Cave diving is a combination of speleology and underwater expertise. Both constituent disciplines affect the equipment and techniques involved.

Before undertaking a diving programme in which cave diving plays a part, contact should be made for specialized training and advice with the relevant national bodies concerned in the home and field nations (e.g. Cave Diving Group in the UK, NSS Cave Diving Section in the USA, etc.).

Because of the inability to surface easily from an underwater cave, any item of equipment whose direct malfunction could cause a fatality (e.g. breathing set, regulator, torch/flashlight) should be duplicated. Octopus regulators are not considered adequate in this respect. A minimum of three torches/flashlights should be carried, each with the burn time of twice the estimated dive time.

The diver must always be in contact with a guideline to the surface. This line should be laid and controlled by the diver, using a hand-held line reel. This shall be of sufficient strength to prevent accident or breakage as the situation demands, and shall be as visible as possible (color may depend on the type of water to be dived).

All vital equipment such as knife, contents gauges, torches, etc. should be worn where they are easily accessible, ideally on the upper torso or arms. No equipment should be allowed to hang free, possibly causing entanglement or visibility-limiting sediment displacement.

The diver must be thoroughly familiar with any technique to be used in an underwater cave beforehand in open water, ideally in both clear and low visibility.

The use of a standby diver may be relevant in certain situations, but unless this diver is more experienced than the one underwater, and entirely familiar with the system in question, use of the standby diver in an emergency could exacerbate the situation.

If a cave is large enough, and personnel are adequately trained and experienced, dual penetrations can be made. Every member of a team must be well briefed in the dangers of the particular environment to be entered.

Sediment is generally present in caves and, once stirred, it may take several hours to settle, as it is usually very fine grained. Cave divers should avoid disturbing sediments wherever possible, by fine use of buoyancy (6.2.15) control and movement, and should be prepared to cope with the psychological effect of physical enclosure in zero visibility (8.2.17).

Currents in marine caves can be exceptionally strong, rising to over 5 knots. These may suddenly reverse in direction as part of a usually complex underground water circulation pattern. Changes in movement in marine caves may not be in phase with surface tides. Equipment and dive planning will take into account such variations in the physical conditions in a cave during the course of a dive.

Pockets of air inside caves may be toxic or may contain no oxygen. Gas may also be present in an explosive mixture. Therefore gas found in enclosed cavities should only be breathed with caution.

Stress is always present in cave diving, in excess of levels experienced in open-water diving. This has been a major contributory cause of fatalities. Divers must make every effort to reduce stress levels before and during a cave dive.
No more than one-third of the total air supply shall be used on the inward dive. A minimum of two-thirds of the air supply shall be conserved for exit and emergency reserve. If decompression is indicated, the reserve 'third' of the air supply should not be regarded as being available for that purpose. Additional scuba systems may be carried and used to extend cave penetration distances or times. As a consequence of long horizontal cave penetrations at moderate depths, cave divers have accumulated a significant experience of safe decompression diving using US Navy Exceptional Exposure Tables (USN Tables, 1986, deep diving/decompression sections).

Deep diving in caves is extremely hazardous, and it should be recognized that in an emergency, evacuation to recompression facilities can be exceptionally difficult from a cave environment.

If more than one diver is present in the cave, then each diver must fulfill the conditions outlined in each paragraph of this section.

Cavern diving is different from cave diving in that while it is also diving in a spatially restricted environment, free emergency ascents can be made. Natural daylight, although possibly dim, is available. Many of the procedures relevant to cave diving will apply.

8.2.20. Noxious gas in bottom water
Noxious gases such as hydrogen sulfide, ammonia and methane commonly occur in anoxic halos to concentrations of fecal matter under fish cages and mussel rafts as well as in areas of sewage settlement. Hydrogen sulfide may be absorbed through the skin and can diffuse into masks through the material. Divers should therefore wear full dry suits and positive pressure helmets (NOAA Manual, 1975). Caution should be exercised in taking specimens of sediments or water where dissolved noxious gases are suspected because when these de-gas at atmospheric pressure potentially significant volumes of explosive gas may be exsolved.

8.2.21. Deep diving on air
This section deals with diving on compressed air at depths deeper than 30 m. Dives in excess of this depth are inherently more dangerous because of the increased possibility of decompression sickness and the greater time that it will take a diver to reach the surface in the event of an emergency. Incidents at depth are simply farther away from surface support. Normally decompression diving should be kept to a minimum in deep diving and where decompression stops are necessary, they should always be carried out with very conservative manipulation of tables. See Section 11 for effects of varying the dive profile.

In most countries the recommended maximum depth for employed divers diving on air is in the region of 50-60 m. Some countries enforce a legal maximum depth on air, which may or may not apply to scientific divers: UK, 50 m or deeper with exemption; France, 60 m; South Africa, 60 m; USA, 58.5 m (190 ft). In the USA the American Academy of Underwater Sciences recommends that divers be certified by progressive experience to depths of 30 ft (9.2 m), 60 ft (18.46 m), 100 ft (30.8 m), 130 ft (40 m), 150 ft (46.1 m) and 190 ft (58.5 m). In Canada, the Canadian Association for Underwater Science recommends that divers be certified in progressive depth increments of 10 m with a depth limit at 40 m, unless special deep diving training has been provided. The Woods Hole Oceanographic Institution (USA) and most research organizations in the United States require a limit of 40 m unless special authorization has been granted by the Dive Control Board.
Bounce dives to just shallower than 50 m, not involving decompression may be made, provided that the divers are fully worked up (4.9). Deep diving must be preceded by recent dives of increasing depth to acclimate the diver’s body with the greater pressures encountered. A bounce dive, however, is by definition a short dive which does not allow enough time for poorly vascularized tissues to become saturated with a higher concentration of dissolved nitrogen, and therefore these dives should not be more than 5 minutes bottom time. The divers are advised to follow a shot-line and there should be a fully kitted up standby diver with no nitrogen loading. The working divers should be instructed that an emergency situation will be considered to exist if they do not return to the surface within a few minutes of dive plan time. Repeated short dives with short surface intervals should not be carried out.

Bottom time should not be so long as to dictate a decompression time of more than 20 minutes. This time limit should be decreased if conditions are bad, i.e. cold water, heavy swells, strong currents, etc. A planned decompression time of more than 20 minutes involves the dive organizers in complying with stricter regulations concerning on-site compression chambers in some countries. In all cases diving should be carried out so as to avoid extension into the Extreme Exposure Tables.

The support vessel should be capable of transporting divers to the work site in comfort, transporting the dinghy, providing recompression facilities if necessary and carrying shot weights and buoys, ropes and anchors and also have a ship-to-shore radio.

An absolute minimum diving team for deep diving is 4 divers, plus the boatman, standby diver and compression chamber operator if necessary. The standby diver should be fully equipped to dive at the working pressure if necessary. He/she should not have undertaken diving so recently that he/she would be liable to decompression stops after a very short duration at depth as this would make it dangerous for the rescue diver to bring an injured diver to the surface.

Where deep diving is taking place it is always safer to have recompression facilities on the support vessel. These facilities should consist of a compression chamber with lock-in and transfer under pressure facilities and a trained operator whose sole responsibility is maintenance and operation of the chamber. This arrangement is often not feasible. See Section 11, Table 11-3 for proximity to chambers.

The Dive Supervisor, Dive Marshal or Expedition/Project Leader should be thoroughly familiar with the local recompression facilities and inform the appropriate authorities of the diving programme so that they may be more capable of helping should an emergency arise.

Deep diving in remote areas should be carried out using dive plans that keep the divers on the conservative side of the normal decompression tables at all times, unless the support vessel or nearby base is fully equipped to treat decompression cases.

