef was clearly visible from the constant dropping of large anchors and the associated damage caused by chains dragging across the bottom.

Boats would drop anchor in a deep sand patch and back down close into the shallow reef area against the wall of the volcanic crater that formed the shoal. In addition to the concerns expressed by the commercial operators over degradation to the resource, boat captains were concerned about the possibility of crushing a tourist between boat hulls. The industry began a lobbying campaign to have both bow moorings placed in the sand patches to stop anchor damage and pins placed in the crater walls to tie the sterns of the vessels off and eliminate the potential of crushing a snorkeler.

Due in a large part to the safety concerns expressed by the commercial operators working in concert with the regulatory agencies, a permit to install both cement blocks as bow moorings and eye bolts as pin

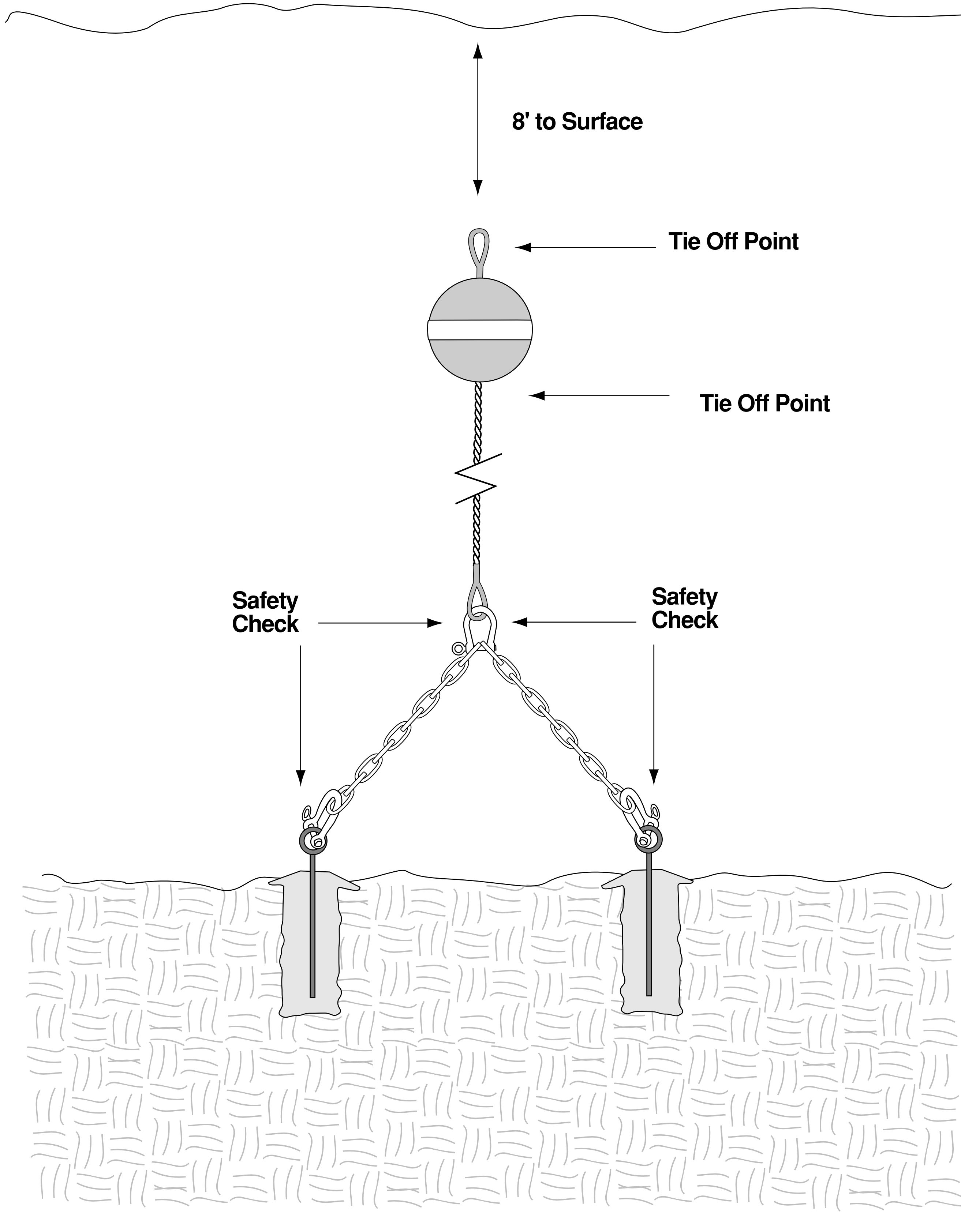
8' to Surface
Tie Off Point
Tie Off Point
Safety Check
Safety Check

Figure 1

stern moorings was rapidly approved and the moorings installed in less than a year. During this time, a Day-use Mooring Advisory Committee made up of both federal and state regulatory agencies, TORCH, UH Sea Grant and others was also established to review and advise on the installation and management of the moorings (Table 1).

Regulatory/Industry Stalemate

Although the ocean recreation industry had been lobbying to install the pin technology in several locations, Molokini was the only site they were able to obtain a permit to use the eye bolts. As indicated previously, safety concerns assisted in expediting this permit. In all other locations where the moorings were desired, it seemed nearly impossible to get the regulatory agencies to begin the permit process. The main problem was that the state agency tasked with granting the permit for the buoy was not the same agency tasked with granting approval for anchoring the pin. Neither agency seemed to be willing to begin the process without the permission of the other. In addition to state permits, an environmental assessment had to be approved and a general permit needed to be obtained from the US Army Corps of Engineers.

Industry took matters into their own hands in late 1988 and began installing the pins along the Kona coast without the permits. They had obtained a $10,000 grant from the rock and roll band the Grateful Dead to finance the initial installations and with many operators and much secrecy, began putting in the eye bolts. Forty six sets of pins were installed, although no tackle or buoys were attached.

A new foundation, the Malama Kai Foundation was formed during this installation period to assist in additional fund raising efforts. TORCH had discovered that because they lobbied, they could not offer non profit tax breaks to individuals or organizations that donated to the moorings. To rectify this situation, members of TORCH worked with community members to form a partnership for fund raising.

For almost two years, the industry used the pins without any buoys successfully, diving down and attaching their vessels directly to the pins, in some locations. Unfortunately, a newspaper reporter who was also an avid diver finally published an article on the pins in Kona in late 1989. As the pins had not been permitted, the diver operators had in fact broken the law and prosecution proceedings were initiated. As the installation process had been a community endeavor, with no one person in charge, the community all became involved and no one person could be identified as the main perpetrator. It became a political nightmare for all sides, even Jerry Garcia from the Grateful Dead came to Hawai'i to testify. The Hawai'i State Legislature finally took matters into their own hands and passed a Bill mandating that the issue be resolved and that the dive operators be allowed to use the moorings.

During that same legislative session, the agency with responsibility for the buoys was transferred into the agency that had responsibility over the substrate so that permits for activities such as moorings could be better managed. The Department of Transportation's Boating Branch was transferred to the Department of Land and Natural Resources (DLNR) and became the Division of Boating and Ocean Recreation (DOBOR). They willingly stepped up to the plate and assumed regulatory responsibility for the moorings. More importantly, they also assumed the liability, but requested that the commercial operators using the moorings keep records of their use.

Statewide Day-Use Mooring Program

Between 1986 and 1992, the ocean recreation industry continued growing at a phenomenal rate. Annual gross revenues grew by an average of 17% during this time frame. The value of the industry grew from about $270 million in 1986 to $560 million in 1992. The number of businesses also increased substantially. This growth increased the risk of ocean and coastal resources being overused, degraded and ultimately made unattractive to the very users that made up the market (MacDonald and Markrich, 1992). One of the top priorities continually expressed by the industry was the need to implement a day-use mooring program statewide.

In December 1992, a statewide conference was held which was sponsored by the UH Sea Grant Extension Service, TORCH and the Department of Business, Economic Development and Tourism (DBEDT), Ocean Resources Branch (ORB). Experts in the installation, use and management of day-use moorings for the Florida Keys, and the Caribbean were invited to participate and share their experiences on day-use mooring systems elsewhere. All regulatory agencies (both federal and state) which would need to review the permits were also invited to attend. Community and commercial ocean recreation participants were asked to bring their list of desired sites statewide.

The all day conference was held on Oahu and shortened versions were also held in Maui and Kona, Hawai'i. The end results of the conference were: 1) general agreement among all participants including the regulatory agencies that the moorings were needed and permits for installation should proceed, 2) DLNR's Division of Boating and Ocean Recreation reiterated their commitment to assuming liability and regulatory authority for the moorings, 3) 270 sites were identified and agreed upon statewide for inclusion in the day-use mooring program, and 4) a new type of technology was introduced by John Halas of the Florida Keys for use in soft substrate.

DBEDT's Ocean Resources Branch and the UH Sea Grant Extension Service worked with DLNR's DOBOR to write the environmental assessment for the moorings. TORCH provided latitude/longitude positions for each site, summarized substrate types in each location and worked with the community to rank use at each of the sites (Table 2 and 3). All this information was also reviewed by the Day-use Mooring Advisory Committee before final submittal for the permits.

Unfortunately, due to significant turn over in staff, it took a year and a half to obtain the general permit from the Army Corp of Engineers. During this time, TORCH members took turns calling the regulatory agencies and requesting information on the status of the permit. Because of the familiarity that all the regulatory agencies had with the benefits provided by the moorings, there was not significant changes requested, nor requests for additional information required, so actual processing of the permit was expedited, once the processing began. Additionally, most of the agencies which had to review the permits either had been to the workshop or sat on the advisory committee for the moorings.

At the same time the permits were going through the review stages, TORCH, the UH Sea Grant Extension Service and DBEDT's ORB, brought John Halas back to Hawaii to run an installation training at Molokini. Because Molokini already had permits, the new technology which Halas had introduced at the workshop for soft substrate was able to be installed on an experimental basis and additional eye bolts were installed along the crater wall. Dive operators from each island, through TORCH, sent divers to participate in the training. Five Manta Ray anchors (See Figure 2.) and 20 additional pins were installed during the three day training session. The new Manta Ray anchors will eventually be used to replace the cement blocks that were installed in 1988 as bow moorings.

Current Status

In September of 1995, final permits and approvals for the moorings were granted. The US Army Corps general permit also provided for a shortened process to add additional mooring sites that may be needed. The US Army Corps permit also required that a monitoring program be developed for the day-use moorings. Again, the Day-Use Mooring Advisory Committee with assistance from the University of Hawaii's Marine Option Program developed monitoring protocols and submitted them for approval. Since use monitoring of the initial Kona mooring sites had been requested by DLNR, a data base already existed for installation and use monitoring. Date sheets were designed to record installation and use of the moorings (table 4 and 5). An additional data sheet and data base were established to track maintenance of the moorings. (Table 6).

Underwater survey protocols were also developed for pin and control locations to be surveyed. Two representative sites on Oahu, Maui, along the Kona coast and one on Lanai were chosen for the monitoring surveys. ORB provided the funds for the first year of monitoring. Subsequent funds for monitoring will need to be obtained creatively. As moorings were installed at the chosen study sites, underwater baseline transects were completed at 10.25 meter

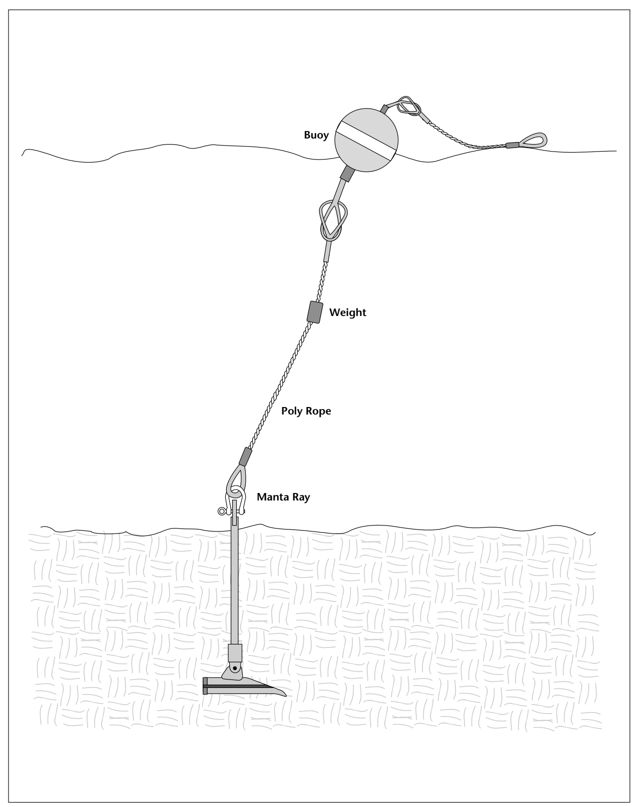

Figure 2

quadrant sites along a 100 meter transect line. Sites will be surveyed quarterly to assess change.

In addition to obtaining permits, a fund raising strategy had to be developed to raise funds for the moorings, since all funds to purchase the equipment and install the moorings would have to be raised through private donations. An Adopt-A-Buoy program was developed as a partnership between the Malama Kai Foundation and DLNR. Adoption certificates were designed (See Figure 3) and a perpetual recognition board was developed which will be hung in the DLNR visitor center to recognize all contributors who donate $500 or more.

