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DIVER EDUCATION SERIES

Oceanography for Divers

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PREFACE

This book updates two earlier books in the Diver Education Series: *Oceanography for Divers: Waves, Tides, and Currents* and *Oceanography for Divers: Hazardous Marine Life*. These are now combined into one book, *Oceanography for Divers*. This book presents two aspects of oceanography important to the diver under one cover. Each section includes references or notes relative to the topic.

WAVES, TIDES AND CURRENTS

To dive safely, the diver must have a working knowledge of waves, tides, and currents. Lack of understanding and respect for ocean currents and surf can have serious consequences.

Unfortunately, inland divers are unable to receive proper training in ocean diving techniques during their basic courses. Consequently, the inland diver, whether novice or experienced, must acquire special instruction upon making the first trip to the ocean. Furthermore, a diver who learns the proper techniques for diving in the currents of the Florida Keys must acquire additional ocean training when traveling to Pacific surf beaches, Gulf oil rigs, or New England shipwrecks.

This paper will provide the diver with a general understanding of the physical characteristics common to lakes and oceans. Diving techniques are described to help the diver understand how to safely handle himself/herself under various conditions.

These written descriptions, however, are *not sufficient in themselves* to prepare the diver for an ocean experience. The diver must acquire special instruction and dive under the supervision of an instructor or experienced ocean diver when desiring to advance his/her qualifications to include ocean diving. Proper training, common sense, good judgment, and physical fitness are prerequisites for ocean diving.

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Waves at Sea

Waves are a series of undulations generally propagated on the water's surface by the force of the wind. Ocean waves are usually measured in terms of their length, height, and period. *Wave length* is the horizontal distance between successive crests, *height* is the vertical distance between crest and trough, and *period* is the time required for the movement of two successive crests (or troughs) past a given reference point (Figure 1).

Waves are moving *forms*—a transfer of energy from water particle to water particle, with very little mass transport of the water. The volume of water transported by the passing wave form is negligible for waves of little steepness (under normal conditions) and can be disregarded for all practical purposes. The water particles within a wave move in an orbital motion. The surface particles move in a circular orbit exactly equal to wave height; below the surface, the orbits become smaller and, in an ideal deepwater wave, the diameters diminish with increasing depth (Figure 2).

Common water waves develop under the influence of newly formed winds (Figure 3). Air pressure changes and the frictional drag of the wind develop ripples on the

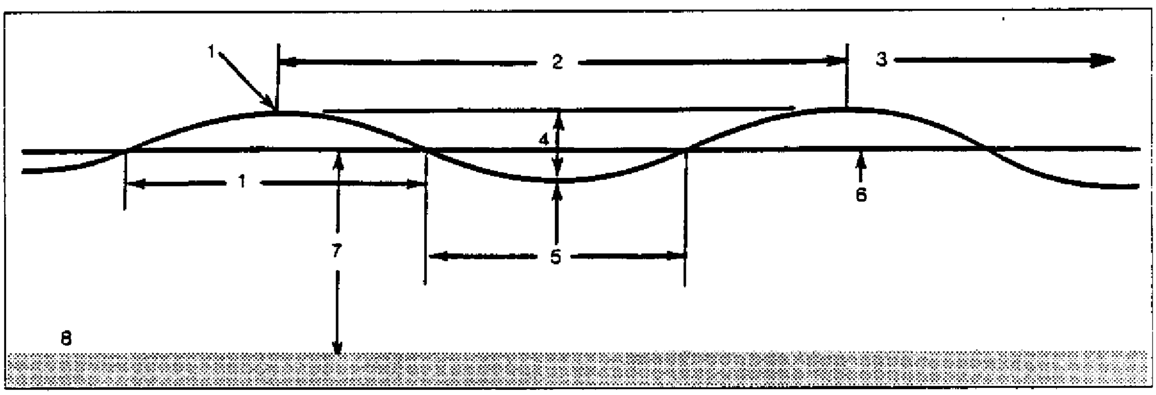

Figure 1. Wave Characteristics.
1) wave crest; 2) wave length; 3) direction of wave travel; 4) height; 5) wave trough; 6) still-water level; 7) depth; 8) ocean bottom

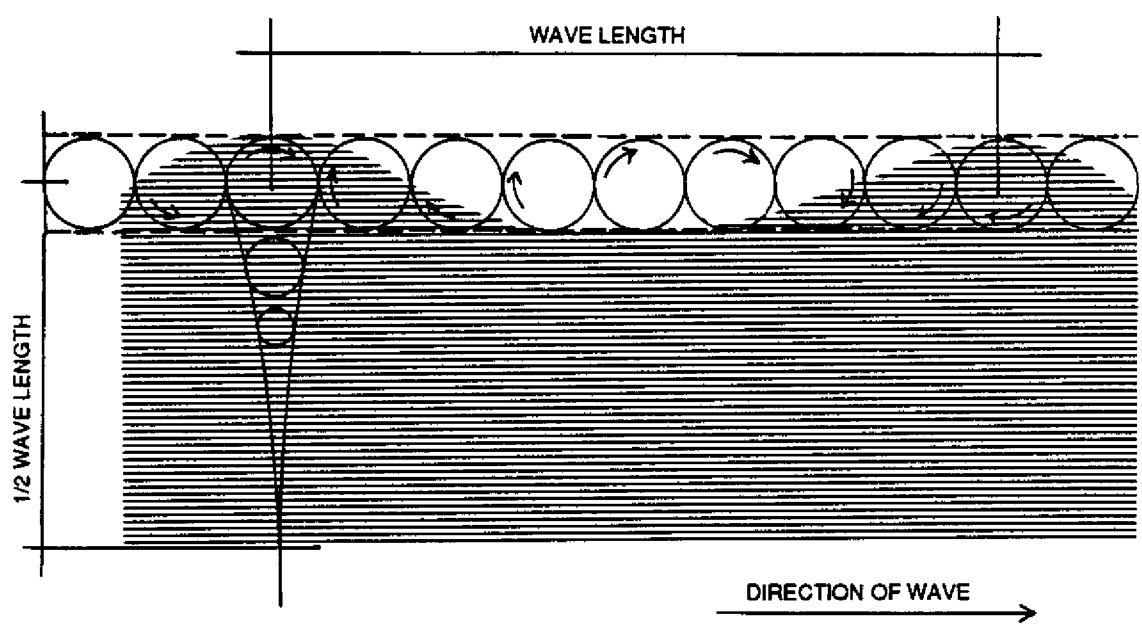

Figure 2. Cross-Section of Wave (traveling from left to right). Circles represent water particles in the wave.

water surface. These evolve into waves whose dimensions tend to increase with the wind velocity, duration, and *fetch* (the length of the area over which the wind is blowing). Energy is transferred directly from the atmosphere to the water. The waves grow in height and steepness (height/length ratio) until, in some cases, the wave breaks at a steepness of about 1:7 to form whitecaps.

In a steady wind, waves of various dimensions develop with progressively increasing heights and periods until a steady state is reached in which the sea is fully developed for the prevailing wind speed. This steady state is maintained as long as the wind remains constant. These waves, generated locally by a continuing wind, are known as *sea*. Although this local sea originates in a single wind system, it is a combination of many different superimposed waves trains with various heights and directions. This gives the appearance of a rapidly changing ocean surface.

Sea persists only in the fetch area and for the duration of the generating wind. When the wind velocity decreases or the wave leaves the fetch area, it is called a *swell wave*. Swell waves are characterized by long, rounded crests and decreased wave heights, and they are more regular in height, period, and direction than sea waves. As a swell wave progresses in the absence of a sustaining wind, its height decreases with a consequent reduction in wave steepness. This change in wave form is known as *wave decay*. Wave decay is caused by a loss of energy brought about by internal friction, wind resistance, current action, and solid objects (ice, seaweed, land masses, etc.) in the path of the wave.

Waves in Shallow Water

As the wave forms approach shore and move across shallow bottoms, they are reflected, diffracted, and refracted. When a wave encounters a vertical wall, such as a

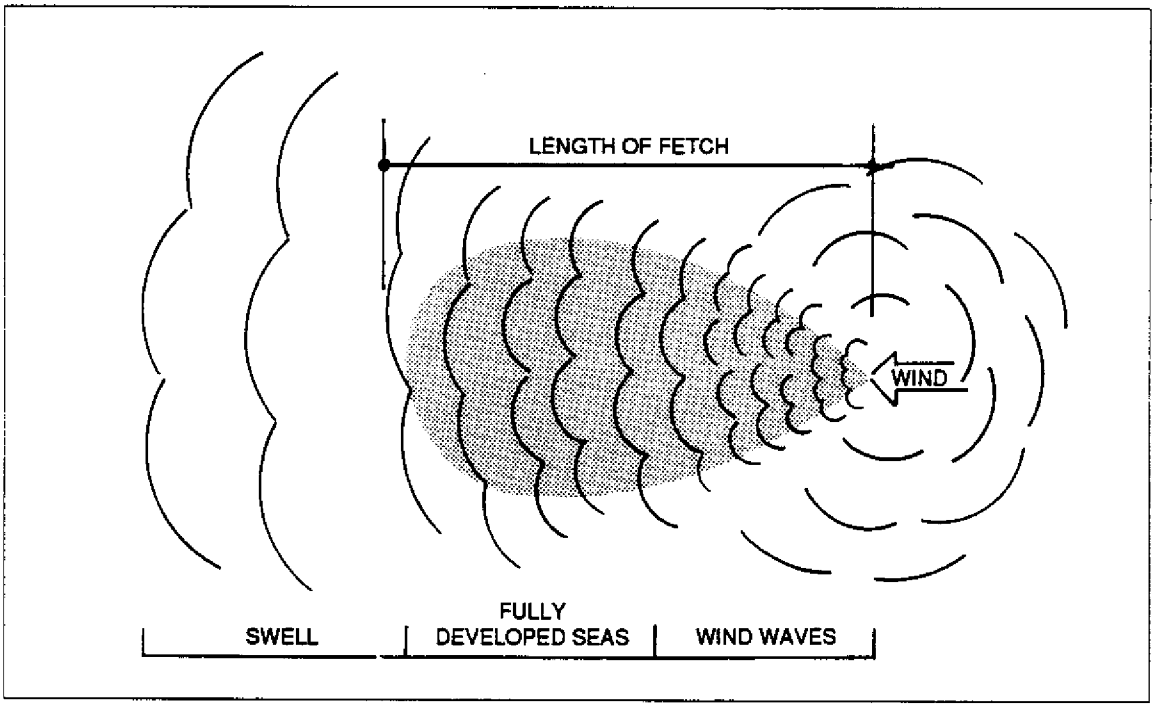

Figure 3. Wave Development.

rocky cliff rising from deep water or a seawall, it is *reflected* back upon itself with little loss of energy (Figure 4). If the period of the approaching wave train is regular, a pattern of standing waves may be established in which the orbits of the approaching and reflected waves modify each other in such a way that there is only vertical water motion against the cliff and only horizontal motion at a distance out of one-fourth wave length. Submerged barriers, such as coral reefs, will also cause reflections.

When waves encounter an obstruction, the wave motion is *diffracted* around it. As the waves pass the obstruction, some of their energy is propagated sideways due to friction with the obstruction, and the wave crests bend into the apparently sheltered area (Figure 5).

As the wave train moves into shallow water, friction on the bottom causes it to slow. Since different segments of the wave front are moving in different depths of water, the crest bend and the wave direction constantly change. This is called *refraction*.

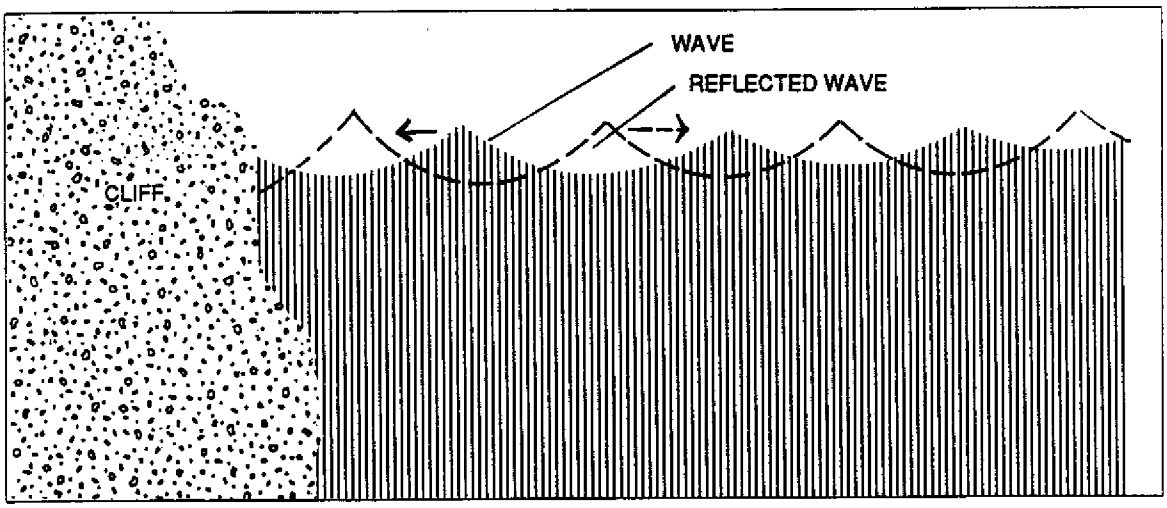

Figure 4. Wave Reflection.