8.2.22. Warm and hot water (sabkha)
A sabkha environment consists of a tropical bay or lagoon where evaporation greatly exceeds freshwater input. Salinity is usually high, and salts may be precipitating. Water temperatures may be over 40°C. Most of the waters of this environment are in shallow water shelves facing arid or hot deserts, and thus the diving is usually in shallow, warm to hot water with weak currents and no dangerous surf. Being close to the surface during diving where an intense sun will be at high angles for most of the day, and being in warmer than normal water, means that the divers have to take precautions to avoid sunburn, sunstroke, dehydration and hypertherm-
Divers can drown even in comfortable shallow water and momentary unconsciousness brought on by the special hazards of the environment can lead to drowning.

Divers are advised to wear a light 't'-shirt and to cover the back of their necks from the direct rays of the sun; waterproof sunburn lotion should also be applied liberally, especially to the backs of the legs and arms because in the normal swimming position, these face upward. Divers should drink copious amounts of water as they will be dehydrating while in the water as the body attempts to cool itself by sweating; a process that will not be noticed by the diver in warm to hot water. Hyperthermia, or ill-effects brought on by sustained high body temperature, must be avoided. Symptoms are general weakness, faintness leading to momentary unconsciousness and often a faint muscular trembling accompanying light-headedness. If these symptoms are perceived during the course of a dive in this environment, immediate surfacing and inflation of the life jacket must be carried out by the diver.

Because waters are more saline than normal sea water, irritation of the eyes, nose and throat membranes is likely, but unless exposure is prolonged, no immediate or long-term effects are likely. Care should be taken to wash the divers as well as the diving gear with great care following each dive.

8.2.23. Super saline water
The observations and procedures that will be referred to in this subsection draw on the experiences of scientific divers in the Dead Sea. Most extreme cases of super saline water are also in similar environments and less extreme cases that may occur in less arid conditions will have some of the negative attributes common to super saline water. The Dead Sea is situated in an arid zone, where air temperatures in the summer can reach as high as 45°C and in the winter do not drop below 10°C, while the temperature of the upper layers of the sea can be as high as 35°C in the summer while not dropping below 18°C in the winter. The Dead Sea is a basin of net water inflow that acts as an evaporating pan. Salinity can reach as high as 280 g/kg and the corresponding density can be as high as 1230 kg/m3 or about 23% higher than normal sea water. The relative proportions of the chemicals dissolved in the Dead Sea are totally different from their proportions in normal sea water. The Dead Sea waters are rich in calcium, magnesium, potassium and bromine. The high salinity and the dissolved chemicals make the water painful and irritating to the eyes and to the membranes of the nose and throat, so that contact with these organs induces profuse weeping and temporary blindness, breathing is impaired and vomiting may be induced. These waters should not be swallowed, and ingestion of large quantities can be deadly. Moreover, the immersion of open wounds, or even scratches, is extremely painful although not dangerous. In short, for divers, super saline waters are a dangerous, or at least an extremely unpleasant environment.

The high density of super saline water demands the use of about 30 kg of additional weight. These weights cannot be worn on a single belt and must be spread around on several belts to evenly distribute the weight. This makes movement difficult and energy-consuming before a dive and also adds significantly to the time and effort spent in dive preparations. Moreover, by increasing the mass of the diver, the additional weight makes swimming under water more difficult, energy-demanding and air-consuming. The corresponding need for even more compensating weight prohibits the use of under-suit exposure clothing on those occasions when it might otherwise add to the diver’s comfort.
The high salinity and peculiar chemical composition of the Dead Sea and presumably similar waters demands absolute prevention of the immersion of the face and this necessitates the use of positive pressure full-face masks. These masks prevent buddy breathing, do not permit mouth inflation of the buoyancy equalizer, are slightly less convenient for pressure equalization, have sufficient buoyancy of their own to cause some discomfort and cannot be transferred from one diver to another without slight adjustments. Slight adjustments to the ABLJ should be made with a direct feed rather than with the more difficult to control emergency air bottle, which should be kept for emergencies. Scuba air supply bottles cannot be replaced during the course of a dive as the face mask, second stage and bottle are a single unit. The full-face masks and their regulators may be mechanically more complex and therefore more prone to failure than a normal mouth-held regulator. In the super saline saturated environment the divers and all equipment require painstaking cleaning and maintenance after each dive.

8.2.24. Lagoons and estuaries
In both lagoons and estuaries, a common hazard is often bad visibility caused by particulate and rotting plant material in the water. The water is commonly colored and lights often cause the water to turn bright red and brown as the light is filtered through the colored water. Even at depths as shallow as 5 m in estuaries on bright, sunny days, the water can become very dark. Total darkness approaching that of a night dive is commonly encountered in these environments below 10 m and although lights may somewhat alleviate the problem of visibility, they will not have the effect that they have on a night dive in clear water.

Currents in lagoons are usually slack, and the water is often stratified in both salinity and temperature. In estuaries, however, currents are commonly strong, especially in the race or bore of the river. Fast water diving methods (8.2.8) should usually be used when diving in estuaries. In the case of a shore dive in the channel of an estuary, the dive plan should leave time for a submerged return to shore as upon surfacing the divers will usually find themselves caught in faster moving water than they were encountering on the bottom. If they cannot resubmerge to more slowly moving water near the bottom without incurring a decompression situation, they may find themselves swept along rapidly in the river far from where they put in or in the worst case, out to sea. Under no circumstances should the divers in this situation submerge and begin a repetitive, hard working decompression dive when they are likely to exhaust their air swimming against current.

8.2.25. Holiday Environments
Scientific diving is commonly done in out of the way places where interference by local people or holiday-makers with diving operations is usually not a problem. Some scientific diving sites, however, involve working from shore areas in which there are people ranging in numbers from a few interested locals to swarming crowds of holiday-makers. Fishing boat traffic and water sports must be taken into consideration as well as shore constraints in dive planning.

Apart from the normal 'hazards' of holiday environments, such as late nights and incautious entertainment, diving in areas where large numbers of families are on holiday introduces some special conditions. Divers must remember that their operations are disturbing the local environment. Extra hazards to divers occur as diving sites are often within sight of large numbers of people with little to do; increased boat traffic over the dive site and actual visiting of the site by other divers can both slow down the work and be very irritating especially if divers are...
fatigued. Normal conduct of operations often becomes difficult and extra time should usually be built into operational plans for dealing with non-party members, it is very important for good relations to be maintained with locals and holiday-makers, however, and remaining polite is important. Although it may not be a legal requirement, it is often a good idea to notify the local police or the local water police about dive operations.

Security of diving equipment and samples can be a real problem if public facilities are being used for water access. Although most people are quite honest and not liable to steal equipment, swarms of children may get in the way and have a tendency to pick things up out of curiosity. It is advisable to have all gear, especially the many small items, in bags or boxes so that few opportunities are presented to the curious or the malicious. Theft of diving equipment after the dive, usually when it is drying after post-dive washing, is a common problem.

8.2.26. Whirlpools

'Whirlpool' is a common name given to rotating turbulent water masses that are one of the high energy environments in which diving is usually avoided for reasons of safety, but in which interesting physical and biological processes take place.

Freshwater waterfalls, with turbulent water and whirlpools are associated with a number of interesting processes relating to rock erosion and solution, biological processes in the pool below the waterfall, and fish migration up the waterfall. In narrow sea channels, around some headlands, or at the entrance to sea lochs or fjords when tide is running, eddies and whirlpools commonly occur. The rotating water mass, or whirlpool, can be differentiated from a common eddy because in a whirlpool the water tends to make many circuits and rotate rapidly enough to create a force upon bodies caught up, and force them to the outside of the gyre, as well as often pulling them down.

Very little scientific diving has been done in this environment, but work which has been achieved suggests that conditions for diving in whirlpools are not prohibitive, provided that common sense precautions are carefully observed. The obvious risks arise from the diver being thrown against rock outcrops, against the bottom, or getting tangled in ropes or moorings and dragged downward by the lateral drag on their body. Similarly, the surface cover boat may be in considerable danger, and the boat and diver may be easily separated. While the speed of motion and turbulence may be disorienting, they are not dangerous, provided that the diver does not collide with any solid object.

