ATOLL RESEARCH BULLETIN

No. 143

THE SAFE USE OF OPEN BOATS IN THE CORAL REEF ENVIRONMENT

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Issued by

THE SMITHSONIAN INSTITUTION

Washington, D. C., U. S. A.

February 16, 1971

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INTRODUCTION

For the past two and a half years I have been employed at Heron Island Research Station, Great Barrier Reef of Australia. The work has entailed much time in small, open boats in many weathers. Often it was necessary to travel to reefs up to twenty miles away. Diving, collecting, and surveying often meant using boats in conditions that were potentially hazardous.

Small boats are available at the Research Station and, of the scientists that occasionally use them, few have any practical experience in such matters, yet more and more scientists are finding it necessary to rely on themselves. I have seen the most intelligent academics make incredible blunders when using boats, blunders that in slightly different circumstances could have had serious consequences.

It is my hope that these notes will provide useful information for those scientists working in the coral reef environment. Although written especially with the Great Barrier Reef of Australia in mind, this information should prove useful elsewhere.

BOATS SUITABLE FOR CORAL REEF WORK

For working around coral reefs a boat should be both maneuverable and of shallow draft. Light weight is also an advantage, except possibly in a boat used only for diving. When working on a small island that receives little protection from its surrounding reef it is often an advantage to be able to pull one's boat well up on the beach (usually with the help of a rubber roller), since such places offer few possibilities for a safe anchorage. A light boat is also very useful in that it can be "walked" over the reef crest, etc. when water is very shallow. However a lightly loaded aluminum boat is very subject to the wind, and can be blown along at a surprising speed. This can prove very troublesome at times, especially when one is trying to row.

I have had the most experience with aluminum boats and have found them to be quite satisfactory. They are quite light and yet strong and capable of carrying very heavy loads. A very good boat is the 17'6" DeHavilland "Hercules" which when powered by a 40 hp outboard motor is capable of carrying large loads in rough seas and yet when lightly loaded is fast and quite maneuverable. Another aluminum boat I have had much experience with is the 12 foot DeHavilland "Sea Otter". Powered by a 10 hp. outboard motor it will cruise nicely at about 12 knots with 2 persons plus gear. Even with a good load both these boats will retain enough freeboard to be relatively safe in rough seas. There are many other different makes of aluminum boats, all having advantages and disadvantages.

Although I do not recommend outboard motors for every use they appear to be ideal for work around coral reefs. A boat powered by an outboard engine is very maneuverable, especially if lightly loaded. This enables one to approach very close to a reef or to thread one's way through the patch reefs of a lagoon. It also makes loading or unloading passengers or equipment onto a reef easier. Experience with sizes of up to 40 hp. has proven to me that an Evinrude outboard motor can be a reliable and very versatile engine. An outboard motor can be removed easily from the boat, making it lighter for hauling up on the beach or on board a ship. It can be exchanged between one boat and another, is readily tilted up when in shallow water or at anchorage, and can even be run for short distances in a semi-tilted position if power is necessary in very shallow water. A shear or drive pin, or even a propeller can be replaced quickly and easily. One major disadvantage of any outboard motor is the high rate of fuel consumption. On occasion I have used two outboard motors, a large one for traveling from one reef to another, and then a smaller (e.g. 5 hp) one for going over a reef or when prolonged slow running is necessary (e.g. echo sounder surveys). The light weight and reliability of the modern outboard makes it very useful indeed.

A note on steering systems is appropriate since front steering by means of a steering wheel is becoming more popular. There appear to be advantages and disadvantages to both methods. Generally I prefer the simpler method of steering directly and there is much less of the unpleasant "pounding" in the stern than up forward, however it is usually much wetter. With wheel steering the motor cannot be tilted so readily nor motors exchanged so easily. A lightly loaded boat can pound in a most unpleasant manner up forward in a short, steep sea. Electric shifts, steering cables, etc. reduce the overall reliability of any boat. The steering wheel up forward on the other hand is much like driving a car, gives better vision in front and is usually much drier when traveling at high speed.

Various designs of jet propelled boats plus the already popular inboard-outboard may prove very useful for work on coral reefs. Generally an inboard engine (especially diesel) is more reliable and more economical to run than an outboard; however most are heavier and more expensive than an outboard.