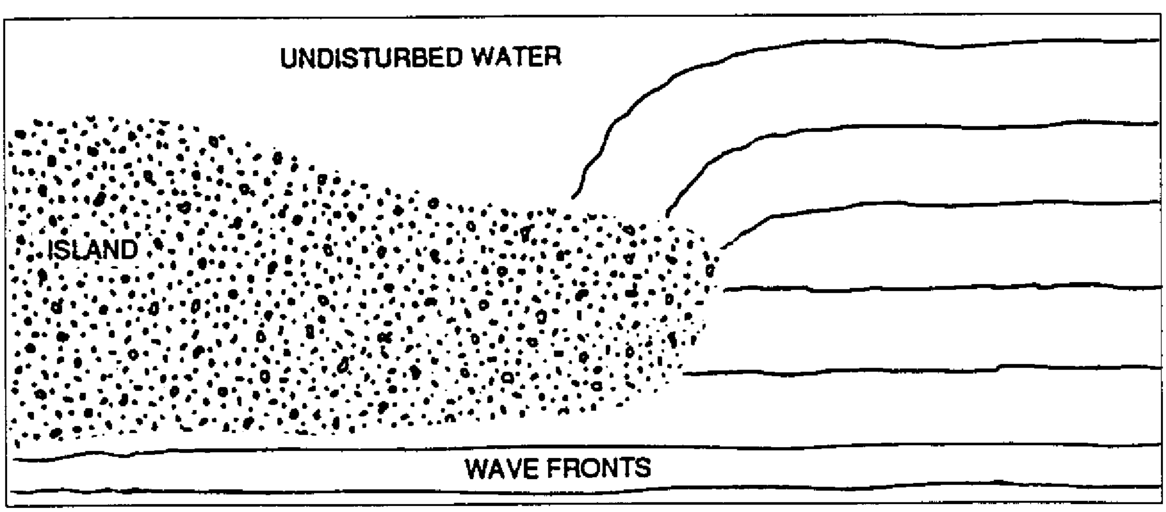

Figure 5. Wave Diffraction.

Essentially the wave crest or front parallels the bottom contours. A simple example of refraction is that of a set of waves approaching a straight shoreline at an angle. The part of each wave nearest shore is moving in shallower water and, consequently, is moving slower than the part in deeper water. Thus the waves fronts tend to become parallel to the shoreline, and the observer on the beach will see waves coming directly toward him.

On an uneven shoreline the effect of refraction is to concentrate the wave energy on points of land and disperse the wave energy in coves or enbayments. Submarine depressions, or canyons, also cause the waves to react in a similar fashion. The waves dissipate over the canyon and increase in intensity on the perimeter of the canyon.

Any irregularities in bottom topography in shallow waters will cause refraction to some degree. Thus, a knowledge of the behavior of waves as they enter shallow water is of considerable significance to scuba divers when planning entries from shore. By observing wave patterns and by studying the shoreline configuration and bottom topography, the diver can select locations where wave energy and, consequently, wave height is least. This will aid entry and nearshore work.

Surf

As swell, waves traverse vast expanses of ocean with little modification or loss of energy. However, as waves enter shallow water, the motion of the water particles beneath the surface is altered. When a wave enters water of depth equal to or less than one-half the wavelength, it is said to "feel bottom." The circular orbital motion of the water particles becomes elliptical, flattening with depth. Along the bottom, the particles oscillate in a straight line parallel to the direction of wave travel.

As the wave "feels bottom," (Figure 6) its wave length decreases and its steepness increases. Furthermore, as the wave crest moves into water where the depth is about twice that of the wave height, the rounded crest changes to a higher, more pointed mass of water. The orbital velocity of the water particles at the crest increases with increasing wave height. This sequence of changes is the prelude to the breaking of the wave. Finally, at a depth of approxi-

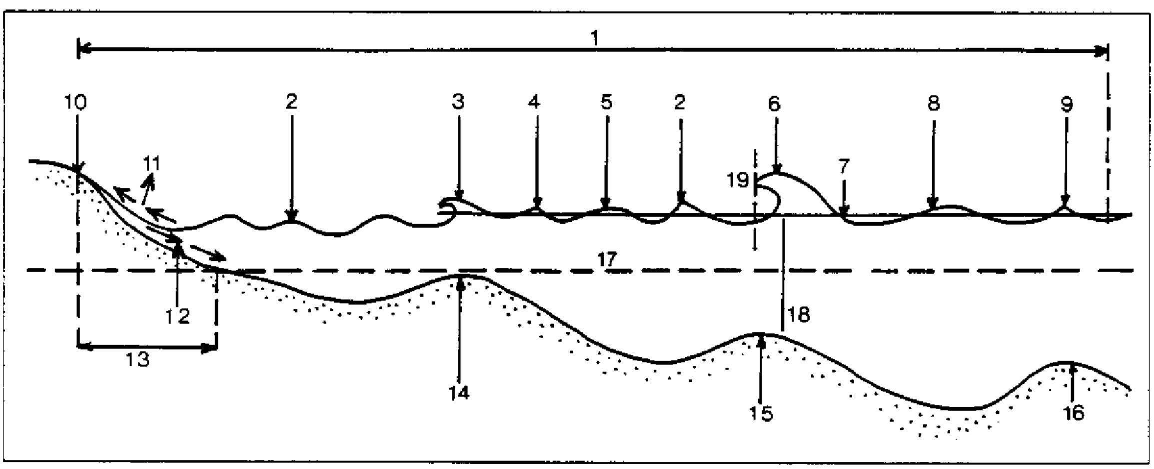

Figure 6. Surf Zone.
1) surf zone; 2) translatory waves; 3) inner line of breakers; 4) peaked-up wave; 5) reformed oscillatory wave; 6) outer line of breakers; 7) still-water level; 8) waves flatten again; 9) waves break up but do not break on this bar at high tide; 10) limit of uprush; 11) uprush; 12) backrush; 13) beach face; 14) inner bar; 15) outer bar (inner bar at low tide); 16) deep bar (outer bar at low tide); 17) mean lower low water (MLLW); 18) breaker depth, 1.3 height; 19) plunge point.

mately 1.3 times the wave height, when the steepest surface of the wave inclines more than 60 degrees from the horizontal, the wave becomes unstable and the top portion plunges forward. The wave has broken; this is *surf*. This zone of "white water," where the waves finally give up their energy and where systematic water motion gives way to violent turbulence, is the *surf zone*. The white water is a mass of water with bubbles of entrapped air.

Having broken into a mass of turbulent foam, the wave continues landward under its own momentum. Finally, at the beach face, this momentum carries it into an uprush or swash. At the uppermost limit, the wave's energy has diminished. The water transported landward in the uprush must now return seaward as a backrush, or current flowing back to the sea. This seaward movement of water is generally not evident beyond the surface zone or a depth of 2–3 ft.

The backrush is not an *undertow*. Undertow is one of the most ubiquitous myths of the seashore. These mysterious currents are said to flow seaward from the beach along the bottom and "pull swimmers under." There are currents in the surf zone and other water movements which may cause trouble for swimmers, but not as just described. Such problems will be discussed later.

If the water deepens again after the wave has broken, as it does where bars or reefs lie adjacent to shore, it may reorganize into a new wave with systematic orbital motion. The new wave is smaller than the original one, and it will proceed into water equal to 1.3 times its height and break. A diver may use the presence of waves breaking offshore as an indicator of rocks, bars, etc. and plan his entry or approach to shore accordingly.

One characteristic of waves most evident to an observer standing on shore is the variability in the height of breakers. They generally approach in groups of three or four high waves, followed by another group of relatively small waves. This phenomena is frequently the result of the arrival at the same time of two sets of swells (from two different storms or sources), of nearly the same wave period. When the crests of the two sets of swells coincide, they reinforce each other and produce waves higher than those of either set (Figure 7). When the crests of one set coincide with the troughs in the other set, a cancellation effect results in smaller waves. By studying the waves, the diver can determine the *surf beat*, or frequency of the pattern, and time his entry (or exit) to coincide with the period of minimum wave height. Two groups of waves, each with a period of about 12 seconds, combine to cause an overall surf beat period of 2 minutes. Consequently, under such conditions, a period of minimum wave height can be expected every 2 minutes.

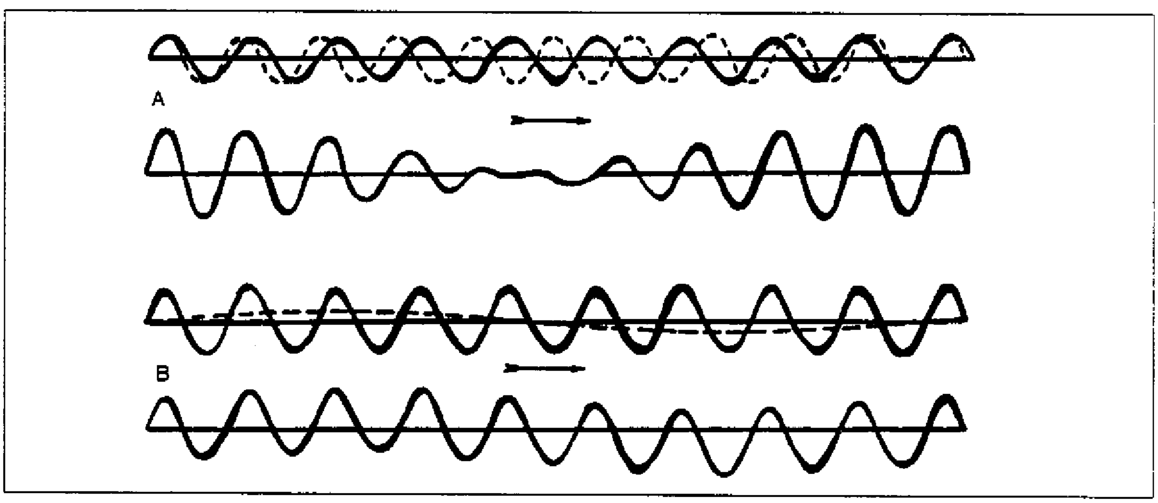

Figure 7. Wave Interference and Surf Beat.
A. Two waves of equal height and nearly equal length traveling in the same direction, with resulting wave pattern.
B. Short waves and long swell traveling in the same direction, with resulting wave pattern.

Currents

In and adjacent to the surf zone, *currents* are generated by waves approaching the bottom contours at an angle and by irregularities in the bottom. When waves approach the shore at an angle, a *longshore current* is generated which flows parallel to the beach within the surf zone (Figure 8). Longshore currents are most common along straight beaches. The speeds increase with breaker

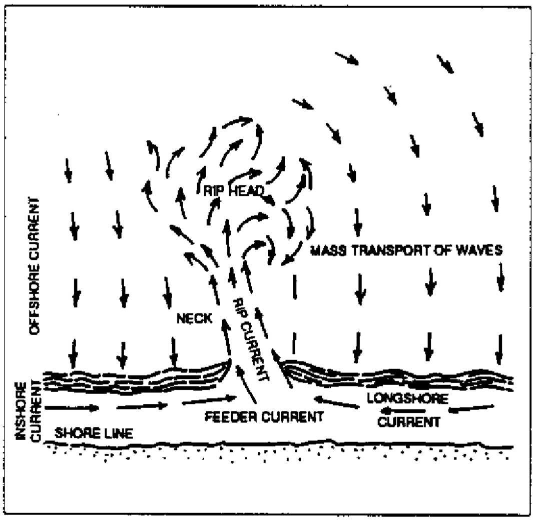

Figure 8. Nearshore Current System.

height, decreasing wave period, increasing angle of breaker line with the beach, and increasing beach slope. Speed seldom exceeds 1 knot. As previously discussed, wave fronts advancing over nonparallel bottom contours are refracted to cause convergence or divergence of the energy of the waves. Energy concentrations, in areas of convergence, form barriers to the returning backwash, which is deflected along the beach to areas of less resistance. These currents turn seaward in concentrations at locations where there are "weak points," extremely large water accumulations, gaps in the bar or reef, submarine depressions perpendicular to shore, etc. and form a *rip current* through the surf.

The large volume of returning water has a retarding effect upon the incoming waves. The waves adjacent to the rip current, having greater energy and not being retarded, advance faster and farther up the beach. This is one way to visually detect a rip current from shore. The rip may also be transporting large volumes of suspended material, creating a muddy appearance.

The knowledgeable diver will use modest rip currents to aid rapid seaward movement. An unsuspecting swimmer, when caught in a rip, should ride the current and swim to the side, not against the current. Outside the surf zone the current widens and slackens. The diver can then enter the beach at another location. The rip current dissipates a short distance from shore.

Most shorelines are not straight features. Irregularities in the form of coves, bays, points, etc. affect the incoming waves, tidal movements, and the resultant current patterns. When preparing for a dive where beach entries and exits are necessary, the diver must take wave approach, shoreline configuration, and currents into account. Entries and exits should be planned to avoid high waves, as on the windward side of points, and to take maximum advantage of current movements. Avoid dives that require swimming against the current. Never undertake a dive from an ocean beach without considering these factors.

Sand Beach Entry and Exit

The width of the surf zone and the severity of breaking waves will be influenced significantly by the slope of the beach. On a *gradually sloping beach* the surf zone will be wide since the wave will break, re-form, and break again. The diver must observe the wave pattern and surf beat in order to time his movement into the surf zone. The best technique for entry is usually to get completely outfitted (including fins), select the best time (least wave height), and move into the zone backwards while watching the oncoming waves. As soon as the water is deep enough, the diver should start swimming. He must swim under the incoming waves, not attempt to swim over them. A diver should not stand up and face an oncoming wave. If a float is used, it should be towed, not pushed into the waves.

The weight of the equipment, the shift of the center of gravity, the restriction of the diving suit, the cumbersome fins, and the fogginess of the mask are all factors which complicate entries through surf. A diver can compensate for the shift in center of gravity and the weight of the tank by moving with his knees slightly bent, feet apart, and leaning slightly forward. When moving, the diver should slide his feet along the bottom and not attempt to take big steps. If a diver falls or is knocked down, even in shallow water, he should not attempt to stand and regain his footing. He should conserve his energy and swim or crawl to deeper water (or back to shore).

