MEASURING the SEA:
Do-It-Yourself
OCEANOGRAPHIC
EQUIPMENT

Dr. Andreas B. Rechnitzer

Dr. Andreas B. Rechnitzer pioneered the use of scuba and deep submersibles for science, developed innovative equipment for determining underwater explosive effects on marine life, collected and inventoried marine animals in new ways that have become standards for marine ecologists, and involved himself in extracting underwater ship remains from the reefs of tropical seas. During the earlier years of his career he found himself at sea without much more materials for fabricating oceanographic devices than that on board most pleasure craft. Six years of graduate school also meant skimping on expenditures, so the most expedient route to getting oceanographic tools that would suffice was creativity. Accordingly, the devices and ideas described in this chapter hark back to those days. Surprisingly, many of the "primitive" samplers have not changed much in function once they were commercially produced. Jerry-rigging is fun and sometimes a lifesaver. On occasion he found himself overweighted with samples while scuba diving. Unused plastic sample bags filled with discharged scuba air became balloons that made the ascent effortless. On one occasion he was drifting in an arm of the Gulf Stream after surfacing from a long scuba dive. With the tending surface craft just barely visible, he tilted the electronic strobe of his camera rig toward the boat, and it served as a daytime lifesaving beacon for himself and five buddies! Although this chapter stresses simple approaches to oceanographic tool construction, Dr. Rechnitzer has designed some sophisticated devices for sampling to ocean depths of seven miles.

This he did during the four years that he was the scientist-in-charge of the bathyscaph *Trieste.* They were used during the *Trieste* descent to the maximum-known depth in the ocean of 35,800 feet.

The mariner can expand his knowledge about the world beneath his keel through measurements and sampling. The purpose of this chapter is to describe and illustrate how to create some effective, inexpensive, and fun oceanographic instruments for use by the deck-bound boater.

As many boaters enjoy getting into the water, particularly in the Caribbean area, this chapter includes descriptions of instruments and methods that can be used by a snorkel or scuba diver. Diving as a means of acquiring samples and measurements has become a universal scientific method. In some instances it is the only method available to validate measurements, samplings, and observations. The use of instruments by divers is still in a state of evolution, so perhaps your ingenuity may add a new device.

The oceanographic instruments described in this chapter can, in most instances, be improvised from components normally onboard. Rope-line, boat hook or broom handle, empty food container, a man's old sock or lady's pantyhose, a plastic bag, a wine bottle or jug, grappling hook are but a few examples. See a more complete materials list at the end of this chapter. The list is a memory jogger to include items that may not be onboard, but should be if all of the instruments and techniques are to be tried. Most of the materials are readily available from hardware or drug stores. Only the basic features and principles are described, as some ingenuity and creativity is left to the boater as part of the pleasure to be derived when doing-it-yourself is individuality.

SOUNDING AND LOWERING LINE

The basic unit for the surface-bound boater is the lowering line and lowering weight. Properly calibrated with depth units, it can be more eloquently called a sounding line. Since it will be used frequently as a key component, a 100-foot length of ⅜-inch manila hemp rope should be dedicated for oceanography use. Nylon, like most other synthetic fiber rope, tends to strech under a load. If you are looking for accuracy, then stick to hemp rope. The line you are going to use should be fitted with ⅜-inch rope thimbles at each end so that it can be rapidly attached and detached from a variety of devices.

To calibrate the line with durable and meaningful markings, a decision needs to be made whether to use feet, fathoms, or meters. Each is convertible to the other. The scientific standard is the meter that equals 39.37 inches or 3 feet 3⅜ inches. The fathom remains a handy unit since it is built into our arm spread. Being readily available, it has long been the measurement of the fisherman and mariner. The fathom can be approximated by the adult boater by simply spreading the arms out level with the deck—fingertip to fingertip for a 6-foot man usually comes very close to 6 feet without adjustment. Mark 6 feet off on a piece of line. Grasp the line between the thumb and curled forefinger, and stretch the line across the chest. If slack remains, move the arms backward to make it taut (this is often required for people less than 72 inches tall). Remember the position where the fathom was made taut. Repeating that position as the line is paid out or taken in will give a quick measure of the sampling depth. Some like to have a similar fast method for ½ fathom or 3 feet. Your nose is a halfway point. Hold one end at your nose while looking straight ahead. Grasp the end of the line as above and stretch as before, but with only one arm.

The interval you choose to use on your line can be made by painting a bright band around the line. A different color at each tenth interval simplifies counting. For an accurate measure, the line should be loaded with a 15-pound weight when marking. Hemp, unlike the synthetic-fiber ropes, does not stretch significantly, so is the best for this purpose. Less durable markings can be made using electrical tape, string, and other materials.

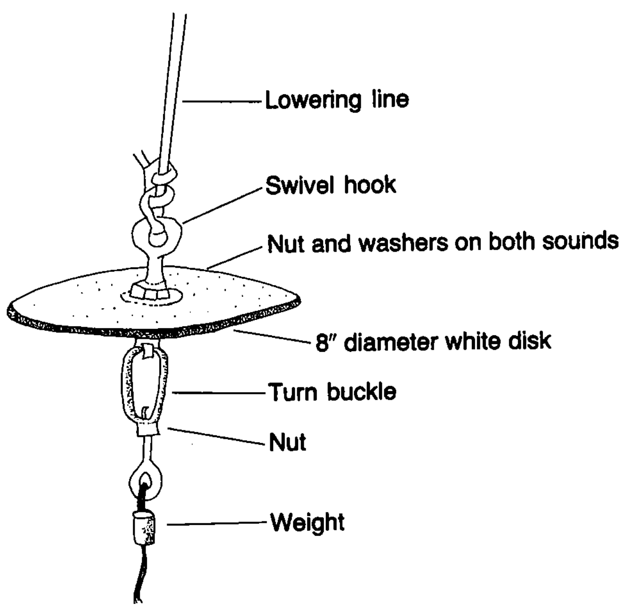
SOUNDING WEIGHT

The type of line just described when fitted with an elongated lead weight served the earlier mariner as the bottom sounding line. Don't forget it can still fill the bill when the echo sounder isn't functioning. A sounding lead can be purchased from a marine supplier or can be fabricated from a variety of high-density items: a window sash weight, a length of pipe filled with sand or cement, lead weights from a diver's belt, scrap metal, a light anchor, or a pipe wrench. The more streamlined and dense the sounding weight, the more rapidly the line can be paid out, and the less likely it will be to hang up on the bottom. To sample the bottom, the weight tip can be hollowed out and the depression filled with beeswax. When the weight strikes the bottom, a small amount of bottom will become embedded in the wax. Even wheel-bearing grease will perform the recovery function.

