In: Pollock NW, Godfrey JM, eds. Diving for Science 2007.
Proceedings of the American Academy of Underwater Sciences 26th Symposium.Dauphin Island, AL: AAUS; 2007.

# Scientific Diving Safety: Integrating Institutional, Team and Individual Responsibility

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## Abstract

Scientific diving enjoys an enviable safety record. An unusual cluster of accidents occurred over an eight-day period in August 2006, when three incidents associated with disparate science operations resulted in four fatalities. The first involved a 37-year-old graduate student in Florida, freediving to hand-capture an estimated 300-lb green sea turtle. The second involved a 56-year-old researcher in New Jersey, diving from a research vessel to install a sensor on an underwater observatory platform positioned 50 ft underwater. The third involved two US Coast Guard divers (31 and 22 years-of-age), diving from a Coast Guard icebreaker, 500 miles north of Barrow, Alaska. The collection demonstrates how easily seemingly reasonable situations can lead to incidents. Safety depends upon appropriate regulations, crew training, operational practices, individual capability and individual responsibility. Review of the three fatal incidents is used to frame the need for active strategies to reinforce the complementary function of institutional, team and individual responsibilities in scientific diving.

## Introduction

Scientific diving in the United States currently enjoys a relative autonomy from external regulation. The exemption from commercial diving standards was issued in 1982 after extensive lobbying by the scientific diving community. The success of the petition was due, in large part, to the excellent safety record of scientific diving. Continued freedom relies upon the continuation of that enviable record. This requires the commitment of every individual involved in or responsible for any aspect of scientific diving.

An unusual cluster of accidents occurred over an eight day period in August 2006. The three incidents, each related to a science operation, resulted in a total of four fatalities. The collection provides a powerful example of how easily seemingly reasonable situations can lead to incidents. The cases are used to discuss strategies to reinforce the complementary nature of institutional, team and individual responsibility in operational safety discussed.

## August, 2006 Case Reports

### *August 10 - 3 mi (5 km) south of Sebastian Inlet, Florida.*

A 37-year-old male graduate student failed to surface after a breath-hold dive attempting to hand-capture an estimated 300-lb (136 kg) green sea turtle to bring it to the surface for study.

Background: A group of turtle researchers was conducting a turtle survey from small vessels. The goal of one graduate student was to develop a project to study male sea turtles that, unlike females, do not come into shore for nesting. The technique for hand capture of turtles was well established: A swimmer grabs the carapace fore and aft from above and behind, levers the aft end down, and directs the swimming turtle upwards. Additional swimmers are usually available to provide assistance. Scuba is not worn, as it makes the diver too slow to complete the capture. In this case, the experienced victim jumped into the water from the boat when he saw the turtle just below the surface. He held on and was taken underwater. Emergency services were contacted when the victim did not surface within four minutes.

Outcome: The events occurring underwater are unknown. There was not a second swimmer in the water watching the events. The victim's body was found four days later, with no wounds evident.

***August 14 - offshore of Atlantic City, New Jersey.***

A 56-year-old male diver died after entering the water from a research vessel to install a sensor on an underwater observatory platform positioned 50 ft (15 m) underwater. The problem developed shortly after the diver entered the water. He was unresponsive during the initial communication check.

Outcome: The events occurring underwater are unknown. Cause of death was attributed to a pre-existing medical condition.

***August 17 - 500 mi (800 km) north of Barrow, Alaska.***

A 31-year-old female and a 22-year-old male died while conducting a familiarization dive from the surface of the ice alongside a 420-ft (128-m) US Coast Guard icebreaker. The vessel was conducting science missions for the US National Science Foundation.

Background: The dive coincided with a period of ice liberty, when normal operations were suspended. It was approved for familiarization purposes. The tenders supporting the dive were largely inexperienced, with most of the training they received provided immediately prior to the dive.

The female had conducted only seven polar dives, all surface-supplied. The male had completed no polar dives. Each diver wore approximately 60 lbs (27 kg) of weight. Each was tended on a separate line. Communications with the surface were to be maintained by line signals. The plan was to dive to a depth of 20 fsw (6 msw). A third diver experienced a suit leak and left the site to get changed aboard the ship.