A high surf on a *steeply sloping beach* is extremely dangerous for a diver in full equipment. The waves will break violently directly on the beach, with a very narrow surf zone (only a few feet wide). A diver wearing fins may be up-ended by the force of the water running down the steep slope after a wave as broken. The diver must evaluate both the shoreline and the surf conditions to determine if safe entry is possible. Under severe conditions, the best judgment may be to abort the dive. To make the entry, the diver should move as close to the water's edge as possible, select the proper time (smallest wave), and move into the water and under the oncoming wave *as soon as possible.*

On steeply sloping beaches in Hawaii, divers sometimes carry their fins through the surf instead of wearing them. This method allows rapid entry and better footing. Once beyond the surf zone, the diver dons his fins. Prior to entry, the diver must inflate his buoyancy compensator (or lifejacket) in order to be slightly positive buoyant so he can put on his fins once beyond the surf zone. However, *an entry without fins is not recommended.* If local conditions are such that an entry with fins is not possible, then the entry without fins must be made with considerable discretion and a great deal of caution. A fully equipped scuba diver overweighted and caught in the surf zone without fins is virtually helpless. The diver should select another entry location rather than attempt entry through surf without fins.

When exiting through surf, the diver should stop just seaward of the surf zone and evaluate wave conditions. The exit should be timed so that the diver rides the back of the last large wave of a series as far up the beach as possible. At a point where the diver can stand, he should turn his back toward the beach, face the oncoming waves, and move toward the beach with his body positioned to retain his balance. If the oncoming waves are still at chest level or higher, the diver should dive head first into the wave and stand up as soon as possible when the breaking part of the wave has passed. If the wave is below chest level, the diver should simply lie on top of the wave, keep his feet under him, and ride the wave toward shore. A fatigued diver should not attempt to regain his footing, but ride the wave as high up the beach as possible and crawl out on his hands and knees. On exits through the surf, the float should be pushed in front of the diver and released if necessary to avoid injury or entanglement.

Rocky Shore Entry and Exit

When entering surf from a *rocky shore*, the diver should not attempt to stand or walk. A fall can be extremely hazardous. The diver should evaluate the wave conditions, select the backwash of the last large wave of a series, and crawl into the water. The backwash will generally carry the diver through the rocks. Once the diver is moving, she should not attempt to stop or slow down. If the diver retains a prone swimming position and faces the next oncoming wave, she can grasp a rock or kick to keep from being carried back toward shore. She can then kick seaward after the wave passes. Floats should be towed behind the diver.

When exiting on a rocky shoreline, the diver must stop outside the surf zone and evaluate wave conditions. Exit toward the beach is made on the backside of the last large wave of a series. As she loses momentum, she should grasp a rock or kick in order to avoid being carried seaward by backwash. The diver should maintain position, catch the next wave, and move shoreward. The diver will finally find it necessary to crawl from the water. When exiting through surf, the diver should always look back in order to avoid any surprise.

Tides and Tidal Currents

The *tidal phenomenon* is the periodic motion of the ocean waters in response to the variations in attractive forces of celestial bodies, principally the moon and sun, upon different parts of the rotating earth. On the seacoasts this motion is evidenced by a rhythmic, vertical rise and fall of the water surface called the *tide* and horizontal movements of the water called *tidal currents*. Essentially, tides are long-period waves having a period of 12 hours and 25 minutes and a wave length equal to one-half the circumference of the earth. The tidal cycle is 24 hours and 50 minutes.

Although the sun is larger in mass than the moon, the moon's effect on the earth is much greater because of its proximity to the earth. The moon appears to revolve about the earth, but actually the moon and earth revolve about a common center of mass (the sun). The two bodies are held together by gravitational attraction and pulled apart by an equal and opposite centrifugal force. In this earth-moon system, the tide-producing force on the earth's hemisphere nearest the moon is in the direction of the moon's attraction (toward the moon). On the hemisphere opposite the moon, the tide-producing force is in the direction of the centrifugal force (away from the moon). The resulting effect on the oceans is that two bulges of water are formed on opposite sides of the earth's surface. The earth rotates on its axis once each day, and one can visualize that it rotates constantly inside a fluid veneer (the oceans). This concept views the tidal "wave" as standing motionless while the ocean basin turns beneath it. Ideally, most points on the earth should experience two high tides and two low tides daily. However, due to changes in the moon's declination (position) relative to the equator, a diural (daily) inequality in the pattern of the tidal forces occurs at many places.

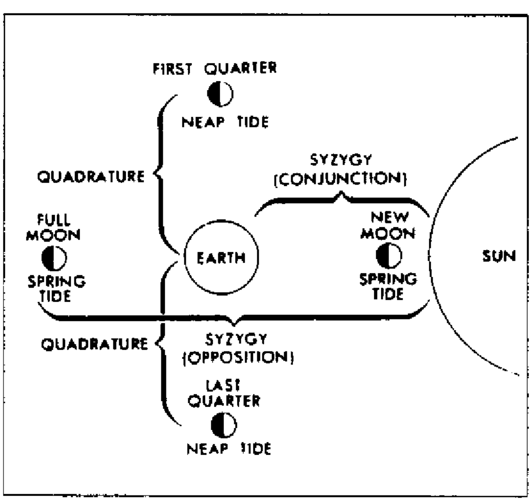

Figure 9. Tide Cycle.

There are similar forces due to the sun, and the total tide-producing force is the result of both the sun and the moon, with minute effects caused by other celestial bodies. The sun tides increase or reduce the lunar tides. The two most important situations are when the earth, sun, and moon are aligned (in phase) and when the three form a right angle (out of phase) (Figure 9). When they are in phase, the solar tide reinforces or amplifies the lunar tide to cause *spring (highest) tides*. Spring tides occur at new and full moon. *Neap (lowest) tides* occur when the sun and moon oppose each other (out of phase). The tidal range is further influenced by the intensity of the tide-producing forces. When the moon is in its orbit nearest the earth (at *perigee*), higher perigean tides occur; when the moon is farthest from the earth (at *apogee*), the smaller apogean tides occur. When new or full moon and perigee coincide, the great perigean spring tides (highest tides of the year) occur. When first quarter or third quarter moon and apogee coincide, the small apogean neap tides occur. A slight delay or lag may be noted between a particular astronomic cause and the resultant tide.

Although the tide-producing forces are distributed over the earth in a regular manner, the sizes and shapes of the ocean basins and the interference of the land masses prevent the tides from assuming a simple, regular pattern. The position of the tide relative to the moon is somewhat altered by the friction of the earth as it rotates beneath the water. This friction tends to drag the tidal bulge, while the gravitational effect of the moon tends to hold the bulge beneath it. The two forces establish an equilibrium and, in consequence, a point on the earth passes beneath the moon before the corresponding high tide.

A body of water has a natural period of oscillation that depends on its dimensions. The oceans of the earth's surface appear to be comprised of a number of oscillating basins, rather than a single oscillating body. The response of a basin of water to tide-producing forces is classified as semidiurnal,

diurnal, or mixed (Figure 10). In a *semidiurnal* tide, typical to the Atlantic coast of the United States, there are two high and two low waters each tidal day, with relatively large differences between the high- and low-water heights. The *diurnal* tide, such as along the northern shore of the Gulf of Mexico, has a single high and single low water each tidal day. In

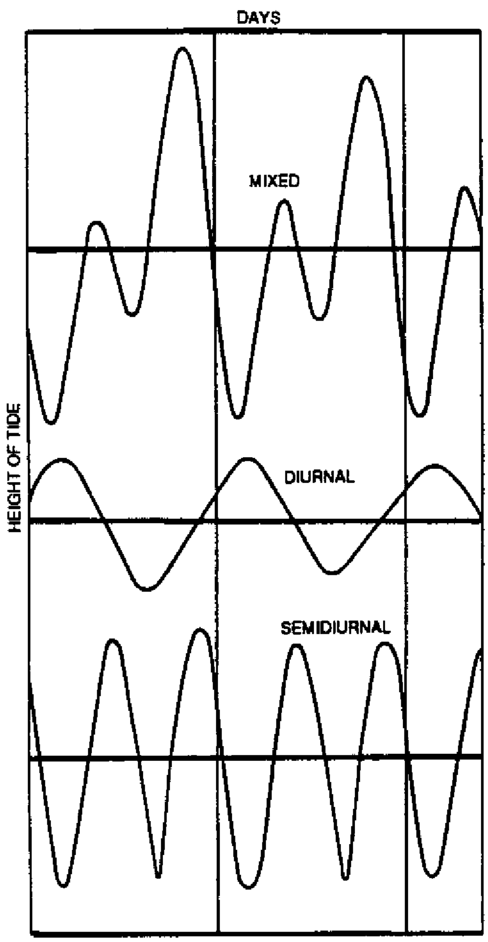

Figure 10. Types of Tide Curves.

the *mixed* tide, the diurnal and semidiurnal oscillations are both important factors and the tide is characterized by a large inequality between consecutive high-water heights, low-water heights, or both. Such tides are prevalent along the Pacific coast of the United States.

The tidal range will vary considerably, depending on the configuration of the shoreline, time of month, time of year, wind conditions, etc. On small oceanic islands, the range may be a foot or less. However, along the coasts of major continents, the tidal range is exaggerated at the shore. Estuaries with wide funnel-shaped openings into the ocean tend to amplify the tide range even more. The width of the tidal wave that enters the mouth of the estuary is restricted as the channel narrows; this constriction concentrates the energy and increases the height of the wave. The frictional effects of the sides and bottom on the channel tend to reduce the energy and height. The classic example of this phenomenon is the Bay of Fundy, where the tidal range exceeds 40 feet. Only a few hundred miles away, Nantucket Island has a tidal range of about 1 foot.

Tidal current, the periodic horizontal flow of water accompanying the rise and fall of the tide, is of considerable significance to the diver who must work in restricted baymouth areas, channels, etc. Offshore, where the direction of flow is not restricted by any barriers, the tidal current flows continuously, with the direction changing through all points of the compass during the tidal period. In rivers or straits, or where the direction of flow is more or less restricted to certain channels, the current reverses with the rise and fall of the tides. In many locations there is a definite relationship between times of current and times of high and low water. However, in some localities it is very difficult to predict this relationship. Along channels or waterways the relationship will change as the water progresses upstream.

At each reversal of current, a short period of little or no current exists, called *slack water*. During flow in each direction, the speed will vary from zero at the time of slack water to a maximum, called *strength of flood* or *ebb*, about midway between the slack periods. The *current direction* or *set* is the direction toward which the current flows. The term *velocity* is frequently used as the equivalent of *speed* when referring to current; however, in proper terminology velocity implies direction as well as speed. Tidal current movement toward shore or upstream is the *flood*; the movement away from shore or downstream is the *ebb*.

Divers are encouraged to consult local tide tables, confer with local authorities, and make personal evaluations of the water movements in order to determine time of slack water and, consequently, the best time to dive. Tide tables and specific information are contained in various forms in many navigational publications. Tidal current tables, issued annually, list daily predictions of flood and ebb tides, and of the times of intervening slacks.

In some channels or straits the diver will be limited to 10–20 minutes of safe diving at time of slack water. Specific precautions must be taken when working in these areas. Dives must be planned and time precisely. Scuba diving may be least desirable. Surface-supplied diving equipment, with heavy weighted shoes, may be required for the diver to work in the currents. The diver should not attempt to swim against the tidal current. If he is caught in a current, he should surface, inflate his lifejacket and swim perpendicular to the current toward shore or signal for pick up by the safety boat.

Wind Currents

The primary generating force of currents is the wind, and the chief secondary force is the density differences in the water. In addition, such factors as water depth, underwater topography, shape of the ocean basin, land configuration, and the earth's rotation affect oceanic circulation.

The stress of wind blowing across the sea causes the surface layer of water to move. This motion is transmitted to succeeding layers below the surface; however, due to internal friction within the water mass, the rate of motion generally decreases with depth. Although there are many variables, a steady wind for about 12 hours generally is required to establish a *wind current*. A *seasonal current* experiences large changes in direction or speed due to seasonal winds.

A wind current does not flow in the direction of the wind due to the effects of the rotation of the earth, or Coriolis force. Deflection by Coriolis force is to the right in the northern hemisphere and to the left in the southern hemisphere. This force is greater in higher latitudes and more evident in deep water. Current direction varies from about 15 degrees off the wind direction along shallow coastal areas to 45 degrees off the wind direction in deep ocean. The angle increases with depth, and at greater depths the current may flow in the opposite direction to the surface current.

The speed of the wind-derived current depends on the speed of the wind, its constancy, the length of time it blows, and other factors. In general, about 2 percent or less of the wind speed can be expected in deep water where the wind has been blowing steadily for at least 12 hours.

A number of ocean currents continue with relatively little change throughout the year. These large-scale currents are primarily the result of the interaction between the general circulation of the atmosphere and the ocean water.

Seiches

When the surface of a large, partially enclosed body of water, such as one of the Great Lakes or a bay, is disturbed, long waves may be set up which will rhythmically oscillate as they reflect off opposite ends of the basin. These waves, called *seiches*, have a period that depends on the size and depth of the basin. The seiche is a rather common phenomenon not frequently observed by laymen because of the very low wave height and extremely long wavelength. A seiche can be regarded as a standing wave pattern.

In the Great Lakes, seiches are induced by differential barometric pressure changes and, most frequently, winds. For example, a strong wind blowing for several hours along the axis of Lake Erie will drive the surface water toward the leeward end of the lake, raising the water surface there as much as 8.4 feet and lowering the level at the windward end of the lake. This oscillation, which diminishes rapidly in amplitude, has a period of 14–16 hours. Lake Erie is particularly subject to seiches because the lake is shallow, nearly parallel with the prevailing winds, and has a basin of fairly regular and simple shape.

In 1954 a severe seiche in Lake Michigan, resulting from both wind and barometric pressure changes, caused an abrupt increase in water level to 10 feet above normal in the vicinity of Chicago. At least seven lives were lost.

In bays that open to the ocean, seiches are almost always caused by the arrival of a long-period wave train. Once the water is set in motion by the initial wave, seiches continue at the natural period for that harbor or bay.

Diving in Currents

Currents are caused primarily by the influence of surface winds, changing tides, and rotation of the earth. They are essentially flowing masses of water within a body of water. Divers must always take currents into account in planning and executing a dive, particularly a scuba dive. Large ocean currents such as the Gulf Stream of the Atlantic and Japan Current of the Pacific flow continuously, although there may be local variations in magnitude and position. Local wind-derived currents are common throughout the oceans and on large lakes.

