A Review of the Nature of Diving in the United Kingdom and of Diving Fatalities (1998-2009)

Brian Cumming
Clare Peddie
Jim Watson
British Sub-Aqua Club
Telford's Quay, South Pier Road, Ellesmere Port
Cheshire CH65 4FL UNITED KINGDOM

The nature of United Kingdom diving is reviewed with descriptions of parameters such as dive site types, depths, water temperatures, underwater visibility, weather conditions and currents. Branch-based diving organisations are described with emphasis on the British Sub-Aqua Club. UK diver training systems rely heavily on the buddy system where skills and capability building of a buddy team emphasize buddy rescue skills, leadership skills and navigation. Dive management roles for different BSAC diver grades are summarized. Supervision, equipment, branch structure and decompression management, commercial training and the pace at which it takes place are all important attributes of UK diver training. The purpose, scope and data collection method of the BSAC Incident Report precedes the diver fatality analysis discussion of 140 of the197 incidents between 1998 and 2009.

THE NATURE OF DIVING IN THE UNITED KINGDOM

Types of Dive Sites

The 17,000-km coastline of the United Kingdom (UK) is highly diverse with more than 1,000 islands that provide a wide range of habitats for divers to explore including wrecks, caves, reefs, walls, piers, kelp forests and inland rivers and lakes.

The nautical history of the UK, the busy shipping lanes and many shipping casualties from two World Wars in which the UK was heavily involved has provided more than 44,000 shipwrecks distributed around the coastline, a significant proportion of which are visited by UK divers. The wrecks from World War I and World War II are deteriorating, and wave action has served to break up the shallower wrecks. However, a large proportion of the deeper wrecks remain intact and untouched. These wrecks provide a focus for the proliferation of marine life and a source of historical interest for divers.

"The nautical history of the UK, the busy shipping lanes and many shipping casualties from two World Wars in which the UK was heavily involved has provided more than 44,000 shipwrecks distributed around the coastline, a significant proportion of which are visited by UK divers."

The underwater topography in the UK is influenced by the highly varied geology and the effect of several ice ages. Therefore, the rock structures provide many reefs, walls and caves in which a very diverse and beautiful marine assemblage flourishes. Divers in the UK often become involved with voluntary organisations that record and survey marine sites and are active in the conservation of the sea.

Depths

Diving in the UK is available at all recreational depths (0-50 m), and there is a significant body of technical divers who explore wrecks in the mixed-gas range. Diving in the UK is sufficiently challenging that divers exploring deeper sites (>30 m) are encouraged to carry independent redundant gas supplies in the form of pony cylinders or twin sets.

Water Temperature

The water temperature in the UK is not as cold as expected from the latitude of the islands because of the influence of the Gulf Stream, which causes the temperatures on the west side of the UK to average 1°C to 2°C higher than on the east coast. In addition, temperatures seasonally range from 5°C (41°F) in winter to 18°C (64°F) in summer in the south of the islands and 4°C (39°F) in winter to 13°C (55°F) in summer in the north.

The majority of divers in the UK use a neoprene or membrane drysuit with an additional layer of thermal insulation underneath. Divers need to wear a neoprene hood and neoprene gloves that vary in thickness depending on the season. In the summer months in the south, divers can dive comfortably with a semidry neoprene suit, but most divers opt for a drysuit to give them year-round flexibility. The use of a drysuit adds additional bulk and the need to provide specific training in the use of the suit.

Underwater Visibility

The underwater visibility varies between 0 and 30 m depending on the seasonal growth of plankton that occurs during the spring and autumn seasons and the sediment load from estuaries and sediment churn during frequent windy periods. The underwater visibility and/or the loss of light due to surface plankton makes carrying a torch (dive light) necessary for almost all dives in the UK.

Weather Conditions

"The water temperature in the UK is not as cold as expected from the latitude of the islands because of the influence of the Gulf Stream…."

The prevalent weather conditions in the UK mean that the surface conditions are frequently unsuitable for diving in the open sea, especially in winter. Divers can be subject to seasickness and exposure, and good judgment is required to choose dive sites sheltered from the wind and to avoid uncomfortable sea crossings.

Consequently, diving in the UK is seasonal, with the majority of diving taking place in the sea from April to October because conditions in the summer are generally warmer and the sea conditions are more often favourable. Some divers make use of inland sites or sheltered sea lochs to maintain diving throughout the winter months.