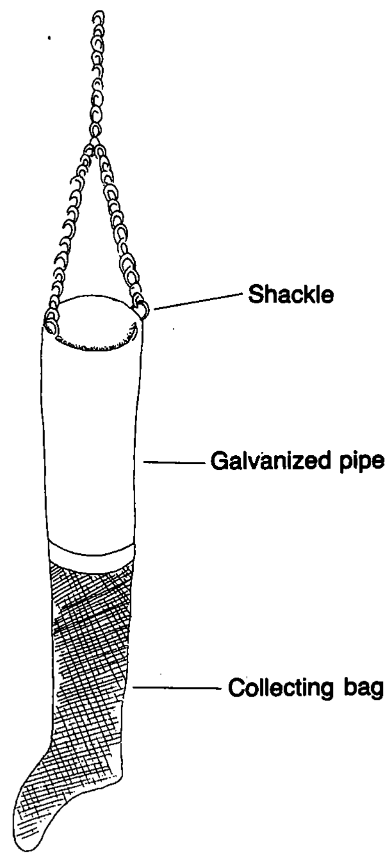
WATER CLARITY

Boaters traversing waters, shallow and deep, often wonder how far it is to the bottom or how far down one can really see. A simple device is the Secchi disk. A white disk eight inches in diameter that can be fashioned from plastic, wood, or metal will give the boater his own Secchi disk. The disk must be kept horizontal with the surface. Stability can be obtained by fitting the center with one eyebolt end of a turnbuckle. Remove one of the threaded bolts from a complete turnbuckle. Add a large washer and nut on each side of the disk. This will provide strength and suppress wobble. Leave enough free threads to fit back into the turnbuckle. Lock it with the nut. Now you have a connecting point for the lowering line and the take-down weight. Raising and lowering of the disk at the depth of visual extinction will give a meaningful and repeatable indication of water transparency. Lowering the Secchi disk on the windward side of the boat will keep it in the best position for viewing. Be aware that variations in readings for water having one transparency will occur because of the sea surface changes and particularly the position of the sun.

As a rule, the high transparency common in the open ocean lessens as the coastline is approached. The reasons for this are many and include an increase in plankton populations that thrive on the more abundant nutrients combined with suspended sediment particles derived from storm-disturbed bottom and land runoff. The scuba diver can acquire useful transparency information from the use of the Secchi disk before entering the water to photograph or just to make observations. Here are some typical Secchi disk readings for the east coast: Long Island Sound, 2–3 meters; Woods Hole Harbor, 6 meters; Gulf of Maine, 17 meters; Caribbean Sea, 24 meters.



Secchi disk to test water clarity



Bottom sampler

SURFACE CURRENT

The drift bottle continues to be a good means to determine the general direction of surface currents. Sturdy, empty soft-drink and liquor bottles when capped make good drift bottles. Slip a card inside that gives the date, location, your address, and any reward and a request for the finder to fill in information as to place and time of discovery. Toss the bottle over the side and wait for it to be found. The boater has to accept that it may be a long time before he receives a return, but the wait is worth it if he finds out that the bottle traveled hundreds of miles.

Surface current in the immediate area of an anchored boat can be determined by timing the drift rate of orange peels, wood chips, confetti, and any other material that will float. Surface current will often bring an anchored boat's bow into the current. Dropping any of the above items off the bow allows the boater to follow the drifting indicator alongside the hull. Time and distance calculations will give the current velocity.

BOTTOM SAMPLER

To sample the sea-floor sediments and rocks, a pipe dredge can be fabricated easily using a short length of galvanized pipe. One and one-half to two feet of pipe with an inside diameter of two inches or larger is very effective. Add a three-foot-long chain yoke attached by shackles to the front of the pipe 180° apart looking at the pipe end on. To this chain yoke, shackle a single length of chain 3–6 feet long. The combined weight of the chain yoke and the single length will make the pipe dig into the substrate. On the back end of the pipe tie on a man's foot sock. Pull it over the outside of the pipe and secure it with a few turns of high-strength line or a strap clamp. When the lowering line is attached to the single chain, the instrument is ready for use. Let out more line if it comes up empty. More line out makes it dig in more readily.

BOX-TYPE BOTTOM SAMPLER

A larger-capacity box-shaped pipe dredge can be constructed from threaded galvanized pipe parts available from a home-supply store. Band iron, which is also readily available at hardware retailers, is another option. It can be bolted or welded to provide the basic box frame. An eighteen-inch-wide-by-36-inch-long-by-6-inch-high frame fitted with heavy canvas aprons attached to the forward crosspieces (top and bottom) will serve to protect the collecting bag inside the frame, regardless of which side decides to be the bottom.The collecting bag can be a burlap bag or one fabricated from plastic screen, galvanized hardware cloth, or heavy fish-net material; all are suitable. The collecting bag can be joined to the dredge with soft galvanized wire passed through grommets or the bag material. A six-foot yoke of chain and a lot of tow line out will get the dredge to the bottom. Window sash weights added to the tow line about ten feet ahead of the dredge will get the dredge to fish with less line out. Operating any dredge in rocky areas invites a dredge hang-up. Therefore, attach the lowering line to the aft crosspiece. Tie one end of a weaker tow segment to the chain tow bridle and the other end to the tow line, so as to create a slack loop in the main tow line when towing. This arrangement permits breaking the point of tow from the front and shifting it to the rear of the dredge when you get hung up. Usually, the dredge will break free of a hang-up using this setup, and a retrieved dredge beats building a replacement.

SITE LOCATION

Site location, survey, and recording will likely arise as needs when you have found something worth returning to again. Marking a site with a buoy is the logical first act. However, remember that untended buoys disappear quickly for a variety of reasons. When in sight of land, an unmarked location can be relocated with no buoy aids, by selecting two or more intersecting range bearings with an angular spread of 60° to 120°. Structures, terrain features, trees, or other fixed terrestrial features offer readily available options.

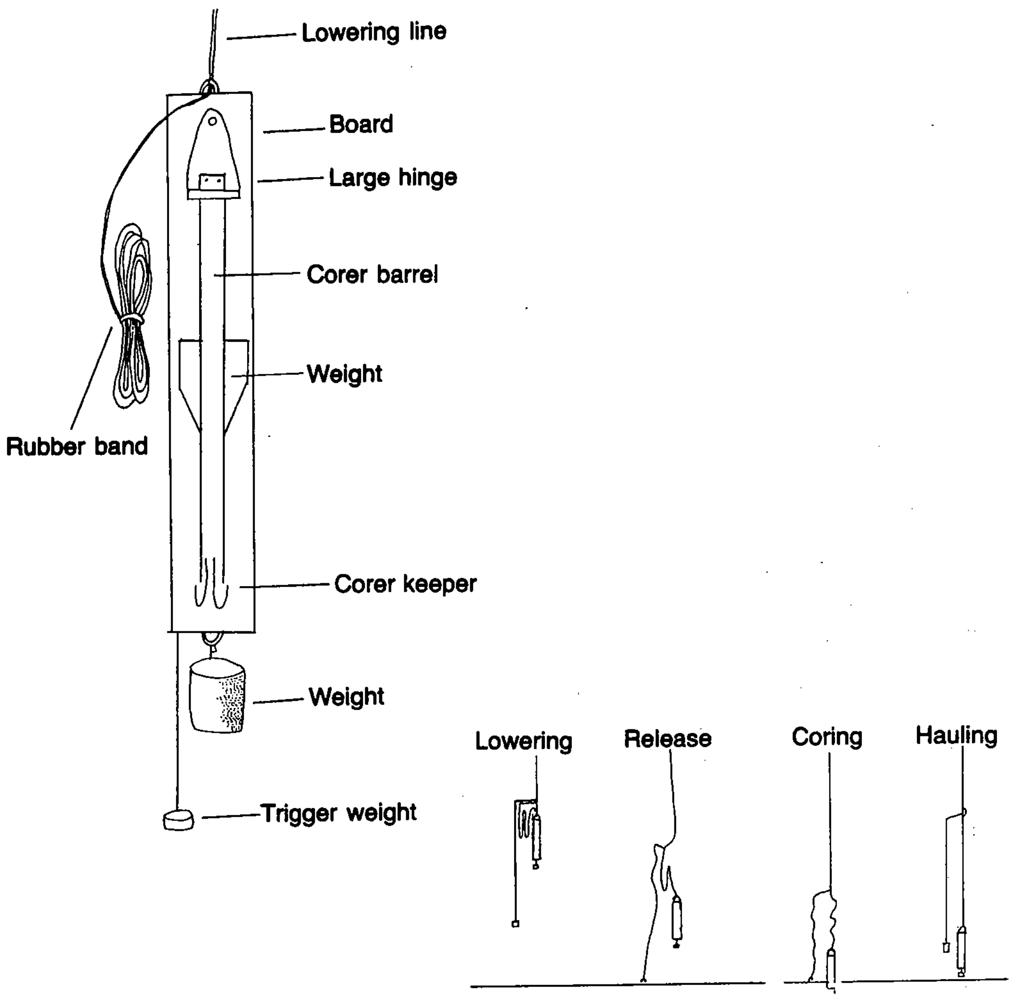
Record your range-bearing selections in adequate form and keep two or more ranges for each location in the boat. One might be the edge of a prominent building lined up with a conspicuous tree or pole. The second might be a shoreline rock formation that is in line with the notch of the horizon hills. When you are ready to return to your site, line up one or the other range bearings and proceed along a course that keeps the first range-bearing reference in line. When you reach the location where the second range-bearing features are also in line, *you're there.* A third range, if available, should also coincide at the same time.