The current velocity may exceed 2–3 knots. Attempts to swim against this type of current may result in severe fatigue. Sometimes in the Gulf of Mexico, as well as other portions of the ocean, there may be no noticeable current at the surface, but there will be a 1- to 2-knot current at a depth of 10–20 feet. Or there may be a current at the surface and no current at 10–20 feet down. The diver should observe the following precautions:

- Always wear a personal flotation device.
- Be in good physical condition.
- A safety line at least 200 feet long with a float should be trailed over the stern of the boat during diving operations when anchored in a current. Upon entering the water, a diver who is swept away from the boat by the current can use this line to keep from being carried far down current.
- Descent should be made down a weighted line placed at the stern, or, if unavailable, down the anchor line. Free swimming descents in currents should be avoided. If the diver stops to equalize pressure, he may be swept far down current. Furthermore, if a diver has to fight a current all the way to the bottom, he'll be fatigued, a hazardous situation underwater. Ascent should also be made up a line.
- When a bottom current is encountered at the start of the dive, the diver should always swim into the current, not with it. This will facilitate easy return to the boat at the end of the dive. He should stay close to the bottom and use rocks if necessary to pull himself along in order to avoid overexertion. If the diver wants to maintain position, he should grasp a rock or stop behind a rock, rather than attempt to swim. The same technique should be used by a fatigued diver to rest.
- A qualified assistant should stay on the boat at all times. This will facilitate rescue of a diver swept down current.

Weather

Weather is always a factor to consider when planning offshore diving operations in large lakes or the ocean. Divers must be familiar with local weather conditions and monitor weather forecasts. Different areas may have unique weather conditions, and the diver must consult with local authorities regarding weather conditions and changes. In some areas, offshore operations from small boats are prohibited by weather and, consequently, wave conditions during certain portions of the year.

When diving offshore, abrupt wind and sea condition changes can transform a pleasant day into a nightmare. The diver should not venture too far from shore or from his diving craft when he is aware of the possibility of weather changes. High winds and rough seas can defeat even the strongest swimmer. It is therefore wise to surface periodically and evaluate the weather situation. In the Florida Keys, a squall can sometimes appear seemingly out of nowhere on an otherwise perfect day.

A squall line which appears to be some distance away should be observed for direction of movement, greater development, increased wind velocity, water spouts, etc. If the approaching storm looks severe and is approaching from open ocean, it may be wise to abort the operation and return to shore if you are working from a small boat.

In the Florida Keys, however, these squalls approach quickly and are generally of short duration. If the squall overtakes the fleeing boat, navigation in poor visibility will be very hazardous. Under these circumstances it may be wiser to anchor the boat securely and ride the storm out. If the skipper decides to anchor, he must face his boat into the oncoming waves and let out plenty of anchor line: a taut line can snap and the boat will be set adrift.

Following a heavy rain squall, there may be high winds, and the skipper must exercise caution while getting underway again. Choppy seas and murky water may make it difficult to avoid shallow reefs, floating objects, lobster trap lines, etc.

The diver must remember that a wind blowing from land to sea can be very deceiving. What may appear as calm water from shore may be a raging sea at the outer reef. Returning to shore into the waves will be difficult.

Serious storms and severe wave conditions can be expected on the Great Lakes in September, October, November, and December as a result of local weather phenomena. This period of instability relates to the energy system established when cold atmospheric air encounters the air heated by the warmer lake water. The result is sudden storms and high seas. Again the diver is encouraged to consult with local authorities and monitor weather forecasts before diving offshore. Divers are also encouraged to acquire instruction in boat handling and seamanship. Courses are available from the U.S. Coast Guard Auxiliary, sportsman groups, etc.

Conclusion

Since the beginning of time, the waters of our planet have stimulated the imagination of man. Under these waters lies an exciting world of beauty and challenge. The underwater explorer and researcher can now, as never before, venture to greater depths and to the most remote corners of the ocean. However, he/she must be equipped with a basic working knowledge of waves, tides, and currents. When divers visit unfamiliar areas, they must consult with local divers and authorities to gain information on particular environmental conditions.

The diver must develop a "sixth sense" in the evaluation of environmental conditions in order to plan dives safely and efficiently. Most divers get into trouble at one time or another by underestimating the potential hazards associated with the underwater environment or by overestimating their physical capabilities and diving skills in coping with adverse currents, waves, etc. Good physical condition, basic knowledge, common sense, and good judgment are prerequisites for *safe* underwater exploration.

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Acknowledgment

Figures 1, 6, 8, 9 and 10 were adapted from Baker, *Glossary of Oceanographic Terms*. Figure 7 was adapted from Bowditch, *American Practical Navigator: Oceanography*. (See References for complete information on these publications.)

Hazardous Marine Life

The life of the marine environment is beautiful and fascinating. Of the thousands of marine animals and plants, relatively few constitute a real hazard to the diver. Although some species are dangerous and may, in some instances, inflict serious wounds, with a few exceptions marine animals are not aggressive. Generally, it is through the diver's own carelessness that injury results. The diver should respect, not fear, marine animals. He must be able to recognize animals that are capable of inflicting damage, know how to avoid injury, and be able to administer proper first aid in event of injury inflicted by marine organisms. *In addition to specialized training in diving related accident management/first aid, all divers are encouraged to acquire training in standard American Red Cross first aid practices or the equivalent.*

This discussion will characterize the major groups of marine animals that are known hazards to the diver. No attempt will be made to discuss individual species in detail. Geographically, the discussion will concentrate on the tropical waters of Florida, the Caribbean, and the Bahamas; however, reference will also be made to animals of the western coast of the United States and the South Seas (including Australia's Great Barrier Reef). *Divers are encouraged to consult with local authorities regarding marine hazards whenever they travel to unfamiliar diving areas.*

For marine animal identification readers are encouraged to consult any of a number of popular publications such as National Geographic Magazine, Cousteau publications, nature guides, and the many excellent pictorial publications by various noted photographers [5, 6, 9, 22, 26, 27].

For convenience, the marine animals will be divided into the following categories:

- marine animals that sting;
- marine animals that abrade, lacerate, or puncture;
- marine animals that bite;
- marine animals that have venomous bites; and
- miscellaneous hazardous marine animals.

Marine Animals That Sting

Most marine animals that inflict injury by stinging their victim belong to the phylum *Coelenterata*. This phylum includes about 10,000 species in three major classes: *Hydrozoa* (hydroids, fire coral, and Portuguese man-of-war), *Scyphozoa* (jellyfish), and *Anthozoa* (sea anemones and corals). Although all *coelenterates* have stinging tentacles, only about 70 species have been involved in human injuries. However, over 90% of the venomous wounds and stings suffered by divers are from members of this phylum.

Coelenterates are characterized by their unique stinging cells, or *nematocysts*, which are situated in the outer layer of tentacle tissue. This apparatus consists of a trigger hair which, when touched, actuates a spine, followed by a hollow thread through which a paralyzing drug is injected into the victim. When a diver brushes against or becomes entangled in the tentacles of some coelenterates, thousands of tiny nematocysts may release their stinging mechanisms and inject venom.

Symptoms produced by the stings will vary according to the species, locality, extent and duration of contact, and individual reaction variations. Chemical toxins promote an allergic reaction in the skin. Some individuals are more sensitive than others to stings and will exhibit more severe reactions. The more nematocysts that strike the victim, the greater the impact. Thus, it stands to reason that larger specimens can be more dangerous than smaller ones. Conceivably, a sensitive individual in contact with a large *Cyanea* could suffer physiological shock and then drown. On the other hand, an encounter with *Cyanea* as well as many other jellyfish species may result in little or no discomfort for some individuals.

Symptoms may range from a mild prickly or stinging sensation to a throbbing pain which may render the victim unconscious. The pain may be localized or radiate to the armpit, groin, or abdomen. Local redness may be followed by inflammatory swelling, blistering, or minute skin hemorrhage. Following contact with some large species, certain individuals may experience shock, muscular cramps, loss of sensation, nausea, vomiting, severe backache, frothing at the mouth, constriction of the throat, loss of speech, breathing difficulty, paralysis, delirium, convulsion, and possibly death.

Stinging Coral. Stinging coral or fire coral is actually not a coral, but a member of the class Hydrozoa. Members of the genus *Millepora* are found among the true corals in warm waters throughout the tropical Indo-Pacific and Atlantic Oceans, Red Sea, and Caribbean. Common Florida and Bahamas species are *Millepora complanta* or *Millepora alcicornis*, which have a characteristic tan-colored, bladed-type growth with lighter (almost white) upper portions. *Millepora* may appear in a bladed growth form or an encrusting form over rock surfaces or on the branches of soft corals such as alcyonarians. The *Millepora* zone of the outer Florida Keys reefs ranges from 10 to 25 feet deep. Contacts with *Millepora* are relatively common, with symptoms generally limited to a stinging sensation and reddening of the skin.

Portuguese Man-of-War. The Portuguese man-of-war (*Physalia physalis*) is often mistaken for a jellyfish. This hydroid, also called blue bottle, floats on the water's surface in all tropical oceans and the Mediterranean Sea. It appears as a blue transparent jelly-like mass with tentacles bearing large numbers of nematocysts trailing several feet down into the water. A single tentacle may have as many as 75,000 nematocysts. The Portuguese man-of-war drifts with the currents and may be found in localized large concentrations. This hydroid, producing a cobra-like toxin, has been responsible for many injuries in Florida and Bahamian waters, with symptoms ranging from minor irritation to shock and respiratory arrest. Other species that produce similar injuries include the *Velella velella* (purple sail) and *Porpita umbella*.

Jellyfish. The class Scyphozoa includes the large, bell-shaped medusae, having eight notches on the margin, and many other species that constitute potential danger for the diver. The sea wasp, represented by several species, including *Chiropsalmus quadregatus* and *Cheronex fleckeri*, is one of the most lethal venomous marine animals known to man. It is an especially dangerous inhabitant of Australian and Philippine areas and the Indian Ocean. Stings of the sea wasp have been responsible for a number of human deaths in Australian waters. Death may follow in 3–8 minutes after contact.

Cubomedusea (Caribbean sea wasps) can inflect a painful sting, however, they are not as potent as their South Pacific and Indian Ocean counterparts and do not cause death. *Carybdea marsupialis* and *Carybdea alata* (the more potent species) abundance will very with time and location. Along the north coast of Jamaica large concentrations may be encountered a few meters below the surface at night.

Less dangerous, but still painful, are the stings of the sea nettle (e.g., *Dactylometra quinquecirrha*) and the sea blubber (e.g., *Cyanea capillata*). The sea nettle is a widely distributed form which has been found as far north as New England coastal waters, as well as in all tropical sea areas. Sea blubbers inhabit areas from the north Atlantic and Pacific Oceans to the Arctic Ocean. Sea bladders increase in size in northern latitudes. The Carolina *Cyanea* are about as wide as saucers; those off southern New England may measure one to two feet across; and farther north the Arctic specimens approach gigantic sizes.

Sea Anemones and Coral. The sea anemones and corals include venomous members which may produce sting symptoms when contacted. Although some forms of coral produce only lacerations, others, such as elk horn coral (*Acropora palmata*), which inhabits the Florida Keys, Bahamas, and West Indies, produce added reaction by means of stinging cells.

Sponges. There are approximately 4000 species of the phylum Porifera, or sponges, of which a few can produce a serious dermatitis or skin irritation. Many sponges may be colonized by other sponges, coelenterates, and numerous other organisms. Contact with the sponge can result in coelenterate stings. Sponge diver's disease has been found to be caused by the tentacles of very small sea anemones which adhere to the sponge, and not by the sponge itself.

Preventive Measures

Complete body coverage with a foamed neoprene diving suits or tight-fitting Lycra nylon body suits have proven to be useful protection. Persons diving in areas of known jellyfish concentration often wear Lycra or neoprene hoods, especially at night. Thin fabric gloves also reduce possibility of injury. However, avoidance of contact with the tentacles is most important. Divers must be able to identify the dangerous species. They should also avoid detached tentacles floating in the water and dead jellyfish found on the beach, since the nematocysts may remain potent for some time.

First Aid for Marine Life Stings

Jellyfish and Hydrozoans. The first aid procedures recommended for common jellyfish and hydrozoan (Portuguese Man-of-war) stings that are considered non-life-threatening in healthy individuals vary with author and geographic area.[1]

Most authorities advise rinsing the injured area with vinegar or Xylocaine (lidocaine) to prevent further discharge of the nematocysts. Injuries from certain species of jellyfish common to the U.S. Atlantic Coast should be rinsed with alcohol rather than vinegar. These include the hair jelly (Cyanea), sea nettle (Chrysaora), and little mauve stinger (Pelogia).

If no other rinsing solutions are available, the injured area should immediately be flushed with seawater and cleaned of debris. Never rinse the sting area with fresh water. Fresh water has an osmotic effect on the nematocysts, causing them to discharge. Also, never rub the area with sand, since this procedure will cause discharge of more nematocysts.

Next, the tentacles that didn't rinse off must be carefully removed with a towel, stick, knife blade, etc. These residual tentacles may also be removed by coalescing them with a drying agent (e.g., flour, baking soda, talc, etc.) and then scraping them from the skin with a thin knife blade. *Avoid personal contact with the tentacles.*

After tentacles have been removed, some authors recommend neutralizing the toxins by applying one of the compounds/solutions mentioned above and thoroughly scrubbing with an antibacterial soap and water.[2] The sting site is dried and an analgesic-antihistamine ointment applied.

Local anesthetic ointments (lidocaine HCl) or sprays (Benzocaine, 14%), antihistaminic creams, or mild steroid lotions (hydrocortisone, 1%) may be soothing [7]. They are used after the toxin is inactivated. A lidocaine spray (Clinicaine by Johnson and Johnson) may be beneficial as an initial decontamination agent as well as a soothing solution [personal experience].