Currents

Tidal ranges between 4 and 10 m and the nature of the topography mean that tidal streams between slack water periods often make dives on certain sites impossible. On the other hand, divers in the UK frequently enjoy the benefits of tidal streams to facilitate exciting drift dives that can carry divers over very long distances in the course of a dive.

DIVING ORGANISATIONS IN THE UK

British Sub-Aqua Club (BSAC)

BSAC is the national governing body for the sport in the UK and has a membership of 35,000 in the UK and abroad. The club was established in 1953 and has an internationally recognised training programme that prepares divers for the rigours of UK diving.

Structure of the Organisation (Branch Based)

About two-thirds of the BSAC membership are also members of smaller branches of the organisation. Each branch has an elected Diving Officer who is responsible for all diving and training matters in the branch and who controls the safety of the divers. The Diving Officer is provided with detailed training plans, training support materials and safety advice by BSAC.

The branch-based structure of BSAC creates a supportive, structured environment in which divers can receive training and experience diving in the UK safely. The branch structure means that new divers benefit from the leadership and knowledge of more experienced divers. The organisation consists almost entirely of volunteers supported by a headquarters of around 20 staff who service the administrative needs of the club. The instructors who provide training within their branches do so on a volunteer basis, and the instructors are qualified through a UK-based instructor training scheme that qualifies more than 300-400 instructors per year. The instructor trainers and the training of instructor trainers are controlled by a National Diving Committee.

In addition to a well-developed and structured training programme, BSAC offers additional courses in all aspects of the sport of diving, and in the last 10 years BSAC has extended the training programme to provide courses in mixed-gas and rebreather diving.

BSAC Schools

In the UK and abroad there are BSAC schools that offer BSAC dive training on a commercial basis to entry-level divers and to existing BSAC members who wish to further their training.

BSAC Overseas Franchises

In Japan, Korea and Thailand, BSAC has franchise organisations that offer BSAC training in those countries.

Other Diving Organisations in the UK

There are other branch-based organisations in the UK: the Sub-Aqua Association (SAA), the Scottish Sub Aqua Club (ScotSAC) and the Comhairle Fó-Thuinn (CFT)/Irish Underwater Council that have a structure similar to BSAC but with a much smaller membership.

Other Training Agencies in the UK

There are several other training agencies active in the UK: PADI supplies a proportion of the entry-level training, as does SSI to a lesser extent. A number of different technical training agencies (IANTD, TDI, ANDI, ITDA, etc.) have serviced the divers who wish to extend their diving beyond the recreational range. These agencies offer training through dive schools and independent instructors but are not structured to provide support for continued diving experience.

UK DIVER TRAINING

The development and style of diving and diver training in the UK have been influenced and directed by the prevailing water conditions and the resources and facilities available.

Buddy System

Virtually all diver training systems rely on and promote the buddy system to provide some level of support between a pair of divers. A widely applied system in many parts of the world is for a number of buddy pairs to dive as part of a larger supervised group. This system requires buddy pairs to have basic skills, with in-water leadership (guiding, navigation, decompression management, etc.) and, if necessary, rescue assistance provided by a guide or divemaster. Such a system

"The branch-based structure of BSAC creates a supportive, structured environment in which divers can receive training and experience diving in the UK safely."

relies on the ability of the divemaster to see and maintain contact with the group, requiring good visibility.

Although in UK waters conditions can be encountered that would allow this system to be operated, the predominant conditions have resulted in UK training agencies (BSAC, SSAC, SAA and CFT) developing and evolving a different system.

The preferred UK system places the emphasis of diving procedure on a mutually supportive and appropriately skilled buddy pair. This means that within each buddy pair there needs to be shared skills and capability including:

- Buddy rescue skills
- Leadership skills
- Navigation

Buddy rescue skills

With the typical visibility conditions in the UK, a buddy pair should be able to reliably remain in sight of each other and be in a position to react to any problem that the buddy might encounter. It would be unlikely, however, that a supervising divemaster or rescue diver could maintain reliable contact. Consequently, the system in the UK has developed to teach full rescue skills from the start of diver training. The consequence of this has been to produce proficient buddy pairs in which either diver can provide rescue support to the other. The inclusion of rescue skills in initial training does increase the amount of time required to complete training but was initially consistent with the structure of club-based training.