Rules regulating the use of the day-use moorings were also drafted and adopted. Informational meetings had to be scheduled with the dive operators using each of the geographically distinct mooring locations to inform them of: 1) fund raising needs, boat, equipment and diver needs to assist in the installations, 2) to obtain general agreement among all operators on the locations for each of the eye bolts, 3) to inform them of the rules regulating the use of the mooring, in order to ensure they understood that the moorings were installed for all to use on a first come first served basis, 4) to ask for their assistance in filling out the use monitoring data once the pins were installed, and 5) to explain the process by which the mooring sites were chosen and how to add additional sites to the permitted list.

Since the permits were approved in September, 1995 much has happened to begin the installations of the day-use moorings. The first five of the 270 moorings were installed in December, 1995 off Waikiki through a generous donation from Atlantis Adventures, Inc. Weather and wave conditions, plus the need to raise additional funds stalled any additional installations until the Spring of 1996. Since that time, 15 moorings have been installed in Waianae off Oahu, 10 have been installed along the Kona coast, and Maui/Lanai are about to begin the installations of 40 moorings. By the end of the summer almost all Oahu moorings will have been installed, and the urgent sites along the coasts of Hawai'i, Maui and Lanai will have moorings.

Special Considerations

One of the key tools needed to install the moorings is a hydraulic drill and the associated power unit. When the permits were granted, only one such drill was available statewide to use for installations. This was anticipated to make the logistics for installing moorings much more cumbersome. On Oahu, a researcher at the UH Hawai'i Institute of Geophysics stepped up to assist. Malama Kai Foundation funded the purchase of an additional core bit and he provided the core drill and power unit to drill the holes with the understanding that he was able to keep all the core samples for his research. He will obtain over 30 additional core samples for his research in exchange for drilling all the holes for the eye bolts.

In Maui County over 120 moorings need to be installed in Molokini MLCD, and the waters of Maui and Lanai. There was no drill available to initiate this process and one of the larger ocean recreation companies, offered to purchase the drill and power unit for the Maui installations. Installations are scheduled to begin later this summer. Molokini MLCD is one of the high priority sites for Maui.

Written the past six months, a new management strategy has been implemented for this resource and a cap has been placed on the number of boats allowed to operate at Molokini. Forty one permits have been granted and now that a stable number of boats is operating out of this resource, a new mooring plan, which replaces the cement bow moorings and adds additional moorings, is being designed and will soon be implemented.

Although most of the mooring sites chosen were located in favorite dive sites, some are also sites where other types of activities such as surfing during periods of high swells occur. In locations where conflicts may occur, it has been necessary to meet with members of all affected ocean recreation constituent groups to work out arrangements that are acceptable to all parties concerned. Without these agreements, the moorings would constantly be cut and of no use to anyone. In one site, agreements had to be worked out on the times of year the pins would have buoys and when the buoys needed to be removed so surfers would not get caught in the buoys with their surf board skegs. At other locations, the moorings were modified so no buoy was used but the dive operators could still use the site. In one location close to shore, complaints of too much use by a large catamaran on weekends dropping over 50 snorkelers in the water next to a heavily used family beach resulted in a negotiated settlement where the operator does not use that location on weekends.

Summary

Overall, it is because of the recognition all parties have about the ability for the moorings to decrease anchor damage and the associated benefits this affords the reef ecosystems that has resulted in the kinds of support and compromises being reached that have occurred thus far in the program. Because the regulatory agencies and the ocean users formed an advisory committee early in the process and worked together to develop the permit application, monitoring procedures, etc. there were no major road blocks to obtaining the permits and approvals needed. Since it was not a priority project for many of the regulatory agencies, it may have taken longer than anticipated but the ocean recreation industry never gave up and continued to call and lobby for the approvals throughout the process. Internal regulatory acceptance combined with outside pressure to expedite the permits played a critical role in establishing the statewide day-use mooring program.

Although not legally acceptable, taking matters into their own hands and installing moorings created the political focus to finally achieve what several years of lobbying was unable to do, obtain permission and initiate the process to establish moorings statewide. The fact that the process is driven by volunteers, all installations and, thus far, all maintenance has been done by volunteers, and funding is through mainly private donations, the state has had to invest very little to establish a system for resource protection statewide. By the state accepting the liability and regulatory responsibility for the day-use moorings, the ocean recreation industry can develop a system that benefits them while also eliminating the resource degradation.

Most ocean recreation businesses realize the importance of protecting ocean resources to sustain their businesses. When government and user groups create partnerships for resource protection and work together to develop technologies that support resource sustainability, it is everyone's gain.

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Hawaii's Day-use Mooring Advisory Committee

Department of Land and Natural Resources

- Division of Boating and Ocean Recreation
- Division of Aquatic Resources
- Volunteer Programs Coordinator

Department of Business, Economic Development and Tourism

- Ocean Resources Branch

University of Hawai'i

- Sea Grant Extension Service
- Marine Option Program
- National Maine Fisheries Service
- The Ocean Recreation Council of Hawai'i (TORCH)

Table 1

Table 2

PROPOSED MAUI COUNTY DAY-USE MOORING PIN LOCATIONS

No.	SITE NAME	LATITUDE	LONGITUDE	DEPTH	BOTTON CONDITION	NOTES
1	Turtle Haven 1	20-49.90 N	156-48.50 W	30’	50/50% Lava Rock w/Sand Channels	Lanai
2	Turtle Haven 2	20-49.90 N	156-48.50 W	30’	50/50% Lava Rock w/Sand Channels	Lanai
3	Sargent Minor	20-45.263 N	156-50.772 W	50’	60/40% Lava Rock w/Sand Channels	Lanai
4	Sargent Major 1	20-45.282 N	156-50.715 W	50’	60/40% Lava Rock w/Sand Channels	Lanai
5	Sargent Major 2	20-45.282 N	156-50.715 W	50’	60/40% Lava Rock w/Sand Channels	Lanai
6	Armchair 1	20-45.043 N	156-50.887 W	30’-40’	75/25% Lava Rock w/Sand Channels	Lanai
7	Armchair 2	20-45.043 N	156-50.887 W	30’-40’	60/40% Lava Rock w/Sand Channels	Lanai
8	Armchair 3	20-45.043 N	156-50.887 W	30’-40’	60/40% Lava Rock w/Sand Channels	Lanai
9	Fish Rock 1	20-44.409 N	156-52.729 W	50’	80/20% Lava Rock w/Sand Channels	Lanai
10	Fish Rock 2	20-44.409 N	156-52.729 W	50’	80/20% Lava Rock w/Sand Channels	Lanai
11	Outside Manele	20-44.476 N	156-53.140 W	30’	60/40% Lava Rock w/Sand Channels	Lanai

Table 3

PROPOSED MAUI COUNTY DAY-USE MOORING PIN LOCATIONS

		FREQUENCY OF USE							INSTALLATION URGENCY			
No.	SITE NAME	once a month	2-3 times a month	once a week	2-3 times a week	4-6 times a week	once a day	2 or more times a day	Urgent	High	Medium	Low
1	Turtle Haven											
2	Sargent Minor											
3	Sargent Major 1											
4	Sargent Major 2											
5	Armchair 1											
6	Armchair 2											
7	Armchair 3											
8	Fish Rock 1											
9	Fish Rock 2											
10	Outside Manele											
11	Cattle Chute											
12	First Cathedral 1											

HAWAII DAY-USE MOORINGS MONITORING PROGRAM
SITE DATA AND BUOY INSTALLATION FORM

BUOY LOCATION

- ISLAND (check one)
  ☐ Kauai ☐ Oahu ☐ Maui ☐ Lanai ☐ Big Island
- Zone (pending DOBOR designation)
- Tax Map District (office use only)
- Site Name (example: Black Point)
- Buoy Number at Site (example: 4)

BUOY PARTS (check one each)

- Buoy Type ☐ Surface ☐ Subsurface
- Riser Line ☐ Nylon ☐ Polypro ☐ Other
  Line Diameter (inches)
  Remarks
- Bridle ☐ N/A ☐ Chain ☐ Cable ☐ Other
  Remarks
- Mooring type ☐ Single Pin ☐ Double Pin
  ☐ Manta ☐ U-bolt ☐ Block
- Stern Pin(s) (check one) ☐ 1-pin ☐ 2-pin

ADDITIONAL SITE INFORMATION

- How to get to the site (describe)
- Site Attractions (describe)
- Other Comments

INSTALLATION DATA

- Date Installed
- Team Leader
- Pin Depth (feet)
- Description of bottom 50 feet around pin
  (Bottom type and percent of cover, e.g. live coral 15%)
- Threatened/endangered species (check any seen)
  ☐ Green Sea Turtle
  ☐ Loggerhead Turtle
  ☐ Leatherback Turtle
  ☐ Monk Seal
  ☐ Humpback Whale
  ☐ Others

SITE COORDINATES

- Latitude (eg. N 020° 06′ 81″)
- Longitude (eg. W 155° 53′ 20″)

1 Shore Reference 1 (eg. 170° on Pt.)

1 Distance 1 (eg. 350 yards)

2 Shore Reference 2

2 Distance 2

3 Shore Reference 3

3 Distance 3

Send completed form to the proper state, county or city department.

Table 4

HAWAII DAY-USE MOORINGS MONITORING PROGRAM
DAILY USE LOG

Page ______ of ______

Island ☐ Kauai ☐ Oahu ☐ Maui ☐ Lanai ☐ Molokai ☐ Big Island

Boat Name ____________________ Company Name ____________________

For Month/Year ____________________

DATE	SITE NAME	BUOY NO.	HOOKUP TIME (military)	NO. OF SCUBA DIVERS	NO. OF SNORKELERS	REMARKS (Repair needed, threatened or endangered species, unusual conditions, etc.)
2/22	*Opti Cove*	*1*	*0930*	*14*	*2*	*Line frayed – replacement*

NOTE: Under *Remarks* describe unusual water or weather conditions, need for repair or maintenance and any sightings of threatened or endangered marine species.

Send completed form to the proper state, county or city department.

Table 5

HAWAII DAY-USE MOORINGS MONITORING PROGRAM
MAINTENANCE FORM

Date of Maintenance Action:		
Island:	Site Name:	Buoy Number:
Items Replaced: (describe all parts which were replaced)		
New Parts: (describe new parts)		

EXPENSES		PAID ITEMS	DONATED ITEMS
Boat Time (______hours@ $_____/hour			
Labor (______hours@ $_____/hour			
New Parts (itemize) 1. 2. 3. 4.	Cost		
Other Items	Cost		
TOTALS			

COMMENTS *(note anything remarkable about maintenance action, new technique or procedure and recommendations for future design or maintenance)*

Form Completed by ________________________________ Date ____________________

Daytime Phone ____________________________________

Send completed form to the proper state, county or city department.

Table 6

Certificate of Adoption

State of Hawaii
and Malama Kai Foundation
Adopt-a-Buoy Program

The State of Hawaii and the Malama Kai Foundation appreciate and congratulate

____

for their generous donation to adopt a buoy located at

____-____.____ N Latitude and ____-____.____ W Longitude

off the island of ________________________.

Michael D. Wilson, Chairperson	*Carolyn Stewart, President*
Board of Land and Natural Resources	*Malama Kai Foundation*

Figure 3

Advances in Environmental Mooring Technology

J.C. Halas
Florida Keys National Marine Sanctuary
P.O. Box 1083
Key Largo, Florida 33037, U.S.A.

Abstract

The use of environmentally sensitive moorings as a means to reduce or eliminate anchor damage has become a widely accepted tool for managing the coral reef environment. Mooring buoy technology has advanced to adapt to the variety of coral reef habitats found around the world. The original limestone embedment mooring eye technique has been modified to accommodate harder volcanic and granite substrates by using high strength epoxy and smaller drill hole sizes. In soft sand, and rubble and grass environments, a deep hydraulically driven anchor rod with a perpendicular resistant plate or helical screw is used to attain sufficient holding power. Large or multiple embedment anchors have been developed with stronger systems to accommodate larger vessels with greater holding power requirements. Extreme tidal ranges, steep slopes, and shallow-sand-covered hard bedrock are challenges for mooring buoy establishment.

Introduction

Since the early 1970s, when dive shop owner Captain Don Stewart first set concrete-filled steel drums on the reefs of Bonaire, Netherlands Antilles in order to secure mooring buoys, anchor damage has been recognized as a negative impact to coral reefs (Stewart pers. com.). The Bonaire system sacrificed a confined area around the mooring point but avoided widespread indiscriminate anchor damage around the dive site. The system was effective for the lightweight boats used in Bonaire at the time, but as larger boats were introduced, heavier systems increased the sacrificed area.

In 1981, six experimental mooring buoys were installed at French Reef off Key Largo, Florida, using an embedment anchor pin that was drilled and cemented into the hard bedrock substrate (Halas 1984). The key that provided a solution for an environmentally sensitive reef mooring was in the work being conducted by Harold Hudson for the United States Geological Survey, studying growth rates in large coral colonies (Hudson 1981). Hudson drilled into coral heads, extracted the core, and filled the void with a hydraulic cement plug. From this came the idea of coring into the solid limestone bedrock and embedding a stainless steel eye pin into the bottom with cement.