Observe the victim for general reactions and shock. It is advisable to lay the victim down and keep him/her as quiet as possible. The symptoms of *shock* include glassy eyes with dilated pupils; wet and clammy skin; weak and rapid pulse; pale or ashen skin tone; increased breathing rate (shallow or deep and irregular); and sensations of coldness [2]. First aid measures for prevention and management of shock [2] include keeping the victim lying down and covered *only* enough to prevent loss of body heat. No attempt should be made to add heat since raising the surface temperature of the body can be harmful. Elevate the feet or end of stretcher 8 to 12 inches.

Giving fluids by mouth has value in shock; however, fluids should only be given when medical assistance is not available within a reasonable amount of time (delay of more than one hour). Fluids *should not be given* when the victim is unconscious, vomiting/likely to vomit, or experiencing seizures, since such states may result in aspiration of fluids into the lungs. Water that is neither hot nor cold (preferably a salt-soda solution; 1 level teaspoon of salt and 1/2 level teaspoon of baking soda per quart of water) is given at about 4 ounces every 15 minutes. Do not give the victim sea water. Discontinue fluids if the victim becomes nauseated or vomits. Obtain medical assistance as soon as possible. Keep in mind that physiologically or emotionally induced shock may be associated with any marine life injury.

Simple pain relief measures (e.g., aspirin tablets, or equivalent, in accord with dosage instructions on container) are considered acceptable. Do not attempt to administer medications if the victim is unconscious or nauseated/vomiting.

Naturally, all stings will not result in severe reaction or shock and require such aggressive first aid measures. For example, fire coral encounters do not involve tentacle removal, and some small jellyfish stings give only minor, momentary irritation. After minor encounters the diver may continue to dive. However, the victims and their buddies must maintain an awareness for more serious reactions. In rare cases, respiratory or cardiac arrest may occur and require immediate life saving action.

Sea Wasps. The box jellyfish or sea wasp (*Chironex flecheri*) found in Australian and South East Asian waters is one of the most dangerous stinging animals in the world. Although records are far from complete, at least forty fatalities have been documented on Australian beaches [33]. Death can occur within minutes and immediate first aid is required. Examination of records show that one-third of the fatal cases are said to have died within three minutes or less following encounter. If death occurs, it usually does so within the first ten minutes; survival is likely after the first hour [13]. A specimen 7 cm in diameter is capable of killing a healthy child, while a specimen 10 cm or larger in diameter may kill an adult. In any event, contact with a sea wasp can result in excruciating pain, occurring immediately upon contact, and increasing in intensity. The victim may become confused, act irrationally, and, subsequently, drown. *Please do not confuse this species with the far less potent and nonfatal ones of the Caribbean (Cubomedusea).*

Since serious, potentially fatal reaction can be anticipated within minutes, the victim must be removed from the water immediately. Avoid personal contact with any adhering tentacles. If at all possible, do not allow the injured area to come into contact with sand or boat surfaces. Such contact may bring more stinging cells into contact with the skin and cause the release of more venom. Immediately and thoroughly douse the sting area and tentacles with liberal amounts of vinegar.[3]

Isolate the envenomed part, if on limbs, from general circulation as soon as possible. First aid authorities specifically discourage the use of a tourniquet. The most recent practice in Australia is the ***pressure immobilization technique*** [1]. With this technique, both pressure and immobilization are applied for best minimization of venom spread. Pressure is applied with a flexible material, ideally a crepe bandage.[5] Bandage first over the sting site, then extend the bandage on each side of the sting to include the nearest joints. Wrap bandage tightly as you would for a sprained ankle. If the bandage causes discomfort for the victim, it is too tight and should be loosened. Immobilize the limb with a wood or paper splint if possible. Keep the victim still.

An alternative method for isolating the venom is the application of a ***venoconstrictive tourniquet or constricting band*** ("loose tourniquet"), which impedes the lymphatic and superficial venous return. This constricting band is loosened for 90 seconds every 10 minutes and should be removed after one hour [7].[6]

Respiratory failure is possible. The victim must be monitored continuously and artificial respiration begun immediately if the victim stops breathing; cardiopulmonary resuscitation may be required if there is no obvious pulse. Do not delay or interrupt this aspect of first aid for any reason if an unconscious victim requires it. Do not terminate resuscitation procedures until directed to do so by medical personnel or as indicated in accord with ARC/AHA procedures. Oxygen breathing is recommended if the equipment is available.

Remove any remaining tentacles by irrigating the area with more vinegar. Do not handle or rub the tentacles unless removal by irrigation is unsuccessful.

Send for medical assistance and antivenin as soon as possible. Australian literature specifically discourages moving a seriously affected victim. Maintain constant observation and keep the victim quiet even if his/her condition improves significantly. Transfer responsibility for the patient to qualified medical personnel upon arrival.

The Commonwealth Serum Laboratories have developed an antivenin for stings of the sea wasp, and sublethal stings have been successfully treated. Australian scientists have investigated the use of a toxoid that will provide immunization against the sting.

Sponges. The fire sponge (*Tedania ignis*), found off Hawaii and the Florida Keys, and the "Do-Not-Touch-Me" sponge (*Neofibularia nolitangere*), common to the Caribbean, are typical offenders. Reactions are characterized by itching and burning, which may progress to local joint swelling, blisters, and stiffness. Soaks in dilute (5%) acetic acid (vinegar) are considered beneficial [7].

Most sponges are composed, in part, of small silicon dioxide or calcium carbonate spicules. These spicules are tiny and difficult to detect with the naked eye. If penetration of the skin by these small spicules is suspected, the particles may be removed by gently applying adhesive tape to the injured area and then removing it. Many of the embedded spicules will adhere to the tape during removal. Toxic sponges may possess toxins which will enter the lesions caused by the spicules. Application of isopropyl alcohol or vinegar should follow this removal procedure. Steroid lotions may help to relieve secondary inflammation. Severe secondary reactions may require medical attention.

Marine Animals That Abrade, Lacerate, or Puncture

A number of marine organisms cause abrasions, lacerations, or punctures when contacted by the diver. Some of these organisms possess venom injection structures and may cause serious complications.

Coral. Wounds inflicted by contact with stony coral are an ever present annoyance to divers in the tropics. The sharp calcareous edges produce wounds which are generally superficial but notoriously slow to heal. Coral cuts, if left untreated, may become ulcerous. Sting cells may further complicate conditions. The initial effects of coral poisoning are pain and an itching sensation in and around the wound accompanied by reddening and welt formation in the surrounding areas. Secondary infection is common.

First aid involves prompt removal of visible debris and cleansing of the wound with hot water and antibacterial soap. It is occasionally helpful to use hydrogen peroxide to bubble out coral "dust." Promote free bleeding; however, keep in mind that excessive probing can cause unnecessary tissue damage. Deeply embedded materials may require removal by a physician. Elevation of the involved limb is strongly recommended. The use of antiseptic creams is a matter of personal preference. Monitor the wound closely and cleanse/change dressings as soon as possible upon return from subsequent dives. Even minor wounds can become seriously infected. Current tetanus immunization is recommended for all divers. For severe wounds, or if complications appear, seek immediate medical attention.

In the past divers were encouraged to wear gloves and diving suits or cloth coveralls for protection when swimming in the vicinity of coral. Carelessness and curious touching of corals has done considerable damage to our tropical reefs. Today, divers are being schooled in proper weighting and buoyancy control as a *conservation measure* as well as a safety and diving technique consideration. In fact, the use of gloves is now being discouraged in some tropical marine parks. The opinion is, "divers without gloves are less likely to touch delicate corals either accidentally or on purpose!"

Barnacles. Barnacles, a marine arthropod, in the adult shell form are found attached to rocks, timbers, ship hulls, etc., in and near the intertidal zone. These shells are sharp and especially hazardous to divers who must enter the water from rocky shore areas, work on ship hulls near the water line, or dive around pilings or offshore structures such as oil rigs. An abrasive injury may be further complicated by the presence of hydroids on and among the barnacles. Caution and protective clothing are recommended. First aid measures are the same as for coral lacerations.

Enchinoderms. Most members of this groups of marine organisms are characterized by radial symmetry and may bear a rigid or semirigid skeleton of calcareous plates or spines on a flexible body way. Included are starfishes, sea cucumbers, and sea urchins. Of all echinoderms, the sea urchins are probably responsible for most injuries to divers.

Sea urchins occur in large numbers and variety in the shallow coastal waters of the world. The spines, common to all sea urchins, vary greatly from species to species. Most spines are solid, with blunt or rounded tips, and are not venomous. Others, however, are long, slender, sharp, and brittle, permitting easy, deep entrance into the flesh. Because of the extreme brittleness, these spines may be difficult or impossible to withdraw in one piece. Some may secrete a painful, or even deadly, venom. In some species, small, delicate, globe-shaped seizing organs called pedicellariae are distributed among the spines. This globe-shaped head, in at least one type, serves as a venom organ and is armed with a set of pincer-like jaws. One such venomous genus, *Toxopneustes*, inhabits the Indo-Pacific and Japanese waters. Symptoms vary from radiating pain to paralysis and respiratory distress. Fatalities have been reported.

More familiar to the United States diver is the genus *Diadema*, which includes the long-spined or black sea urchin common to the Bahamas, Florida Keys, and West Indies. These sea urchins with long, brittle spines are not considered to be a serious hazard by most divers; however, they may produce a painful puncture-type wound with redness and swelling. The fragments of the spine will produce a purple discoloration in the area of the wound. In minor injuries, the spines of some species will dissolve with few complications besides localized discomfort. However, deeply embedded spines will cause irritating discomfort of long duration if not removed. These should be removed with a fine tweezers or small needle (sterilized), the area thoroughly scrubbed with hot water and antibacterial soap, and a sterile dressing applied. Medication to control pain, inflammation, and infection may be required. Consult a physician immediately if symptoms of infection or other complications appear. Surgical removal of deeply embedded spines may be necessary.

Sea urchins with long needlelike spines should not be handled. Ordinary foamed-neoprene, canvas, or leather gloves do *not* afford adequate protection. Divers must exercise extreme caution, especially at night.

Some sea urchins are venomous. It appears that those which can cause serious reactions in a human are more common to the South Pacific. One genus, *Tripneustes*, found in the Pacific Ocean, has a neurotoxin. Injury from the pedicellariae (small, delicate seizing organs scattered among the spines of some species) can cause serious reactions. The symptoms may include immediate intense radiating pain, local swelling, and hemorrhage. This may be accompanied by faintness, numbness, generalized muscular paralysis, loss of speech, respiratory distress, and occasionally death [7]. In such cases first aid/treatment is in accord with the severity of the symptoms. Hot water may provide pain relief [7]. Seek medical attention immediately in the event of such severe reactions.

Some species of starfish can produce a contact dermatitis from a slimy venomous substance produced in the animal's tissue. The "crown-of-thorns sea star" (*Acanthaster planci*) is a particularly venomous species found from Polynesian waters to the Red Sea. Envenomation can induce acute systematic reactions that include paresthesia (sensation of prickling and tingling), nausea, vomiting, and muscular paralysis. First aid measures include immediate application of hot water and subsequent use of a topical solution such as calamine with 0.5% menthol. Medical attention may be required for serious reactions [7].

Cone Shell. The family of marine gastropod Conida is comprised of more than 500 species distributed throughout the tropical seas of the world, but concentrated in the reef areas of the Indo-Pacific. Some species are highly valued by collectors, with *Conus gloriamaris* being worth more than $1,000 per specimen. Every species of *Conus* makes a venom peculiar to that species, and most have a fully developed venom delivery apparatus near the shell opening. Radular teeth are thrust into the victim, and the venom is believed to be injected under pressure into the wound. The venom of a given species of *Conus* may only affect certain animals and be totally ineffective on others. Only about six species of *Conus* are considered deadly to man. *Conus geographus* has been officially indicated in human fatalities and other species such as *Conus magus* are just as deadly.

The sting of a *Conus* usually produces a numbness, tingling, or burning sensation which may spread rapidly and become particularly pronounced about the lips and mouth. Paralysis and coma may follow. Death from respiratory or heart failure may result. Unfortunately, many authorities list no specific treatment for cone shell injuries.

In light of the recommendations that do appear in the literature, the procedure given below should be considered in the first aid management of cone shell injuries.

The first-aider should immediately immobilize the victim and take measures to combat shock. Elevate the affected limb if possible. Apply either *pressure immobilization* or a *constricting band* sufficient to reduce lymphatic and superficial venous return [1] [7]. (See page 17.) Soak the site of injury in hot water or apply hot compresses for 30 minutes to help inactivate the venom and reduce pain or other symptoms.[7] Paralysis and respiratory/cardiac failure may occur. Make routine observations of respiration and circulation continuously. Employ resuscitation or CPR if and when needed. Immediate medical attention and hospitalization are generally required.

Specific precautions and ample protection for the hands are necessary when handling cone shells. Avoid contact with the fleshy portion of the animal. Divers must learn to identify dangerous species peculiar to their locality, and specific precautions must be taken in Indo-Pacific waters.

Venomous Fish. Fish that inflict poisonous puncture-type wounds are found throughout the world, but are most common in tropical waters. They are generally nonaggressive, and injury generally results from careless contact with venom-bearing spines, commonly located on or associated with the fins of the fish.

The common spiny dogfish is a small (up to 3.5 feet in length) shark found along the coast of the Atlantic and Pacific Oceans throughout temperate and tropical seas. Two short, stout spines, one situated immediately in front of each dorsal fin, can cause painful wounds. The venom is found in a shallow groove of the spines and enters the victim with the spine. Injury is immediately followed by an intense, stabbing pain of long duration (possibly 6 hours), severe swelling, and redness. Handle dogfish with caution.

Stingrays of many kinds inhabit tropical and subtropical seas at moderate to shallow depths. They are common in sheltered sandy bays and lagoons where they lie in shallow water on top of or partially buried in the sand or mud. Most rays have a sharp spine near the base of a whiplike tail. Deep, glandular grooves of the spine contain poisonous tissue. The menace is most serious to persons wading or crawling on the bottom in very shallow, protected waters. When stepped on, the ray strikes upward with its tail and may drive the spine deeply into the foot or leg. This usually produces a ragged, dirty wound. The wound usually causes immediate and severe pain. Swelling of the wound area is accompanied by an ashy appearance which later turns red. Symptoms of shock along with fainting, nausea, and weakness may follow, depending on the severity of the injury and the species of stingray. Medical attention is recommended. Wounds in the chest or abdomen are extremely serious and may be fatal. Deaths have been reported. Immediate hospitalization is necessary.