Once below the ice, both divers descended extremely rapidly, reaching maximum depths of 187 and 220 fsw (57 and 67 msw), respectively. The pull on the tether generated by each overweighted diver was mistakenly accepted as repeated 'okay' signals. Concern of surface personnel was voiced but not acted upon until most of the tether line had run out and the third diver returned to the site. The divers were pulled to the surface, initially at a rate of approximately one foot per second, and then as rapidly as possible. The divers reached the surface after approximately 10 min underwater.

Outcome: The divers' air supply was found to be exhausted or close to exhausted. Cause of death was designated as asphyxia and pulmonary barotrauma. Critical errors were attributed to both command and the dive team. Command errors included inadequate oversight and lack of familiarity with Coast Guard and Navy rules. Crew errors included inadequate crew complement, inadequate crew training/experience, deviation from plan, and gross overweighting.

**Case Insights**

While each of the three incidents described above were associated with scientific research programs, none fell under the classic definition of scientific diving. The first incident involved freediving, distinct due to the lack of a pressurized gas supply, and unregulated by most research diving programs. The second situation was more appropriately classified as a working dive. The third problem arose on a dive conducted for training that was completely independent of the scientific mission of the cruise.

The problem, though, is not of definition, but responsibility. Aquatic activities conducted in support of science, direct or indirect, require oversight by diving control boards and diving safety officers. This makes sense if for no other reason than to provide the benefit of the experience of scientific diving leaders to the user group. Techniques to hand-capture turtles are well tested. Proposals to do so as a solo activity, however, would have led to discussions that might have altered the outcome in this case. While few enjoy having their activity regulated, planning that includes those with professional safety experience can be beneficial. It is far better to have this communication before an accident occurs and with an authority trying to help researchers achieve their goals. In this case, the presence of a backup swimmer and a deployable buoyancy device may have made a critical difference to the outcome.

The second incident was attributed to a medical fitness issue. While fitness issues can be exacerbated by exceptional conditions, they can also be exacerbated by relatively benign ones. The shift of blood to the thorax resulting from immersion and the added resistance associated with breathing through a regulator are both physiological stressors faced by divers. The speed with which the problem developed in this case suggests that these normal stressors may have played the dominant role. Medical screening identifies many at-risk persons, but serious problems can arise even after problem-free comprehensive physical exams. The risks of unexpected collapse can be reduced by ensuring that participants remain physically active and fit. Realistically, however, this risk will never be eliminated. It may even increase since the population of divers in general is seen to be aging. Problematically, patterns of medical fitness within the scientific diving community are not commonly reported and physical fitness is generally not well monitored after initial evaluation (Ma and Pollock, 2007).

The third incident demonstrates how things can still go wrong in a system with well-established rules that include multiple levels of oversight and responsibility. Violations could have stopped the fatal dive operation at several points before it was carried out. The fact that it was not stopped may reflect an assumption of protection given the other levels of approval. To its credit, the Coast Guard conducted a full investigation of the incident and openly released the findings. The findings confirm that having regulations is not enough. In this case, the chain of command likely obfuscated individual responsibility and led to calamity. Too many individuals were not sufficiently aware to ask the right questions, and a faith in the system deterred action.

**Programming Safety**

Once solely the concern of the individual, societal norms have shifted much of the responsibility for safety to higher authorities. This is generally effective for product safety and public safety but in no case should it release individual responsibility. Safety programs are most effective when each level, from institution to individual, actively support initiatives (Figure 1). For scientific diving, it is the umbrella organization, such as the American Academy of Underwater Sciences (AAUS), that brings together experts in operations and safety to develop general standards of practice appropriate for the work and able to meet all mandatory regulatory codes. The resultant documents serve as the parent standard. Institutions review the parent standard and make modifications appropriate to the demands of their operating circumstances. Since most in the administration will not have the necessary expertise, the diving control board, typically acting through the diving safety officer and sometimes with the help of outside experts, is tasked with ensuring that the right protections are in place. The key responsibilities of the institution are to ensure that appropriately trained personnel are available to develop the institutional standards and that adequate support is provided so that the standards can be met effectively by all workers.