"With the typical visibility conditions in the UK, a buddy pair should be able to reliably remain in sight of each other and be in a position to react to any problem that the buddy might encounter."

In response to changing attitudes to diving and diver training, in part due to establishment of professional agencies in the late 1990s, a more basic initial qualification structure began to be introduced but still retained important underwater rescue skills including the requirement for a controlled buoyant lift (CBL) of an unresponsive buddy. This allows divers with the entry-level qualification (BSAC Ocean Diver) to respond effectively should their buddy need assistance. It also means that due to initial training typically taking place in a swimming pool or similar sheltered water conditions that Ocean Diver students progressing to open-water training is capable of assisting their instructor should the instructor become incapacitated. The lack of resuscitation skills is then covered by the requirement for surface support.

Leadership skills

Although the skills requirement is for one member of a buddy pair to lead a dive, UK-based training provides leadership skills from entry-level qualifications so that both members of a buddy pair have some capability in this important role. This is to ensure, when two similarly qualified divers are diving together, that the conduct of the dive is by mutual understanding and agreement. In addition, it allows the handover or assumption of control from the designated dive leader during the dive if it becomes necessary to do so. There are prescribed "Dive Leader" level qualifications within the training programmes of UK-based organisations, but their specific role is orientated more toward leading less experienced divers or leading more challenging dives.

Navigation

With a reduced sphere of visibility the ability to navigate reliably is an important skill. In UK waters this ability becomes more important due to the prevailing types of diving. Wreck and offshore diving normally require the use of a shotline as a reference to facilitate reliable location of the site and to control and manage a safe ascent. Shore diving usually has limited entry and exit points, and the seabed configuration is rarely as well defined as a typical coral reef.

Consequently, the ability to navigate underwater to locate and navigate around a dive site and to ensure that a shotline or appropriate exit point can be located is considered an essential skill. Basic skills of pilotage (navigation by natural features) and simple compass navigation are therefore taught at an early stage, with more advanced techniques such as distance line and wreck orientation being taught at second-level courses.

Supervision

Supervision of groups of divers, especially the less experienced, is still important. Because of the prevailing conditions, where it is not possible to supervise a group underwater, UK training has developed a system for surface supervision to manage diving and has incorporated this into the training for higher diver grades.

One of the key benefits of a branch-based training system is the level of supportive supervision that is provided by the group. An important benefit of this system is the opportunities it provides for cascading experience from senior divers to those with lower grades and experience. This cascading experience is also formalised within the training regime where each grade develops the role played in the management structure (Table 1).

"One of the key benefits of a branch-based training system is the level of supportive supervision that is provided by the group."

Table 1: Dive management roles for different BSAC diver grades

Diver Grade	Dive Management Role
Ocean Diver	Can dive with another Ocean Diver only under an on-site Dive Manager
Sport Diver	Trained to act as an Assistant Dive Manager
Dive Leader	Dive Manager dives to • Known locations • With a charter boat skipper
Advanced Diver	Dive Manager dives to unknown locations (exploration dives)
First Class Diver	Dive Manager for major Expeditions and/or projects

The requirement for Ocean Divers to dive under an on-site Dive Manager derives from the limitations of their rescue skills. The Ocean Diver has the capability to rescue a buddy to the surface, but by having on-site rescue support a full rescue including resuscitation can still be provided.

Support activities

Due to the fact that diver training in the UK developed from a largely branch-based system then, as well as supervisory support, a wide range of supporting services came to be provided by the branches as well. This includes the provision of boats, initially small inflatables and dorys, now including 5-9 m rigid-hull inflatables (RIBs) and even hardboats, compressors, oxygen equipment and more recently gas-blending equipment and portable defibrillators. UK branch-based organisations have also developed the relevant training programmes for these support activities.

Equipment

Because the typical temperature range of UK water is 4-18°C, some form of protective suit is considered essential. In the early stages of the development of diving in the UK neoprene wetsuits steadily became the main choice of divers, but this then required the use of significant amounts of weight to compensate for the buoyancy the suit provided, and there was a subsequent development of the need to compensate for buoyancy loss at depth. The introduction of buoyancy devices like the Fenzy adjustable buoyancy lifejacket and subsequent development of stab jackets, buoyancy compensators and more recently wings all introduced complexity and the need for training in their use. Initially dealt with by specialist courses, their use was quickly incorporated into core diver training programmes. The development of drysuits followed a similar pattern but has produced the added complication that there is the potential for a diver to use two means of buoyancy adjustment and the potential need, in an emergency, for a buddy to control four potential buoyancy sources. The growth of technical diving further compounds this.