The diver can avoid contact by entering the water cautiously and shuffling his feet as he moves through shallow water and never lying on the bottom without first looking for rays. Fins and foamed rubber boots offer only limited protection.

About 1,000 species of catfish are found primarily in fresh water and may assume many sizes and shapes. Generally, the body is elongated with oversized head, and the mouth area usually has long barbels or feelers. The skin is usually thick and slimy, without scales, although bony outer plates may exist in some.

Some species have a stiff spine in the front part of the dorsal and pectoral fins. Venom glands are located in the outer skin or sheath of the spine. The venomous spine is equipped with a device which can lock it into an erect position. The wound is generally accompanied by an almost instant stinging, throbbing, or scalding sensation, with radiating pain and numbing; redness and swelling follow. Bacterial infection is possible. Care must be taken to avoid injury when handling venomous species.

Weeverfish, of the family Trachinidae, are small but extremely venomous fish found along the eastern Atlantic and Mediterranean coasts. Because of an aggressive temperament, combined with a well-developed venom apparatus, they present a specific danger to divers. Weevers habitually bury themselves with only part of the head exposed. With little or no provocation, they dart out with fins erect and gill covers expanded and strike at any offending target.

The dorsal and opercular spines are venomous. This venom is similar to some snake venoms and acts both as a neurotoxin and a hemotoxin. A weever wound normally produces instant burning or stabbing pain that intensifies and spreads. Within 30 minutes the pain may be severe, and the victim may lose consciousness. A large spectrum of symptoms includes headache, fever, chills, delirium, nausea, vomiting, sweating, palpitations, and convulsions.

Weevers are commonly encountered while wading in shallow water; care must be taken to avoid contact. Adequate footwear (high-top tennis shoes) may provide some protection. This fish should neither be antagonized into an attack or handled in a careless manner.

The members of the scorpionfish family can be found in all tropical and temperate seas. The wound from any of these fish will produce serious results, and a few of the stonefish group, *Synanceja*, may rank with the cobra in the deadliness of the poison secreted. Most species have venomous dorsal spines; some have venomous anal and pelvic spines. These fish are divided into three main groups — scorpionfish (*Scorpaena*), zebrafish (*Pterois*), and stonefish (*Synanceja*).

Scorpionfish inhabit shallow-water bays, lagoons, and reefs—and have also been observed 60-80 feet deep in the waters of the Bahamas. *Scorpaena gutlata* ranges from central California south into the Gulf of California and *Scorpaena plumieri* (and related species) are found on the Atlantic coast from Massachusetts to the West Indies and Brazil. They may be found among debris, rock, or seaweed. Scorpionfish have nearly perfect protective coloration which enables them to blend into their background and become almost invisible.

Zebrafish are beautiful and ornate fish which swim about coral reefs of the Red Sea and Indo-Pacific seas with their fanlike fins extended in a display fashion. Although extremely beautiful and prized by fish collectors, the fins of this fish contain 18 potentially lethal spines, each equipped with venom.

Stonefish are encountered in tide pools and shoal areas of the Indo-Pacific [16]. They lie motionless while concealed or partly buried and appear to be fearless. The fish is equipped with as many as 18 spines with enlarged venom glands. In natural concealment, the fish looks like a piece of mud or debris. They present a particularly dangerous hazard to a barefooted wader.

Other fish which may inflict venomous wounds include toadfish, surgeonfish, dragonets, rabbitfish, and star-gazers. For a detailed account of these fishes, consult Halstead [19,21].

Prevention of injury from all venomous fish is based on the diver having a healthy respect for the potential seriousness of the wound, being aware of the habits of particular species common to the waters in which he is swimming, and being alert and observant to avoid contact with concealed or camouflaged fish. When diving in an unfamiliar area, consult with local authorities.

First aid for venomous fish wounds includes alleviating pain, combating shock and the effects of the venom, and preventing infection. Since unconsciousness is common, the victim should be removed from the water promptly. Pain will be severe. Have the victim lie down and apply measures to prevent/combat shock. Keep the affected limb level with the body and as still as possible to minimize the spread of venom. Carefully wash out or irrigate the wound with cold salt water or with sterile saline solution.[8] Attempt to remove any remaining portions of the spine sheath. Medical attention will be needed for further treatment of the wound and prevention of infection.

Application of a constricting band that occludes only superficial venous and lymphatic return may be of some value, according to Auerbach and Halstead [7]. This loose tourniquet should be released for 90 seconds every 10 minutes to preserve circulation.[6] Do not use the pressure immobilization technique for wounds from venomous fish spines [1]. Do not use a tourniquet.[9]

Soak in plain water as hot as can be tolerated (up to 50° C/122° F), for at least 30 minutes. Use hot compresses on areas that cannot be immersed. Heat may produce rapid pain relief and is believed to destroy the venom. Be careful not to scald the tissue. *Immersion in hot water appears to be the most important first aid procedure for venomous fish injuries universally agreed upon by authors/authorities.*

Marine Animals That Bite

Moray eels, family Munaenidae, are represented by about 20 species and are confined primarily to tropical and subtropical seas, although several temperate-zone species do exist in Californian and European waters. Morays dwell mostly on the bottom in crevices and holes under rocks or in coral. They possess powerful jaws with strong, sharp teeth capable of inflicting severe lacerations. The morays seldom attack unless provoked; however, several *unprovoked* attacks have occurred. Their bite is of the tearing, jagged type.

The diver should exercise due diligence and caution when exploring crevices and holes in areas where morays are known to exist. A moray should not be agitated. Though some divers successfully hand-feed morays, this activity is not recommended. In some dive resort waters moray eels aggressively approach divers in search of a handout. If approached, do not strike at the eel; remain calm, do not hold out your hand as if offering food. A moray may become aggressive in defense of its territory.

Barracuda. Barracudas are potentially dangerous fish found widely distributed throughout the tropical and subtropical waters of the Atlantic and Indo-Pacific. Their size (which may exceed 6 feet); knifelike, canine teeth; and failure to exhibit any undue fear of man have earned barracudas the false reputation of an extremely pugnacious and dangerous fish that will attack rapidly and ferociously. Although several spearfishermen have been severely injured when attempting to handle speared barracuda, it must also be noted that there are few, if any, documented unprovoked barracuda attacks on divers.

Barracudas are curious fish that may be attracted by excessive movement, bright or colored objects, and, particularly, shiny metal objects that reflect light (i.e., jewelry). It is not unlikely that a barracuda would strike at a speared fish. This is a particular hazard for spearfishermen who carry fish on a stringer attached to their belts. The potential of an accidental encounter with subsequent injury is probably higher in murky water where the barracuda is less likely to see the entire diver and strike at a portion of the diver or the movement which resembles prey.

Prevention of attack appears to be one of respect and caution when diving in waters inhabited by barracuda. Divers should avoid wearing bright or shiny objects. Unnecessary agitating and hand-feeding of barracuda are discouraged, as is spearing.

Sharks. Sharks are probably the most feared of all marine animals. There are about 250 species of sharks which inhabit all the oceans of the world; however, only 32 have been implicated in attacks on humans and are considered potentially dangerous to divers and underwater swimmers. There are considerable differences of opinion regarding the potential risk of a shark attack. Myth and public opinion fostered by popular film productions such as "JAWS" has resulted in unwarranted anxiety for many novice divers. There are only 50 to 100 shark attacks reported annually worldwide [9].

Cross (1967) gave the following figures on the frequency of shark attacks. During 1959 there were 11 authenticated attacks in the vicinity of the United States, of which three were fatal. By comparison, in the same year in the United States there were over 400 people killed by lightning and another 1,000 injured. In 1960, there were 42 reported shark attacks on humans throughout the world; none were fatal. Of all reported shark attacks during these two years, none have involved helmet-equipped divers, and only a few have involved scuba divers. Almost all attacks have been on swimmers, waders, or persons dangling their arms or legs from surface floats or rafts. However, in more recent years the incidence of shark attacks on scuba divers appears to be progressively increasing and now accounts for one-third of all shark attacks [13].

Statistically, the greatest danger of shark attack exists in tropical and subtropical seas, between 30 degrees north and 30 degrees south of the equator. Particularly dangerous areas are Queensland, Australia, and South Africa. Seventy percent of all the attacks have occurred within 5 feet of the surface and 62.2 percent within 300 feet of shore. Most attacks have occurred when the water temperature was greater that 70° F, with January as the peak attack month in tropical waters. The greatest risk appears to be between 1500 and 1600 hours (3:00–4:00 pm).

Sharks appear to be attracted by blood (fish or human), flashing lights, colored material, thrashing about, explosions, or unusual noises. The presence of blood highly excites sharks and may radically alter their normal habits. The diver is certainly in most danger if he is injured, bleeding, or carrying speared fish that are bleeding. Sharks apparently have a well- developed sense of smell and will "home in" on blood. They have unique sensory mechanisms which enable them to hear (feel) vibrations from a considerable distance. Thus, they are more apt to "home in" on surface splashing or underwater noises. Erratic, panic-like movements executed by a frightened swimmer are believed to excite sharks and increase the probability of attack.

In spite of differences of opinion about many aspects of sharks, *all authorities agree that sharks are completely unpredictable.* Although sharks usually seem aloof and quiet, they can become viciously aggressive, and for no apparent reason. Although nurse sharks, sand sharks, and leopard sharks are considered harmless by some divers, attacks have been reported. A University of Michigan scientist was bitten on the leg during July 1972 while diving in the Florida Keys; the attack was without warning or provocation.

Many opinions have been expressed on how to chase sharks away; however, it has been fairly well established that procedures such as shouting underwater, blowing bubbles, striking on scuba cylinders, striking rocks together, or, if on the surface, splashing with a cupped hand will not frighten a shark. In fact, it is believed by some authorities that these actions will actually attract sharks. Although several chemical and electronic shark repellents have been developed and used with some success, most authorities feel that there is still no guaranteed effective repellent.

Many divers use a pole (4–8 feet) equipped with an explosive power head for protection or to kill sharks. The power head consists of a chamber and firing device which detonates a 12–gauge shotgun shell or 38- to 45-caliber bullet when pressed against the target. This type of weapon is popular in Australia and said to be extremely effective in killing sharks. A certain degree of accuracy is required to hit the shark behind the eyes and dead center over the base of the spine for an effective kill. A wounded shark may be more dangerous, and the blood and thrashing movements may attract more sharks. The power head is also an extremely dangerous weapon, and accidental firing could result in considerable injury to the diver or other swimmers. Some authorities feel that the hazard of the weapon is greater than the hazard of shark attack. Keep in mind that some states and countries have strict laws regulating the possession and transport of firearms and that some authorities may consider such devices to be illegal.

Many authorities advocate the use of a "shark bully," constructed to meet personal preference. This defensive weapon consists of a short pole (3–4 feet) made of hardwood, metal, or weighted plastic with a blunt end fitted with a roughened material to prevent slipping on the shark's skin. The best place to strike an aggressive shark is on the snout, or nose. The strike or blow should be as hard as possible. This blow may discourage the shark, and the reactive force pushes the diver aside as the shark passes.

Some divers prefer the use of a gas injection device or "shark dart" [25]. The device consists of a CO_2 cylinder contained in the holder; a firing mechanism; a sharply pointed, stainless steel, 5/16-inch, hollow needle; and a pole (length varies depending on the model). The size of CO_2 cylinder also varies with the model. This weapon is effective to depths of 25 feet with a 12-gm CO_2 cylinder, 40 feet with a 16-gm cylinder, and 100 feet with a 26-gm cylinder. A multiple-shot, compressed-air model is also available. Divers must handle these devices with care in order to prevent injury to themselves or others. Keep in mind that a gas injection weapon may also be subject to local laws and regulations. For example, under strict interpretation of Michigan law, a shark dart (gas injection weapon) is illegal to possess.

To disable a shark, the diver thrusts the needle of the shark dart into the shark's abdominal area. The needle easily punctures the skin and, subsequently, the CO_2 cylinder is punctured by the firing mechanism, and the gas is released. This small volume of high-pressure gas entering the shark suddenly displaces the water inside him and forces it to take the path of least resistance. The pressure wave reverberates throughout the shark, blows the stomach out his mouth, and destroys his internal organs. The expanding gas forces the shark to the surface. He is instantly immobilized.

When diving in water known to be inhabited by sharks, the diver should observe the following:

- Avoid solo skin or scuba diving. Visual sighting and early warning will allow the divers time to leave the water at signs of aggression. One of the two divers is more apt to sight the shark immediately. Also, in the event of an attack, help is immediately available.
- The diver should leave the water immediately if injured or bleeding.
- Diving or swimming in turbid, shark-infested waters should be avoided, if possible. A portion of a diver's leg and fin might have the appearance of a fish on which the shark would feed whereas a fully visible diver might be discouraging. Moreover, if the diver is aware of the shark's presence and activities, he has a better chance of taking defensive measures, if necessary.
- Light-colored clothing and bright, flashing equipment are more likely to attract sharks according to some authorities and should be worn with caution or avoided in high shark risk areas. *However, we have not noted an increase in the number of shark attacks associated with modern trends in brightly-colored diving equipment.*
- Panic must be avoided if a shark is sighted. Half the battle of shark safety is over once the shark is sighted. Rapid movements or immediate ascent to swim on the surface may excite the shark and cause it to move in and investigate. The diver should remain calm and face the shark. If the shark appears to simply be passing by (most of them do), leave it alone. If the shark moves in and is persistent, the diver should stay on the bottom and move slowly and quietly out of the area, preferably toward the boat or other safe place (i.e., shark cage). The diver should not surface but stay on the bottom as he moves toward his boat position. Safe refuge may be sought in a crevice or behind rocks.
- The diver should never attempt to wound the shark with a spear gun or knife. These actions are virtually useless and may make matters worse.
- Teasing and spearing sharks is discouraged. They are difficult to kill and can react in a fantastic frenzy if hurt.
- Speared fish should never be carried on a stringer attached to the diver.
- A "shark bully" or "shark dart" is recommended for defense in areas of exceptionally large shark populations or where sharks are noted for aggressive behavior. Striking a shark with the bare hand can result in lacerations and bleeding.
- Divers should not dangle arms and legs from surface floats.
- Since the shark is unpredictable, he must be respected, and the diver must be prepared to abort the dive in some instances.