TIDES

The tides of the Great Barrier Reef of Australia are semi-diurnal, and unlike many coral reef areas of the world there is here a marked tidal range. In the southern part of the Reef the range is over 8 feet, elsewhere it can be much greater.

It is of the utmost importance for scientists working around coral reefs to have tide tables (which may need to be adjusted for outer reef areas), and to know the state of the tide. If tide tables are not available, it is an easy matter to determine the time of either low or high tide by marking the beach as the water advances or recedes. Knowing that the tide changes every 6 hours and that the time of the tide advances each day by approximately 50 minutes, one can approximate the time of any tide for days in advance.

It will save much trouble and possible damage to one's boat to mark out across the reef a channel clear of niggerheads, by driving poles into the reef or erecting markers of some kind. This will indicate when the water is sufficiently deep to enable a boat to come and go safely. On many reefs the lee, especially the western end, gives the best approach to an island or reef.

During the time I have worked at Heron Island I have seen many foolish mistakes made regarding the tides. It should be obvious that if one desires to do any work on the reef flat without diving, one must plan his visit to coincide with a low spring tide, when most of the reef flat will be exposed for about 3 hours (water only a few inches deep). It is also important to note that the height of the tides is not even; of the two highs in 24 hours one is higher than the other. For example, during the summer the lower of the two low tides occurs during the night.

Spring tides (having the greatest range) occur twice each month, coinciding very closely with the new and full moons. The height of any tide can be affected by the wind; the wind can pile water up on a reef or it can speed up the drainage of water from a reef flat. On a low spring tide there will usually be very little water on the reef flat from approximately one hour before until two hours after the time of low water, giving a maximum of 3 hours working time. When working in an enclosed lagoon one must be very careful not to get "trapped" in the lagoon by a falling tide.

For underwater photography the neap tides are often the best as visibility in the water is better then.

Tidal Stream

This aspect of the tides is often not so apparent as the vertical movement and varies both in intensity and direction. The tidal stream is usually called a current, and on the Great Barrier Reef it changes its direction with the change of tide. The highest velocity occurs with the spring tides and varies from 2 to 7 knots.

Information regarding the tidal stream can be found in the Australian Pilot, Sailing Directions, or other nautical publications, and is usually printed on charts using arrows to indicate directions. If one works on uncharted reefs it may be a good idea to find out the directions of the currents by the use of dyes. This information may influence one's choice of a work area. The wind can modify the strength or even the direction of a tidal stream, and it is possible that during neap tides a strong wind blowing against the stream may even reverse its flow. It is often necessary to time one's activities to coincide with the weakest tidal stream. Any collecting will be affected by the strength and direction of the current, especially when working in a channel between reefs, or on the windward or front of a reef. When working just off a reef it is easy to pick out swirls, or eddies of the tidal stream (tidal rip) as it flows past the reef and often the interface between the two bodies of water is very sharply defined. Generally the lee of a long reef is less affected by the tidal stream than the more windward areas. The stream is often felt on the reef flat during high tides.

A very important aspect of the tidal stream is that when it is flowing against the wind, a very steep and unpleasant sea can develop. This is especially characteristic of channels between adjacent reefs, or over very shallow areas. When traveling between reefs in an open boat with a wind blowing one should endeavor to choose the time when the tidal stream is favorable.

APPROACHING AND GOING OVER A REEF

To safely approach and go over a reef depends on being able to see the margin of the reef, and on knowing how much water covers it. With a high spring tide it should be possible to go over a reef just about anywhere, except on the windward sides of many exposed reefs where there are often large niggerheads, some of which may be over 5 feet high. The niggerheads usually occupy a rather narrow zone within approximately 100 yards of the outer reef margin. This zone should be navigated with caution! Often the niggerheads occupy the highest part of the reef (reef crest), which adds to their danger.

Proper use of tide tables and direct observation of water depth will enable one to ascertain whether or not there is sufficient water to go over a reef. It is also important to note that all reefs are not of the same height, and that even on one reef the windward area is usually higher than the lee.