One often unacknowledged consequence of improvements in suit technology is that divers in the UK are spending increasing amounts of time underwater because they are staying comfortable for longer. In the early days 20-30 minutes would have been considered a long dive, but in more recent times dives of at least an hour are becoming common and not just for technical divers. This has the impact of increasing bottom time and consequently increasing the amount of staged decompression time required. UK divers accept decompression penalties for the benefits of increased dive duration it provides. As a result of this acceptance, travelling UK divers frequently find it difficult to understand and accept the limitations employed by commercial operations in clear-water locations where dive time and depth limits are controlled to limit dives to well within no-stop decompression limits and short surface intervals for two-cylinder dives.

"One often unacknowledged consequence of improvements in suit technology is that divers in the UK are spending increasing amounts of time underwater because they are staying comfortable for longer."

Decompression

Two different features of UK diving contribute to the attitude toward decompression in UK diver training. With more than 44,000 wrecks in UK waters it is unsurprising that a large proportion of diving takes place on wrecks themselves or for the marine life that inhabits them. Wrecks in shallower waters are usually broken up or dispersed by wave action, thus deeper wrecks are often favoured by divers. Deeper depths together with a reasonable amount of time exploring such a wreck will require the acceptance of a decompression penalty. Scenic diving on the other hand may potentially take place at any depth, but unlike tropical reefs where the majority of life is in the top 5-10 m, temperate waters such as in the UK have variety throughout the depth range. In addition to that, on rocky shores kelp beds are predominant and difficult to swim through, and so diving normally takes place beyond the range of the kelp (12-30 m, depending on water clarity).

Before the advent of reliable dive computers in the 1980s, diving on tables would require an assumption of a square profile dive at the maximum depth regardless of the actual profile. UK diver training used tables (Royal Navy and then RNPL) that used multiple five-minute stops for simplicity and to add additional safety margins. This subsequently had a knock-on effect with divers accepting substantial penalties to maximise their enjoyment of diving. This has led to a wider acceptance and increasing use of nitrox to provide a safety margin rather than to reduce decompression time.

Branch Structure

Diver training in the UK developed on the basis of a branch structure in which groups of individuals joined together to provide training and support services as noted previously. Training is provided by experienced branch members. Instruction is most commonly done on a 1:1 basis. This allows the student more focused and personal attention and is consistent with the typical UK limitations of open-water teaching. Such a training strategy would have an implication for the cost of training if the instructors were not giving their time and effort free of charge.

The support of senior members of a branch who are not instructors provides an additional dimension to the development of divers. Little consideration or research has been completed to date on the benefits that accrue for all parties from having one or more people in this role-model position.

Commercial Training

The original training of divers in the UK took place at a very small number of commercial training establishments where the founder members of branches received their initial training. As the branch system developed, the training of divers and instructors was incorporated in their own programmes.

There always remained a level of commercial training available, and growth was slow until the 1980s, when a steady and significant growth in the range of commercial training organisations, usually U.S. based, began, and it has continued to increase since that time. Initially, the training programmes were not specifically oriented toward UK conditions. This did cause some problems, including fatalities, as a result of large dive group sizes, for example, but this has been addressed in conjunction with the UK Health and Safety Executive (HSE) and the training organisations themselves.

Speed of Training

Branch instruction is founded on a model of weekly meetings of the branch. This usually centers around a swimming pool where initial practical diver training takes place. Pool sessions are typically of one-hour duration. As a result of this, initial training can take some time, not least of which because each new pool session will spend time refreshing skills previously taught that may have deteriorated because of the intervening period. More intensive training consolidates existing skills quickly, requires less repetition and can be completed in fewer sessions. The potentially slower week-on-week training can help to ingrain the training deeper and reduce the loss of learned skills over time, and it is especially suited to those who prefer the less stressful pace, especially the nervous or less confident individual. Although slower in general terms, most branch training is organised to take place over the winter months when less open-water diving occurs. This allows progression to complete open-water training in the early part of the season, leaving the remainder of the season to enjoy diving.

"The potentially slower week-on-week training can help to ingrain the training deeper and reduce the loss of learned skills over time, and it is especially suited to those who prefer the less stressful pace, especially the nervous or less confident individual."