An inexpensive plastic sextant laid on its side is a very effective method for establishing horizontal angles between prominent features. These angles are used in lieu of convenient range bearings. This use of a sextant is superior to using magnetic-compass-determined bearings.

Despite the comment above, if a location is to be revisited a submerged float anchored at the site will assist relocation, and it is less likely to be heisted. The float can be a plastic gallon jug that is tethered several feet off the bottom or wherever in the water column you select. Paint it bright yellow to make the marker easier to see.

BOTTOM SEDIMENT CORER

A sediment corer can be made from any plastic or metal tube that can withstand the force required to penetrate the bottom. The basic components of a corer are: (1) the coring tube with core keeper (one-half inch to two inches in diameter); (2) a weight of adequate size to provide coring penetration after a short free-fall of the instrument (ten to fifteen pounds); (3) a release mechanism and the lowering line; and (4) trigger. A bail should be installed at the upper end of the coring tube. It will serve as an attachment point for the lowering line. At the top of the bail an eyebolt should be added, the head of which will rest in the quick release. The quick-release mechanism is a modified gate hinge (see



Free-Fall Corer Principle of Operation

Bottom sediment corer

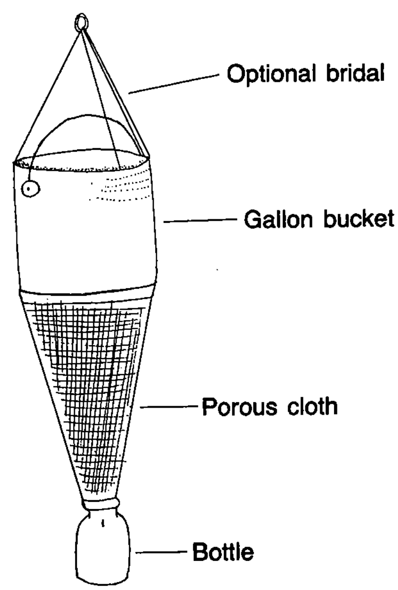
illustration). A trigger line is added to release the corer for its free fall to the bottom. The weight at the bottom of the trigger line should be approximately the same as the corer.

Mud samples are usually sticky enough to adhere to the walls of small-diameter corers without a core keeper. Sand, on the other hand is very apt to wash out without a retaining device. Oceanographers use an expensive brass spring-leaf core keeper and a check vae at the upper end of the tube. An old sock with the toe removed will suffice as a core keeper when it is installed over the penetrating end of the tube. Slip an inch of sock (tube socks are best) over the pipe, and tie or clamp it on securely. The remaining portion of the sock is then stuffed into the corer barrel. A few trials will indicate how long the sock needs to be for your corer. Cut off what is not needed. Push a rod down as a test. In extracting the corer from the bottom, the captured sediment will tend to fall and bunch up the sock, thus blocking the tube. Greater assurance of a core capture and bunching of the sock will occur when the corer is twisted on removal. To generate a twisting motion, the lowering line should be twisted at your end in the direction that tightens the lay of the line.

A ball check valve at the upper end of larger-diameter coring tubes will help retain a core. The upper end of the tube must be open during penetration to prevent water or air compression. To assure alignment of the ball with the tube opening, a straight guide wire should be driven through the center of the ball. The wire is kept in position by drilling a hole in the rigid bail handle. On the descent the ball check valve must be allowed to open. On retrieval it should automatically fall into position by its own dead weight, water flow, and core "pull." Since this scheme requires extra work on a special bail, consider selecting a pipe size to match the cheap toilet tank stoppers that are available. Select either the stopper with the straight threaded rod that screws into the valve or the all-rubber stopper and hinge that fits over a half-inch pipe.

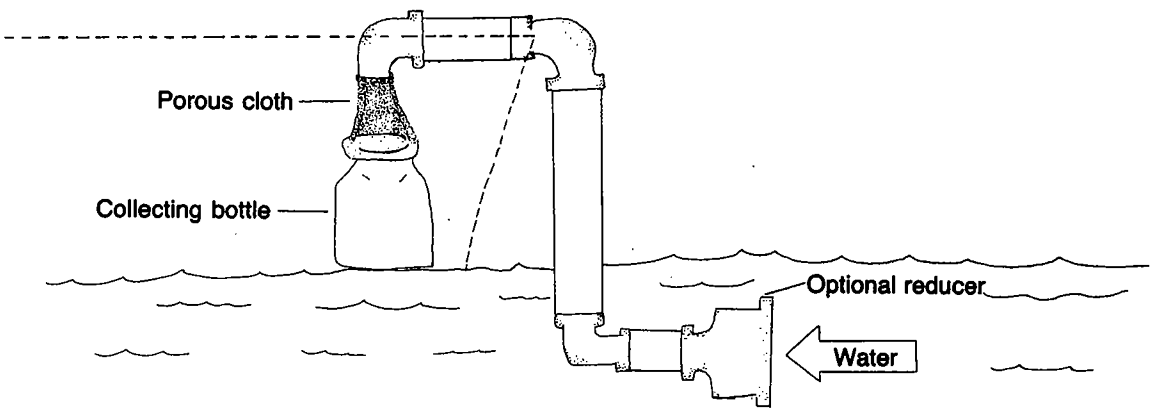
PLANKTON NET

A professional plankton net for capturing microscopic forms requires very precise fine-mesh material such as standard-grade DuFour bolting silk, used for screening flour. However, an effective plankton net for the boater can be fabricated from a simple open-ended cylindrical container fitted with a yoke or bail. For example, remove the bottom from an empty paint can or bucket and you are halfway finished. Clamp a one- to one-and-a-half-foot-long cone of porous cloth material over the open end (like a section from one leg of a pair of pantyhose). Cut off the pantyhose toe and clamp this open end over a small wide-mouth glass jar. The clamp may be a few wraps of strong line (fishing or linen line) tied off with a bow for easy removal. Disassembly after a tow is not necessary, as the bottle containing water and plankton can be brought up through the cylinder and its contents transferred to another container. Speed for a horizontal tow is usually slow (one to two knots), and the filter rate of the cone should not be exceeded. If a vertical col-



Plankton net

lection is desired, then a small weight should be tied to the bottle end. It will both keep the net oriented properly so it won't fish on the way down and expedite lowering time. Many plankters are visible to the naked eye and a hand lens will reveal a lot of detail. Transfer the critters to a small container so they can be kept in focus.