The diver should not give up diving just because there are sharks in the ocean. He should learn to respect them, not fear or dislike them. For additional information about sharks and shark attacks, consult Gilbert [16], Cross [10], Baldridge [8], and the U.S. Navy [30,31].

Killer Whale. The killer whale, *Orcinus orca*, is found in all seas and oceans from the Barent Sea or Bering Straits to beyond the Antarctic Circle. This species is characterized by a bluntly rounded snout; high, black, dorsal fin; white patch behind the eye; a striking jet-black color above the eye; and contrasting white underparts. They are swift swimmers with a reputation of being ruthless and ferocious killers. Killer whales are reported to hunt in packs and are serious enemies of the seal, walrus, and penguin. In spite of recent notoriety of trained killer whales in marine exhibits/seaquariums and various published pictures of divers riding them in the ocean, they must still be considered an unpredictable, potentially serious hazard. They should be treated with respect and at a distance. A human, mistaken for a sea lion, would be a nice snack for a killer whale. Divers are encouraged to leave the water immediately when killer whales are sighted in the area.

First Aid for Bites

Injuries inflicted by moray eels, barracuda, and sharks are generally severe lacerations with profuse bleeding. First aid procedures for controlling bleeding and subsequent shock should be started immediately [2]. Prompt medical attention will usually be required.

Marine Animals With Venomous Bites

Octopus. Along with squid, nautilus, and cuttlefish, the octopus belongs to the class Cephalapoda, phylum Mollusca. The octopus has a powerful, parrot-like beak concealed in the mouth, and, in some species, a well-developed venom apparatus associated with the salivary glands. Because of public notoriety and myth, the octopus is vastly overrated as a hazard. Actually, the octopus is timid and prefers to stay concealed in holes. In the northwestern United States, skin and scuba divers actually hunt large octopi (up to 20 feet in overall length) and "wrestle" them for sport. Certainly, some precautions are required if the octopus must be handled; heavy gloves are recommended. In Florida and the Bahamas the octopi are much smaller, generally not exceeding 2 feet in length.

The bite is similar for all species and usually consists of two small puncture wounds. A burning sensation with localized discomfort may later spread from the bite. Bleeding is usually profuse, and swelling and redness are common in the immediate area. First-aid measures include scrubbing the bite with antibacterial soap. Measures to combat shock should be taken, and medical attention may be required. Recovery is fairly certain.

The Australian blue-ringed octopus (*Octopus maculosus*) and spotted octopus (*Octopus lunulatus*) could inflict a fatal bite. The blue-ringed octopus is being found in ever increasing numbers off the beaches of South Queensland and other areas of Australia, and several fatalities have been recorded [11,20]. It rarely exceeds a length of 4 inches, and has dark brown to ocher bands over the body and tentacles. Brilliant blue circles are scattered over the animal. The venom of this octopus is a neurotoxin and a neuromuscular blocker which can cause painless muscular paralysis.

The initial bite is usually painless and may go unnoticed. The area around the bite will begin to swell within 15 minutes, and the victim will experience abnormal sensations around the mouth, neck, and head; mouth dryness; nausea and/or vomiting; visual disturbances; respiratory distress; and a variety of neurological disorder symptoms. The victim's conscious state is initially normal, even though he may not be able to open his eyes or respond to his environment. Respiratory paralysis finally results in unconsciousness (as a result of hypoxia and hypercapnia) and death occurs unless resuscitation procedures are begun and continued.

If the victim is still breathing, immediately have the victim lie down and immobilize the limb. Use either pressure immobilization or a venoconstrictive tourniquet (see page 17) to reduce the movement of venom.[10] Take appropriate measures to prevent/manage shock, and place the victim on his side in case of vomiting. *Maintain the victim under constant observation!* Be prepared to begin mouth-to-mouth artificial respiration if respiratory paralysis occurs. Artificial respiration may have to be continued for hours and CPR may be necessary. Reassure the victim who can hear but cannot communicate that he will be all right, and that you understand his condition. Transport to a hospital and/or obtain onsite medical assistance as soon as possible.

Sea Snake. About 50 species of sea snakes are found primarily in the tropical Indian and Pacific Oceans. At least one species is found on the Pacific coast of Central America and in the Gulf of California. The sea snakes are closely allied to the cobra and form a specialized group adapted by structure and habit to a marine existence. All are poisonous and many are deadly; however, they will generally not attack without provocation and have often been described as docile in habit, although aggressiveness has been observed in some specimens. Only a few appear to be of significant danger to humans. They have been noted to be attracted by fast-moving objects such as divers being towed by boats [13]. Bites usually result from unintentional contact; fatalities are most common in the Gulf of Siam and the Philippine area.

Few sea snakes exceed a length of 4 feet. They are distinguished from land snakes by a paddle-shaped tail. Coloration is dark above and light below with cross-bands of black, purple, brown, gray, green, or yellow. They inhabit sheltered coastal waters, particularly the areas near river mouths, and may penetrate upstream to the limits of brackish water; a few species are found in fresh water. Sea snakes tend to collect close to shore and among coral reefs in breeding season. Sea snakes generally float on the surface for extended periods of time. Although they are air breathers, they are capable of remaining submerged for long periods.

The bite is usually small with considerable delay (average of 1 hour) between the injection of venom and the reaction. Some victims fail to notice the connection between the bite and the illness since there is no pain or reaction at the site of the bite. Sea snake venom is approximately 2 to 10 times as toxic as that of the cobra; however, they tend to deliver less of it. Only about one-quarter of those persons bitten by sea snakes ever exhibit signs of poisoning [13]. Symptom onset progresses from mild to severe, generally beginning with an ill feeling or anxiety, thickening of the tongue, muscular stiffness, and aching. Later symptoms include shock, general weakness, paralysis, thirst, muscle spasms, respiration difficulties, convulsions, and unconsciousness. Deaths have been reported. Sea snake venom appears to block neuromuscular transmission, inducing generalized and painless skeletal paralysis. The diver should avoid aggravating sea snakes, and, in water known to be inhabited by snakes, he should be alert to avoid accidental contact. Wet suits will offer some protection since the mouth and fangs are relatively small in the average snake.

First-aid measures include keeping the victim quiet, taking measures to combat shock, and reducing the spread of venom. Use either pressure immobilization or a venoconstrictive tourniquet (see page 17) to reduce the movement of venom. Monitor the victim continuously and be prepare to begin artificial respiration/CPR if indicated. Transport the victim *immediately* to the nearest medical facility since antivenin treatment must be started as soon as possible. If possible, accurately identify the offending snake or capture and kill it for later identification. This is helpful for determining treatment procedures. For further details, consult medical references [7,13,19].

Other Potentially Hazardous Marine Animals

Sea Lions. Sea lions and harbor seals are normally curious but nonaggressive as they swim about divers. There are reports of playful but potentially damaging "nips" and loss of a swim fin. During the breeding season, the large bulls become irritable and may take exception to any intruder. Also, a female may exhibit protective reactions toward a diver molesting her young. Divers have been bitten and should avoid ill-behaved animals. One California diver has indicated that a potentially greater danger when swimming with seals is that of being shot with a rifle by a person sitting on a cliff. Some divers wear bright markings on their hoods for this reason.

If bitten by a seal or sea lion, cleanse the wound with soap and water and be aware of the possibility of infection. The diver should consult a physician.

Giant Clam. The giant clam, *Tridacna gigas*, abounds in the reefs of Pacific tropical waters. Specimens may attain a length of 4 feet and weigh several hundred pounds.

Some authorities claim that *Tridacna* have trapped divers by closing on a hand or foot with a vice-like grip. However, discussions with several scientists who have worked on the Great Barrier Reef of Australia indicate that "trapping of divers by giant clams" is questionable and probably fears are unfounded. In any event, the grip can be released by inserting a knife between the valves and severing the two adductor muscles which hold the valves together. The diver is, however, discouraged from experimenting with his own foot.

Groupers and Jewfish. Some species of giant grouper and jewfish may attain a length of 12 feet and weigh more than 700 pounds. They are frequently found around rocks, caverns, and submarine structures such as offshore oil rigs. These fish are not considered vicious but can be unintentionally dangerous because of their curious nature and huge size. One of the most interesting accounts of an aggressive jewfish is given by Zinkowski [34].

Annelid Worms. The segmented marine bristleworm, *Eurythoe complanata*, possesses tufted, silky, chitinous bristles in a row along each side. Upon contact or stimulation of any kind, the bristles rise on edge as a defensive mechanism. The fine bristles penetrate the skin and are very difficult to remove. This results in a burning sensation, inflammation, and possibly local swelling and numbness. Bristleworms are found in the Bahamas, Florida Keys, Gulf of Mexico, and throughout the tropical Pacific.

Bristles are best removed with forceps or, if exceptionally small, by applying tape to the area and gently removing. After removal, application of ammonia or alcohol will alleviate the discomfort. Divers should avoid contact or take special precautions in handling.

The bloodworm, *Glycera dibrochiata*, is found on the Carolina coast northward into Canadian waters. These worms, up to 12 inches long, may be encountered under rocks or coral. They possess strong jaws and may inflict a painful bite. Swelling, numbness, and itching follow the bite.

Electric Rays. Electric rays, or torpedo rays, grow from 1 to 6 feet in length and weigh up to 200 pounds. They may be found on both the Atlantic and Pacific coasts of the United States, as well as other areas of the world. They are shaped somewhat like a normal sting ray; however, their wings are thick and heavy, and their tails are modified for swimming. The giant Atlantic torpedo ray can produce a current of 50 amp at 60 v, enough to electrocute a large fish or knock down a full-grown man. Needless to say, divers must be cautious when approaching or attempting to handle specimens from this group.

Sawfish. Sawfish are members of the ray family that have sharklike shapes and swim by sculling their tails. They are sluggish but powerful and commonly reach a length of 16 feet. The cartilaginous snout is extended in a long, flat "saw," equipped on both sides with sharp scales or denticles which have been enlarged into teeth. Large specimens have been recorded at a length of 22 feet with a 6-foot snout. The snout is swung from side to side to impale fish. The size and snout make this ray a potential hazard for divers; however, it is not likely to attack unless provoked. Caution is recommended.

Marine Turtles. Recently, divers in the Florida Keys have reported minor injuries resulting from aggressiveness by large marine turtles. Several divers were "nipped." Authorities feel that these "nips" were of a playful nature. Still, the size and power of a swimming turtle must be respected by the scuba diver. If you grab on to the shell of a large turtle, the turtle may struggle to escape and injure the diver in the process.

Paralytic Shellfish Poisoning. Paralytic shellfish poisoning is a well-recognized annual problem on the Pacific coast and occurs occasionally along the Gulf of Mexico. Under environmental conditions of warm weather in summer months (March to November on the West Coast) and an influx of nutrients, the toxic dinoflagellates, Gonyaulax sp., undergo a population explosion or "bloom," resulting in the "red tide." The waters abound with patches of planktonic algae that turn the water into a variety of colors including red, yellow, brown, green, black, blue, or milky white.

Unlike many marine animals, mussels and clams ingest and sequester the poison without damage to themselves. Contrary to popular belief, there is no practical method of distinguishing contaminated (or poisonous) mussels and clams from edible ones. Usual cooking methods do not remove the toxin. In some areas, taking of certain clams and mussels is banned during critical months. Abalone, as well as crabs, do not feed on plankton nor are their viscera usually consumed; for both reasons, there is no danger of shellfish poisoning from them. Divers must be especially cautious and consult with local authorities before collecting marine animals for human consumption. All plankton feeders may, at times, become poisonous.

When consumed by humans, the toxin acts directly on the central nervous system, affecting respiratory and vasomotor centers, and on the peripheral nervous system, producing complete depression. With large doses, respiration may cease instantaneously; with smaller doses, symptoms of nervous system involvement are slow and progressively worsen. Gastrointestinal symptoms (nausea, vomiting, etc.) are less common. Death in severe cases is almost invariably the result of respiratory paralysis and usually occurs within 12 hours. Medical attention should be sought immediately if unusual illness occurs after eating mussels or clams. For details of treatment, consult medical references [7,13].

Fish Poisoning. Ciguatera poisoning results from eating a wide variety of unrelated fish that contain ciguatoxin. Ciguatoxic fish feed on certain plants or bottom fish, implicating specific species of algae. It has been suggested that the proliferation of toxic algae may be triggered by contamination of the water by industrial waste, metallic compounds, ship wreckage, and other pollutants. As the feeding progression develops, the toxins appear to accumulate in the fish. Larger and older fish are more toxic [9]. More than 400 species have been implicated. Over 75% of the cases reported involve barracuda, snapper, jack, or grouper. Hawaiian carriers also involve the parrot-beaked bottom feeders.

Approximately 24 persons are hospitalized annually in southern Florida for ciguatera poisoning from barracuda. There is no seasonal variation, but larger specimens are believed more likely to be toxic.

The onset of symptoms is generally within 15 to 30 minutes of ingestion, with an increase in severity over the following 4 to 6 hours. Rarely, the onset may be delayed for up to 24 hours. Many (about 40–70%) victims have a sudden onset of abdominal pain followed by nausea and vomiting, a watery diarrhea, and a metallic taste in the mouth. There is a wide spectrum of other symptoms, from numbness of the lips, tongue, and throat to fever and chilling sensations. If poisoning is untreated, death from respiratory failure may occur. Divers must be cautious about fish they eat. Unusual illness following consumption of fish, especially barracuda, should receive immediate medical attention. The attending physician should be informed that fish has been consumed within the last 30 hours.