Commercial diver training is orientated toward a more compact and continuous delivery of training. The continuous delivery of skills encourages quicker consolidation of skills and knowledge and reduces the need to relearn or refresh skills. The growth in opportunities for commercial delivery of training coincided with a change in working life practice in the UK with people having a busier working life and much reduced available free time as a consequence. The attraction of a shorter and more predictable training programme therefore had identifiable benefits.

The demand to complete training quickly also ties in with the substantial growth of the holiday market for people in the UK. Foreign travel to tropical locations remains a major growth area. With diving as a major attraction, there is an increasing tendency for people to either learn to dive on holiday or gain their qualification in the UK with the objective of diving overseas.

THE BSAC INCIDENT REPORT

The Purpose and Ethos of the BSAC Incident Report

BSAC collates data on all UK sports diving incidents and publishes an annual report. This report is available to all, free of charge, and can be accessed through BSAC's website: *www.bsac.com/incidents*.

The aim of the report is to highlight issues of diving safety so that the lessons learned can be shared with as wide a diving audience as possible. BSAC uses the information derived from these reports to help with the development of its training programmes and to make recommendations on all issues relating to diving safety. All personal information is treated with the utmost confidentiality; no individuals or locations are identified, and no critique or comment is given against individual diving incidents.

The free BSAC "Safe Diving" booklet at *www.bsac.com/safediving* is a summary of the key factors a diver should consider to ensure a safe and uneventful dive. One important source of information for this booklet is the lessons derived from the annual incident analysis.

Scope of the BSAC Incident Report

The BSAC incident report includes any incident that involves sports diving; it does not deal with commercial diving (except where a commercial school or instructor is engaged in a sports diving activity). It includes information on all sports divers regardless of their affiliation, and it covers diving that takes place within England, Scotland, Wales and Northern Ireland and the territorial waters of the same. It covers diving in swimming pools, inland waters and the sea, and it encompasses any snorkel diving incidents as well as divers using breathing equipment.

"The aim of the report is to highlight issues of diving safety so that the lessons learned can be shared with as wide a diving audience as possible."

The incident report also covers incidents that have happened outside of the UK that involved BSAC members in some way. However, such incidents are not included within the scope of this paper.

Sources of Information

The BSAC incident report draws information from a number of different sources:

- Divers report incidents using the BSAC incident report form; see *www.bsac.com/incidentform*. This form has been adopted by a number of sports diving agencies in the UK, and such reports generally come from the individuals involved in a specific incident or from an operator-controlled dive site. This reporting mechanism is our preferred format as it presents information in a manner that is directly compatible with the incident database.
- The Maritime and Coastguard Agency (MCA) is the UK agency responsible for coordinating the response to marine incidents (and some inland sites). The MCA feeds information on diving incidents to BSAC.
- The Royal National Lifeboat Institute (RNLI) operates a lifeboat service around the UK in response to requests for assistance from the MCA. The RNLI supplies information on diving incidents to BSAC.
- Free-form reports are gleaned from a number of sources such as ad hoc statements sent to us directly or derived from credible Internet sources.
- BSAC uses a press-cutting agency to supply press reports on diving-related incidents that are published in UK newspapers.

Data Capture

Because of the serious nature of fatal incidents and the inevitable involvement of the emergency services, we are very confident that we capture information on all the diving fatalities that occur in the UK. Often we receive reports on such incidents from a number of different sources. We are equally certain that we do not capture information on all the nonfatal diving incidents. However, we are confident that we gather enough information on nonfatal incidents to be able to derive a good understanding of the nature of these incidents and the lessons that can be derived from them. The information gathered is fed into a database together with a synopsis of the incident. The synopsis is a factual (nonjudgmental) summary of the incident constructed from the information received; it contains no personal information, and it is published in the annual report.

Dive Survey

To be able to put diving incidents into perspective it is essential to have a background understanding of the type of diving that is taking place and of the demographics of the people involved. To this end, in the summer of 2007, BSAC undertook a countrywide survey at 35 representative dive sites. This survey investigated the demographics of those involved, their diving histories and the nature of the diving that they undertook. This survey involved almost 1,000 respondents, and it has enabled BSAC to develop a good picture of UK diving. Information from this survey has been used in this paper to put a number of factors into context.