The original six systems installed in 1981 at French Reef in the Key largo National Marine Sanctuary tested a variety of attachment materials. The embedment pin and use of floating line without cable or chain became the key elements of the system. With slight modifications over the next several years, the experimental six buoy system was greatly expanded in the Key Largo National Marine Sanctuary and introduced into the Looe Key National Marine Sanctuary (Halas 1985).

Over the past fifteen years, embedment anchor technology has evolved to meet the challenges of mooring large vessels in a variety of substrates over a wide geographical range. Through advanced technology, mooring buoy deployment has become a significant tool for reducing anchor damage in environmentally sensitive marine habitats and an asset in the management of marine protected areas. The development of several practical embedment anchoring

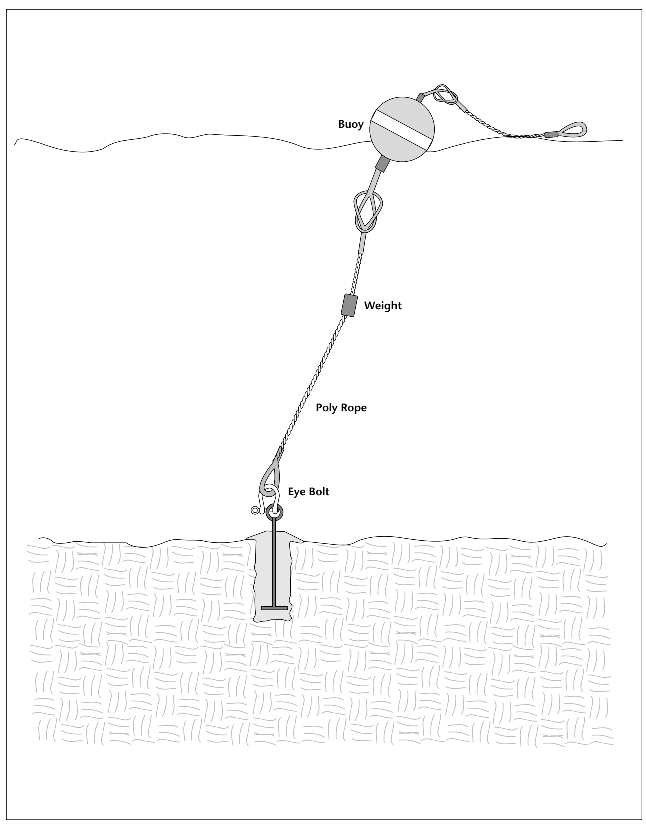

Figure 4

systems has led to advancement in this field. The use of additional hydraulic tools and supporting equipment has also been a factor in the advancement of mooring technology.

Since 1981, the demand for embedment anchors and mooring systems that could be used in a variety of environmentally sensitive substrates has steadily increased. Several adaptations have been developed to meet these needs. When solid limestone substrate is available, coring a hole and cementing a stainless steel pin into the bottom continues to be a strong, long-term, cost-effective method of securing a mooring system in a coral reef environment. The single cemented pin has been complemented by a heavy-duty inverted "U" anchor for larger vessels and heavier sea conditions. Small diameter drill bits and stainless steel threaded pins secured with underwater adhesive epoxy can be effectively used in volcanic areas with extremely hard substrates. The quickly installed small diameter epoxy system is also effective for deep water applications where bottom time is limited.

In unconsolidated substrate such as sand, grass, and loose rubble environments, a Manta Ray anchor, driven in with jackhammer and load-locker is a strong, cost-effective method of securing mooring systems. For heavier duty applications, multiple Manta Ray anchors and deep penetrating helical anchors can provide additional holding power. Most embedment anchoring systems can be installed with portable diver-operated hydraulic tools from a small boat. Hard substrate penetrating helical anchors require greater hydraulic power and a spudded vessel. Embedment anchor systems complement one another, providing security in both hard and soft substrates. They offer a point of attachment for buoy systems that utilize minimal hardware and eliminate the need for heavy chain or cable. These systems can be used with floating line and minimal scope in close proximity to delicate bottom features without sacrificing holding power or causing damage to the surrounding habitat. The use of embedment anchoring systems has also become the preferred mooring technique for demarcation buoys, channel markers, and for securing scientific instruments underwater.

Materials and Methods

Hard bottom: Single pin mooring anchors

Most of the modifications made to the original system have resulted in increased strength and durability of the system, a wider range of substrate use, and a savings in installation time or cost. In the Florida Keys, the original 10.16 cm (4 in.) diameter eye pin hole was reduced to 5.08 cm (2 in.) and the moulding plaster catalyst initially used for making "quick setting cement" was found to be unnecessary when contained within the drilled core hole. Cement setting times are slower than when catalyst is used, but the cement is easier to work with particularly in deep water applications. The smaller core hole reduces drilling time and requires less cement than the 10.16 cm (4 in.) hole without sacrificing any holding power. A 5.08 (2 in.) core barrel is also less expensive and easier to handle than the larger core barrel. The eye pin is made from 316 stainless steel, 45.72 cm (18 in.) long by 1.59 cm (5/8 in.) diameter with a reduced 4/76 cm (1-7/8 in.) welded crosspiece at the bottom, embedded in Portland Type II cement.

Portland Type II cement is recommended by the manufacturer for high sulfate environments and applications in sea water such as boat ramps and sea walls. The more commonly found Portland Type I cement has been used at locations where Type II is unavailable. St. Croix, U.S. Virgin Islands and Belize have both used Type I cement in their installations and have seen no difference. Long term observations of Type I cement (more than 10 yrs.) are not available. In the Hawaiian Islands, a 2.22 cm (7/8 in.) drill bit has been used successfully with Quickcrete cement and 304 stainless steel 45.72 cm (18 in.) by 1.91 cm (3/4 in.) pins (Wilkins and Tabata 1989). These pins were manufactured from smooth stock steel and initially scored to give holding power and later "beaded" with welding rod to give increased surface area without losing rod diameter (Leicher pers. com.). In the Bahamas, good holding power for a heavy 16.76 m (55 ft.) long displacement hull live-aboard boat has been obtained by increasing the standard Key Largo 316 stainless steel pin to 55.88 cm (22 in.) by 1.91 cm (3/4 in.) placed in a 5.08 cm (2 in.) hole with Type II cement (Doyle pers. com.).

In the summer and fall of 1994 in response to encountering a variety of hardbottom substrates and differing conditions for setting mooring pins including a need to quickly set strong single pins in a small diameter hole, a two part underwater adhesive epoxy was tested. Tests In Key Largo were conducted on wet cap rock and included both epoxy-set and cement-set pins. Epoxy-set pins were also rested underwater in a nearshore limestone substrate. Although cemented pins had been used successfully in Key Largo for 13 years, no official pullout tests had been carried out. In Hawaii some minimal pull tests were conducted when pins were initially installed experimentally (Wilkens and Tabata 1989).

The epoxy adhesive has an extremely high shear strength and works best when the drilled hole is 0.32 cm (1/8 in.) over the pin diameter (Koltenbeck per. Com.). The pin is knurled or threaded to provide a rough surface for epoxy adherence which eliminates the need for the cross T used at the bottom of the conventional pin. Using a 1.91 cm (3/4 in.) solid bit to drill the hole for the 1.59 cm (5/8 in.) pin greatly reduces drilling times and eliminates the need for pipe wrenches and core rod. The surface job of mixing cement and delivering it to the bottom is no longer necessary. The epoxy tube and gun can be carried down with the drill and activated underwater as soon as the hole is completed. Delivery of the epoxy adhesive through the mixing nozzle is a clean process producing no turbidity cloud that may result from cement delivery. The epoxy is completely cured in 24 hours and a strain can be placed on the pin at that time in contrast with a cemented pin that requires several days of curing time. The system is particularly well suited for extremely hard volcanic or granite substrates where drilling times are not practical with 5.08 cm (2 in.) core barrels or in deep water (>20 m) applications.

For the pull-tests, several welders constructed 1.59 cm (5/8 in.) and 1.91 cm (3/4 in.) 316 stainless steel pins. The standard Key Largo 45.72 cm (18 in.) by 1.59 cm (5/8 in.) pin was used with a 4.76 cm (1-7/8 in.) cross T in a 5.08 cm (2 in.) diameter hole cemented with Portland Type II cement and cured for five days. The same welder's pin was used without the cross T, knurled and set with epoxy with a one day cure. A different welder constructed a threaded 45.72 cm (18 in.) by 1.59 cm (5/8 in.) eye pin welded in the same fashion as the Key Largo pin. Several 45.72 cm (18 in.) by 1.59 cm (5/8 in.) threaded eye pins were constructed with a longer overlapped weld site and 45.72 cm (18 in.) by 1.91 cm (3/4 in.) threaded pins were also used in the test. A final test was conducted using an inverted U anchor set with cement (Table 1).

Hard Bottom: Multiple Pin/"U" Anchors

As use of the original embedment anchor system spread geographically, a variety of conditions were encountered requiring adaptations to the basic system and installation techniques. Although the original single pin system successfully mitigated anchor damage of small to mid-sized vessels (up to 20 m long) in reasonable weather, the growing popularity of live-aboard dive vessels up to 32 m long posed a problem. With their large size and ability to stay on buoys longer in rough weather, a stronger system was needed to alleviate the damage that their large anchors were causing.

In mid-1987, Steve Smith in the Cayman Islands, needing to obtain greater holding power from the pin system for large live-aboard boats, installed triads consisting of three pins placed in a triangle pattern approximately 0.6 m apart joined together by chain terminating just off the bottom with a pear-link and subsurface buoy. The pear-link provided the attachment point for a strong downline and large buoy. The three pins helped distribute the load over a greater bottom area thereby increasing the overall holding power of the system (Smith pers. com.). Often, however, only one of the pins took the strain of the vessel; consequently, the other two pins served as backups in case of a failure of one of the pins. The triad was eventually modified into a two pin system.

A similar system uses a heavy duty swagged cable, or multiple cables secured by cable clamps, connecting the two pins. The downline is attached by a sliding shackle to the cable so that both pins take the strain thereby increasing the holding power adequately for use by large live-aboard dive boats (Hassen per. com.). Wayne Hassen also successfully modified a traditional welded 1.91 cm (3/4 in.) eye pin by bending 1.91 cm (3/4 in.) rod stock at each end so that it fit into a 10.16 cm (4 in.) cement-filled hole with no welding involved to accommodate his growing fleet of large live-aboard dive boats.

In other areas, systems using two anchoring points have proved to be successful. In Hawaii, pins were doubled up with two short chains attaching the pins to the downline and a subsurface buoy in order to provide a backup anchor point (Leicher pers. com.). In Cay Sal, Bahamas, Capt. Tom Guarino reported that his 27 meter converted crew boat withstood winds in excess of 50 kts in semi-protected waters while moored to a double pin system by a sliding shackle on a chain connecting two single 45.72 cm (18 in.) by 1.59 cm (5/8 in.) pins cemented into the bottom approximately 2 meters apart (Guarino pers. com.). Peter Hughes has successfully deployed a double galvanized 2.54 cm (1 in.) pin system with holes drilled about a meter apart at an angle to one another so that the combined pull on the pins opposes the direction of pull out (Hughes pers. com.). Cable and chain connecting double pins tend to become wear points and should be checked periodically for replacement needs.

Another rigid triad was deployed in Saba, Netherlands Antilles in March, 1989 at the request of the

Saba Marine Park manager to accommodate three large live-aboard dive boats that had begun operations there. Seven units were installed consisting of three approximately 0.6 meter lengths of heavy channel iron welded together on the same plane symmetrically with a pad eye in the center for the downline and 3.81 cm (1-1/2 in.) holes accommodating 0.76 m (2-1/2 ft.) long by 3.18 cm (1-1/4 in.) galvanized all-thread rods at the end of the channel iron arms. Three 5.08 cm (2 in.) by 60.96 cm (24 in.) holes were drilled into the bottom and the 3.18 cm (1-1/4 in.) all-thread rod was cemented into the holes and secured to the channel iron with double nuts. Some difficulties were experienced with positioning the rigid triad on level solid substrate for all the drill holes. Occasional loosening of the nuts occurred after a period of use.

At the same time the rigid triad was deployed, the two-pin concept was modified to eliminate chain or cable and associated hardware by utilizing an inverted U-shaped anchor to provide additional holding power and eliminate the possibility of a welded eye failure. Two inverted U anchor were installed experimentally to accommodate large boats, one in Saba and one in the British Virgin Islands in March, 1989. The Saba inverted U was fabricated from a one piece, approximately 1.68 m (5-1/2 ft.) long by 1.91 cm (3/4 in.), 316 stainless steel all-thread rod by lathing the center 45.7 cm (18 in.) and bending it into a U with 60.96 cm (24 in.) long legs positioned 30.48 cm (12 in.) apart. Petit two-part epoxy paste was applied to the legs while out of the water and the unit taken into the water and inserted into 3.18 cm (1-1/4 in.) holes predrilled into volcanic basalt rock. Tapped into place with a hammer, the inverted U anchor formed a low profile ring without any welds. This provided a non-moveable attachment point for a single shackle and downline (simplifying the downline attachment) while distributing the load over a greater substrate area. The BVI inverted U was manufactured from 1.91 cm (3/4 in.) 316 stainless steel smooth stock bent into a U with 60.96 cm (24 in.) legs 30.48 cm (12 in.) apart but with 5.08 cm (2 in.) cross pieces welded to the end of the legs. This unit was secured with Type II cement in 60.96 cm (24 in.) deep by 6.35 cm (2-1/2 in.) diameter holes providing the same profile and distribution of load as the Saba inverted U.