Tetrodotoxin poison is one of the most potent poisons found in nature and is characteristic of pufferfish, porcupine fish, and sun fish. The toxin is distributed throughout the entire fish with the greatest concentrations in the liver, gonads, intestine, and skin. In Japan, eating *fugu* has been a gastronomic version of Russian roulette for centuries. The meat has no fiber; it is almost like gelatin—light in taste, like chicken—a gourmet's delight. The consumer is said to experience extraordinary neurological sensations. In a 10-year period the toxin claimed nearly 200 lives in Japan with about 60% of the puffer poisonings proving to be fatal. Yet fugu is the epitome of gourmet dining in Japan [32].

The onset of symptoms is as rapid as 10 minutes or can be delayed up to 4 hours. Initially, the victim develops oral tingling (paresthesia), which rapidly progresses to light-headedness and generalized tingling sensation. These sensations are rapidly followed by nausea, vomiting, and paralysis. Monitor victims continuously and acquire immediate medical attention. Resuscitation procedures may be required shortly after the onset of symptoms [7]. Most western authorities feel that it is best to avoid consumption of all puffers, even when prepared by experts. Keep in mind that toxic puffers are found in the Indian Ocean, South Pacific, Hawaiian waters, Sea of Cortez, tropical Western Atlantic (including Florida, Bahamian, and Caribbean waters), and in other waters throughout the world. A few non-toxic northern puffers are used as food fish [32].

Scombroid poisoning is possible from fish tissue that has been exposed to the sun or left to stand at room temperature for extended periods. Within a few minutes of eating the toxic fish, which has a peppery or sharp taste, the victims develop nausea and vomiting. Various other symptoms, such as intense headache, massive red welt development, and intensive itching, follow. Immediate medical attention is needed.

Freshwater Life Hazards

Compared to the oceans, freshwater streams, ponds, and lakes have relatively few forms of animal life that present a specific danger to divers. The diver must, however, be aware of those few species that can inflict considerable harm. Shelby and Devine were among the first to emphasize aquatic hazards to the diving community [28].

Reptiles. The venomous cottonmouth water snake, *Agkistrodon piscivorus*, is found in lakes and rivers south of latitude 38 degrees north. This snake is probably the diver's most serious aquatic hazard. It predominantly inhabits stagnant or sluggish water but has been observed in clear and moving water.

There has been a persistent notion that the cottonmouth would not bite underwater; however, Shelby and Devine documented two fatalities caused by cottonmouth bites [28]. The cottonmouth is considered pugnacious, adamant, and vindictive when disturbed and will attack unprovoked. It does not show fear toward humans as most other aquatic snakes do; its behavior is unpredictable. Attack is more likely to occur in the evening.

Recognition is difficult since its color varies from jet black to green with markings absent or vaguely similar to the copperhead (*Agkistrodon contortrix*). Consequently, in areas where the cottonmouth is known to exist, it is advisable for the diver to regard any snake that does not swim away when encountered as a cottonmouth. The best defense is a noiseless, deliberate retreat. Wet suits afford reasonably good protection but can be penetrated by larger specimens. Bare hands should be tucked under the armpits. The diver should never attempt to fight since this will probably only result in multiple bites. Although evidence is inconclusive, it appears that the snake will not dive deeper than about 6 feet.

The timber rattlesnake (*Crotalus horridus*) is an excellent swimmer on the surface. Skin divers should be alert and avoid contact.

First aid for venomous snake bites includes:

- Reassure the victim and keep the victim quiet.
- Take measures to combat shock.
- Immobilize the bitten extremity and keep it at or below heart level.
- Monitor the victim and seek immediate medical attention.

Consult American Red Cross first aid manuals for further information [2].

Turtles. Three species of aquatic turtles may be hazards to the diver if provoked and mishandled, especially large specimens. Though not venomous, they may inflict a serious, dirty wound. The alligator snapping turtle (*Macrochelys ternminchi*) found through the watershed of the Mississippi River, is vicious and aggressive when provoked. It has powerful jaws and sharp claws. The alligator snapper is recognized by three, distinct, keel-like lines running longitudinally the full length of the upper shell. There are also wart-like projections about the head and forelimbs. The alligator snapper is extremely long and muscular and can strike rapidly by extending the neck.

The common snapper (*Chelydra serpentina*) is smaller and similar in appearance to the alligator snapper. This species is considered by some authorities to be more vicious when provoked than the alligator snapper.

The softshell turtle may also inflict a serious wound. Contact with these turtles should be avoided or special precautions taken in handling.

Standard first aid for laceration wounds is recommended [2]. Tetanus immunization is recommended.

Alligators and Crocodiles. The American alligator has been encountered by divers but is not known to be aggressive or to cause injury. Yet the potential of injury is present, and divers should be cautious. In Central and South America, the crocodile may certainly constitute a hazard to divers, and in Africa the crocodile is responsible for many human deaths each year. The saltwater crocodile of the coast of Queensland, Australia, is very large (up to 30 feet) and reported to be a vicious aggressor.

Mammals. The common muskrat is the only warm-blooded animal that would probably attack a diver in U.S. fresh waters. It attacks only in defense, and the wound is usually minor. However, the possibility of rabies is present and serious. It is important for the diver to seek medical advice if bitten and for the animal to be captured or killed for laboratory examination. If encountered while diving, the muskrat should not be provoked. If it is provoked into attack, escape is virtually impossible.

Fishes. The only freshwater fishes of noted hazard to divers are the freshwater sharks of Lake Nicaragua in Central America and the piranha fish of the Orient and South America. In U.S. waters, the only fish capable of inflicting serious injury are those of the catfish family, which are discussed in the section on venomous marine fish, and the gar. The gar fish commonly weighs in excess of 100 pounds and, if provoked by spearfishermen, has the capability of inflicting wounds with needle-sharp teeth.

The previous discussion has concentrated on the freshwater life hazards of the United States. Certainly, it is only common sense for the diver to consult with local authorities prior to consult with local authorities prior to commencing diving in others parts of the world.

Marine and Freshwater Plants

Kelps, the great brown algae of northern waters, is considered a potential hazard for divers. West Coast kelps, the bladder kelp, are large, and some grow to lengths of over 100 feet. A tough holdfast anchors the kelp to the rocky bottom and air bladders float the plant to the surface, where it spreads out to form a thick, floating canopy. The diver, in moving about underwater, may find himself under such a canopy. If he must surface under the kelp, the diver should select the least dense area of growth and extend his hands overhead to part the kelp and make an opening for his head. He can then visually determine the shortest and safest route to open water, submerge (feet first), and swim under the kelp canopy. The surfacing process can be repeated if necessary. Attempting to swim "through" the kelp on the surface usually results in severe entanglement. When swimming in or around kelp, the diver should frequently check projecting equipment to keep free of entanglement. Ribbon kelp is similar to bladder kelp, but tougher.

Surf grass or eel grass grows in the surf zone. Though possible, entanglement is not common. The surge may wash it over a diver, causing panic. However, when the surge reverses, the grass will move away and the diver may surface.

A number of freshwater plants are found in dense growth in some inland lakes. Divers can become entangled in the plants, and surfacing may be difficult. Panic is the diver's worst foe in a plant entanglement situation. In one recent incident, a Michigan diver became entangled in a weed-covered bottom and surfaced in a panicked state. He was treated for an air embolism at the University of Michigan. An entangled diver should stop, relax, and systematically untangle himself. Naturally, the buddy will be of considerable aid.

Diving in Polluted Waters

Man has polluted his environment. As the contamination of our rivers, lakes, and oceans continues, one certainly must question the quality of the water that thousands of divers from the U.S. and Canada enter each year. Aside from the inorganic pollutants such as mercury, lead, beryllium, antimony, and cadmium, there is a more serious threat. Bacteriological pollution is a fact. Many microscopic bacteria, such as typhoid bacillus, can be easily detected by health authorities. However, many protozoans are not as easily detected.

Lamirande reports the death of a diver in Florida from a rarely diagnosed, incurable disease of the central nervous system caused by the amoeba *Naegleria gruberi* [23]. This amoeba has been found in lakes of Florida, Texas, and Virginia, as well as several foreign countries. Several deaths due to this amoeba have been recorded in the United States in recent years. The amoeba may lie dormant for many years until nutrient levels in the body of water are concentrated enough to stimulate uncontrolled development. *Naegleria gruberi* may enter the body through the nose, bore into a nasal nerve, and migrate to the brain, where they multiply by the thousands. The result is slow, agonizing death.

Though fatalities of this sort appear to be uncommon today, we cannot predict what will happen tomorrow. Toxic pollutants including organic mercurials, hydrocarbons, and some heavy metals can prove harmful to the underwater swimmer. Toxic chemical spills, solvents, herbicides, sewage, and petroleum by-products can constitute unacceptable risk for divers. Divers must use considerable discretion regarding dives in obviously polluted waters. Being aware of this hazard isn't really enough. The only true defense is to take appropriate actions to eliminate pollution or accept the fact that acceptable waters for diving (and drinking) may progressively disappear.

Conclusion

Prevention of injuries is the best policy. Through proper diving techniques, buoyancy control, environment familiarity, and common sense precaution, most diving injuries can be prevented. Carelessness and improper diving techniques lead to injury. Do not handle marine organisms that you are unfamiliar with and do not take chances with those which you know can inflict injury.

Most divers are unprepared to administer proper first aid. Generally, they simply lack the proper "tools." A review of the procedures given in this paper indicates that a properly equipped tropical diver should include the following items in a personal or group kit:

- Large bottle of vinegar and/or alcohol (at least one pint);
- Antibacterial soap;
- Tweezers/needles/surgical blade;
- Constricting band;
- Sterile dressings and band aids (ample supply of assorted sizes);
- Chemically activated hot packs. (These are most convenient for field use and may be of some benefit. Keep in mind that the recommended procedure for pain relief by heat is immersion in hot water, which would require a metal container that can be used for heating water and large enough to allow immersion of an injured hand or foot, a small stove, and waterproof matches);
- Aspirin;
- Adhesive tape;
- Tourniquet;
- Anesthetic and/or antihistamine cream; and
- Snake bite kit suction device.

All divers are encouraged to complete a basic/advanced first aid course. Whenever diving in an unfamiliar area, the diver must consult with local divers, professional lifeguards, diving instructors or other knowledgeable authorities regarding potentially hazardous marine life and first aid for specific marine life injuries.

There is still much to be learned regarding first aid for marine life injuries. Changing trends in modern basic first aid practices raise questions regarding "acceptable" procedures for managing a marine life injury.

Some diving instructors in the United States are quick to condemn the first aid procedures specified by Australian authorities. However, North American divers do not live daily with the potential serious consequences of injuries inflicted by such animals as the sea wasp, the blue-ringed octopus, and sea snakes. We must acknowledge the opinions of those persons who deal with these animals on a routine basis. Diving instructors and divers must remain abreast of new developments in first aid. Efforts must be made to establish universally accepted procedures. In the meantime, United States divers must know what first aid practices to expect when working with divers from foreign countries.

Notes

1. For the treatment of jellyfish and hydrozoan stings, in the past many authorities suggested liberal use of a solution with high alcohol content (e.g., isopropyl rubbing alcohol: 40%) instead of sea water since the alcohol allegedly immediately inactivates the nematocysts. Monosodium glutamate (meat tenderizer) has also been a standard item in many tropical divers' first aid kits for years. Formalin has also been considered effective. Other inactivating solutions cited in various publications include household ammonia, urine, petroleum products (gasoline, kerosene, etc.), and beer. However, recent studies suggest that these solutions may be ineffective [14].

Recent research at James Cook University (Australia) and by the Royal Australian Navy School of Underwater Medicine revealed that application of methylated spirits, 100% alcohol, and alcohol mixtures with seawater produced dramatic, instantaneous discharge of the nematocysts, and this was associated with increased clinical sensitivity [14]. The James Cook University group found that *the application of 3% to 10% acetic acid (or vinegar) was most effective in preventing the massive discharge of nematocysts associated with the application of alcohol and other common solutions tested.* Further studies by Carl Edmonds, M.D. of the Diving Medical Center in Australia (one of the foremost world authorities on marine life injuries) concluded that vinegar and Xylocaine (lidocaine) will prevent further nematocysts discharge. Surprisingly, Edmonds also found that selected commercial preparations, anti-sting lotions, and the enzymatic product, Adolf's meat tenderizer were clinically ineffective [14]. The same was found for other common solutions such as urine, household ammonia, and so on.

However, further studies have revealed that certain species of jellyfish common to the eastern U.S. coast should be treated with alcohol rather than vinegar (South Pacific Underwater Medical Journal, 16(3), 1986).

2. Australian authorities specifically state that the area affected by a jellyfish or hydrozoan sting must not be washed with soap and water for 24 hours [4,33]. This measure is not indicated by most U.S. authorities.

3. These first aid procedures for sea wasp stings are summarized primarily from Australian literature [4,13,33]. However, in accord with more recent research, vinegar is indicated here, rather than the alcohol (or methylated spirits) indicated by the Australians.[14]

4. The application of a standard tourniquet, which stops the flow of blood (pulse), was recommended in the past, but first aid authorities currently discourage its use. Remember *that the decision to apply a tourniquet is in reality a decision to risk sacrifice of a limb in order to save a life!*

5. For severe sea wasp stings, soak the bandage in vinegar.

6. The diver is advised to note whether U.S. authorities will, in the near future, switch their preference to pressure immobilizaton for reducing the spread of venom in the cases of sea wasp, cone shell, blue-ringed octopus, and sea snake.

7. Some diving manuals recommend that the first aider make a small incision at the site of a venomous fish wound, cone shell wound, and blue-ringed octopus wound to encourage bleeding and venom removal and to facilitate irrigation. However, in light of modern trends in first aid and the potentially limited value of the incision method, according to physicians, this author is inclined to not recommend this procedure.

8. See Note 7.

9. See Note 5.

10. See Note 7.

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