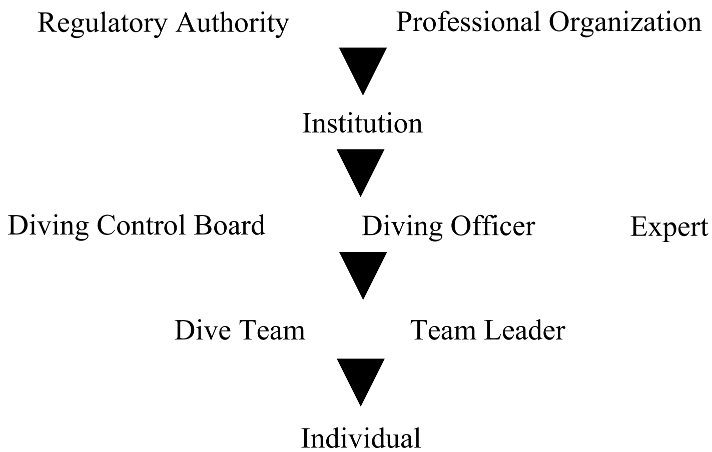


Figure 1. The hierarchical structure of scientific diving regulation.

The diving control board, again generally acting through the diving safety officer and possibly additional experts, is responsible for ensuring that dive teams and individual divers are both capable and adequately trained to understand and follow the standards. The dive team leader assumes the role of the safety supervisor operationally, when the diving safety officer will likely not be present. The dive team works collectively to support the team leader and each other.

The ability to perform safely ultimately comes down to the capabilities, training and support of the individual diver and his or her awareness and motivation. Having rules is not enough to ensure safety: The individual must know the rules and have the capacity to follow them appropriately. Understanding the rationale behind any rule is important to having it followed. Regulations deemed to be of little personal value will typically be the first ones ignored. Each person must be committed to the system to achieve adherence. The individual is influenced by a range of resources (Figure 2). One of the most critical roles of the diving safety officer is to help the individual diver reconcile input from these sometimes disparate resources.

## Hazards to Safety

Hazards to safety begin with the educational process. A generational loss of knowledge can compromise a rising group. Problems that had to be overcome by an earlier generation may not reach the level of awareness of a subsequent generation. This can leave the less informed at a disadvantage in some circumstances. Reductionism can create a similar threat. Diving education has progressively been streamlined as equipment has become more reliable and easy to use and optimization of teaching/learning techniques has become a subject of study. While streamlining can reduce the time and effort necessary to master basic skills, it may also eliminate some of the struggle that serves to develop a capacity for problem-solving in the student.

Time pressure is another hazard faced by scientific divers. The demand for high productivity in multiple professional areas makes it increasingly difficult to allow as much time as desired for either training or task accomplishment. While educational streamlining helps in terms of meeting paper goals, a vicious circle can be established that leaves individuals less than well prepared.