"We are confident that we gather enough information on nonfatal incidents to be able to derive a good understanding of the nature of these incidents and the lessons that can be derived from them."

Diving Incident Data — Scope of Analysis

The current incident database contains information that goes back to 1997, and this paper contains information from this database drawn from the period January 1, 1998, to December 31, 2009 — a period of 12 years.

BSAC uses a first-level categorisation for incidents as follows:

1. Fatalities
2. Decompression illness (DCI)
3. Surface or boating incidents
4. Ascent-related incidents
5. Technique-related incidents
6. Equipment-related incidents
7. Illness (non-DCI) or injury
8. Miscellaneous

Clearly, an incident could fall into more than one of these categories, but to avoid any double counting the more serious category (as indicated by the ranking above) is used. For example, poor technique that resulted in a rapid ascent, DCI and a fatality would be categorised as a "Fatality." However, if a fatality and DCI were avoided then it would be categorised as an "Ascent" incident.

In the 12-year period analysed in this paper there were a total of 4,799 incidents recorded in the database, and their distribution into these eight categories are shown in Figure 1. As can be seen, the smallest category is "Fatalities," and this chart shows 187 fatal incidents. Ten of these fatal incidents involved double fatalities, thus the total number of fatalities that occurred in this period is 197, analysed in more detail in the body of this paper.

Figure 1: Distribution of incident classification for incident data, 1998-2009

> "In some cases it was very clear exactly what happened, but in a number of cases there was insufficient evidence to be certain of the events, leading the authors to include an assessment of the most likely explanation."

ANALYSIS OF FATALITIES

Each fatal incident was reviewed to establish, as far as possible, the primary factor that led to the death; where relevant, secondary factors were also included. In some cases it was very clear exactly what happened, but in a number of cases there was insufficient evidence to be certain of the events, leading the authors to include an assessment of the most likely explanation. Finally, there are a number of cases where there is simply too little information to support any analysis of causal factors. The causal factors are reviewed in descending order with the most frequent first.

Insufficient information

This is the biggest category. In 57 of the 197 incidents (29 percent) there is simply too little known of the incident to be able to draw even tentative conclusions as to the causal factors. There are three main subdivisions of incidents in this category:

- Incidents where there are no surviving witnesses — This group includes solo divers, divers who became separated from their buddies before any apparent problem arose and divers involved in double fatalities.
- Incidents where insufficient detail is reported — These are less common since reports from coroners' court hearings are often, ultimately, obtained.
- More recent incidents where information has yet to be reported — As stated above, a valuable source of information is derived from coroner inquests. However, coroners' inquests can often happen years after an event, and there is no central source of coroners' reports nor is there a free right of access to such information in the UK.

The rest of this analysis looks at the remaining 140 incidents in which causal factors could be identified and their frequency (Table 2).

Table 2: Comparison of causal factors for 140 fatal incidents

Primary causal factor	Number	Frequency
Non-diving medical problem	38	27.1%
Rebreather	15	10.7%
Equipment problem	13	9.1%
Out of gas	12	8.6%
Inadequate pre-dive checks/brief	12	8.6%
Inexperience	10	7.1%
Buoyancy - light	10	7.1%
Buoyancy - heavy	8	5.7%
Narcosis	5	3.6%
Tangled (rope, debris)	5	3.6%
Trapped in wreck	5	3.6%
Other trauma	3	2.1%
Other rapid ascent	1	0.7%
DCI	1	0.7%
Unconsciousness	1	0.7%
Separation	1	0.7%
Total	140	100.0%

Nondiving-related medical problems

Thirty-eight cases (of the remaining 140) are ascribed to nondiving-related medical problems. In the great majority of cases these involved heart attacks, but there were a small number of strokes. Of these 38 cases, 27 are confirmed, and the remaining 11 are judged to be medical problems based upon the circumstantial evidence available. Two of these cases involved snorkel divers where it is not certain that any formal dive training had been received. It is arguable whether these incidents should be included in any analysis of diving incidents. However, they are recorded in the database for completeness.