And now for the most important aspect of reef navigation near a reef--being able to see it! During good conditions a reef is very easy to see, the higher the observer the farther away a reef can be seen. From about one mile one can usually see the breaking surf, especially on the windward side as viewed from the lee. With any swell running this can be depended upon to indicate the presence of a reef. As one closely approaches a reef, marked color differences will become apparent; the deep blue of deep water changing to the green of shallow water and then the brown of the reef below the surface. Unfortunately these colors are only apparent under the following conditions: sun relatively high in the sky and at least a gentle breeze disturbing the surface of the water. Therefore, during early morning and late evening, with an overcast sky or during a dead calm, a reef becomes almost impossible to see except by the presence of surf breaking or thhe presence of a tide rip. From the above it is obvious that any scientist traveling around an unfamiliar reef should do so only during optimum conditions. Traveling at night except in a very familiar area can be extremely dangerous.

When going over a reef one should proceed slowly, watching for the brown patches that might represent niggerheads. If there is some uncertainty regarding the depth of water one should go very slowly, swim in and test the water, tilt the motor and row the boat across, run the boat across with the motor semi-tilted, or if the wind is favorable, just let it blow one across. When leaving a lagoon on a falling tide one can often use the current of escaping water to drift across the reef crest if the depth is insufficient to use the motor. If one is working extensively in a lagoon or over a reef flat it is very useful to use a small, shallow draft outboard motor.

Avoid a breaking surf at all costs, even the swell surging up on a reef during low tide on a calm day is potentially dangerous.

Windward and leeward approaches to a reef

The lee of a reef is the safest place to either work or land from a boat. During low tide, a reef is in effect a very good breakwater, with calm water behind it. Ideal conditions for landing are a wind blowing off the reef and a sea with practically no swell (this may never occur!). At such a time one can bring the bow of the boat up to a solid looking outcrop of the reef very slowly, and with one person holding the boat, the others can get out. The anchor can be put on top of the reef and the wind will hold the boat out. The boat must not be allowed to ride close to the reef. This sounds easy, but can in fact be very difficult to do without damaging the boat or injuring someone.

It is important to realize that any approach to a reef must be made with the boat normal (perpendicular) to the reef margin, as the boat can only be controlled by movement ahead or astern. A good practice in any tricky situation is to drop an anchor some way out from the reef, then as the approach is made, the anchor line is payed out until the boat is next to the reef. The first person out will hold the boat, the anchor line will keep the boat in position. The line can be made fast and another line or anchor put on the reef, thereby holding the boat between the two lines. This method of coming in on a line has many applications; a good example is beaching a boat through a surf. Here, the last stages of the approach might better be made stern first, as a wave breaking over the bow is less likely to fill the boat than one breaking over the stern. The above presupposes a light to moderate surf. In a heavy surf no attempt should be made to approach either a reef or an island.

A windward approach can only be attempted during very calm weather. Again this is often best done by running back from an anchor line, with the utmost care taken to insure that the waves do not throw the boat onto the reef. The anchors are used to hold the boat at just the right distance out.

The utilization of some natural features of a reef can often make landing much easier. For example if the reef margin is irregular, one often finds relatively calm areas just behind a small "headland" or projection of the reef. A well developed "groove and buttress system" can provide convenient little "harbors" from which one can safely land, even in fairly rough seas.

WIND AND CURRENT EFFECTS

The effect of the wind on the water is the most important factor influencing the use of small boats in working around reefs. In relatively shallow water areas like the Great Barrier Reef a very small increase in the velocity of the wind can, in a very short time, generate a very rough sea with short, steep waves. In such a sea traveling between reefs or working the more exposed parts of reefs is often unpleasant and can be dangerous. The effect of the tidal stream has already been mentioned. Experience with an area will enable a person to judge what conditions of wind and sea are most conducive to safe and reasonably comfortable working, although the pattern is often complex and not readily understood.

Usually I seldom travel between reefs if the wind is blowing harder than 15 knots, especially if I must drive into the seas. Running with the wind can be done at wind speeds of 20 knots or higher. Only very calm days are used to visit and work the very windward areas of most reefs. Any scientific project that will entail traveling over a mile or working the margins of a reef should have a program that is flexible enough to accommodate changes in the weather. Given moderate weather conditions, for any wind or tide, there is usually some part of a large reef that can be visited. The lee of any reef is by far the safest place to work, the flanks are often characterized by rough water and the windward areas, except in a very calm sea, are dangerous.