During this same general time period, inverted U anchors were also developed by Craig Quirolo of Reef Relief Foundation for "Big Boat Moorings" off Key West, Florida in response to the increase in large boat visitation in the lower Florida Keys. These were similar to the BVI inverted U except the legs were positioned 45.72 cm (18 in.) apart (Quirolo pers. com.). In May, 1990, twelve heavy duty inverted U anchors were installed on the Flower Gardens Bank in the Gulf of Mexico, 161 km off the coast of Texas by the Gulf Reef Environmental Action Team (GREAT). These were manufactured with heavy 2.54 cm (1 in.) 316 stainless steel stock with 60.96 cm (24 in.) long legs 30.48 cm (12 in.) apart with cross bars on the end of the legs and set with Portland Type II cement in 7.62 cm (3 in.) diameter holes. The 3.81 cm (1-1/2 in.) downline was connected to a large 76.2 cm (30 in.) buoy. This strong system was tested by a 30.48 m (100 ft.) crew boat (converted for diving) during thirty minutes of sustained 35 kt winds with gusts to 50 kt 161 km off shore. The system held without any sign of failure (Rinn pers. com.). The twelve-buoy system has now been incorporated into the Flower Garden Bank national Maine Sanctuary program.

A four-point mooring system was deployed to get strong holding power in limestone substrate for anchoring the 30.48 m (100 ft.) by 15.24 m (50 ft.) Mobile Support Base (MSB) barge for the NOAA Aquarius underwater habitat off Key Largo, Florida. The bow moorings were placed 183 m out and the stern moorings placed 85.34 m out from the barge. Each mooring point consisted of a heavy-duty pad eye with approximately a one square meter footprint secured by four 3.175 cm (1-1/4 in.) by 1.22 m (4 ft.) all-thread stainless steel rods, drilled and cemented into the substrate and double-bolted to the pad eye. A high strength non-shrink 5 star marine grade grout was used to cement the pins. Sampson braid nylon line 5.08 cm (2 in.) in diameter was used as a downline from a large 132 cm (52 in.) diameter steel buoy. Another length of Sampson Braid line connected the buoy to the barge. The system withstood 45 kt. sustained winds with gusts to 60 kts from tropical storm Gordon with seas building to 5.5 meters while saturation divers were brought out of saturation. This is a good example of how the original pin concept was expanded to greatly increase holding power in the same limestone substrate.

Soft Bottom: Manta Ray mooring anchors

The original pin system was designed to protect coral reef environments, but as mooring projects moved into areas without hard limestone substrate, there was a need to secure mooring anchors in soft bottom areas consisting of sand, grass, or rubble. These were the locations traditionally served by weighted moorings with their concurrent problems (VanBreda 1992).

Initial solutions were not entirely satisfactory (Halas 1985). A 318 kg railroad wheel anchor moved with a 14.63 m (48 ft.) boat attached in 20 kt. winds, and a 1.68 m (5-1/2 ft.) Chance screw anchor augured into the sand eventually worked out.

In the spring of 1990, a Manta Ray anchor, used to secure utility pole guy wires, was tested for underwater use in the Key Largo National Marine Sanctuary in the grass and sand areas of Grecian Rocks and Key Largo Dry Rocks. The original Manta Ray anchor tested consisted of the MR-1 flat anchor plate with a 2.13 cm (7 ft.) by 2.54 cm (1 in.) galvanized rod threaded at each end with an accompanying "triple-eye" nut at the top. Later, to adapt the land model Manta Ray anchor to the marine environment, a few modifications were introduced. Now, a large eye nut replaces the restrictive "triple-eye" nut used for utility poles and easily accommodates several shackle sizes. Land models have three components threaded and screwed together, but marine Manta Ray anchors are welded into one piece units to prevent unscrewing of the system with the shifting orientation of the attached boat. Hot-dipped galvanizing after welding protects against corrosion. Minor modifications were made to the installation equipment (load-locker, baseplate, and adaptor setting bar) to facilitate underwater installation.

The anchor inventory was increased by adding marine models with larger anchor plates for increased holding power. A variety of anchor sizes are now available for different bottom types. Probably the best for most mooring buoy applications, the MR-SRM weighting 19.3 kg (42.5 lbs.) provides a broad surface of 916.12 sq. cm. (142 sq. in.) for greater holding power in soft substrates. For extremely soft bottom material such as mud, silt, or very loose sand, the "Muskeg" (36.3 kg, 2,593.5 sq. cm. or 80 lbs., 402 sq. in.) has been designed to provide even greater surface area and weight to maintain holding power. The MR-1M (15.2 kg, 458 sq. cm. or 33.5 lbs., 71 sq. in.) is versatile and can provide a suitable, less expensive anchor for smaller vessels in protected waters. Smaller and narrower, the MR-2M anchors (14.3 kg, 271 sq. cm. or 31.5 lbs., 42 sq. in.) may penetrate more easily into rocky rubble areas and develop strong holding power for small boats. These and the MR-3M anchors provide good mooring anchors for demarcation buoys. All the marine Manta Ray anchors have a structural rating of 9,074 kg (20,000 lbs.). For the greatest holding power, it is best to use the largest anchor that can reasonably penetrate at least 2.13 m (7 ft.) into the substrate.

To install the marine Manta Ray anchor systems underwater, a diver drives the Manta Ray anchor into the substrate using a BR-67 Stanley underwater jackhammer and drive steel gad set. After attaching an adaptor setting bar to the eye nut, the 2.13 m (7 ft.) rod is driven below the substrate and a two-piece base plate positioned over the protruding bar. Handlers on the surface exchange the BR-67 jackhammer for the load-locker hydraulic tool which, when in place on the base plates on the bottom, grips the adaptor setting bar in order to pull up and "toggle" or set the anchor plate. A pressure gauge on the load-locker measures the force exerted in pulling up and setting the anchor and provides a rating of the holding power of the system. When the eye of the rod protrudes above the substrate, the load-locker is disengaged and a 45.4 kg (100-lb.) lift bag is used to return it to the surface. Other heavy installation pieces are also retrieved with lift bags.

Although its optimum use is in hard-packed sand, the Manta Ray system provides secure holding power for moorings in loose sand, rubble, and grassy sea beds where the railroad wheel and 1.68 m (5-1/2 ft.) screw anchor had proved inadequate. The Manta Ray will also drive past or through rocks, shells and small buried coral heads successfully and loads often reach more than 7,713 kg (17,000 lbs.) of force. Immediately after installation a mooring buoy array can be attached and used.

Soft bottom: Multiple Manta Ray anchors

For stronger moorings in soft substrate, boats over 17 m long, sea conditions over 1.5 m waves, and for long term attachment to the mooring system, multiple Manta Ray anchors have been successfully used. To satisfy these conditions and provide redundancy, the National Park Service in St. John, U.S. Virgin Islands successfully installed triple Manta Ray anchors for a single mooring similar to the tripod pin system (Kelley pers. com.). Double Mantas, either using a chain-connected triangular metal "fish plate" or a sliding shackle over a connecting chain, have also been used successfully to provide increased holding power. The sliding shackle or "fish plate" in tension serves to distribute the load between the Manta Ray anchors. The system causes little disturbance when used with a subsurface buoy which holds the chain off the bottom.

Soft bottom: Helical anchors

Helical plate or "screw" anchors were invented in the early 1900s Helical anchors used in the marine environment are generally for heavy-duty long term anchoring or "hurricane" applications in substrate containing deep soft sediments. They can be installed with a hydraulic system mounted on a platform or by a diver using a slow turning high-torque hydraulic power head. The current designs use either hollow or solid square stock iron shafts that can be lengthened by adding extensions to reach a desired torque reading in deep loose substrate. Very strong holding values can be obtained when these systems are deployed with extensions deep into the substrate. The systems perform well in resisting side loads and have the capability of being removed if necessary. "Teeth" added to the leading edge of the helical plate provides some cutting capability in hard substrates when bored in with downward pressure from a spudded supporting vessel. A floating line or a line with a subsurface buoy can prevent terminal tackle contact with the bottom.

Mooring Installation equipment

The basic hydraulic system means of deployment for embedment anchor systems (Halas 1984) accounts for the majority of mooring installations. Hydraulic power from a hydraulic power source through hoses to a hydraulic power driven tool is an efficient means of deploying embedment anchors in a variety of conditions. Hydraulic systems provide continuous power to drive underwater tools and are reliable for long term use.

The power source can be either from a power takeoff (PTO) unit attached to the main propulsion engine of the support boat or from a portable power unit. Advancements in portable power units incorporate lightweight twin cylinder gas engines mounted on light, rust-free aluminum frames using "power on demand" throttle linkage. The result is a savings in weight and an increase in efficiency and reliability.

Plastic hydraulic hose using nonconductive reinforcement is advantageous for underwater use. The neutral to slightly negative hose, compared to a heavy wire reinforced hose, minimizes contact with the bottom. Stainless steel ends and quick disconnect fittings provide good long lasting corrosion-free connections. A small, but powerful, Stanley DL09 hand-held drill modified with a trigger guard and added cross handle serves as a strong reliable light weight drill. Using two different adaptors, core barrels with 3.18 cm (1-1/4 in.) by 7 threads can be used as well as smaller diameter drill bits with a 1.59 cm (5/8 in.) by 11 hub. Core barrels using surface set or impregnated diamonds are used by geologists taking core samples and in mooring pin installations. Thick-walled core barrels using carbide teeth provide a faster, more aggressive cut in limestone. In hard basalt volcanic rock, hammer drills or sinker drills using fluted drill bits or drill steel are needed to effectively and efficiently penetrate the substrate with 1.91 cm (3/4 in.) to 2.2 cm (7/8 in.) holes. The Stanley HD-45 is an effective tool for this, requiring no additional flushing with water or air. In these smaller holes, good holding power can be obtained with epoxy.

For Manta Ray application, the BR-67 jackhammer is effective in most situations encountered. In the Exumas Cays, Bahamas, Ray Darville has effectively used a portable water pump to work MR-SRM Manta Ray anchors into 2.4 m of consistent sand, free of major obstructions, and set or turn the Manta plate while still under the influence of the water jet (Darville, pers. com.). Large Muskeg anchors on chain have also been deployed in the harbor at Highbourne Key, Exumas by water jet in soft consistent sand bottom (Doyle pers. com.).

For helical anchor installations originally performed from a spudded platform in shallow water, a slow turning high-torque hydraulic motor has been developed to enable diver-operated installations in deeper water. A long resistant leverage arm or anchor is required to resist the back force created during installation. The use of air powered drills is generally considered less effective than hydraulically driven drills. If a large compressor and air bank is available, however, an air drill can be considered for small installation projects. A heavy duty model air drill can effectively drill a 55.88 cm (22 in.) by 5.08 cm (2 in.) diameter hole in limestone using approximately four 2.25 cubic meter (80 cubic ft.) SCUBA tanks of air (Doyle pers. com.).

Results

Pull tests conducted on topside wet Key Largo cap rock using both epoxy adhesive and Portland Type II cement produced very high pull out rates in most cases. The extreme force distorted anchor eyes and compromised welds before failure. These values were greater that the load limits of commonly used lines and shackles and therefore would not have been reached in an actual mooring situation. Eye distortion began to occur at approximately 7,720 kg (16,000 lbs.) and continued until weld failure occurred at approximately 9,087 kg (20,000 lbs.). Higher rates were achieved when the weld site was lengthened along the eye pin shank. In some cases, voids in the substrate contributed to ground failure before eye pin distortion occurred.

The first attempt at testing the pull out strength of the inverted U anchor embedded in cement resulted in the pulling apparatus breaking at 17,193 kg (37,840 lbs.). During a second attempt with a new stronger device, an extremely high value (29,534 kg. or 65,000 lbs.) was attained before the cross piece weld on one leg failed at the bottom of the hole. The force suddenly dropped to 15,903 kg. (35,000 lbs.) but the inverted U anchor continued to hold and did not pull out although the stainless steel stretched from a U-shape to a V.

Tests were conducted underwater with single stainless steel anchor pins and underwater adhesive epoxy on near shore limestone hard bottom. The bottom tested appeared to be somewhat more porous than the topside Key Largo cap rock. Values attained were slightly lower than surface tests but still reached strengths from 4,089 kg (9,000 lbs.) to almost 8,178 kg (18,000 lbs.) before the anchor pins began moving up through the substrate (Table 1).

Discussion

The need to develop strong mooring systems in a wide variety of bottom types has led to the advancement of mooring technology by combining the original embedment anchor concept with additional modifications, tools, and methods. To meet the problems posed by varying substrates, embedded anchors effective for those situations have been developed or adapted. A suite of tools enabling efficient installation has been a key element responsible for implementing moorings in the diverse conditions encountered in the world's reef systems. Embedment anchors and mooring systems are now used globally to protect tropical coral reefs and the list of locations where they are found continues to expand (Table 2).