Rebreathers

Twenty-seven cases (of the 197 fatalities) involved divers who were using rebreathers. However, seven of these fall within the "insufficient information" category, leaving 20 cases in the remaining group of 140 in which it is possible to draw conclusions. In five of these 20 cases the rebreather is not thought to be implicated in the fatality in any way (for example, a rebreather diver suffering a heart attack). This leaves 15 cases where it seems clear that the use of a rebreather was at the root of the incident. In 11 of these 15 cases it is believed that the diver made some error in the use of the equipment, the most common error being a diver entering the water without correctly switching on the equipment. In the remaining four of the 15 cases it is thought that some error occurred in the equipment itself. One of these cases involved what was described as a "homemade" rebreather, another involved a failed diaphragm, another involved "an oxygen surge," and the last was due to "an oxygen leakage" from the equipment.

It seems very likely that cases of diver misuse and equipment problems were also present in some of the seven cases where there is "insufficient information." However, there is no evidence available to prove this.

"It seems very likely that cases of diver misuse and equipment problems were also present in some of the seven cases where there is 'insufficient information.'"

Overall, 27 of the 197 fatal incidents involved divers who were using rebreathers (14 percent). Our 2007 survey indicated that only 4 percent of divers were regularly using a rebreather. The disproportionate number of rebreather diver deaths strongly suggests a significant increase in risk when using such equipment. It is not suggested that rebreathers are inherently unsafe, but it would seem that there is a substantially increased opportunity to make errors.

Equipment problems (excluding rebreathers)

In 13 cases equipment problems are cited as the primary causal factor. These cases exclude technical problems with rebreathers. While such events could be said to be equipment problems, they are counted separately because they are felt to be a distinct and critical causal factor. In three cases the event was initiated by a regulator free flow. In three cases a regulator fault occurred that led to a loss of gas supply. Two cases involved weighting systems in which the diver was unable to drop weight (in one case the belt was tied on). Two cases involved buoyancy device (BCD) control failures. In one case the inlet valve jammed open and resulted in a rapid ascent, and in the second case the inlet valve jammed in the closed position and the diver was unable to gain buoyancy. One case involved a direct-feed hose failure. One case involved a cylinder pressure gauge that was over reading and resulted in the consequent and unexpected loss of gas supply. The final case involved a diver who was diving in a semidrysuit that was too big, became very cold and resulted in a chain of events that ultimately led to her death.

Out of gas

In 12 cases it is clear that a diver running out of breathing gas was the primary factor that caused the incident. Often these cases led to a failed attempt to use a secondary gas source, loss of buoyancy (sometimes due to a lack of gas to inflate a buoyancy device), separation and drowning. Two cases involved divers reentering the water to recover lost equipment and doing so with very low gas supplies. Overall, 36 of the 140 fatalities involved divers running out of breathing gas, although in many cases this was a secondary or tertiary factor brought on by other primary causes (such as being trapped underwater).

"Arguably inexperience is a root cause of the great majority of fatal incidents."

Inadequate predive briefing and/or equipment checks

Twelve cases fall into this category. Seven of these involved an incorrect equipment setup that was not discovered until the diver was underwater. The main issues here were a failure to connect drysuit or BCD direct-feed hose or a failure to turn breathing gas on prior to entry into the water. Three cases involved divers who unknowingly entered the water using their pony regulator instead of their main regulator and then ran out of gas unexpectedly early in the dive. One case involved a double fatality where the divers entered the water and encountered difficult and unexpected conditions that led to their deaths with one reported finding of the inquest being that the "dive brief was inadequate."

Inexperience

Arguably inexperience is a root cause of the great majority of fatal incidents. Had the divers been more experienced then they would not have run out of gas, not entered the water without proper equipment checks, etc. However, in some cases divers have undertaken dives (or been led on dives) that were clearly significantly beyond their current level of ability. One example of this is where a diver is diving to a depth way beyond the maximum defined by his qualification status. In 10 cases inexperience was considered to be the primary causal factor for the deaths, and all these cases involved divers who were under instruction at the time of the fatal incident. Three cases involved an instructor with two or more trainees; two of these involved students struggling with their air supplies, and one involved a student who became tangled in line and then became low on air. Generally, these incidents involved events that would have been trivial for more experienced divers. Typical examples include water in the face mask, water in the mouthpiece or difficulty clearing ears. However, an inability to control these events often led to panic and subsequent drowning. One case involved a diver's first UK dive, first drysuit dive and rough sea conditions.

In all cases had the training been conducted in more benign conditions (depth, visibility, water movement, etc.) it is very likely that a serious outcome could have been avoided.