When handling the lighter, outboard-powered boats in a wind, it must be remembered that they will tend to drift sideways very quickly. Any tricky maneuvering should be done directly facing the wind. The wind will also tend to blow the bow of the boat off-course since the bow is usually higher, and is less weighty. One has better control of a boat if it is run slowly up into the wind or current, rather than slowly along with it. This is important when picking up a person or a mooring float. When traveling any distance with an outboard boat it is best to go with the wind or waves. Excessive speed in rough seas is not recommended, as with a light planing boat it is possible to plane down a wave and bury the bows in a trough, or to be thrown sideways and lose control of the boat with possible disastrous results. It is safer to maintain at least a reasonable speed, as the boat is less likely to be filled by a cresting sea when the speed of the waves and the boat closely approximate each other. Heading into the seas or "punching into it" can be a wet and thoroughly unpleasant business unless at very slow speeds, yet it is perhaps safer in really rough weather. It is important when calculating fuel needed for a trip to remember that different sea conditions will require varying amounts.

Be cautious when working in an area where a change of wind direction can have serious consequences--in the tropics squalls can bring on very sudden changes in wind direction and velocity.

JUDGING THE DEPTH OF WATER

The color of open water on a clear day with a high sun and a breeze will indicate the approximate depth very well at close distances. Deep blue water is about 50 feet or more, light green or blue-green water from several feet to about 30 feet over a sandy bottom. Most important of all is brown, which indicates reef below the surface of the water (several inches to 20 feet).

Judging the depth of water over the reef flat is difficult because of varying clarity, wind effects, etc. Often only a few inches will determine whether or not one can use an outboard, therefore they are critical. The presence of niggerheads and other scattered debris complicates the picture. The best method by far is to have a marker on the reef. A little foresight here will save many broken drive pins and damaged propeller blades. When water depth is at all questionable, never rely on your eyesight to determine it. Sometimes, especially with high cloud, polaroid sunglasses enable one to pick out the margins of a reef more easily than with the naked eye.

NAVIGATION AND BEARINGS

This is not the place to explain the principles of navigation; one must assume that any scientist traveling by open boat out of sight of land is able to read a chart and plot a course. However a few notes might prove helpful. When determining one's position on a reef, it has been my experience that it is best not to rely too much on bearings taken with a hand compass. The motion of a small boat is usually so great that bearings can only be considered approximate. Horizontal angles taken with a sextant are best when plotting one's position from a small boat. It is now possible to buy small inexpensive, plastic sextants which will stand up to such rugged conditions and yet are sufficiently accurate for most work.

Navigating between reefs with cays on them need not be so precise if the distances are not great, as islands can usually be seen from 2 to 8 miles away. However it is not wise to rely on eyeball navigation as the visibility at sea is a very uncertain thing indeed. Always carry a compass. The choice of compass depends on many factors: whether it will be permanently attached to the boat, its position in the boat, the location of the motor, etc. When steering from the stern and using a small portable compass, I have found a small box compass made by the Swedish "Silva" company to be very satisfactory. This compass uses two parallel lines to enable one to steer a preset course and has the advantage of allowing one to sit at some distance from the compass and still steer a course. Other types require one to be able to read the actual degree markings which necessitates a fairly large compass close to one's face (awkward requirements for some small boats). I might add here that steering a compass course from a small boat traveling at any speed is at best a rather uncertain business. I shall not treat the problem of compass deviation here, except to say that I have experienced little with aluminum boats and the compass at least 6 feet from the motor.

It is useful when working a given area to cut or trace out the appropriate section of a chart including a compass rose, and to lacquer or varnish it to a board. With a set of parallel rules, this will be most convenient for plotting one's position.