Advancements in mooring technology have broadened the scope of embedment anchors, but mooring buoy site selection remains an important element in establishing a strong permanent mooring attachment point. Where there is a solid limestone base, the site selection process can be uncomplicated but becomes more complex with other bottom substrates. Increased boat size and the need to tolerate stronger sea conditions in narrowly defined sites can add to that difficulty. Although increasing the area for site selection will improve the chances of establishing a stronger mooring attachment point, a mooring installation should not be forced into an unsuitable substrate that may not have sufficient holding power.

Some challenges remain. Steep slopes composed of widespread living coral colonies growing over loose deep rubble, like that found on Bonaire's reefs, pose problems for secure non-damaging mooring anchors. Walls or steep drop-off areas, especially those situated in shallow waters such as found in Palau, make embedded anchor placement difficult. Great tidal ranges require adaptive systems. Strong currents impede installation techniques. A bottom consisting of sand at a depth of one to two meters over hard substrate is particularly difficult for establishing a secure mooring. A means of overcoming human frailty by providing a theftproof system without heavy duty hardware remains a challenge in some localities.

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I would like to express my gratitude to all the people I have worked with in the United States and overseas during mooring buoy installation projects that have added to the body of knowledge on mooring anchor system technology. Harold Hudson, who provided the original inspiration for the embedment pin system, has continued to be supportive as new techniques have been introduced. Jeff Fisher and the team at Foresight Products, Inc. have assisted me greatly since the introduction of the Manta Ray anchors by working to adapt the anchors and equipment for use underwater. I appreciate the time and energy expended by Norm Schmotzer of B & A Manufacturing Co., and Wayne Ray, representing Stanley Tools and Hydraulic Supply Company, to help quantify the strength of the cement and epoxy embedment pin systems resulting in an additional pin installation technique. I owe special thanks to my wife, Judith F. Halas, for all her help.

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Results of tension tests on mooring anchors embedded in cement and underwater adhesive epoxy and mooring system materials pulled to failure. Starred sample numbers indicate underwater tests and ++UC indicated probable upward compression of the substrate.

TENSION PULLOUT (TESTING TO FAILURE) SEPTEMBER, 1994

SAMPLE NO.	APPLIED LOAD (kg)/(lbs.)	MATERIALS	FAILURE MODE/NOTES
CEMENT MATRIX Mooring anchor pins (45.72 cm long) in limestone substrate			
#1	9,226 kg 20,300 lbs.	1.59 cm 316 StSt Pin with foot. 5.08 cm hole.	Eye weld failed, Pulling vehicle Broke
#2	8,272 kg 8,200 lbs.	1.59 cm 316 StSt Threaded pin, 1.91 cm hole.	Substrate failed, Steel eye began to Distort at 4082 kg.
#3	9,210 kg	1.59 cm 316 StSt 20,300 lbs. 1.91 cm hole.	Eye weld gave, part. thread Pin continued to hold.
#4	17,193 kg 37,840 lbs.	"U" anchor, 316 StSt 1.91 cm Pin w/foot, Two 5.08 cm holes.	Stretched to "V", no pullout, cracked ground, broke test Device
UNDERWATER ADHESIVE EPOXY MATRIX Mooring anchor pins (45.72 cm long) in limestone substrate			
#5	5,965 kg 13,129 lbs.	1.59 cm 316 StSt threaded pin	Bottom failed with 12.7 cm cone. UC**
#6	5,809 kg 12,784 lbs.	1.59 cm 316 StSt Threaded pin	Bottom failed with 27.94 cm cone, UC**
#7	7,221 kg 15,893 lbs.	1.91 cm 316 StSt Threaded pin	Bottom failed, 7.6 cm cone, bent anchor
#8*	4,396 kg 9,674 lbs.	1.91 cm 316 StSt threaded pin	Bottom failed, 7.6 cm cone, UC**
#9*	8,163 kg 17,966 lbs.	1.91 cm 316 StSt Threaded pins	Bond failed, UC**
#10*	4,083 kg & 5,965 kg 8,987 lbs.& 13,129 lbs.	1.59 cm 316 StSt threaded pin	Bond failed, two-way bend.
#11	11,616 kg 25,567 lbs.	1.91 cm 316 StSt Threaded pin.	Bottom failed, UC**
#12	28,885 kg 63,572 lbs.	"U" anchor, 2 legs, 1.91x61 cm 316 StSt	Weld failed on one leg, 5-resets req. to extend test, no pull-out. Held at 28,885 kg
#13	7,221 kg 15,893 lbs.	5/8-in. 316 StSt Knurled.	Bottom failed
#14	11,930 kg 26,258 lbs.	5/8-in. 316 StSt No threads.	Steel failure.
SYSTEM MATERIALS TEST:			
#15	4,710 kg 0,365 lbs.	1.03 cm Wichard 316 StSt shackle	Cross pin failed at thread. 1
#16	6,437 kg 14,166 lbs.	1.19 cm Wichard 316 StSt shackle	Cross pin failed at thread.
#17	9,419 kg 20,730 lbs.	1.27 cm Tawain 316 StSt shackle	Cross pin failed at thread.
#18	2,512 kg 5,528 lbs.	1.91 cm Polypropylene line.	1 of 3 braids failed.

Table 1

Locations in mid-1996 where environmental reef moorings or embedded mooring anchors have been installed. Approximate numbers of current moorings are indicated. One star in the last column represents a site visited by John Halas to train personnel and/or install mooring systems. Double stars indicate an additional site visit and additional mooring installations.

REGIONS UTILIZING ENVIRONMENTAL REEF MOORINGS

REGION	INITIAL INSTALLATION DATE		APPROX. NUMBER BY 1996
U.S.A., South Florida	June,	1981	500 *
Cayman Islands, B.W.I.	Sept.,	1986	205 *
Netherland Antilles, Saba	April,	1987	20 *
U.S.A. Hawaiian Islands	July,	1987	45 *
Malaysia, Peninsular	July,	1987	150 *
Turks and Caicos, B.W.I.	Dec.,	1988	35 *
Netherlands Antilles, Saba	March,	1989	7 **
British Virgin Islands, B.W.I.	March,	1990	170 *
Belize, C.A.	May,	1990	52 *
Thailand, Phuket		1989	10
U.S.A. Texas Flower Gardens	May,	1990	12 *
Samoa, American	June,	1990	6
U.S.V.I. Nat. Park, St. John	Nov.,	1990	40 *
U.S.V.I. St. Croix	Feb.,	1991	20 *
St. V. & Grenadines, Mustique	March,	1991	25 *
Jamaica, Negril	Nov.,	1991	35
Jamaica, Montego Bay	Dec.,	1991	13 *
Honduras, Bay Islands		1991	10
Bahamas, Bimini Chain	Jan.,	1992	76 *
Bahamas, Lucay G.B.I.	March,	1992	75 *
Puerto Rico	May,	1992	64 *
Anguilla, B.W.I.	June,	1992	50 *
Micronesai, Palau	Sept.,	1992	25 *
Bahamas, San Salvador	Dec.,	1992	36 *
Bahamas, Exumas/Land & Sea Park	Feb.,	1993	105 *
St. V. & Grenadines, Tobago Cays	March	1993	50 *
Bahamas, Nassau	June	1993	25
Egypt, Hurghada (Red Sea)	July,	1993	48 *
Australia, Whitsunday Is.	August,	1993	5 *
Belize, Cay Caulker	Sept.,	1993	39 *
Bahamas, Exumas/Land & Sea Park	March,	1994	10 *
Saipan	May,	1994	10 *
U.S.A., Hawaii/Molokini, Maui	May,	1994	6 **
Bahamas, Gingerbread/Bimini	June,	1994	12 **
Bahamas, Harbour Is./Eleuthera	June,	1994	18 *
Indonesia, Bali Barat Nat. Park	Sept.,	1994	8 *
Indonesia, Konodo Nat. Park	Sept.,	1994	8 *
St. Lucia, Soufriere/SMMA	Dec.,	1994	42 *
Dominican Republic	Jan.,	1995	30 *
Bahamas, Abaco/Hog Cay	Feb.,	1995	3 *
Bahamas, Abaco/Green Turtle Cay	May,	1995	6 *
U.S.V.I. St. Thomas/Reef Ecol. Fr.	May,	1995	50 *
Indonesia, Komodo Nat. Park	Sept.,	1994	8 **
St. Lucia, Soufriere/SMMA	Dec.,	1995	11 **
Jordan, Aqaba	Jan.,	1996	10
Paupa New Guinea, Walinde Bay	March,	1996	14 *
Micronesia, Yap	March,	1996	16 *
St. V. & Grenadines, Tobago Cays	May,	1996	46 **
U.S.A., Great Lakes (No. IL Scuba)	May,	1996	3
Aruba/Watersports Assn.	June,	1996	22 *
Bahamas, Abaco/March Harbour		1996	15
Micronesia, Kosrae		1996	3
Egypt, Hurghada/HEPCA-Winrock	Proj	1996	225 **
APPROXIMATE TOTAL MOORINGS BY 1996:			2,530

Table 2

The Cayman Islands

A Case Study for the Establishment of Marine Conservation Legislation in Samll Island Countries

by G.C. Ebanks and P.G. Bush

Abstract

The Cayman Islands have experienced a tremendous rate of growth in the last twenty-five years and tourism, particularly diving tourism, has emerged as one of the two main pillars of the country's economy. Ever-increasing numbers of visitors and the parallel economic growth and development of the Islands continue to place significant stress on the marine environment.

In response to early warnings of inevitable environmental degradation, Government introduced the Marine Conservation law in 1978. Since 1978 additional measures have been taken, culminating in the establishment of the Marine Parks system in 1986. Although much has been done towards management of these protected areas, the legislation which regulates activities within the Parks today does not adequately address the main conservation issues facing the Cayman Islands. These are a. overuse of the reefs and b. degradation of the marine environment resulting from coastal development. Solutions to these problems are being sought and steps are being made toward the creation of new legislation to ensure that future development is more sensitive to the environment.

Key Words: marine conservation law, growth and development, marine parks.

The Marine Conservation Law

The Marine Conservation Law (1978) created the entire framework for Cayman's marine conservation laws and regulations and is arguably the most important piece of conservation legislation passed in the Cayman Islands to date.

It outlawed the taking of any marine life while on SCUBA and prohibited the use of noxious substances for the taking of marine life. The Law set a size and catch limit and a closed season for the spiny lobster (Panulirus argus), while the taking of any other species of lobster was prohibited. In addition, a catch limit for conch (Strombus gigas) was established and the use of spearguns and nets regulated. The collection of coral and sponges was outlawed and the displacement or breaking of any coral or underwater plant formation during construction or dredging was prohibited, unless licensed by Government. A restriction was placed on the taking and export of certain marine species and the discharge of harmful effluent and raw sewage into the sea was made illegal. The Marine Conservation Board which is responsible for the general administration of the Law was established.

The Law also empowered Executive Council (the main governing body of the C.I.G.) to make Regulations prescribing marine parks, restricted marine areas, minimum catch sizes for certain species, closed seasons, and Regulations to control many other activities such as anchoring and fishing. Regulations protecting female sea turtles and their eggs during the months of May through September were passed with the Law in 1978. The social and political climate at that time did not allow the Law to encompass all of the recommendations made by the Natural Resources Study but provisions written into the Law have enabled the subsequent introduction of more detailed legislation.

A Strategy for the Establishment of Marine Parks

After some years of working with this Law it became evident that, with ever increasing numbers of visitors to the islands and an expanding population, marine resources were being placed under greater and greater stress and needed more protection than the Marine Conservation Law, as it then stood, could offer. Dive operators, who for years had been lobbying for the establishment of marine parks and some local fishermen complained of the noticeable degradation of the reefs and the declining numbers of fish, conch and lobster. At that time, September 1984, the Government employed a Scientific Officer and Assistant Scientific Officer for the Natural Resources Laboratory. The function of the Laboratory was to monitor the coral reef, lagoon and mangrove ecosystems of the islands. This was the first time that the building originally constructed to accommodate the investigators affiliated with the 1975 Natural Resources study would have a full-time staff as had been recommended. Information provided by the Laboratory, the pressure of public opinion and a change of Government at the 1984 General Elections all acted to provide the impetus for a first try at the establishment of Marine Parks in the Cayman Island. This first attempt met with failure, both on the political and social fronts. However, in late 1985, certain factors once again converged to provide the political mandate necessary to allow for a second try.

A two person team - one biologist and one lawyer - was assembled within the Government Portfolio responsible for conservation and charged with the responsibility of developing the Marine Parks Plan and map. A large broad-based committee comprised of watersports operators, fishermen, commercial boat trip operators, Government biologists and local environmentalists was set up. This committee held an intensive series of meetings to establish the zone types, zone boundaries and associated rules for Grand Cayman.