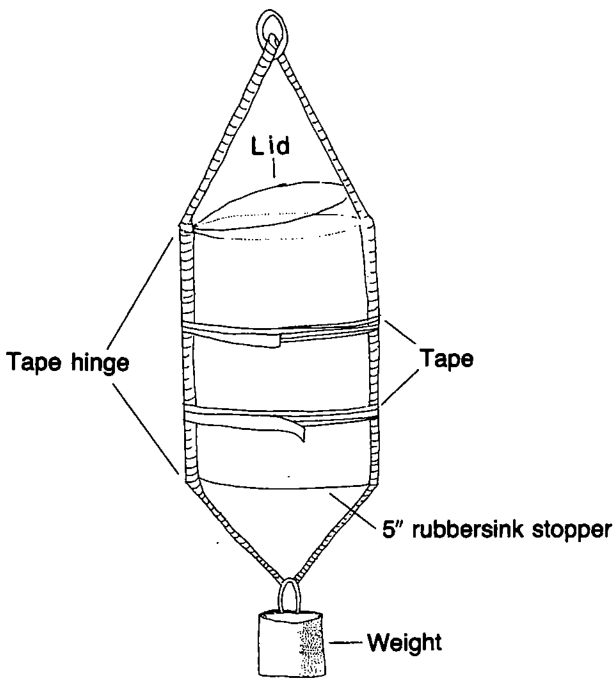
Surface plankton pump

SURFACE PLANKTON "PUMP"

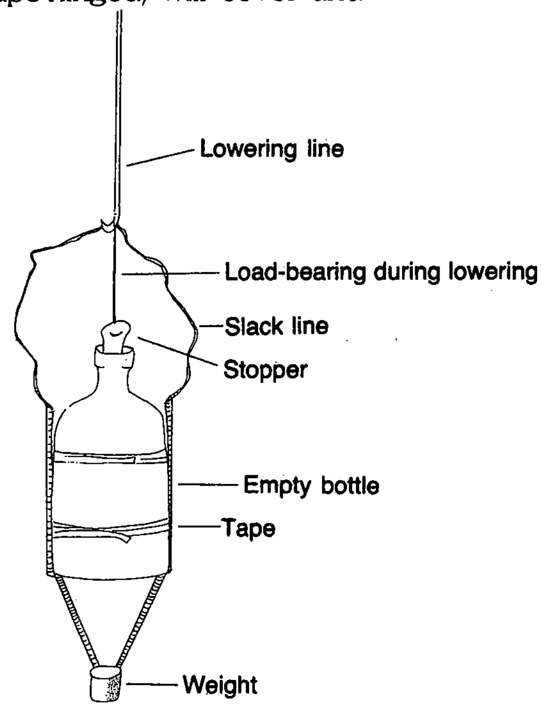
When under way and the lower limb of an "L"-shaped pipe configuration is pointed forward and submerged just below the surface, water pressure will fill it to overflowing, even to deck height. This is then a near-surface plankton-sampler option. Construct the basic unit of one-and-a-half-to-two-inch PVC or galvanized pipe. Adding another "L" limb and a down-directed elbow makes a more convenient point to place a plankton catcher. Any container with a filter barrier around its opening will capture lots of plankton. Again, consider using a segment from one leg of a pantyhose. The finer (smaller) mesh filters will assure retention of the miniscule creatures. The filter can be attached to the down-spout and to a wide-mouth jar in a configuration similar to the towed plankton net. This device can also serve as a steady source of fresh seawater for an aquarium or bait tank. To this unit extra capped pipe can be added to build in stability so that it can be readily hung on the gunnel without special hold-downs and used as a more permanent fixture.

WATER COLUMN SAMPLER (1)

A simple and cheap water-column sampler can be fabricated from a coffee or paint can, a flat rubber sink stopper, and some tape. The top (plastic or metal) of the can is hinged with tape to open and close as a valve. The bottom of the can is perforated from the inside out so a five-inch rubber sink stopper (free-floating or tape-hinged) will cover and



Water-column sampler fashioned from a tin can



Water-column sampler made with a corked bottle seal the holes when loaded from above the water. The lowering line is attached to the bail. A lowering weight is attached to the can sides by two lines for balance. The lines are taped or tied to the can. To capture a water sample at a specific depth, the sampler is alternately raised and lowered a foot or two to pump water in and out of the sampler to clear it of water captured en route. Once retrieval is started, it should be one continuous motion. This sampler can be used to determine the water temperature at a particular depth. See Water-Column Temperature section.

WATER-COLUMN TEMPERATURE

Use a water-column sampler to carry an inside-mounted alcohol or mercury thermometer that is attached by Velcro fasteners. The water temperature will not change significantly en route to the surface. You can measure the temperature of the water once it is on board and without sending it down, but sending the thermometer to depth provides needed time for the thermometer to reach the correct temperature. Holding the sampler at depth for several minutes before retrieval will give the best results. Read the thermometer while it is still immersed. See next section on Finding the Thermocline.

FINDING THE THERMOCLINE

Most water columns include a level of rapid temperature transition. Usually the transition is from the warm mixed layer near the surface to much colder below. Using the water-column temperature instrument make a series of instrument lowerings. If there is a significant temperature difference between a near-surface sample and a hundred-foot sample, then begin, via trial-and-error lowerings, to find the level of change (the thermocline).

WATER-COLUMN SAMPLER (2)

Here the trick is to send an empty, capped soft-drink or wine bottle to depth and open it there to take in a water sample while using but a single line. The empty bottle sampler is also easy to construct from a half- or even a one-gallon glass jug. Plastic jugs will collapse with the pressure increase, so are not suitable. The narrow-mouth container selected should be plugged with a rubber stopper or a cork. A galvanized eyebolt inserted through the stopper and fitted with a washer and a nut to make it leak-proof when inserted into the jug will perform reliably. A regular cork can be fitted similarly, or a screw-in drawer-pull knob. Two lines, about two feet long, are tied to the eyebolt and then fastened firmly with tape to the sides of the bottle. It is important that a slack loop of equal length (about 4–5 inches) be left in each of these lines before taping. This will allow the cork or stopper to be pulled out after supporting the instrument weight on the way down. A jerk on the lowering line will pull the cork and shift the load to the two lines leading to the take-down weight. The lines should be taped to the bottle at two or more levels to assure that they do not slip when the take-down weight is added to the lines that are joined below the bottle. The ready-to-lower instrument is attached to the lowering line at the eyebolt. At depth the lowering line is given enough of a jerk to pull the plug out of the bottle. Water will rush into the bottle because of the pressure difference (less inside), and the two lines will be supporting the bottle and the lowering weight. A variation of this scheme is to pierce the cork horizontally with a needle or drill and fasten a single line to the cork. The free end is tied to the lowering line to take the lowering load. This sampler will usually perform well to depths of one hundred feet.

The scuba diver can use a similar stoppered bottle and depend on his strength to pop the cork. Caution is advised, as the pressure outside the bottle significantly exceeds the internal pressure (14.7 pounds more every 33 feet of depth). The resulting negative pressure inside the bottle at 100 feet may become a hazard if the opening is covered by any portion of the diver's body, as it will suck on and removal may be painful to impossible at depth. Returning to shallower depths will loosen the grip. Unpredictable implosion (catastrophic crush) of glass bottles can also be expected.

The water sample can be viewed by the naked eye for its usually minuscule inhabitants. A low-power magnifying glass or microscopè is most helpful for enjoying the myriad life forms that can be sampled in a one-half-gallon container.