Diving strategy, therefore, is to leave the boat or shore in calm water, enter the turbulent water as unencumbered as possible, move freely with the rapidly moving water, and then exit into calm water for recovery, possibly by a second boat. Such manoeuvres should only be attempted by experienced divers, with very good back-up and surface support.

The downwelling plume of turbulence from a small waterfall of a few meters head can be approached safely underwater, or on the surface, with care. If the diver ventures into the most turbulent zone he/she is immediately swept downstream and out of danger. With larger waterfalls the impact of falling water and objects such as trees carried by the water, would be extremely dangerous. There are no records of divers attempting to approach the plume of a large waterfall from below, or to work in this environment, although some projects have been suggested. The greatest danger would exist if there are any currents or gyres, which drag the surface water into the immediate fall zone of the waterfall. This is quite likely, and any waterfall pool should be studied very carefully and tested with floating objects the size of a human

SECTION 8. DIVING IN SPECIAL AND EXTREME CONDITIONS
body, before any diver enters the pool. Any work of this kind must be treated as highly experimental, and divers must be advised to use every possible safety precaution and back-up.

Canadian divers have developed very effective techniques for working in white water conditions of rapids, rock pools and small waterfalls. These techniques could probably be extended to cope with the situation of larger waterfall pools.

8.2.27. Underwater volcanoes and igneous intrusions
Diving in the vicinity of volcanic activity can only be described as extremely hazardous. Obvious dangers include explosive gases, excessively hot water and high turbidity. The only case where scuba divers have directly observed underwater lava flows is Hawaii where in 1970-1973 a number of lava flows entered the sea from a subaerial eruption from the flank of Kilauea Volcano (the Maunaulu vent) on the island of Hawaii (Moore et al., 1973). Because these flows originated subaerially, the lavas had several days' time to de-gas before entering the sea, and they were not nearly as explosive as they would have been in the case of an underwater eruption. Underwater eruption is prohibitively dangerous and is never recommended for diving except in the case of hydrothermal vent activity, which normally is limited to gaseous emissions (black smokers). Actual eruptions underwater are probably best analyzed by remote instrumentation.

In the case of subaerial eruptions which enter the sea, the most dangerous factors to consider are heated water, turbidity and gaseous explosions. Heated water accumulates at the sea surface owing to its low density. The thickness of a heated surface layer will be a function of the amount of lava entering the sea and the degree of mixing at the shoreline. Longshore currents may greatly aid in the dispersal of heated water. Divers should avoid heated surface waters. This can be done by entering the sea outside the area of influence and swimming under the heated plume to active sites (Moore et al., 1973; Grigg, 1973). On steep slopes divers should be aware and cautious of avalanching rock and gaseous explosions. This can be done by swimming several meters above the bottom. Observations of such volcanic flows can only be made under conditions where small amounts of lava enter the sea. Decisions concerning the safety of such missions must be made on-site. Another factor to consider is turbidity. Directly over underwater lava flows the water is often extremely turbid, too turbid in fact to operate safely. To avoid areas of high turbidity, divers should operate on the upstream side of active lava flows or possibly at slightly deeper depths. A third factor to avoid is operating surface vessels which have seawater cooled engines in areas of heated plume water. Engines exposed to such conditions may overheat to the point of on-site failure. Divers should wear protective wet or dry suits, which serve as insulation to the heat as well as acting as protection from sharp, freshly fractured lava surfaces.

Divers operating in submersibles at hydrothermal vent sites might also take into consideration these suggestions to divers. The degree to which caution must be taken will depend on local conditions and the nature of the submersible, which can best be judged by on-site observers and divers.

8.2.28. Hot springs (potentially dangerous hot water)
Excessively high temperatures are rarely encountered in diving (8.2.22; 8.2.23). Hydrothermal springs or hot water vents can nevertheless be found in volcanic areas. Although emitted heat can be very high, it is generally concentrated in a few spots and rapidly dissipates into the surrounding water. Only in closed, small basins with limited water exchange can temperature rise
to dangerous levels, while in lakes and the sea, even very close to the vents, temperatures suddenly drop to values of the normal environment. With water vents, gas is often present. Sometimes it rises as bubbles or pressure-driven bubble streams at elevated temperatures. Depending on the amount of gas and the depth, it may form a column rising toward the surface before it dissipates and can be dissolved.

Owing to differences in density, waters of different temperatures are usually easily seen because of the induced clear water turbidity marked by 'trembling' light, but when the vents carry chemicals in solution or in suspensions, they are smoke vents.

A normal diving suit is usually sufficient protection against hot water, that nevertheless must be approached with care. Real danger of scalding is a very rare situation. Long exposure to warm water can nevertheless cause hyperthermia of divers with consequent dizziness, headaches and difficulty in breathing, which can lead to unconsciousness and collapse of a diver. Usually a rest in a cooler place will promote a rapid recovery from incipient hyperthermia, and medical assistance is seldom needed. When one has to dive in warm water or near hot springs, physical exercise should be kept to the practical minimum.

8.3. Artificial, experimental and unusual situations
Diving is increasingly being carried out in situations that range from the commercial scientific (fish tanks, shellfish rafts, etc.) to the scientifically bizarre (e.g. studying algae growth in nuclear reactor cooling tanks). Although some of the subsections here will not apply widely through the diving community, the recommended procedures are derived very largely from the experience of the technically developed countries and will have increasing application in developing countries.

8.3.1. Fish tanks, cages, farms, shellfish, rafts, diving in enclosures and other containers
Large containers are being used with ever increasing frequency by scientists and fish farmers. While diving procedures in large dammed impoundments and land-based tanks should take account of the special recommendations for confined spaces (8.2.18), culverts (8.3.3) and inside storage tanks, many enclosures are deployed in open water and require somewhat different practices. This section deals specifically with diving in and around floating enclosures.

Types of enclosure: Floating enclosures are usually made in three types of material, impermeable sheet plastic (e.g. polythene, PVC), closely woven material (e.g. plankton net, sailcloth) and fishing net. Usually the sheet plastic and closely woven material are used for scientific experiments while fishing net is predominantly used for the manufacture of sea cages in aquaculture. Ideally the plastic and closely woven enclosures will be relatively rigid fixed volume systems while the net bags are usually loosely constructed.

The basic design of each system is similar, comprising a flotation collar, a container supported by the collar and a mooring system. The flotation varies according to the design but in the larger systems it usually doubles as a service platform. In this case it will be substantial and reasonably stable. Moorings can be independent but frequently several enclosure systems are interlinked by chain or rope to a common anchor.

Diving procedures: Diving on enclosures is usually associated with deployment, maintenance and dismantling. The particular dangers are entanglement and being trapped between adjacent systems. A sharp knife with a saw-tooth edge must be carried. If convenient
the knife should be worn on the forearm or the inside leg. Since enclosure systems are large and often complex pieces of apparatus, it is advisable for divers who are unfamiliar with the system to dive initially with someone who is familiar with it, or failing this, to be briefed fully on the layout and design before entering the water. Since most enclosures are supported from the surface, the diver often has to approach the equipment from below. The diver should be aware that the escape route in an emergency frequently could be to descend before making for the surface.

**Diving around enclosures:**

**Underwater.** The biggest risk while underwater is becoming tangled in the ropes and associated equipment. Netting, especially larger mesh material, can be exceptionally dangerous, particularly when unsupported or otherwise loose. When handling netting underwater extreme care should be taken and the diver should always attempt to face the netting in order to minimize the chance of the material being caught around the demand valve clamp. This is probably the most vulnerable part of the diving equipment and is most inaccessible to the entangled diver. The low pressure hoses of twin hose demand valves can be crimped and the diver’s air supply cut off by tangled netting or rope. Single hose valves are not so vulnerable. Where possible it is advisable for one of the team of divers underwater to stand off from the apparatus in order to be readily available to disentangle the buddy diver. Strong scissors could also be carried since they will probably be more effective than a knife for cutting slack netting.