This was followed by the development of a public information campaign which included a slide show on the benefits and uses of marine protected areas as applicable to the Cayman Island, and island-wide Ocean Awareness week in the schools, special radio broadcasts, and presentation of the slide show to all service clubs, youth groups, churches and schools. Meetings were also held in the Town Hall of each district on the island where local biologists and other members of the Committee explained the proposed Grand Cayman Marine Parks system to the public. In general the plan was extremely well received, but strong objections to parts of the plan as well as suggested alternatives were carefully noted and taken back to the Committee. These points were discussed and a revised version of the plan was drawn up which reflected the input of the community without compromising the purpose of the protected areas. In March 1986 Government accepted the plan and the Marine Parks Regulations for Grand Cayman came into effect. A similar method was used in Cayman Brac and Little Cayman and one month later both of these islands also had marine parks.

After several years of analysis of the techniques used to gain support for the establishment of the parks a few key reasons for success have become evident. First, a significant volume of information on the marine resources (both scientific and local) was readily available for use. Due to the narrow shelf around the Islands, there was a tremendous amount of local knowledge of key areas, especially among dive operators and fishermen. The use of local biologists in the preparation of the plan and its presentation to the public greatly reduced the potential for cultural conflicts. For example, it is easier to convey the need for conservation measures to local fishermen of one is able to use familiar expressions and terms for habitats and fishes. Also, the public testimony of key figures in the community on the current status of fisheries stocks etc. had a great impact on the skeptics. While their small size may be disadvantageous in some respects, small islands present a "captive audience" easily targeted by all available media and public meeting. Lastly, the fact that the input received from the public was taken into account lent much credibility to the public review process.

The Marine Parks and Enforcement Methods

Salm (1984:213) provides a detailed set of guidelines, based on sound ecological theory, for the determination of the sizes and boundaries of marine protected areas and highlights the value of the zoning technique.

While lack of time, resources and personnel prevented the strict application of Salm's guidelines to the establishment of marine parks in the Cayman Islands, the principle of zoning was heavily utilized in order to cater as much as possible to traditional activities and to reduce user conflicts. The Cayman Islands Marine Parks system utilizes three types of zones: the Marine Park Zone, the Replenishment Zone and the Environmental Zone).

The Marine Park Zones were created primarily to protect the coral reefs and associated organisms incur most heavily used diving areas. In these zones taking of marine life, alive or dead, is prohibited except that line fishing from shore and beyond the drop off is permitted. Seine nets, spearguns, pole spears and fish traps are totally prohibited. Anchoring is also prohibited except that boats 60' or less may anchor in sand as long as a grappling hook is not used and neither the chain nor rope lies on the coral. Anchoring is also permitted within the designated Port Anchorage areas. The Replenishment Zones were created to ensure protected breeding and nursery areas for marine life, especially conch (Strombus gigas) and lobster (Panulirus argus). Spearfishing and fishtraps are strictly prohibited in these Zones but anchoring and line fishing are allowed.

To ensure the preservation of a portion of the undisturbed, mangrove-fringed North Sound lagoon environment, a single Environmental Zone was created. All fishing and anchoring are prohibited and no in-water activities are allowed. A speed limit of five knots or less applies in the Zone.

Regulations making spearfishing a licensed activity were passed simultaneously with the Marine Parks legislation. Applicants must fulfill certain age and residency requirements and must produce a clean

Police Record.

With the introduction of Marine Parks legislation the penalties for violating the Law and regulations were made more severe: a judge may now impose a fine of up to CI$5,000 and a term of imprisonment of up to twelve months, and may order the confiscation of all equipment and vessels used to commit to offence. Initially enforcement of the Law and Regulations was carried out by volunteer Fisheries Officers but now the Parks are patrolled by Marine Enforcement Officers seconded from the Police force. There are two Enforcement Officers for Grand Cayman and one for Cayman Brac and Little Cayman. It is hoped that these numbers will be increased in the future.

Additional Measures Taken to Protect the Marine Environment

Lang and Land (1976:2) noted the significant damage being caused to the reefs on Grand Cayman by the anchors of both large and small vessels. In 1984 when the Government's Natural Resources Unit began to monitor the health of the Cayman's coral reefs it became evident that anchor damage was still the main threat to the continued health of the reefs. The damage being caused by cruise ship anchors was particularly severe. Smith (1988:231) recorded 3150 square metres of previously intact reef being destroyed by one cruise ship anchoring on one day.

After the introduction of the Marine Parks legislation the C.I.G. provided the funds necessary to purchase the equipment to implement a mooring system for dive boats and recreational vessels. This mooring system is based on that used in the Key Largo National Marine Sanctuary, Florida (Halas 1985:239-240). Today 205 dive sites in the Cayman Islands have permanent moorings. Of this total 119 are located of Grand Cayman; 60% of the sites on Grand Cayman are located within the Marine Park on the western coast. The question of providing permanent moorings for cruise ships has still not been resolved.

New Regulations passed in 1988 make it an offence for a vessel of any size to anchor in such a manner as to cause damage to coral anywhere in Cayman's territorial waters. In 1988 Regulations giving the Marine Conservation Board the authority to control access to Bloody Bay Wall were passed. This area is located in the Marine Park on the north coast of Little Cayman and one of Cayman's most famous and popular dive sites. The Board is currently in the process of gazetting the Directives which will be used to licence boats using the area.

Current Problems and Proposed Solutions

Overuse of the reefs, particularly on Grand Cayman, is perhaps the most pressing marine conservation problem in the Cayman Islands today.

Long before the introduction of marine parks, dive operators has discovered and named particular dive sites e.g. Orange Canyon, Bonnie's Arch and Big Tunnels. Repeat visitors make special requests to return to these favored sites. These sites are all located along the west coast of the island where the reefs are easily accessible, the weather conditions are most often favorable and where the majority of hotels and condominiums are located.

It is estimated that 85% of the diving taking place on Grand Cayman occurs on the reefs in this area. The West Bay peninsula continues to attract the vast majority of tourist oriented development. Two large hotels have recently opened and another is due to open late in 1990. All of these hotels have large diving franchises connected with them. However, the first draft of the proposed Marine Control Law, which advocates controlling the growth of the watersports industry, has been produced as a result of dialogue between the watersports industry and Government. Certain symptoms of rapid growth are also beginning to cause concern in other areas of life and the Government has recently placed a five year moratorium on hotel development. In the meantime, a 10 year Tourism Development Plan has been commissioned by the Government and environmental concerns have featured heavily in all discussions to date.

Large scale speculative development of the mangrove swamps on the western coast of the North sound continues. Typically this development involves the digging of canals, lakes and yachting basins; inevitably a certain amount of dredging in the open Sound is required to provide enough material to fill the land. Much of the mangrove swamp of the West Bay peninsula has disappeared; the Central Mangrove Swamp is the only remaining major body of undisturbed mangrove on Grand Cayman. Small areas of mangrove swamp have been designated as Wetlands of International Importance under the Ramsar Convention and two of these have been declared Animal Sanctuaries under the Animals Law.

In response to the overwhelming number of dredging proposals, the Government has recently formed a Coastal Works Advisory Committee. This Committee embodies, for the first time, both biological and technical expertise to advise Government. Its terms of reference are to review and make recommendations on all proposed coastal development. The Government has also recently secured funding for a consultancy which will look at the environmental costs of providing fill material for developing by dredging and discuss alternatives.

Ironically, the existing Marine Parks Regulation do not cover dredging as the political situation in 1986 made passage of such legislation difficult. At the moment there is an unwritten policy that dredging should not be permitted in the Replenishment Zone area of the North Sound, or in the marine protected areas in general. It is hoped that, with the proposed creation of a Department of the environment, these sentiments will be translated into legislation.

The Natural Resources Unit, now with a staff compliment of eight, continue to monitor the marine resources of the island. Conchs and finfish populations studies are conducted annually and an in-depth study on the status of the Nassau grouper (Epinephelus striatus) fishery is nearing completion. Unit staff have also been deeply involved in assisting the National Trust for the Cayman Islands in providing environmental education materials to the school, and to the adult membership on the Trust. Education of the Caymanian public has done much to promote the idea of controlled growth and development based on the sustainable utilization of resources. It is now generally well accepted that the creation of marine conservation legislation and marine protected areas has been a first and major step in protecting our marine resources. Ensuring their continued survival will require constant vigilance and cooperation on all fronts.

Caribbean Travel and Life

Save Our Sea

The Cayman Island lead the Caribbean into the era of region-wide marine preservation

by Kay Showker

The Cayman Islands now have stiffer fines for dumping and the destruction of marine life than any country in the Caribbean. This recently approved measure increases 100 times the fine that can be levied on any ship—cargo, tanker, cruise, or pleasure—from CI$5,000 to CI$500,000 (about US$5,200 to US$518,000).

When the Honorable Thomas Jefferson, Executive Council Member for Tourism, Environmental and Planning of the Cayman Islands Government, announced this new policy at the meeting of the Third Caribbean Conference on Ecotourism in Grand Cayman last May, environmentalists seized upon the Cayman's initiative to push for region-wide action. They called for a task force to draft regional laws to protect the Caribbean's marine environment. The group, working under the Caribbean Tourism Organization, will review existing international legislation affecting the Caribbean region and will propose new guidelines. The resulting code will be called the Cayman Convention on Caribbean Marine Environmental Protection.

Holding this year's Ecotourism Conference in the Cayman Islands could not have been more appropriate. Dedicated to marine conservation with the theme "Protecting the Caribbean Sea: Out Heritage, Our Future," the Conference (cosponsored by the Caribbean Tourism Organization and the Cayman Islands) focused on how the Caribbean as a region can safeguard its delicate marine environment. Few Caribbean nations have set a better example than the Caymans, which began hosting scuba divers soon after the sport was first introduced 36 years ago; the Caymans themselves have served as a model for marine conservation efforts on many other islands.

The Caymans were the first Caribbean destination to promote-diving vacations in a big way. Today, some 85,000 divers visit this three island country every year. In addition, Grand Cayman, as an important cruise-ship port in the Western Caribbean, receives an average of 16,000 visitors a week aboard liners—a 14 percent increase over last year. Therefore, it is not surprising to find the Cayman Government getting tough in an effort to reverse the destruction that the rapid growth in tourism has had on the islands' marine life. What may be surprising is the road traveled to achieve the kind of commitment that the government now manifests.

Although the Cayman's first conservation laws were passed in 1978, the laws by the government's own admission-were not sufficiently enforced until the first Marine Park Regulations were passed in 1986, 29 years after the first dive shop opened on Grand Cayman and almost a decade after Bonaire had established its Marine Park. But a Cayman park might never have happened had it not been for the Cayman Island Watersport Operators Association (CIWOA).

Born initially out of safety concerns, the group took on the conservation cause when it began to witness the detrimental impact that increasing numbers of divers, snorkelers, boaters, fishermen, and cruise ships had on the reefs. CIWOA rallied public support and lobbied the government for tougher environmental action. Particularly, the group sought to establish a marine park system, which it deemed essential to the government's ability to enforce conservation laws. CIWOA eventually helped design the parks.

For the first time, the Cayman Islands Marine Park Regulations clearly defined the areas for protection in three levels: Replenishment Zones to prohibit the taking of conch and lobster year-round, a single Environmental Zone to preserve portions of the mangrove-fringed North South Lagoon, and Marine Park Zones where anchoring and fishing are strictly regulated to protect delicate coral reefs. The kinds of activities permitted in each zone—from diving to boating to fishing—are clearly spelled out. The system prohibits dumping, damaging, or taking of coral and sponges. Newer regulations make it illegal to damage coral anywhere in Cayman territorial waters. A licensing system was established to limit access to Bloody Bay Maine Park, home to the famous Bloody Bay Wall. A pamphlet that outlines these laws, Guidelines for the Preservation of Diver Damage, is distributed to visitors. It details how divers must maintain buoyancy control, avoid dangling gauges and alternate air sources, keep their fins from scraping reefs and resist touching and disturbing any and all sea creatures.

But even before CIWOA had received government sanction, its members began setting up moorings for boats, having learned that anchors are one of the major causes of reef destruction. There are now 206 mooring sites surrounding Grand Caymans, Little Cayman, and Cayman Brac, and more are being installed all the time. CIWOA also advises boat captains on anchor locations and even suggests the best anchors to use. By developing a good working relationship between its members and the government, CIWOA continues to have influence on environmental matters. Many CIWOA members sit on government committees, such as Planning, Tourism, Development, and Conservation.

Strengthening the conservation laws is only one step the Cayman Government has taken to demonstrate its commitment to environmental protection. Following the election of a new government in 1992, the Tourism portfolio was restructured to include the newly created Department of the Environment and the Department of Planning. A Ten-year Tourism Development Plan, reviewing the impact of cruise tourism on the Cayman environment, has recommended limiting the number of ships calling at George Town Harbour to three ships a day, or 5,500 passengers.

The Cayman Islands have set a fine example for their Caribbean neighbors. So far, however, little has been done to safeguard the Caribbean's marine world on a regional level (see side bar, "Reefs at Risk"). Hopefully, this will change when proposals made at May's Ecotourism Conference become reality. Plans call for the formation of a Caribbean Ecotourism Society to keep a data and resource bank. In addition, a Regional Advisory Council, Made up of representatives from private and public sector groups concerned with environmental matters, will form a link between national and regional ecotourism activities; and an Ecotourism Unit at CTO headquarters will service the activities of the Society and Council, organize future Ecotourism Conferences, and help to implement actions the groups propose.