WATER-COLUMN SAMPLER (3)

A first-class water sampler can be fabricated from PVC pipe large enough to be effectively sealed at each end by the crown of a plumber's plunger cup. The large diameter of the pipe allows free flow of water through the sampler on its way down. To make your own you will need, from a plumbing supplier, a piece of PVC pipe and two plumber's plunger cups whose crowns (not concave side) match the pipe to give a satisfactory seal. Stretched surgical tubing, available at most drug stores, will serve as the closing energy source. The two plunger cups are fastened together with the tubing through the PVC pipe section. The center of each plunger cup should be fitted with a small eyebolt for fastening the surgical tubing to the cups. A small thread loop is added to each eyebolt. The instrument is cocked by pulling the two plungers clear of the openings and stretching the surgical tubing until these loops can be hooked to a release mechanism on the side of the pipe. Release of a slip pin passing through the two-thread loop allows closure on command.

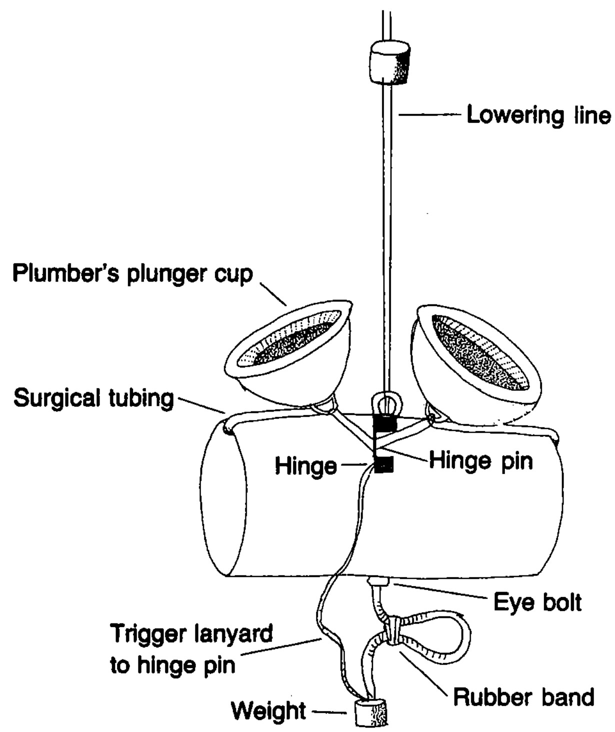
One side of a cabinet hinge mounted on the pipe can serve as the receptacle for the release pin. The hinge pin may need to be reduced in diameter with crocus-cloth abrasive paper. As the release pin must be perpendicular to the lowering line, a screw eye should be installed to direct the trigger pull line into the proper angle to free the plunger cups.

A jerk-the-line release scheme is a handy way to close the sampler.

Therefore, two lines need to be added: (1) one to hold the full weight of the sampler and lowering weight (this line is to be purposely parted when the jerk is made); and (2) one to pull the pin free.

TIDE GAUGE

To determine the daily vertical tidal excursion at a strange anchorage, a calibrated vertical staff gauge is needed. A simple two-part instrument involves an anchor and a vertical measure pole that pierces the surface to catch the minimum-maximum of the tide. A metal or wood yardstick attached to a broomstick, boat hook, or longer pole and anchored outside of your swing circle can be read to a high degree of accuracy. The



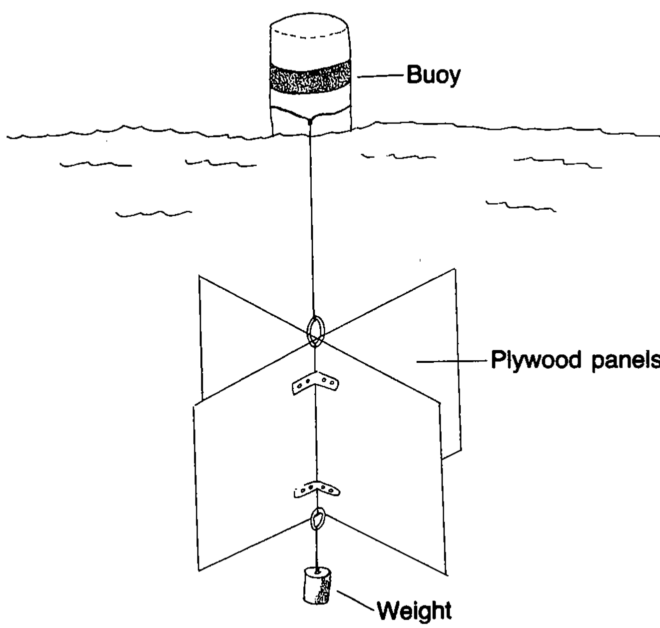
A more complicated water-column sampler using plumber's plunger cups support pole can be fitted with a screw eye or a drilled hole for attaching the bottom anchor. The pole must be held vertical. Attach an air-filled plastic jug to the staff below the water surface if needed to keep it upright. In lieu of the regular yardstick, the vertical staff can be marked in one-half-foot intervals with painted bands, a wrap of tape, notches, wood screws driven in partway, or nails. These markings are easier to read when the staff is beyond easy reading ranges. These minor changes to the mop/broom handle or boat hook do not alter the staff enough to prevent it from being used again for its original purpose. The same instrument can be used to measure the height of small waves.

Another approach to a tide-gauge design is necessary when waves are present. Small perforations in the bottom of a standpipe allow water to enter the pipe at a rate that is sufficient to match the change in tidal level, and slowly enough not to be influenced by the fast changes in water-depth characteristics of the waves. A straight lightweight wire that pierces the center of a float and moves inside a two-inch or larger standpipe should be dropped into a PVC or other pipe. The wire should extend above the pipe through its full excursion from low to high tide. Read every hour, it will be the indicator of tide with reference to some arbitrary level. A cap on the pipe pierced by a hole will help keep the indicator rod from sticking and tilting.

A variation on the indicator is to hang a small weight over a pulley at the top of the pipe and connect it to the float with a flexible wire or small line. The weight would then move across a prepared scale clamped to the vertical pipe. This instrument needs to be restrained from lateral motion. Therefore, it functions best when fastened securely to a rocky cliff, dock, or piling. A marigram (tide curve) can be developed by hourly readings.

WATER CURRENT

A simple water-current instrument design that will allow water-current measurements at various depths is known as a drogue. A water-current drogue is a submerged plywood or plastic cross that offers enough surface area to assure that the drogue is carried with the water mass and at the same speed. Attached to the submerged cross is a surface float that pierces the surface enough for visual tracking. This component can be affected by surface winds, so attention must be given to keeping it small. Two pieces of ⅜-inch or ½-inch plywood 2 feet by 2 feet fitted together in the form of a cross (like the divider in a cardboard box that provides four compartments) can be achieved by making a cut (⅜ inch or ½ inch) from the center of one edge to the center of each board. Sliding the two pieces together along the slots produces the four wings. Reinforcing "L" brackets (eight) will make it a solid cruciform structure. An eyebolt attached at each end of the drogue at the intersection of the two boards will provide attachment points for the tether line and added weight to *just* sink the drogue. The surface buoy can be made of a variety of materials to which a light vertical staff can be attached, e.g., a wooden yardstick or broom han-



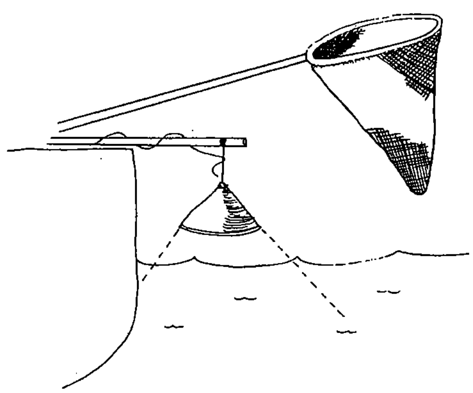
A drogue to measure water current

dle tied to a plastic gallon jug. Ocean currents are now known to run at different velocities and various directions at different depths. The line from the float to the drogue should be adjusted to test various depths.