The base of the enclosures often has heavy weights, which serve to tension ropes, etc. The locations of these should be known and care should be taken to avoid cutting them free accidentally. When swimming beneath the entire system the diver should make sure that there is plenty of clearance. Ropes held taut by such weights make useful hand holds for the diver and can be used in controlled ascents and descents.

**At surface.** It is often necessary to use diving equipment at the surface when servicing enclosures. These structures are most vulnerable to wave action particularly at the point where flexible material is attached to a rigid framework. Before diving, account must be made of sea state, and, where several units are linked, care must be taken to avoid getting trapped between
the floating support structures. In some cases a surface attendant should stand by to prevent the units coming too close together.

**Diving within enclosures:** Diving within enclosures is usually associated with repairs or recovery of dropped equipment. Where possible the practice should be avoided since it can cause claustrophobic feelings and can be deleterious to the experiment. It is inadvisable to dive in systems narrower than 2 m in diameter.

It is usually impracticable to dive in pairs within an enclosure, so a fully-kitted standby diver should be in immediate readiness to dive if required. In an emergency it is most likely that the diver will be freed from the enclosure by cutting the material and escaping through the wall. Even in a normal situation the diver will need assistance to climb out from within an enclosure.

Normal lone diver practices must be adhered to. In addition to the diver’s own safety-line or, more preferably, communications cable, which should be held taut by the surface attendant, a weighted shot-line down the center of the enclosure tied to the support framework is a useful reference point and provides a means of effortless vertical movement for the diver. It is frequently difficult and often undesirable to fin actively when inside an enclosure.

It is possible to repair punctures in watertight enclosures by clamping the damaged sections between suitably sized rigid plates or strips of wood. This requires divers both inside and outside the enclosure simultaneously. Although the material is usually translucent to some degree, it is often difficult for the divers to locate each other on either side of the wall. The best procedure is for the two divers who are to make the repair to arrange to rendezvous at some point on the surface and then to descend together to the damaged area keeping contact by touch through the flexible wall of the enclosure. The buddy diver for the ‘outside’ diver should stand off and watch the procedure.

When watertight enclosures are damaged they usually collapse. This can create difficulties for anyone diving inside since the airlift effect of the exhaust bubbles tends to draw material around the diver. It is important to be aware of such a possibility since the collapse tends to happen without warning, particularly when the diver is working at the base of the system. It is difficult to swim in such a situation but easy to escape either by hand hauling up the shot-line or by careful use of a buoyancy aid such as an ABLJ or inflatable dry suit. In an extreme situation, the diver should be prepared to make an emergency escape through the enclosure wall by cutting through it.

There are no texts specifically on the methodology of enclosure techniques for scientific purposes. The introductory chapter in Grice and Reeve (1982) illustrates some of the types of floating enclosures used. Although there are many books on aquaculture, there are as yet no suitable descriptions of the types of sea cages used in the industry. New designs are constantly being developed, which further emphasizes the need for the diver to be familiar with the particular system before entering the water.

8.3.2. Support, launch and recovery of gear
The supporting role of the diver has proved invaluable time and time again to the marine scientific community. The majority of equipment used in marine research is complex and expensive and often the safe deployment and recovery can be aided by divers.

It is assumed that the equipment is either bulky, heavy or both. Diving techniques may need to be worked out to overcome the problems involved in being on or near heavy or
awkward gear moving relative to a ship. A good dive boat should be used (9.2), and the
mother ship must have a smaller boat ready for immediate launch in case of emergency.

All straps, shackles and lifting gear must carry the relevant in-date test certificates pertaining
to the legislation of the particular country or countries involved. Prior to the start of a dive, ar-
rangements should be made to ensure that no sewage or rubbish is dumped over the side for
the duration of the launch or recovery. Apart from the obvious discomfort for the divers, it can
also attract unwanted visitors such as sharks.

There is a possibility that a diver may drift away from the ship; this may be caused by the
way on the ship or currents and wind. Divers should carry emergency flares and a dye pack.
A whistle is a good idea for short distances. When night work is involved the diver should
carry a flashing light.

There is little difference in diving technique when handling heavy gear, and most of the con-
cern is brought about by being on or near equipment weighing 2 to 20 tonnes moving relative
to the ship. This type of equipment may either be a towed body, a submersible, something
that is lowered to the sea bed or a buoy or float. These may be launched either from the side
or the stern of the vessel. Some of the following apply to one situation only:

1. Straps and lifting gear may have to be tested under mandatory regulations.

2. The launch should take place on the windward side of the vessel so that the vessel drifts
away from the equipment.

3. Fenders should be large enough to allow a 0.6 m gap between the equipment and the
ship under maximum compression, so that in the event of a diver getting between the two,
room will remain. These fenders should be attached to the equipment so that in a swell they
move with the equipment, are not forced out and will not roll along the ship's side.

4. Two lines should be rigged fore and aft on the equipment to a towing point on the sup-
port boat which should tow off stem first in order that the coxswain can see what is happening
and may apply full power to one tow line or the other if necessary.

5. If it is possible, release of lifting gear should be by remote means. If this is not possible,
then the hooks should be fitted with grab lines, and the divers should wear protective helmets.

6. Care should be taken that no diver is caught beneath a pitching stem, particularly if the
ship is transom sterned. In vessels with spoon counters it has been found that divers are dis-
placed with the water, although this should not be relied upon.

7. In stern launch procedures, it is general practice to have way on the parent vessel. As this
requires the use of the propeller, close contact must be maintained between the bridge and the
diver's boat. When the propeller is started or revs increased, there may be a large surge and
this is potentially dangerous.

8.3.3. Locks, culverts, ships' propellers or hydraulic inlets

There is absolute necessity in diving around heavy machinery or hydraulic intakes for the
diver to ensure that nothing will be moved, started or operated while the diver is in the water
other than carefully planned and executed test procedures. All automatic operating systems
must be disabled and the engineer, ship's captain or the person otherwise incharge of the
operation of these systems must work closely with the diver and his/her handlers. It is strongly
advised that the diver and the surface handler be in constant communication both for the effi-
cient carrying out of the tests or inspections and for the safety of the diver. The danger of a diver being sucked onto the grill over a hydraulic inlet must be avoided. Procedures for locking the propeller shaft, etc. are laid down in Navy manuals and commercial diving manuals.

8.3.4. Diving underway
For the purposes of this section, the term 'underway' shall apply to ships moving through the water. Also see Section 8.3.5.

A vessel will require a diver-support boat under these circumstances:
1. If it is of such a size that it cannot approach divers safely in prevailing weather conditions.
2. If it is of low manoeuvrability whether inherently or as a result of apparatus deployed from the ship.
3. If a diver’s body heat will be lost rapidly when he would otherwise be towed through the water.
4. If delays in recovery of the divers are possible.

Separation procedures: Where appropriate the divers shall carry flares, fluorescent dye packs, a strobe light and a whistle. If the risk of a diver being separated from the support boat is thought to be great, radio beacons should be worn or fixed to a surface buoy on a shot-line. Consideration should be given to the use of acoustic communications or pinger and tracking devices. There may be circumstances, for example working on fishing gear, when it is safer to reduce extraneous gear to a minimum in order to reduce the chances of becoming snagged on the moving apparatus.

If a diver is seen to be drifting astern and the support boat is unable to pick him/her up, a previously prepared buoy shall be dropped to mark his/her position. The diver should make every effort to attach himself/herself to the buoy, which will be fully fitted with rescue equipment. The buoy should be large enough to be found and should have a radar reflector.

When working on towed apparatus, there should be a trailing-line leading to a substantial surface float. This can be fitted with one or more quick release clips so that divers leaving the apparatus are marked at the surface. If one diver has reason to surface, he/she should ascend the trailing-line. The surface support boat should be stationed alongside the trailing-line float.

If it is noticed that a diver is missing, the marker buoy should be dropped immediately to provide a reference point.