As Jefferson concluded at the Conference, "Our way of life and our economies depend upon the maintenance and preservation of our marine resources. This can be achieved only with a strictly enforced marine environmental code. It is our hope that other countries will follow suit. All of us with tourism interests in the region, including the cruise lines, can benefit, indeed profit, from a protected and preserved Caribbean."

Reefs at Risk

By Marci Bryant

Islands are surrounded by water—that's their nature. But until just three years ago, no one had ever completed a region-wide study of the Caribbean's shallow-water corals, which affect the sea and all other life forms within and around it. Then in 1990, The Nature Conservancy, cooperation with the University of Miami, the Smithsonian Institution, and the MacArthur Foundation, undertook the task of ranking and classifying 147 corals found in eight biogeographic regions from southern Florida to Central America. And the results were shocking. More than half of the corals studied in southern Florida, the northwest Caribbean, and the continental Caribbean were either endangered or rare; and more that one-third of those studied in the other five regions (the Gulf of Mexico, the Bahamian Archipelago, Puerto Rico, the Lesser Antilles, and Bermuda) were in the same predicament.

The coral populations were ranked in three categories—fragility, abundance, and distribution. "The objective with the ranking is to provide a tool to conservation agencies so they can direct their programs," said Brad Northrup, director of the Conservancy's Caribbean programs. "It struck me that there are specific areas that clearly need some immediate conservation efforts." The study, which was completed earlier this year and will be updated annually, found that "several coral reef systems off the Florida Keys, the Virgin Islands, Puerto Rico, and the Lesser Antilles of the Eastern Caribbean were seriously deteriorating. "A damaged reef might never be healthy again..." said Kathleen Sullivan, an investigator in the study. "Once it is damaged, it will erode away faster than it can recover."

When reefs break down, coastlines are threatened by every tropical storm. Erosion of the beaches affects tourism, which in turn affect the local quality of life. Fish, which divers and snorkelers on vacation expect to see in abundance, will also move farther out to sea as their habitats and food sources become scarce. These same fish sustain the livelihoods of local fishermen.

"The traditional focus has been protecting terrestrial ecosystems. This study shows that reefs are as rich in diversity as the rain forests ad deserve equal conservation efforts," said Nature Conservancy zoologist for the Latin American Caribbean Program, Roberto Roca. The Dominican Republic has 14 parks of which only six are marine; Trinidad and Tobago have 10 parks, one is marine; and Puerto Rico has more than 15 parks, non of which is marine.

Meanwhile, coral reefs continue to be "stressed." Ocean dumping, untreated sewage, coastal development (deforestation and mining), and careless boaters, fishers, and divers are among the culprits causing the destruction. "Basically, anyplace where there are a lot of people and a small shelf areas, the reefs are damaged," said Sullivan.

But the waves of destruction may soon be calmed by "Rescue the Reef", a Nature Conservancy program that works with the local populace to create the basic infrastructure needed for marine park management and other long-term projects. The program, started in January 1993 with a grant from Scubapro, a scuba equipment manufacturers, is already active in the Dominican Republic's Parque del Este. Rangers are being hired, trained, and provided with equipment. In Florida, volunteer divers are identifying and tracking endangered marine species via satellite.

Now that the Conservancy's study has set up the guidelines for how to determine marine rareness, "Rescue the Reef" can work to prevent it.

To become a member of "Rescue the Reef", send a check for $30 (members will receive three newsletters and a waterproof logo sticker) to Rescue the Reef, c/o The Nature conservancy, 1815 North Lynn Street, Arlington, Virginia 22209; or call (800) 628-6860. Some major credit cards are also accepted.

Caribbean Travel and Life

Take Back the Reef

Tiny Bonaire plays the Caribbean's leading role in reef protection and marine preservation.

by Norie Quintos Danyliw

Since the beginning of this year, Bonaire has been charging an admission fee to divers—the first major diving destination in the Caribbean to do so. After quite a furor last year over the impact of such a fee on dive tourism, including dire predictions of a massive diver boycott of Bonaire, the fee seems to have been accepted by most involved as necessary to keep the Bonaire Marine Park healthy. This is the way it works: Anyone planning to dive in the Bonaire Marine Park (which includes all the waters from the high water mark to the 200-foot depth contour surrounding Bonaire and Klein Bonaire) must pay a $10 fee, good for one year of unlimited diving. Residents of Bonaire are not excluded from paying the fee. Visitors may pay at the Bonaire Marine Park headquarters in town or at any island dive operator. A tag and admission ticket are issued; the tag must be attached to dive gear and be visible at all times. Dive operators have the legal obligation to inspect tags before filling tanks with air. Bonaire Marine Park rangers will also check divers for tags. All monies collected (expected to be about $150,000 in 1992) will go directly to the Marine Park for upkeep and maintenance, law enforcement, information and education, and research and monitoring.

This is pretty activist stuff, especially for an island on the edge of the Caribbean that few people have even heard of. But Bonaire's no stranger to activism, nor has it ever been afraid to be the first on the block to take action, particularly when the reef is concerned. I 1971, while dive magazines were publishing page after page of spearfishing equipment ads, and spear guns were widely considered standard scuba equipment, the island of Bonaire was banning spearfishing from its waters. Soon after came a project to place permanent moorings at popular dive sites to prevent anchor damage of reefs. Four years later, the government banned the taking of coral—alive or dead—from its waters. And in 1979, Bonaire took its biggest step, becoming the first island in the Caribbean and perhaps the world to declare all its surrounding waters a protected marine park. Last year, Bonaire was the first to offer free advanced buoyancy classes to every single diver in 1991 in order to improve diver comfort and reduce diver damage to the reef. That year also saw the birth of the Dutch-Bonairean Turtle Club, a group raising funds to save the endangered sea turtles.

A mere mote on most maps, Dutch Bonaire, about 50 miles off the Venezuelan coast, is hardly the logical choice for pacesetter in the fight to protect the reefs. Other Caribbean nations have paid lip service to marine conservation and there are even some marine parks that predate Bonaire's, but most of those were and continue to be "paper" parks with little or no active management.

Bonaire is on the cutting edge of dive ecology—years ahead of places that are many times its size—including the United States. Indeed, perhaps Bonaire's minute size has been an advantage in this matter. Bonaire is basically a one-industry town. "Let's face it, we {Bonaire} don't have Aruba's beaches nor Curacao's commerce. What we have is great diving," says Sand Dollar dive operator Andre Nahr. And that industry is growing. Last year, Bonaire had 15,000 divers making an average of 10 dives each. That's a lot of reef contact, especially on the more popular dive sites. Twelve years ago, Bonaire got only 4,700 diving visitors; in 1970, only several hundred. With this rapid growth, Bonaireans have come to realize that it makes good economic sense to preserve the reef-if not for the nobler sake of future generations—then for the sake of their own livelihoods. Also, with only 12 dive operators on the island—all pretty much in the same boat—achieving consensus and cooperation is feasible. According to Bonaire Marine Park manager Kalli De Meyer, another advantage of size is that "people notice. They notice if the groupers disappear—which has happened here—or if a particular reef gets damaged—which has also happened here. People see the impact on their environment more readily and greater pressure can be put on the government."

But perhaps most significantly, Bonaire's activism—which has not been limited to the sea but extends to land as well—has been launched , driven, and buoyed by a combination of factors: a receptive government, concerned conservation groups, and some very committed residents.

Undoubtedly the single most important person in this story is "Captain" Don Stewart, who arrived on Bonaire in 1962. A crusty Californian, Stewart came to collect ornaments for the aquarium trade and became involved with the expansion of the island's first hotel—the Flamingo Beach Club. Like many intrepid divers during the early years of scuba, Stewart was an avid spear fisherman. He worried little about the marine environment—not because he didn't care, but because it seemed inconceivable that the sea might one day fail to replenish what was taken; there seemed to be an endless supply of fish, coral, shell—all of it available for the taking.

But one day it him. He has been quoted as saying, "I originally discovered conservationism after I put on one of the biggest spearfishing tournaments in the islands. I saw hundreds of fish piled up there for no reason . . . and I stopped that very moment." Stewart hung up his spear gun and began actively campaigning for a prohibition.

The spearfishing ban was passed by the Bonaire government in 1971. But Stewart's activism didn't stop there. He saw the damage wrought by anchors dropped at dive sites and developed the concept of permanent moorings for scuba diving vessels. First used on Bonaire, mooring systems are now being introduced all over the world (though many major diving destinations still prefer to throw in an anchor). Today, more that 75 permanent moorings, now maintained by the Marine Park, ring the islands of Bonaire and Klein Bonaire. Stewart considers this his greatest achievement.

By the late 70s, various concerned groups were pushing for stronger legislation and the creation of a marine park. The Park was established de facto in 1979 (though the supporting legislation was not passed until 1984), as the first in the Netherlands Antilles. Funding for management of the Marine Park came for the Dutch government and a grant from the World Wildlife Fund-Netherlands.

Unfortunately, despite the good intentions, money ran out a few years later, and with it went active management of the Park. "In essence, it became a paper' park—a park in name only—with what little management there was being done by CURO (Council of Underwater Resort Operators), says De Meyer.

The diver operators—working voluntarily and as a unit— took over such functions as the maintenance of moorings and closures of overused dive sites. Most importantly, they kept the idea of the park alive, educating thousands of visitors about Park regulations, even though these rules went unenforced for years.

But however admirable CURO's efforts were, Bonaire's reefs were beginning to show signs of wear. Not all of the damage could—nor should—be attributed to divers. Non-ecological construction, thoughtless waste management, and certainly other users often marine environment such as boaters, fishermen, and swimmers had also taken their toll.

Finally in 1990, after increasingly vocal calls for action by various groups, including Prince Bernhard of the Netherlands, the Bonaire government commissioned an evaluation with a view towards resuscitating the Marine Park.

The resulting recommendations formed the basis for the revised Marine Ordinance, which the Island Council of Bonaire passed in June 1991. Once again, the Dutch government came up with funding and technical assistance for a period of three years on the condition that a visitor fee be introduced, which would make the park self-sufficient beyond 1993.

The reception of the admission fee for divers has been generally positive, if guarded. Leonora Reich, 68, who first came to Bonaire more than 20 years ago, recently brought her grandson, 13, to Bonaire to learn how to dive. She took him down to Leonora's Reef, the dive site named after her by old pal Captain Don Stewart, and pronounced it "in surprisingly good shape." And what of the new diver fee? "We pay $10 to commercial enterprises all the time that don't do one thing to help the environment, and we don't even blink. If it [a divers' fee] does what it is meant to do, and that is to preserve the island's reefs for my grandson's grandson, then it is money well spent."

Dee Scarr, a dive guide and a part-time Bonaire resident, agrees, "People seem very glad, as I am, to participate in the maintenance of the Park. It's just one more piece of evidence of this island's desire to keep its reefs healthy, which is one reason I'm here in the first place." Still, there are those who contend that divers have been unfairly targeted, when swimmers, snorkelers, and boaters use the Park too. De Meyer defends the fee. "Yes, divers are bearing the load of financing the Marine park. But they are 90 percent of the users of the Park and they are the ones who will most directly benefit as well. In fact, divers can see the fruits of their investment immediately—in moorings that are well maintained, in shore markers that designate a dive site . . . in many cases we've even marked the easiest point of entry and exit . . . that's all for the benefit of divers."

Though the diver fee is certainly the most important regulation to come out of the revised ordinance, other significant changes were also implemented. Among them: the ban against the taking of sea turtles, the strengthening of the spear gun prohibition, and the reduction of the unrestricted anchorage zone.

Everyone agrees that more can and needs to be done. Tom van't Hof, independent consultant to the Netherlands Antilles National Parks Foundation, notes, "Indeed there is a great need to do more coastal zone planning. We've noticed increased runoff and resulting damage to the reefs due to non-ecological construction practices. We need to come up with strategic and sensitive planing in future development projects. The revitalized Marine Park is in a good position to play a major role in this."

More also could be done in the education and enforcement level. Says Michael Gaynor, a dive instructor and a Bonaire resident, "You see people of through the airport all the time carrying bags of shells, coral, sea fans—out in the open— and nobody says anything."

Still, Bonaire's achievements far out pace many other diving destinations and are an example to the region of what a community, however small, can accomplish. Says Andre Nahr, current president of CURO, "We don't want Bonaire for just 10 years. We want it for 50, 100, 500 year from now." So do we.

You Too, Can Save a Reef

Whether sailing, scuba diving, snorkeling, swimming, or just beaching, you can do your part to preserve the reef and protect marine life wherever you happen to be in the Caribbean. Here are some dos and don'ts from Bonaire's dive masters.

• If you dive or snorkel, avoid silting up the bottom with your fins and touching living corals. Divers should practice good bounce control to avoid accidentally bumping into coral; most dive shops offer free workshops in advanced buoyancy control.

• Though the point is debatable, many experts recommend that you refrain from feeding a fish food inappropriate to its diet (like Cheez Whiz) as it can make a fish ill, change its behavior, or otherwise upset the natural balance of the environment.