NIGHT SURFACE COLLECTING

Many small marine organisms and fish, like moths, are attracted to a light source at night. A very enticing light is a regular light bulb (100–150 watts) installed in front of a white painted reflector. Place the reflector about a foot above the water so that the collector's eyes are shaded from the bulb. Use a fine-mesh dip net to capture the variety of small organisms attracted to the light and others that come to feed on the high concentration of food.

A powerful underwater light will perform similarly. Again, the dip net can be used to sample the animals that gather in front of the light. In the event that you want to study the feeding behavior of a basket starfish at night, hold an underwater light close to the basket star. In moments it will actively capture those attracted by the light into the reach of its waving arms. Large organisms such as squid and schooling fish will also seek the lighted area, sometimes in very large numbers.



A bright surface light will attract many small organisms and fish at night.

BIOLUMINESCENCE

Bioluminescent organisms are widely distributed in the ocean. Many are microscopic and their individual illumination faint, yet visible to the dark-adapted human eye. The plankton samplers described in this chapter will capture forms capable of producing this living light. Transfer your samples to a jar and seek out a dark location. The organisms frequently need an external stimulus before they will light up. In a jar they will respond to the shaking of the container. The motion of your boat through the plankton population is usually enough. If you have been swimming, those clinging to your bathing suit will glow when struck by freshwater, so turn off the lights and rinse in the dark with *small* applications of freshwater. Stirring the ocean with a paddle or boat hook in an area of high bioluminescence will generate some spectacular fireworks. Photographing the phenomenon requires a high-speed film and longer-than-normal exposure time. Some species have built-in biological clocks that keep them from flashing until nighttime hours are reached. Accordingly, don't be surprised if your daytime collections fail to luminesce—wait until dark.

SOUND RECORDING

Sounds in the sea can be detected and recorded using a tape recorder that can be attached to a microphone or an earphone. To protect an inexpensive earphone made for portable recorders from seawater flooding, simply cover it with a plastic food-storage bag. Better still, coat it with neoprene paint. Your boat's sounds may drown out the ambient noises, so a quiet boat (anchored or engine stopped) is desirable. Living organisms produce noise in almost all geographic locations. Rain is also a big contributor to sound in the sea, so put the microphone over the side when the weather is foul. The microphone need only be immersed a foot to obtain sounds. Deep lowerings are not necessary to hear a majority of the cacophony present.

SOUND SPEED

Sound speed in the sea is approximately five times faster than sound speed in air. The average sound speed is 4,800 feet per second. To measure sound speed, use your underwater microphone to pick up the sound generated by a firecracker floated in a sealed can or sunk below the surface. To extend your range out to a mile, you need the help of a second party to signal when the explosion takes place. A flag signal or CB signals are examples. A stopwatch will suffice for determining the time interval from explosion to arrival. Water depth can be done from your own boat. Signal generation and echo arrival divided by two equal water depth.

DEEP-SEA SAMPLER

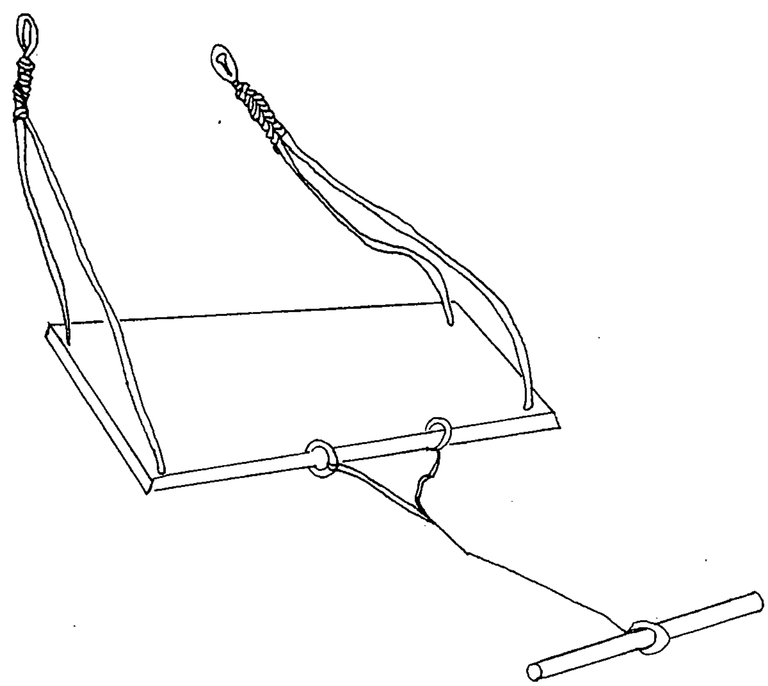
Deep-sea sampling can be accomplished in a couple of relatively low-cost ways. A regular marlin fishing pole equipped with a 12V or 24V DC motorized reel filled with piano wire can allow you to comfortably fish and sample to depths of 1,000–2,000–3,000 feet! The small diameter and superior strength of the piano wire is adequate to handle a window sash weight or a large lead sinker and the catch. Some species large and small will take a regular fishook. You'll feel each strike. Other animals are easily lured into a baited trap. A cylindrical hardware cloth trap rolled into a tube and fitted with funnel-shaped entrances is easy to bait and handle. A rectangular trap fitted with conical entrances is another design option. A five-gallon light metal container with a wide mouth lid and punched holes one to one and a half inches in diameter, baited with old fish, will attract and hold some unusual denizens of the deep. These traps can be lowered and retrieved with the electric reel. Lacking the reel and pole, traps can be sent to the bottom with releasable weight and a buoyancy unit. Gasoline is lighter than water, and five gallons will provide approximately ten pounds of lift. The cage and contents (in water) need to be less than this lift force, and should be tested before adding the releasable and expendable weight. An automatic time release can be derived from a few Lifesaver candies that dissolve in seawater. Using such soluble units as a connecting link, the trap will be free for its buoyancy lift back to the surface. You should run time tests on the Lifesavers in 37°–40° water and under tension (equal to the load that will be put on them). Check several flavors for the one that performs best for you. A very lightweight whip should be added so that the free-fall unit can be found when it is again at the surface. Glass fishnet floats can withstand substantial external hydrostatic pressure and yield good buoyancy. A net bag full of these floats is an option to the boater.

DIVER TOW

Towing a snorkel or scuba diver is a fun way to investigate a large area in a hurry. In all instances the towed individual(s) should be required to hang on physically so that on release the diver(s) are free from any possible entanglement.

For towed scuba divers who want to cruise at depth, a weight or depressing force is required. A first method is to use a single tow line with grapnel, tow-line loops, tow bar, boat anchor, or depressor board. In either case, the diver must be able to control his depth by body movements or deflections of the depressor. Towing speed is a slow 1.5 to 2.0 knots. Higher speeds strip off faceplates and put a strain on the teeth and jaws trying to retain the mouthpiece. Observations are degraded also at higher speeds. A 200-foot line ½ inch to ⅝ inch in diameter loaded at the end with 25 pounds of lead, steel, or concrete balls can be used. The divers should hang on at or near the weights. For the convenience of divers who drop off the tow with the expectation of returning to the tow without surfacing, an extra 50 feet of negatively or near-negatively buoyant line should be allowed to trail behind the weights for easy pickup.