ANCHORS AND MOORINGS

All boats should have at least one anchor aboard at all times, plus sufficient line or chain to be able to anchor in most depths of water likely to be encountered. On reefs located in shallow shelf areas it is possible to carry enough line to anchor practically anywhere, and in the advent of motor failure, anchoring and waiting for help can save time and trouble, perhaps even lives. With the development of various synthetic ropes, especially nylon, very strong line comes in small diameters, and it is now possible to carry enough line to anchor in at least 30 fathoms of water. A tangled and snarled heap of line in the bottom of the boat is worse than useless, and the only method to carry a long line in a small boat is on some kind of spool, which should have a hole through the center so the line can run free, with the spool spinning on a bar. The anchor should be attached directly to a length of chain, then to the line. The longer the chain the better, but because of its weight, 30 or 40 feet are often all that one can take. The weight of the chain helps to keep the pull on the anchor horizontal, avoids sudden jerks and it cannot be cut by rubbing over sharp obstructions on the bottom.

The two most common types of anchors, and in my opinion the best, are the standard "pick" anchor for coral or rock, and the "Danforth" for sand or mud. The choice depends on the conditions anticipated; often one is justified in carrying both. Note: the Danforth anchor will hold in coral, but the pick anchor is almost useless in sand. However the Danforth anchor is liable to get so well "hooked" in coral that it is very difficult to extricate without diving. For small boats (12 to 16 feet) it is often a good idea to have an anchor slightly larger than is recommended for the size of boat, as the Danforth anchor should be fairly heavy in order to work efficiently.

When anchoring, the best procedure is to come slowly up wind or current until the desired spot is reached and then to reverse and let the anchor go as the boat backs away. The amount of line let out should be approximately 3 times the depth of water, more may be necessary in sand to insure a good hold. To bring up the anchor the best method often is to have one person run the boat ahead while the other brings in the slack line until it is vertical, then a good tug from above or even slightly ahead will usually free the anchor. If the anchor has become fouled, one should try pulling from different directions, using a series of sharp tugs. Anchor with care, especially at the end of the day. Many boats are lost every year due to faulty, inadequate or even nonexistent ground tackle.

When anchoring next to a reef during low tide make sure the boat is far enough out so it doesn't swing in against the reef with a change of wind. Two anchors are often required to hold a boat properly. Near the reef crest during high tide, note that waves may begin to break as the tide ebbs and water level falls.

A mooring is nothing more than a length of chain or line, secured to a heavy object that cannot be moved by a boat pulling against it. It is very useful when one works in one area for an extended period of time, and can be made by wrapping a line around a boulder. A float will help see and pick up the end of the line. Some advantages of a mooring are: the line is much shorter than an anchor line and therefore the swing of the boat will be much less, reducing the possibility that change of wind will cause it to be stranded or damaged with the falling tide. A mooring can be made more secure than anchoring as the shorter chain can be much heavier and can be attached to a heavy cement block.

It is worthwile, especially in remote areas, to give some thought to the securing of one's boat for the night or with the approach of bad weather. The loss of the boat during a sudden storm or change of wind at night could be embarrassing, especially as it is simple and inexpensive to secure it properly.

SAFETY MEASURES

Before going anywhere in a boat someone on shore should be informed of the destination and estimated time of return; this is very important. All boats should have aboard at all times the following items: anchor plus sufficient line, if boat is small enough a pair of oars, day and night distress flares, a large bailing bucket, sufficient life preservers for all persons aboard, a small compass, a container of drinking water. If a motor is used, some tools and spare parts should be in the boat; if the motor is an outboard carrying extra shear or drive pins, a set of spark plugs and even another propeller is a good idea. The above may seem like a lot of "stuff" but in terms of human life or even inconvenience it is not excessive.

If possible boats should have built-in buoyancy, which can be in the form of foam plastic blocks fastened underneath the seats.

It is a good idea to time one's return well before sunset, so that if necessary a search can be made before it gets dark. Perhaps the best safety device is one of the small transistorized "walky-talky" radios. They are rugged and the more powerful ones have a range of up to 20 miles in a direct line over the water. This will enable one to remain in contact with the base, and have much more freedom in changing plans, without being forced to rigidly conform to a prearranged schedule.

Now, a final word concerning safety while in the water. When diving from a boat in an area subject to a tidal stream it is most important to dive up-stream from the prevailing current, then in the case of exhaustion or a cramp a person can drift back to the boat. A line trailing in the water behind the boat is also a good idea. Because of friction the tidal stream is not as strong on the bottom, and therefore can increase almost unnoticed by a busy diver, who upon surfacing can find himself being swept away with an empty air tank.