• To prevent distress to marine life, avoid handling marine creatures, e.g., tormenting a puffer fish to make it puff up, riding a sea turtle.

• Even dead coral and empty sea shells have their roles. They often provide shelter for tiny reef animals; eventually, they get crunched up and provide the white sand we travel so far to see. Avoid taking them home with you. (In Bonaire it is illegal to remove anything—living or dead—from the Marine Park.)

• Boaters should keep in mind that anchoring causes permanent damage to coral reefs. If at all possible, find a mooring. If there is not one available, keep frequency of anchoring to a bare minimum. (In Bonaire, anchoring is strictly forbidden except in a small harbor area in town or for fishing boats of less than 12 feet.)

* Avoid buying items made out of coral, shell, or turtle shell. On some islands it is illegal. U.S. Customs also prohibits the importation of items made out of endangered animals. Unless you are certain your purchase is neither illegal nor ecologically harmful, it's best to avoid the issue altogether.

Channeling Revenues to Resource Protection

Kalli De Meyer
Bonaire Marine Park Manager.

I believe that most people here would agree that resource management and protection is of paramount importance for the development of sound economic growth in the field of tourism especially where there is "ecotourism". More blandly stated a healthy environment is the goose which lays the golden egg for tourism and the protection of that goose is really in everyone's best interests...

It should come as some surprise, therefore, to learn that, according to a recent report by OAS (OAS/NPS, 1988), of the established marine protected areas in the Caribbean only 29% may be considered "fully protected" - if the USA is excluded this figure drops to a mere 16%. Furthermore that only 24% have effective day to day management and that a stunning 50% are without personnel. Considering their economic importance this is staggering . . . Why is this the case?

Brief Case History of the Bonaire Marine Park

(Let me briefly share with you our experiences on Bonaire) Bonaire has always been very proactive when it comes to conservation:

• Turtle nests and eggs have been legally protected since 1961

• Spearfishing was banned way back in 1971 an act equivalent in many ways to what would be the banning of underwater cameras today.

• Capt. Don Stewart, the first person to set up a dive business on Bonaire and quite a figure in his own right, can be justly proud of setting up the first system of moorings to avoid having his dive boats anchoring on the reef.

• On Bonaire the corals, which are of course the building blocks of any reef, have been legally protected since 1975.

These regulations show an increasing concern for marine environmental protection which culminated in 1979 in the establishment of the Bonaire Marine Park.

With Tom van't Hof as the Park's first manager and Eric Newton his local counterpart the Park go off to a flying start. Perhaps most importantly, comprehensive legislation was drafted which established the Marine Park as a protected area from the high water mark to the 200' depth contour both around Bonaire and the smaller adjacent island of Klein Bonarie. Research and monitoring programs were set up, a system of more than 40 moorings was established for use by dive boats, shore access points were marked and extensive information on the Park, including a book, were produced and distributed.

And the goal of the Marine Park - simply to ensure a sustainable marine environment.

With so much going for it, why was it then that after 5 brief years, active management of the Marine Park ceased? (I should emphasis that this is not to say that marine protection and the concept of the Marine Park were things of the past-the dive operators took it upon themselves to maintain and expand the mooring system through Capt. Don's pioneering "Sea Tether" program. They also continued to brief divers about the existence of the Marine Park and did their best to ensure that Park regulations were adhered to. But the Marine Park had ceased to be actively managed and many of its important functions such as the provision of information and education, research and monitoring and patrolling were simply not being fulfilled)

The fatal flaw was lack of a firm financial basis for the Marine Park. The original project was funded by World Wildlife Fund, Holland with additional subsidies from both the Dutch and Antillean governments. This covered the initial start up costs. However once grant funding ran out . . . so inevitably did active management.

So, What's the Answer?

(I'd like to share with you what our solution has been)

In 1979 when the Marine Park was first established there were just 4 dive operations on Bonaire catering to less that 5,000 diver annually. By 1989 there were already 8 dive operations catering to approximately 15,000 diver annually (i.e. over a 10 year period the number of dive operations had doubled and the numbers of divers had tripled!). Roughly 75% of the tourism to Bonaire is dive related.

This tremendous growth in the tourism sector led to renewed concern for the resource base-Bonaire's spectacular coral reefs-and sufficient impetus was generated both on and off island that in April 1991 the Marine Park was revitalized.

Again grant funding, was very generously supplied by the Dutch government, was used to cover the initial start up costs but this time the Dutch government very wisely stipulated as a condition of providing the grant monies that the Marine Park must become self supporting within the term of the grant i.e. within 3 years.

A decision was therefore taken that, since tourism relies directly on the natural resources of the island, it should be the one to pay for the upkeep of the Marine Park and at this point any number of funding options were considered including raising existing tourist taxes, introducing a new tax, franchising the hotels/ dive operations or passing the costs on to the end users-those who in fact benefit most directly from a well managed and well maintained Marine Park-the divers.

Eventually, after extensive discussions with all concerned, but particularly with members of the dive community and hoteliers, it was decided (I can't really say "agreed") to implement a $10.00 per annum admission fee which would be paid by everyone scuba diving in the Marine Park. This was promptly written into the legislation together with regulations concerning what use could be made of these fee monies and the first tickets and tags were sold on the 1st January 1992.

Despite some initial unease about the admission fee on the part of local dive operators and an influential dive magazine, the admission fee system has found a whole hearted support amongst divers and has been a tremendous success. Dive operators ensure the success the program by selling admission tickets on behalf of the Marine Park and they have been able to fit the sale of admission tickets neatly into their regular "check-in" procedure. When a diver pays the admission fee they receive a ticket and plastic tag-the tag is then attached to an item of dive gear the diver will have with them in the water. For those of you coming to Bonaire for the field seminar you will have the opportunity to witness this process first hand.

And the Secret to (continued) Success in Managing Protected Areas?

One of the keys to success has to be .. . GET THE FINANCING RIGHT!

Here are some points to bear in mind:

1. It is important to distinguish between "one off" and "continuing" expenses. One off expenses like start up monies or special projects can most easily be covered by applying for grant funding either from a government or NGO or through corporate or private sponsorship depending on the amount involved.

2. It is very difficult to get continuing expenses, such as operational expenditure, met in this way-this is where concession, user fees and the like come into their own.

3. Finally, it is important to utilize as many different funding options as possible in order to channel as much money as possible into resource management.

• Our start up funds came from the Dutch government and were used primarily for the purchase of capital equipment (boats, cars, telecommunications, office equipment) etc.

• Diver admission fees are used to cover basic operational and personnel costs. The money from admission fees comes directly to the Marine Park so none is frittered away or lost in transit. By the end of 1992 we were indeed able to meet our own day to day running costs.

• We offer souvenirs for sale-at the moment this is limited a to few T-shirts and caps-but it should be realized that the sale of souvenir items may prove to be a very lucrative source of additional funding. We are currently trying to involve the local tourism industry in selling souvenirs on our behalf.

• For special projects we apply for NGO funding. For example we just received grant funding from World Wildlife Fund Holland to bring a scientist from Europe to spend 3 months working with the Park Manger in order to set up a long term monitoring program for the Marine Park.

• We have plans to set up a "Friends of the Bonarie Marine Park" to accept private donations. We do accept, and in fact have received private donation, both of money and, just as importantly, donations of equipment e.g. dive equipment, computer hard+ software .

• We solicit as much volunteer support as we can both from the local community and from visiting tourists (for data collection, administration, mooring maintenance as well as a host of other things). We have one scientific project right now which is being run entirely by volunteers.

In conclusion, it is clear that tourism, especially "ecotourism", is an industry which is growing and expanding at a phenomenal rate. The health of this industry relies directly on the health of the tourism "product" it seeks to sell in other words the natural and cultural resources of the tourist destinations. As resource protection agencies it is our task to work with the industry, with government, with funding agencies, and with the consumer to channel as much funding as possible into resource protection by whatever means at our disposal.

And any message to the tourism industry, I guess, is don't be too stingy on the food if you want that goose to continue laying!

Reference

OAS/NPS. 1988 Inventory of Caribbean Marine and Coastal Protected Areas.

Summary

Limited only by your imagination!

- government funding (often difficult to obtain and difficult to work with but may be a good source for start up funds)
- NGO grants e.g. WWF, Nature Conservancy (excellent for special groups)
- user fees (most appropriate for tourist destinations)
- concessions (most appropriate for tourist destinations)
- private donations ("friends" of . . .)
- corporate sponsorship (may be money, equipment, office space)
- sales (souvenir articles)
- trust endowments
- inkind services and support (volunteers local and international – Earthwatch, Cedam)

Section VI

Getting Started on a Mooring Buoy Project of Your Own

Overview

In this section you will find sources of additional information, sources for possible funding and a guide to assist you in planning a mooring buoy project of your own.

Contents

Listing of Sources to Contact for Additional Information on Mooring Buoy Project

Center for Marine Conservation
1725 DeSales St. NW
Washington, DC 20036
Pamphlet: The Use Of Moorings As A Management Tool

Dor-Mor Inc.
RFD #2
Box 476
Claremont, NH 03743
603-542-7696

Environmental Moorings International
172 Lorelane Pl.
Key Largo, FL 33037
305-451-5984
Components for Halas System

Foresight Products Inc.
116 Cass St.
Traverse City, MI 49684
616-941-4212 or 800-748-0471
Manta Ray

Florida Keys Marine Sanctuary
Mile 100
U.S. Highway 1
Key Largo, FL 33037
305-451-6476
Information on Halas eyebolt system

Hazelett Corp.
217 Lakeshore Dr.
P.O. Box 600 Colchester, VT 05446
802-863-6376
Elastic rodes

Helix Mooring Systems, Inc.
170 Spring St.
Southington, CT 06489
603-672-1930 or 800-866-4775
Distributes helical moorings from A.B. Chance Products

Sea Spike Marine Supply Co., Inc.
994 Fullerton St.
Farmingdale, NY 11735
516-249-2241
Mushroom Anchors

Environmental Funding Sources

Greenpeace
1436 U Street, NW, Washington, DC 20009
202-462-4507

The Nature Conservancy
785 Market Street , San Francisco, CA 94103
415-777-0487 415-777-0244 fax

Ocean Futures Foundation
Atten: Jon Englander
2050 S. Santa Cruz St., Ste. 1000
Anaheim, CA 92807
714-939-6399 714-939-6398 fax

Project AWARE Foundation
Atten: Jenny Miller Garmendia
30151 Tomas Street
Rancho Santa Margarita, CA 92688-2125
866-80-AWARE
949-858-7657 949-858-7521 fax

PADI Foundation
Atten: Charles Rettig
9150 Wilshire Blvd., Ste. 300 , Beverly Hills, CA 90210
310-281-3243 310-859-1430 fax

Patagonia Environmental Grants Program
Patagonia, Inc.
PO Box 150, Ventura, CA 9300

Reef Relief
PO Box 430, Key West, FL 33041
305-294-3100

Surfrider Foundation
122 S. El Camino Real #67
San Clemente, CA 92672
714-492-8170

The World Conservation Union (ICUN)
Marine and Coastal Activities
Rue Mauverney 28
CH-1196 Gland, Switzerland

Mooring Buoy Program Planner

I. INITIAL PLANNING PHASE:

- Identify all user groups, local organizations and government agencies and their roles
- Educate community and government agencies on need for moorings
- Identify how to reach pertinent government agencies to grant permits, etc.
- Discuss liability issues
  - Identify need for legislation to enforce mooring use (if any)
  - Identify methods of enforcement (including volunteer)
  - Identify needs (for or against) establishing marine parks, sanctuaries, etc. To further protect coral reefs
- Research

General water quality of area

Needs assessment of sites for mooring buoys Types of Substrates, etc.

Types of suitable mooring systems available

- Identify parties to perform administration
  - Over-all Project Planning
  - Fund-raising
  - Mooring Buoy Installation
  - Mooring Program Enforcement
  - Mooring Buoy Monitoring (physical condition/ deterioration) Regular Maintenance Program for Mooring Buoys
- Needs assessment of training program for installation and maintenance
- Identify local user groups, government agencies and/or NGO's to support project
  - With publicity
  - With cash
  - With volunteers
  - With equipment
- Develop Time Line

II. ECONOMIC AND ADMINISTRATION

- Gather data required for permit proposals
- Write proposals for permits
- Plan and implement fund-raising events
- Obtain various sources of funding
- Obtain financial support for phone and fax support

III. INSTALLATION

- Map and mark mooring buoy sites
- Develop complete equipment and materials lists
- Recruit volunteers:

People
Boats and captains

- Determine best mooring system type to use based on research:
  - Halas System (pin)
  - Helix
  - Hughes
  - BEWR
  - Manta Ray
- Find suppliers of mooring systems and other equipment and materials
- Customs assistance & duty-waivers from government agencies for imported equipment
- Needs assessment for technical assistance
- Logistics Shipping times/places/dates of materials Shipping times/place/dates of equipment Management of personnel

IV. MOORING BUOY PROJECT PROGRAM MAINTENANCE:

- Develop system of monitoring and logging condition of mooring buoy
- Develop system of monitoring and logging condition of mooring site
- Develop system of responsibility for each mooring buoy's replacement (& parts)
- Develop on-going financial support system
- Develop system of logging maintenance of each mooring buoy