If a diver drifts astern unnoticed, first the whistle and then up to half the flares should be used. It is important that the diver’s flares are acknowledged as soon as they are seen in order to prevent panic. If these are not acknowledged, the diver should proceed in the direction of the ship assuming that no reference buoy has been dropped. If there is doubt as to the direction of the ship, the diver should remain where he/she is; after swimming in the direction of the ship for about half an hour and finding no buoy, the diver should stop to conserve energy.

The fluorescent dye pack should be securely attached to the diver and should only be used if an aircraft is sighted in daylight.

Decompression: Decompression diving underway must be avoided.
8.3.5. Diving on towed fishing nets

Diving on fishing nets is a practice that has developed over the years by research scientists involved in the design and engineering of trawling gear and in the behaviour of fish reacting to the gear (Main and Sangster, 1976, 1978, 1981, 1982, 1983, 1984, 1985). It is not a dangerous type of diving, if approached with both common sense and good diving techniques. However, it is different from almost all other standard types of diving, as the fishing net or fish species under study is always in motion. Therefore the diver has, on most occasions, to keep up with the subject while being towed through the water at speeds up to a maximum of 2 m per second (4 knots) and obtain results.

Direct observation and quantitative measurements by divers on trawl fishing gear require the development of a great deal of personal skill and experience and must be approached with caution. Initially, a great deal of time is needed to develop both skill and the methods that will produce the maximum amount of relevant information during each dive in a limited 'no-decompression' time.

**Choice of diving personnel:** Divers should be experienced and well qualified in all standard diving techniques. Divers must be capable of maintaining an increased breathing rate and preferably be strong in the arms to hang onto fast moving gear and withstand an increased body drag. The divers should not be prone to seasickness, as vessels can work well offshore.

**Basic training:** Although the ideal approach is to work with a team already well versed in fishing gear diving, this may not be possible for various reasons. The alternative is to try to simulate the real thing. A simple approach is to tow a heavy weighted rope behind a boat at a relatively low speed (1 knot). Allow a selected pair of divers to descend to the weight at approximately 10 m depth, hang on and attempt simple tasks while trying to regulate their breathing rate at that towing speed. Increase the speed and complexity of the tasks, as experience permits, e.g. photography or communications. Instruct the divers to move their heads into and across the water flow, to feel the effect of drag on the face mask and mouthpiece. All these simple steps will improve their ability for underwater work and increase their strength at realistic towing speeds.

**Equipment and accessories:** This type of diving requires a lot of common sense. Always remember this when choosing your equipment prior to a dive. Nets are full of snags and diving equipment has many pins, buckles, toggles, etc. Only take equipment that is really necessary for the job in hand. The most suitable diving gear is:
1. Dry suit with suit inflation worn over an appropriate undersuit. This will provide adequate insulation in cold water conditions.

2. Single tank scuba with a quick release harness. It is preferred to a twin set or a back-pack because it is lighter to handle on the heaving deck of a ship and is less of a drag on the individual at higher towing speeds.

3. Single hose regulator fitted with a contents gauge rather than the twin hose demand valves. It has been known for the second stage to purge due to the water flow, but this is not a common occurrence and can be overcome by a small piece of easily removable tape or by fitting a stronger spring. If taped voice recordings or communications are necessary on a dive, then a mouth box can be fitted to the second stage in place of the mouthpiece. This is preferred to the full-face mask although either will reduce the pressure on the jaw muscles and will also keep the lower face warm and protected against jellyfish stings.

4. A depth gauge, watch and knife are essential. The knife should be worn on the forearm rather than on the thigh or lower leg. In this position it is less prone to snagging and it is more accessible in a current which tends to straighten the body.

5. A small cassette tape recorder in a watertight housing with a remote microphone on a 'flying lead' allows many minutes of continuous real-time information to be stored. This system eliminates the use of writing, etc. A diver-carried, self-contained, low-light video-recording system with an audio track is probably the ultimate in free diving efficiency.

6. A large inflatable boat with a powerful engine is recommended. This tender/tender boat should have a diving ladder for easy access, VHF radio for communication with the towing vessel and all necessary safety equipment.

**Pre-dive procedures at sea:**

1. A total understanding of the geometry of the gear by the divers and a pre-dive briefing with skipper, crew, divers and boatman is essential so that everyone understands what is expected of each person.

2. A team of five divers is ideal, preferably diving in pairs with a maximum of three diving at any one time depending on the task. Two divers is the most practical team, with the third used as a standby diver in the tender boat.

3. The skipper of the fishing vessel should inform other vessels in the area of the proposed diving program and ask them to stay clear. The 'A' flag must be shown.

4. Operations will almost certainly be dictated by weather conditions and it is usually the tender boat being unable to cope with the sea state that will cause cancellation of the exercise.

5. Although the expected diving depth has been pre-planned, unexpected changes in depth due to surface wind changes and cross tides can alter the ship’s course into deeper water. Be aware of the depth that must not be exceeded and carry decompression tables for emergency use.

6. The tender boatman will be in a position behind the towing vessel. It is often impossible to follow air bubbles unless there is a calm sea; therefore, the boatman should look astern of his craft as well as to the sides and ahead. It is beneficial to have a lookout with a radio situated on the stem of the towing vessel as that person is higher above the water and can see farther.
Free diving on towed fishing nets: There are basically three types of moving fishing gear: seine net, pelagic or mid-water trawls and demersal or bottom trawl.

1. **Seine net.** This is the easiest type of gear to work with, as the net begins from a stationary position and slowly increases in speed through the water up to about two and a half knots. The danger point, in this category of net, is the fact that the netting is quite loose and floppy in the stationary mode. The meshes can easily snag a diver, but as the net moves forward, it becomes quite firm and safe to hold on to.

2. **Pelagic net.** This can be the most dangerous type of net to the diver because it can be towed over very deep water. The net can also drop through the water column for a number of reasons. If a diver were caught up in a trawl and the buddy diver could not release him/her, the ship could not be stopped and the net would have to be winched up to the surface at a speed that the diver could endure.

3. **Bottom trawl** (see Figure 8-2). This is safer than other gear to dive on, as it is towed over the bottom and in the event of any mishap, the ship can be stopped without fear of the net sinking into deeper water. There are problems of sand and mud being thrown up by the otterboards and passing back along both sides of the trawl, often completely obliterating part of the wires and netting. Until experience is gained, it is essential that the vessel tow a straight course to minimize this danger.

**Observing technique:** The divers begin either from the stern of the towing vessel or the tender boat positioned alongside the vessel. Jumping from the stern of the fishing vessel appears to be more dangerous than it really is. A diver entering the water from a large boat is more relaxed than kitting up in a small tender boat. Prior to entering the water, the dry suit must be really well vented of air and the weight belt should be slightly heavier than normal. The team should enter the water and swim down the chosen warp while remaining together. It is not advisable to hang on to the warps as they are greasy and may have broken strands of wire. The divers should be able to follow the warp to the sea bed by treading water and dropping through the water column. This allows time to regulate breathing, check that all divers are in the right frame of mind for the task in hand and adjust cameras, instruments, etc. The divers swim past the otterboards, sweeps and bridles until the net approaches and both divers can then either catch hold of the net and be towed through the water, or alternatively allow the whole net to pass by. The latter method is used really only for filming techniques. Never attempt to swim with the fishing gear as the diver cannot sustain fast speeds for any length of time. On completion of the exercise, return to the net and stay together, leavetogether and do not waste time on the sea bed. Check depth and time and ascend to the awaiting tender boat. On the surface stay close together. Never use blob-lines or marker floats as these can be lethal when working with fishing gear (6.2.7).

**Towed underwater vehicles:** To overcome the many problems of divers hanging onto towed nets, the use of a towed wet vehicle carrying two divers, cameras, communications equipment, etc. is extremely valuable and much safer than the divers remaining free in the water. However, this can be expensive and may need a bigger team to operate it. Nevertheless, this system can produce remarkable results in a relatively short time.