A towing board or aquaplane can be created from a flat board or plywood sheet. The size and shape of the board is not particularly critical. Two square feet of surface per diver can give sufficient pressure to raise and sink the towed diver and still not cause excess fatigue. Bridle schemes may vary from a single "V," where a single line is attached to the board by eyebolts or through a drilled hole. Drilling the hole about one-third the way from front to back will make it easier to change the angle of the foil in order to dive or rise. A variation is to attach two lines on each side; one at the front, one at the rear, and the same on the other side. The side lines must be of unequal length, so that the board is level with the direction of tow. To reduce arm strain, add a T-bar "seat" to the back edge of the depressor by a length of rope short enough to allow the diver to sit on it and still move the board. An in-



Use a diver tow to investigate a large area quickly.

dication that the divers have dropped off the tow can be accomplished by adding buoyancy to the aquaplane so it will surface. A surface buoy attached to each diver will also show that they are no longer moving with the boat. For safety, smoke and light flares (strobe lights too) are available for those planning to operate in rough water, areas of strong current, or other hazardous conditions.

UNDERWATER RECORD KEEPING

For recording observations underwater, a soft graphic pencil and a white plastic board meet the need. A number of plastic sheets like frosted mylar fit the bill. Ascot papers, Appleton Papers, Inc., also serve the purpose well and are available from most art stores. Several pencils should be available, as sharpening pencils underwater is difficult. Pencil holders can be fashioned with a band of rubber or tethered by a line. Velcro kit glue-ons are handy and readily available in precut pairs from the variety section in most chain drug stores.

To upgrade the slate to a more multipurpose tool, a plastic protractor can be added for measuring angles of sea-floor features such as ripples. An edge can be devoted to linear measurements by adding a plastic rule. Using preglued Velcro components, the list of possible add-ons is wide open to your choice. A brass hook with a spring-loaded clip can be added for easy attachment to a belt.

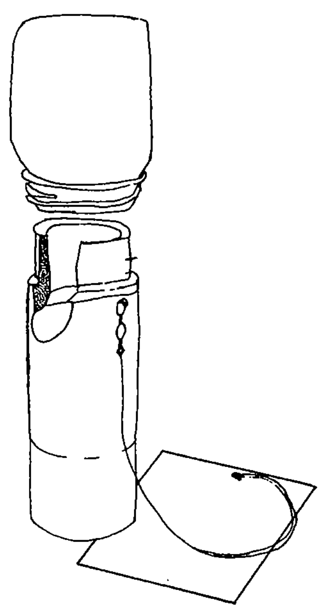
METER SQUARE

To count organisms on the sea bottom, a meter square has become a professional standard. Fabricating a meter frame light enough for a diver to carry is easily achieved by bending a three-sixteenth-inch rod 90° at one-meter intervals to form the four sides. If a cross made of the same material is fastened by line or wire, the square can be divided into quarter-meters. A quarter-meter may be a more preferable area to study or sample. The frame is laid on the bottom, and sampling or counting is accomplished. If the sampling is to include the inhabitants in the sediment, a four-inch or larger aluminum sugar scoop is very effective; so is a two-pound coffee can, for scooping the area.

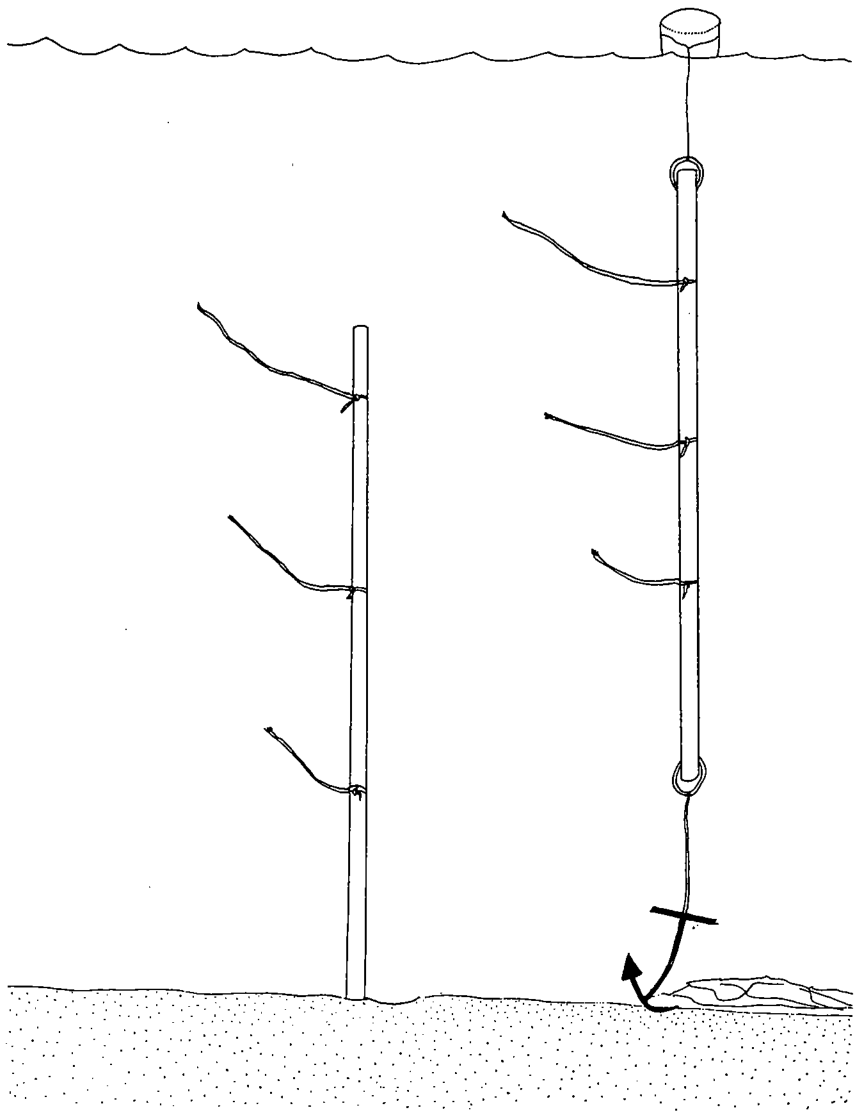
A plastic window-screen bag can serve here as both a collecting bag and a sifting screen for larger organisms. Plastic window screen has a number of uses at sea because it is strong, withstands salt air and water, and is easy to fashion into a variety of useful configurations. Keep some on hand.

DIVER CORER

Samples of the substrate and the creatures in it can be sampled using a simple coring tube of pipe. The top of the corer should slip into the mouth of a wide-mouth sample container. The diver can slip a stiff



A diver corer is a simple tool to sample the substrate.



Orbital motion poles

plate of aluminum or plastic under the corer mouth to hold in even a sand core. The diver presses the corer into the substrate about 5–10 cm; he tips it sideways slightly, and then slides the plate into the sediment and over the corer mouth. The corer and plate keeping the core intact are removed simultaneously. The heavy contents of the corer are transferred underwater without spilling because the corer body is inserted below the lip of the jar. Clipped to the corer body, a PVC or galvanized pipe 15–20 cm long suitable for use are readily available. If a collar is desired for a better seal on the sample body, then select two pieces of pipe and join them with a coupling.

UNDERWATER CURRENT MEASUREMENTS

Enjoy the revelations of water motion that can be illuminated by fluorescein dye. A saltwater and fluorescein mixture added to the ocean will flow with and tag water masses. It can be photographed as well as be seen. Current direction and speed can be determined accurately. A point source of dye can be carried to a midwater location or to the bottom in a bottle. Opening the bottle starts the study. To identify the presence of horizontal shear, remove the cap and allow the bottle to sink from just below the surface to the bottom. The open bottle will emit a uniform trail of tagged water. The sink rate and trajectory will usually not be too erratic, so that a nearly vertical trail will be produced. If horizontal shear is present, the contrasting water-mass movements will soon be revealed. Using a lookbox, faceplate, or scuba, the vertical trail of dye will be seen moving with the prevailing current(s) at the same speed and direction. Although there will be some spreading of the dye with time, the observation can be followed with accuracy. Add a small weight to the bottle if improved vertical trajectory is needed.