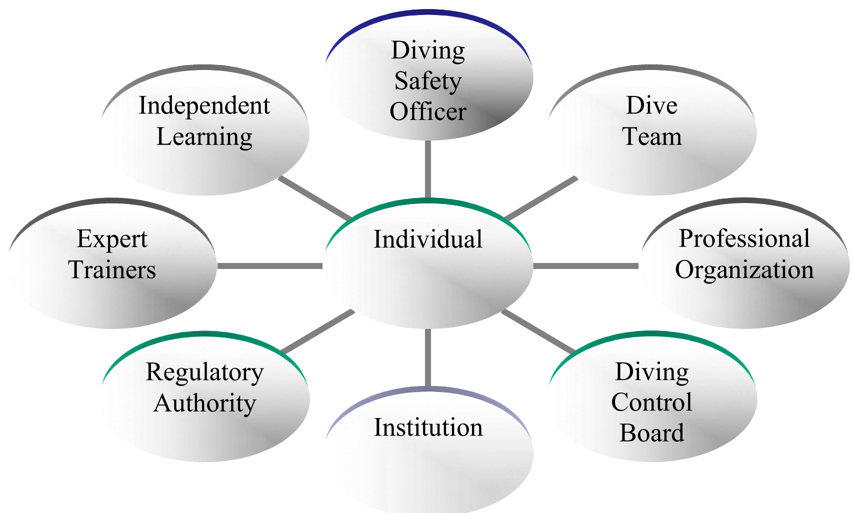


Figure 2. Influences contributing to individual scientific diver safety

Loss of mentorship can be a problem arising from the streamlining of training, programs, staff support and collegial interactions. Mentorship allows individuals to learn from the skills and mistakes of others. This can have a great positive impact on the level of performance of the mentee and can help to reduce the problem of generational loss of knowledge. Mentorship in scientific diving is critical since so many of the challenges that can arise are idiosyncratic. The ability to effectively problem-solve is often increased through mentorship relations.

The final hazard to be discussed is the faith in indestructibility most pronounced in (young) males and those who gravitate to activities classified by society as (relatively) high-risk. Risk-takers frequently know the rules and may even believe them appropriate for general application, but they also believe that their personal abilities preclude the necessity to be restricted. The hazards are compounded when risk-taker mentality is passed on to someone who may not share the same capabilities. Those in leadership positions must be extremely sensitive as to how their attitudes and actions may be interpreted by those around them. Safety, or lack thereof, starts with attitude. Professionalism may dictate masking personal proclivities to reduce the risk of negative impact on teammates or programs.

## Educating for Safety

Knowledge is critical to support an attitude for safety. Opportunities must be provided to ensure that all personnel can develop and maintain appropriate skills and awareness. Written standards are of little value without the means to ensure that both the letter and spirit of the rules are adopted.

The standard core for personnel training is the clinic format. A modular structure of clinics can provide valuable regular contact. Topic-specific information is exchanged and the opportunity for opportunistic exchange is created. Issues or questions that may otherwise lie fallow will often be brought out. This can be valuable for the individual and the group. Workshops and symposia provide similar benefits in facilitating exchange within the wider professional group. Collaboration with related organizations to develop special-topics workshops provides an excellent opportunity to pool experience.

Alternatives are needed to meet the evolving reality of current professional life. The computer-based focus of many professionals makes electronic communications desirable and cost-effective. Brief summaries of primary or recapped information can keep individuals thinking about scientific diving even if in phases of minimal activity. Including a variety of items - news, incident reports, insights, events, links to related sites - can make the reading interesting to most. Releasing the summaries on a monthly basis may provide the best balance between timely delivery and parsimonious use of distribution lists.

Web-based training (WBT) programs offer another powerful modern tool. Continuing education opportunity can be delivered to the individuals. While online training should not replace the workshop structure in a skills-oriented field such as scientific diving, it provides a great means to augment training. Obligatory training can be scheduled, graded and tracked automatically. Online training can also be used to provide background prior to clinics. This can help to ensure that the time spent in the clinic environment is appropriately spent.

WBT modules can also be useful in promoting awareness across the institutional hierarchy. Administrators that might not attend clinics or symposia might be willing to review computer-based materials. This can help to keep the needs of the program within the focus of upper administration. There is a cost, primarily time, to develop WBT modules. The advantage, however, comes in the minimal forward cost. Access can be provided to advertise or help to justify the program, modifications can be made at little or no expense and, in some cases, and creation of a revenue generating stream is possible.

## Conclusions

We are fortunate to have an excellent safety record for scientific diving. Protecting this record requires vigilance in the face of evolution and inevitable pressures on time and budgetary support. Technology and collaborations can facilitate opportunities for individual learning and integration throughout the organizational hierarchy.

## Reference

Ma AC, Pollock NW. Physical fitness of scientific divers: standards and shortcomings. In: Pollock NW, Godfrey JM, eds. Diving for Science 2007. Proceedings of the American Academy of Underwater Sciences 26th scientific meeting. Dauphin Is, AL: AAUS, 2007: 33-43.