8.3.6. Diving from large ships
For the purposes of this subsection, a large ship will be a vessel of 1000 tons or over, with a freeboard of 5 m or more (8.2.4).

The advantages of diving with a large support ship of this size are the ability to work anywhere in the world's oceans, long endurance at sea, good living conditions, excellent technical back-up, medical facilities, good radio communications, accurate navigation, good laboratory conditions and the possibility of evacuating an injured diver by helicopter. There is also good long-range visibility from the bridge, use of radar and an ability to ride out storms. The opportunity to dive in these circumstances will usually arise from participation in an oceanographic cruise on a large research ship, or possibly research in association with the offshore oil industry or fishing industry or from a naval vessel.

Problems arise from the following factors: high freeboard; difficulty and time needed to launch and recover boats; slow manoeuvrability of a large ship; technical difficulty of starting and stopping main engines; difficulty of bringing a large ship close to shore, rocks or reefs; and danger of being hit by the ship, especially when working near the stern.

**High freeboard:** Boats, equipment and divers have to be lowered into the water; often from upper decks where there is more space. If a work boat is used, this may be stowed on davits. An inflatable will usually have to be lowered from a crane, using strops. The launch should be on the lee side of the ship. In windy conditions an inflatable can swing or rotate and hit against the hull, unless stabilized with line fore and aft. Divers and equipment may be embarked from a companionway or by the crane. Because of the high freeboard, assistance to a diver in trouble can only be given by people already in the diver tender boats.

**Launch and recovery of boats:** Launch and retrieval of boats is time-consuming. In an emergency, an extra boat cannot be launched quickly, and similarly, in an emergency, a boat carrying an injured diver cannot be retrieved quickly. Allowance should be made for these factors when planning operations and planning the equipment carried on boats. Thus all boats should be equipped with a radio to the mother ship, radar reflectors, tool kits, first-aid kits, etc. (6.2.5). If the work is in the open ocean, boats should carry complete survival kits and rations.

**Manoeuvrability:** Large ships have a large turning radius and in addition at slow speeds tend to be influenced by wind. A large ship always has considerable momentum. In the absence of lateral thrusters, a large ship at slow speed or hove to will be strongly influenced by wind. As a result of these factors it usually is not possible or desirable to maintain the vessel in close station to the divers, unless the work permits the divers to drift with the ship. Operations should be planned so that the diving is controlled from the small boats and oriented directly to the boats. The ship may be stationed or drift 1-2 km from the divers.

If the main support ship is needed to launch scientific equipment in conjunction with diving support, it is presumed that the ship will be at anchor, or will have thrusters or dynamic positioning, so that it can maintain station. If dynamic systems are being used, the strictest precautions must be discussed fully with the Ship’s Master and the Chief Engineer before diving commences as these initiate automatically and might engage when a diver is in a dangerous position (Appendix 2 for industrial manuals and regulations).

**Starting and stopping engines:** Large engines must be allowed to heat up and cool gradually. For each ship and engine type there is a strict procedure for the rates at which speed can be increased or decreased. Diesel electric propulsion is an exception since the electric motors can be varied in speed without harming the diesel engines. Similarly, feathering
Figure 8-2. Terminology of parts of a trawl net, showing the components which may have to be photographed or measured by divers.
propellers provide added flexibility. Notwithstanding these factors, it is generally true that large ships which are hove to cannot move quickly ahead without advance warning to the engine room. Conversely, the engine room requires notice of intention to stop. By careful discussion with the Ship's Master and First Engineer, it is possible to establish what procedures can be accepted as the norm and what can be done in an emergency, and hence work out a routine for maintaining the optimum close support of the diving operation.

**Working close to shore and rocks:** The Master of a large ship will not wish to endanger his vessel by bringing it close to shore, reefs or rocks, where quick manoeuvres and rapid changes of speed are essential. It is reasonable for a vessel without thrusters to be kept at least 1-2 km from any navigational hazard. Divers planning geological sampling or study of biological substrate should be aware of this stand-off distance when planning operations.

**Working close to the ship:** When working close to a large ship, there are dangers from being trapped between the hull and any adjacent boat or equipment, from engine water intakes and outflows, from swinging blocks or lifting tackle and above all from the rise and fall of the stem of the vessel. Depending upon the weather conditions and the precise shape of the stem, the degree of 'slap' will vary from ship to ship. Nevertheless, until close experience and inspection have proved otherwise, no diving should be permitted close to the stem of a large vessel. In all operations close to the ship, there must be the closest consultation between the Diving Officer or Dive Marshal and the Ship's Master and First Engineer. Where relevant, crane operators and other technical support crews should be fully briefed also.

### 8.3.7. Severely contaminated water, toxic and non-aqueous liquids

Engineering and scientific projects sometimes require working with large quantities of polluted or toxic water, or with non-aqueous fluids such as diesel oil or paint, or in water with dissolved toxic gases. During installation of instruments or sensors, or in carrying out unexpected maintenance requirements, it may be useful to have carefully prepared divers to work in these unusual circumstances. Such circumstances may arise in studying pollution or leakage from dumped toxic wastes, or within large tanks or containers. The strictest safety precautions must be applied in all such circumstances, and the Diving Officer should conduct careful consultations with experts familiar with the hazardous or toxic chemicals involved.

Never dive in fluids containing highly toxic chemicals such as acetic anhydride, bromine, methyl parathion, acrylonitrile, epichlorohydrin, or chlor dane. Never dive in fluids that contain contaminants that could dissolve the latex rubber in diving suits. Always consult an expert chemist or pharmacologist to assess the risks from the known concentrations of potentially toxic chemicals in the water before diving.

Foam Neoprene suits are almost impossible to decontaminate after severe exposure and do not provide sufficient protection underwater. A complete dry suit should be used, with integral boots, and gloves that can be sealed onto the suit at the wrists. Helmets must totally enclose the head and be sealed to the suit, and the helmet should preferably have a slight excess internal pressure. Exhaust valves should have a double exhaust flap system so that droplets of fluid cannot leak back onto the breathing circuit.

Suit materials must be smooth and slick on the outside so that they can be decontaminated. The surface attendants and line tenders should be protected by appropriate suits and gloves, since the handling of lines and the diver's equipment will inevitably put them at risk. Before
diving, the Diving Officer must ensure that the appropriate decontaminating and scrubbing agents are available on-site so that equipment can be cleaned when the diver exits the water.

Advanced equipment for protection of divers from severely polluted or toxic conditions has been developed by the National Oceanic and Atmospheric Administration (NOAA) in the USA (Barsky, 1986; Tejada, 1985; Wells, 1984).

8.3.8. Sewage contaminated water
Typical situations that necessitate diving in sewage are: sewage works maintenance, sewage outfall construction and maintenance, sewage outfall environmental impact survey and marine engineering site investigation. The main problems encountered are poor visibility and risk to health through bacterial or viral infection. To minimize these problems, first determine whether the sewage flow or volume can be reduced by the operators. Second, carry out the following precautions: minimize exposure of skin to water by using a complete dive suit; use a full face mask; a dry suit is preferable; if a wet suit is used, swim through clean water before and after sewage contamination; use life-lines and diver telephones to maintain contact; have a typhoid and any other prophylactic injections as indicated by local conditions at least one week before the diving; avoid stirring up sediment on the bottom by careful buoyancy adjustment; do not dive with cuts or abrasions; avoid swallowing; wash all equipment and body in disinfectant following the dive; rinse eyes with optrex or some other solution after the dive; rinse ears with earwash solution of 80% iso-propyl alcohol, 5% glacial acetic acid and 15% water after the dive; and spit out saliva frequently after the dive.

If the sewage is untreated (that is raw or only macerated) it is essential to wear a dry suit providing full body cover (8.3.7).

When diving in enclosed vessels such as sludge digesters, roping and voice communication is necessary. Supplied air should be breathed until well clear of the vessel, and the diver should be fully separated from the diving medium. If there is space above the fluid in the vessel, it will almost certainly not be breathable and may be an explosive mixture.