ORBITAL MOTION

Unbroken waves (or swells) that pass beneath a boater's bow give the visual impression that the water is moving in the direction of travel—

not so. A simple instrument will show that there is orbital motion of the water and that there is no movement of water away from its initial position. Also, the size of the orbit decreases with depth. To see this for yourself, a simple vertical array of neutrally buoyant tethered lengths of wool or nylon yarn suspended in the path of a wave will make it possible to observe (by a snorkeler or scuba diver) the path of motion as the yarn responds to the water motion. The instrument is fabricated from a rigid pole with foot-long flags of yarn taped or tied to the pole. To avoid entanglement, intervals that separate the tips of each when pulled toward one another should be selected. To keep the pole vertical, it needs to be anchored firmly to or into the bottom. The pole need not pierce the surface. The closer the top is to the maximum height of the wave, the greater the orbit diameter. As the orbit diameter diminishes with depth, so the yarn lengths can be made shorter in deeper locations.

SAND TRANSPORT

Sand transport in the surf zone and in deeper water can be traced by marking dried sand samples with fluorescein paint (available from a good paint store). The marked sand is placed in a known location marked by a steel rod. Samples taken at subsequent times and distances from the rod can be viewed under an ultraviolet light to reveal the presence and quantity of the tagged sample. Ultraviolet tubes to fit the fluorescent lamp holders are available from stores selling light bulbs. The direction, rate, and amount of movement can be derived from this simple method. Automatic capture of marked sand grains can be achieved by placing flat-surface plates smeared with Vaseline or grease.

BEACH PROFILE

One of the best oceanographic tools available and ready for the boater's use is the Mark I eyeball. It is still used by professional seamen to estimate the height of waves, evaluate weather trends, estimate water depth, discern transitions in water masses, and semiquantitatively measure natural phenomena. A little knowledge and experience can help the boater avoid safety hazards and capitalize on advantages. For example, boaters intending on a beach landing in an unfamiliar location can "read" a sand shoreline profile while offshore. A steep sand beach, when viewed during a temporary calm period, could reflect a recent history of high waves that could prove disastrous to a small boat going to or returning from such a beach. Even during relative calm periods, the waves off such beaches are often described as plunging and are difficult to pass through in a small boat without a dunking or capsize. A shallow beach profile (one with a gentle slope) is more amenable to landings. Such beaches usually contain fine-grain sand, and the underwater profile is likely to be a nearly flat bottom extending out to deep water. The steep-slope beach is usually coarse sand, cobble, and bedrock.

Beach profiles change rapidly, particularly during storms and heavy wave action. Using two calibrated six-foot staffs, a team of two boaters can measure the change. The first staff is rested on the sand. The second is set six feet shoreward. The second boater sights over his fist as it is slid down the shoreward staff until the horizon is in line with the top of the seaward staff. Read the level on the shoreward staff. Repeat daily or weekly.

BOTTLE FISHING

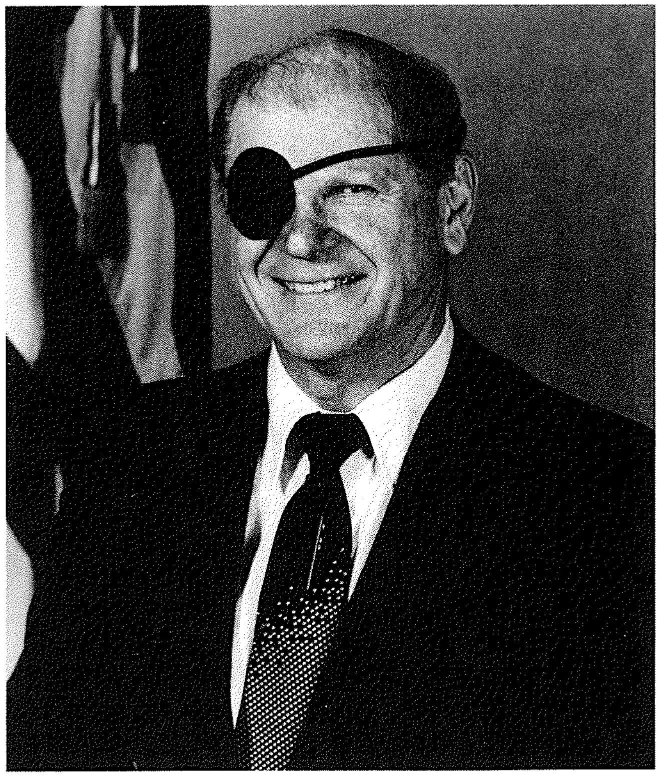
Small empty glass food jars can be used in a variety of ways for sampling and storage of marine life. A clear eight-ounce or larger jar with a wide mouth and heavy wall is ideal for capturing small marine animals, including some of the reef fish beauties and invertebrates—some of which are noxious and not to be handled. Damsel fish are common to most tropical reefs and are usually amenable to herding by hand into the bottle. In the herding hand, the bottle cap is placed over the bottle once the fish has entered the transparent container.

For Do-It-Yourself Oceanographic Equipment
Materials Checklist

* Bags, burlap and plastic
* Beeswax
* Candy, Lifesavers
* Clamp hose
* Cement or concrete mix
* Coffee can, large
* Chain
* Cork or styrofoam
* Dip net
* Firecrackers
* Fish netting and glass fishnet floats
* Flares, smoke
* Fluorescein crystals
* Grease, wheel-bearing
* Hardware cloth
* Hemp rope, 3/8 inch
* Hinges, small and large
* Lead
* Light shade and bulb
* Magnifying glass
* Piano wire
* Paint, yellow, white, and small can of neoprene; some empty gallons
* Pantyhose
* Plastic sextant
* Plastic sheeting
* Plastic window screen
* Plumber's plunger cups
* Plywood
* PVC pipe, fittings and glue
* Nuts and bolts, 1/4 inch and 3/8 inch
* Nylon, frosted sheet
* Radio earphone

* Rope thimbles, 3/8 inch
* Rubber ball, hard wall or solid
* Rubber bands, thick
* Rubber stoppers
* Shackles
* Steel rod and strapping
* Swivel snap hook
* Surgical tubing, rubber 3/8 inch
* Tape, duct and electrical
* Thermometer, alcohol or mercury
* Toilet tank stopper
* Turnbuckles with extra nuts and washers
* Velcro kit
* Window sash weight
* Yardstick, metal or wood
* Yarn, wool or synthetic

Dr. Andreas B. Rechnitzer received degrees from Michigan State University and the University of California; his Ph.D. is from the Scripps Institution of Oceanography. Dr. Rechnitzer has been involved in a broad range of ocean exploration, scientific investigations, education,and management functions. His contributions in the area of technical innovations and systems development are recognized as pioneering efforts, particularly in the United States capability in deep submergence.



Dr. Rechnitzer's honors include the U.S. Navy Distinguished Civilian Service Award, the Gold Medal Award of the Chicago Geography Society, the Richard Hopper Day Award of the Philadelphia Academy of Sciences, the NOGI Award for Science from the Underwater Society of America, the Gold Medal Award from the Underwater Photographic Society, and the Special Award from the National Capitol Film Festival. He has served as the director of the American Society for Oceanography, president (with Jacques Cousteau) of the World Federation of Underwater Activities, and president of CEDAM International, among many other duties. He holds a former world's diving depth record of 18,150 feet. Dr. Rechnitzer is currently the technical adviser to the Naval Oceanography Division, Department of the Navy.