8.3.9. Polluted water and estuarine conditions
Scientists are increasingly required to dive in polluted littoral zones in order to study the impact of pollution caused by biological, agricultural and industrial effluents and discharges. In addition to modern pollution of these waters, many estuaries contain areas that are 'polluted' through the natural processes accompanying restricted water circulation and oxygen depletion. In heavily polluted waters all the procedures associated with diving in sewage contaminated waters should be followed, but the risk of serious infection is not as great. These waters are usually not as unpleasant to dive in as severely contaminated sewage water because the concentrations of pollutants of a corrosive or anoxic character are not so great.

8.3.10. Reactor shielding tanks
Diving in reactor shielding tanks is only carried out when the reactor has been defueled or prior to fueling; there is therefore no danger from excess heat. Most work is of an inspection and repair nature and is thus of an entirely commercial character. The only hazard is remnant radioactivity, and levels are measured using a dosimeter carried by the diver; a dipped dosimeter is often used in planning the course of a dive as it can be placed in positions that the diver will occupy and the radioactivity levels of the dive can be calculated. All diving is tethered with a surface attendant in constant voice communication.
Many large, and some small specialty, diving companies carry out industrial diving in reactor shielding vessels, and scientists wishing to dive in these sites should consult with these companies. Ideally, the scientist should be able to work with the company personnel in carrying out the scientific work with the normal commercial back-up; these are not low-cost diving sites.

8.3.11. Offshore platforms

The presence of the structure itself is the principal factor in determining the safety of diving from offshore platforms. The platform, which is expensive, is not there for its own sake but usually for some industrial or other purpose. The platform is usually associated with a complex of instruments, projecting arms, cables, wires and drilling equipment. A diver swimming into this maze of engineering needs to be fully acquainted with the distribution of equipment. Knowledge of the geometry of the platform and its superstructure is mandatory, especially in low visibility conditions. It is often best to work from inside the frame of the structure, which may be the space most free of wires and cables. In all work scenarios entanglement is a serious risk. Changing tides, currents and the passage of fronts can cause the water to accelerate and change direction suddenly as it passes through and around the frame members.

When a task has to be performed on or near a submerged structure or platform, there must be an extremely detailed plan of the activity to be carried out underwater. This should be limited to a simple job objective for each dive. The surface team and the divers must have detailed instructions and communication between diver and the surface must be carefully defined in the absence of a telephone link.

Diving may be carried out from small oceanographic platforms, experimental engineering or research platforms, or operational oil platforms. If scientific divers are required to work from an oil industry platform, it is probable that they will have to comply with the industrial and commercial diving regulations.

Where petroleum exploration, development drilling or production is being carried out from a platform, the conduct of diving must be very carefully phased so as not to interfere with work. In some cases this will mean that diving has to be carried out while industrial operations are
continued, producing considerable noise and vibration underwater. Great care should be taken to ensure that diving operations are only carried out when there is no risk from heavy equipment or machinery moving underwater.

All diving operations from platforms should additionally be supported by a small boat. This is a great help when the divers need to exchange tools, adjust instruments, bring up samples, etc. Furthermore, in the event of an emergency, a small boat can track the diver, while support personnel on the platform obviously cannot move. In stormy conditions it can be difficult for the divers to approach fixed members of the platform, and it is much safer to home onto a support boat.

Platforms often attract submarine life, including large fish and possibly sharks. Noise may help to keep them away, but this is more than compensated for by the usual attractions of food, garbage, etc. that is discharged into the sea from a platform. Divers working around platforms should always be watching for sharks. In the event of injury to a diver working on a platform far from shore, it may not be possible to evacuate the diver in bad weather (6.3.5; 8.2.15).

8.3.12. Electrical fields

Installations producing pulsed or varying electrical fields such as screens, barriers or 'guides' to control the movement of aquatic animals, and impressed current anti-corrosion cathodic protection systems are the main source of hazard to the diver (Shilling et al., 1976; Mole, 1984). Electrical systems for guiding fish are fortunately used very little either inland or on the coast, primarily because they consume a great deal of electrical power. Inland electrical-fishing operations are associated with groups of people, wires, generators and often non-metallic boats. Military areas where electrical systems may be used are best avoided unless there is full cooperation.

**General:** The physiological effects of electrical fields increase progressively with increasing field strength and depend on the direction of the diver’s body within the field. The direct effect upon the body of electrical shock is related to the magnitude of the current passing through the body, especially the heart. This is known to be variable between people, and there is much variation in data published on the effects. However, the diver may sense the effect of an electrical field or observe progressively erratic behaviour of a compass or of fish. The effects of increased field strength and likely body current can be divided into three main reaction groups:

1. The first reaction or perception threshold or shock with no loss of muscular control, while in fish fright and discouragement are observed. This first reaction is often associated with low frequency pulsed DC fields and large anodes (less than 10 mA DC, 2 mA at 60 Hz or 20 mA at 10 kHz).

2. Painful shock, difficulty in letting go or muscular contractions while in fish electrotaxis is observed. Electrotaxis is a mixed reaction of attraction or repulsion and is associated with forced swimming of mid-water fish. It varies with the direction of the DC electrical field and its strength. Alternating current, as opposed to pulsed direct current, is rarely used for electrofishing as it causes rigid muscular spasm or tetanus. This second reaction is often associated with high frequency pulsed fields set up within the water (less than around 100 mA DC, 25 mA at 60 Hz, 100 mA at 10 kHz).

3. Ventricular fibrillation or in fish electronarcosis, immobilization or with sufficient power or close proximity or contact, death by electrocution. This reaction is associated with short-term
contact or close proximity to large power sources (3 seconds duration; greater than around 500 mA at DC, 100 mA at 60 kHz, 500 mA at 10 kHz. Or 0.03 second duration, 1300 mA at DC, 100 mA at 60 kHz, 1100 mA at 10 kHz). The figures are taken from Haigh (1975), Smoot and Bentel (1971), Shilling et al. (1976) and Cromwell et al. (1973).

The conditions which influence the currents passing through the diver are influenced by a great variety of factors which include the water conditions (temperature and water chemistry, particularly conductivity), the electrical signal (frequency, shape and duration of pulse), the electrodes (size, shape, orientation and separation), the diver’s orientation in the electrical field and the distance apart of wetted areas (wet v. dry suits).

Sites where electrical fields may be in operation comprise installations which are known to vary greatly in both the electrical power used and in the frequency of its pulsation or variation. They include:

1. Near intakes to pumps and turbines to prevent the entry of fish. They are commonly placed upstream of the main debris screens.

2. On complex watercourses or below dams to guide fish into 'passes' through or around obstacles.

3. Near channel entrances or exits to prevent the entry of intruder or unwanted aquatic animals.

4. On or around fish farms to isolate fish for management purposes.

5. In general where fish are required to be captured by stunning. This technique has also been used experimentally for fish shoal capture and the removal of burrowing animals. Recorders of fish activity or numbers by electrical methods are of little danger to the diver when functioning correctly, but can be associated with fish ‘guides’.

6. Cathodic and Impressed Current Protection systems particularly on offshore installations.

7. Military and associated installations and vessels.

8. Proximity to large power carrying underwater cables.

The most obvious hazards are:

1. **When drifting with the current:** The diver may progressively be influenced by the electrical field and become unconscious or could be held on an electrode itself. This situation would include oblique or transverse pulse electrified screens in rivers or near fixed coastal installations.

2. **Installations being switched on during dive operations:** A locked-off key system must be used where this possibility is known to exist.

Although freshwater applications occur (their rarity may be a danger in itself), marine systems require large amounts of power and, except for cathodic protection, alternatives are normally sought. In general, there should be no diving if there is a significant electrical field, and if one is suspected, suitable precautions must be taken; the use of metal dive- boats must be avoided. The development of a suitable test meter is proposed.

The diver should try to maintain constant vigilance of unusual sensations when diving in unknown waters. Watch for unusual fish behaviour and be aware that electrical fields affects compasses, upsetting underwater navigation.
8.3.13. With large or dangerous animals in aquariums
The working divers at an oceanarium dive and work in controlled aquatic environments with a number of exotic species of animals, both mammals and fishes (8.2.12; 8.2.14). Many of these aquatic animals are, or can become, a threat to the uninformed diver.

Before entering any tank or facility with animals, talk to the handlers or curator to learn about the animals you are to dive with. If possible, identify each individual animal and obtain information about its specific behaviour and personality. The more you know about the specific animal's natural or learned behaviour, the safer you will be upon entering their environment.

1. **Behaviour of the species:** Learn the general behavioural characteristics of each animal species, especially larger fishes and sharks. Know antagonistic and aggressive postures and movements. Observe animals and note natural and unnatural movements.

2. **Physical capabilities:** Learn the physical capabilities and capacities of each animal species. Know the range of motion of the animal, i.e. up and down or side-to-side locomotion. Know the strength and speed at which it can move.

3. **Mating season:** Know the mating seasons of each animal species. Males especially become more aggressive, as will females. Male dolphins or manatees may even attempt to copulate with humans during this time.

4. **Females with young:** Female mammals will become aggressive in protecting their young. Do not make any attempt to move toward or touch newborn or young.

5. **Groups or single animals:** Know and understand the social structure or hierarchy system of a group of animals. This will help avoid confrontations with the dominant animal.

6. **Length of time in captivity:** The longer an animal is in captivity, the less fear of man develops and they may become more aggressive. Also in an unnatural environment, unnatural behaviour may develop or be learned. This is especially true with the smaller dolphin or toothed whales.

7. **Climatic changes:** Temperature and barometric changes seem to affect animal behaviour. Cooler water can make animals more perky and aggressive while extremely warm water can make them irritable. Barometric pressure, along with extreme temperature changes can affect sharks and fish behaviour.

8. **Territorial behaviour:** Dolphins, whales and sea lions are territorial and may display aggression toward intruders.

9. **Newly rescued or injured animals:** An injured wild animal can be dangerous and unpredictable. The animal may or may not display aggression toward its captors owing to pain and/or fear.

Diving with animals other than sharks:

1. Upon entry, observe animals and watch for nervous or erratic behaviour.

2. Keep calm, swim slowly.

3. Once animals resume normal behaviour, you may proceed with task at hand.

4. Watch for agitation among the animals while you work.
5. Never make a move toward an animal that may be interpreted by that individual animal as an aggressive action.

6. Aggressive warning signs, usually before physical harassment, may appear as jaw snaps, false charges, fast or erratic swimming, rigid body posture, etc. Exit the tank upon observing this behaviour.

7. Aggressive physical harassment by animals may appear as head butting, tail slapping or sometimes biting (mainly nipping bites with sea lions).

8. To leave the tank, swim along the bottom and up the side watching the animal as much as possible to fend off attack. Still do not take aggressive action. Swimming across the surface seems to be a submissive gesture and you may be subject to greater physical danger.

Diving with sharks (Also see 8.2.12):

1. Upon entry watch for nervous or erratic behaviour.

2. Be calm and swim slowly.

3. Do not block the path of or corner a shark.

4. Never enter a tank with open wounds or pass body wastes once you are in.

5. Aggressive warning signs such as rigid body, arched back pectoral fins pointed down and exaggerated swimming action are but a few signs. Once these signs are observed you should leave the tank as fast but as quietly as possible with no splashing. Splashing and fast, abrupt movements on or underwater emits low frequency sound vibrations which will attract the sharks.

6. In the event of attack:
   a. Face the shark as much as possible while leaving.

   b. If more than one shark, crawl along the bottom then up the side.

   c. If the shark comes in for an attack, bring your knees up to your chest and kick him off. Preferably be on top of him and kick down or underneath and kick up. The shark can spin around much faster than he can move up or down because their locomotion is from side to side. The eyes and gill slits are also vulnerable and can be punched or jabbed to ward off attack.

   d. Always carry bang sticks or shark billys for defence and use a shark cage when possible. There is little defence against a shark that is intent on the kill.

Remember that you are there on the animal’s terms, not yours. You must respect and obey their rules.

8.3.14. Shipping lanes and fishing grounds
If possible, the relevant local and national authorities must be notified well in advance so that ‘notices to mariners’ can be issued. This may be a legal requirement in some areas. Diving anywhere near fishing grounds can cause problems both for the diving party and the fishermen. As part of the pre-dive planning, the local fisheries’ officer or the local fishing co-op or fisherman’s organization must be informed. It is courteous to inform the local fishermen individually insofar as this is possible. Finding out the normal hours that fishermen plan on
being in an area will allow the divers to try and dive during hours when fishing is at a minimum. Don’t bother asking fishermen to change their schedules to suit the diving.

Divers must either tow marker buoys or descend buoyed shot-lines. They must surface up these lines and must signal the surface of their intention to ascend. An affirmative reply must be received before ascent commences. In addition, there should be some remote method of signaling the diver either to stay down or surface. The use of an underwater voice communications system is highly recommended.

Whenever possible, diving should be conducted from a mother ship with a dinghy keeping close station on the divers. Appropriate signals must be hoisted. The support boat should carry radar reflectors. A radar check must be kept aboard the mother ship by the officer of the watch.

Diving involving decompression stops is not recommended as rapid recall of divers may be necessary with the approach of a vessel.

8.3.15. Subterranean artificial environments

**Background:** Some experiments require large tanks underground or in enclosed environments, such as an excavated cavern or mineshaft. This example is provided.

In an effort to provide experimental data on the matter of proton decay, a theorized mechanism of sub-atomic particle behaviour, a test tank 80 by 70 by 60 ft deep, containing 10,000 tons of ultra-pure reverse-osmosis water was constructed in 1981 in a working salt mine near Cleveland, Ohio. It was necessary to choose a site at considerable depth (2,000 ft below ground) in order to provide some shielding from background cosmic rays that would otherwise interfere with the experiment.

The tank was constructed by excavating a hole of the proper dimension and lining it with a double layer of 2.5 mm high density polyethylene. By pumping the water collected between the liners, it is possible to know very accurately the amount of leakage (if any). A floating ceiling of black Hypalon was placed over the tank to ensure total darkness when the detector operates. Two thousand forty eight photomultiplier tubes, each 8 inches in diameter and fitted with a 1 m² plate of light gathering plastic, line each of the six sides of this cube-shaped tank.

**Establishment of diving operations:** Following early successful support efforts, it became clear that diving would be necessary on a routine basis, not just in the installation phase. A diving team was built up, conforming to the university diving program.

Equipment specifically suited to the needs of the project was purchased and stored on-site to ease mobilization and to minimize the opportunities of contamination of the water. Equipment chosen included Viking (bag) dry suits, full-face masks with communications, dual 80 cubic foot tanks and a lightweight umbilical consisting of a safety-line with a communications conductor threaded through it. A compressor was placed on-site.

**Current procedures:** The proton decay (PDK) dive team is made up of university students and employees who must meet all the requirements set forth by the diving safety committee.

Additionally, PDK divers are trained in the specifics of the task (diving in enclosed space, entanglement potential, blackout potential, contamination avoidance, etc.). Special attention is also paid to safety requirements set down by the Federal Mine Safety and Health Administration and the owners of the salt mine in which the experiment is located. The use of mine
safety equipment (hard hats, battery lamps, carbon monoxide scrubbers, safety shoes, ID tags, etc.) is also necessary. For those divers regularly visiting the site, special courses in mine safety and first-aid must be scheduled and completed.

Diving is limited to no-decompression profiles and a 10-ft safety or precautionary stop is taken at the end of each dive. Because of the higher than normal air pressure above the dive tank, adherence to decompression table times introduces a safety factor. The tender makes regular air pressure checks and records the progress of the dive on a prepared form which becomes part of the permanent record.