Buoyancy — diver too light

Poor buoyancy control is responsible for a large number of diving incidents (particularly DCI), and in this analysis 10 fatalities are ascribed to divers being too buoyant. Four cases involved divers losing control of their drysuits and making rapid ascents (inverted in three of these cases). Two cases involved weights; one diver diving without any weights and another who accidentally lost his weights at depth. Two cases involved divers simply failing to maintain adequate buoyancy control. One case involved a diver having problems deploying a delayed surface marker buoy, and one case involved a diver carrying a bag containing a heavy weight clipped to his upper harness. When he adopted an upright posture the bag depressed his drysuit inflator, and he made a rapid ascent to the surface. Six of these cases resulted in a death through some pressure-related injury (pulmonary barotrauma or embolism). In one case an inverted diver drowned, in one case the casualty ended up sinking and drowning, and in two cases the actual cause of death is not known.

"Poor buoyancy control is responsible for a large number of diving incidents (particularly DCI), and in this analysis 10 fatalities are ascribed to divers being too buoyant."

Buoyancy — diver too heavy

Eight cases have diver overweighting as their primary causal factor. Four cases involved divers who sank rapidly at the beginning or during the course of a dive and became separated from their buddies (one of these experienced a burst eardrum). Two cases involved divers who had completed their dives but sank from the surface. One case involved a diver who surfaced rapidly, dived again to conduct his decompression but failed to stop at the required stop depth. One case involved a diver who was heavy and sinking and who was eventually lifted using his drysuit because his buddy could not inflate the casualty's BCD.

Although only eight cases have this problem as their primary causal factor, it is important to note that this issue is also present as a nonprimary factor in 25 of the 140 total analysed fatalities. In a significant number of cases a casualty reached the surface or very near to the surface during the course of an incident only to sink back down again. It is quite clear that if these casualties had managed to stay at the surface their chances of survival would have been greatly increased.

Nitrogen narcosis

Nitrogen narcosis is recorded as the primary causal factor in five cases. All cases relate to divers using air, and the depths were 60 m, 60 m, 57 m, 55 m and 51 m. All cases involved divers making poor decisions and becoming confused at depth. Three cases involved divers failing to follow depth and time constraints. One case involved a diver becoming confused and unable to deal with a tangled rope, and in one case the diver appears to have simply lost consciousness.

BSAC has always stated that the limit for air diving is 50 m (and then only for suitably qualified divers). BSAC also recommends the use of helium mixtures for depths deeper than 30 m (with a maximum limit of 80 m — again, only with suitable training).

Tangled

Five cases involved divers who became tangled in rope and lines. Two cases involved incidents in which divers became tangled in delayed surface marker buoy lines, two cases involved divers who became tangled in lines laid on the bottom (one of these was a solo cave diver), and one case involved a diver who became tangled in a shotline.

Trapped in shipwreck

Five fatalities resulted from divers becoming trapped inside a shipwreck and drowning when their gas supplies became exhausted. One case involved a double fatality. In another case a diver had removed his cylinder to get into the wreck. In another case the casualty was found apparently stuck in a narrow part of the wreck. In four of these cases it seems that the divers lost their way due to reduced visibility caused by their movements inside the wreckage. It is believed that none of these divers were using guide lines.

Other trauma

Three cases involved divers who received nonpressure-related physical traumas. One involved a diver who during a night dive struck his head against a rock in rough sea conditions, lost consciousness and drowned. Another involved a diver who was struck on the head by a boat's propeller, and the third involved a diver who fell under a trailer during the recovery of a dive boat. This last case is arguably nondiving, but it occurred during an action directly connected to diving activities and is therefore reported for completeness.

"Five fatalities resulted from divers becoming trapped inside a shipwreck and drowning when their gas supplies became exhausted."

Rapid ascent

One case involved a diver who for no known reason simply made a rapid ascent to the surface, signaled distress and then sank from sight. Other factors may have been at work, but they are not recorded.

Decompression illness

One case involved a diver who died from a pulmonary embolism. At the surface after an apparently normal dive, he made himself positively buoyant and signaled "OK" to his buddy, then without warning he lost consciousness and subsequently died.

Unconsciousness

One case involved a diver who was undergoing drysuit training in a swimming pool. Without warning she lost consciousness and died after two subsequent heart attacks. The cause of death was recorded as pulmonary edema due to immersion. It is not clear why she lost consciousness in the first place.

Separation

One case involved a diver who, with her buddy, became separated from their boat at the end of the dive. The dive pair was at the surface for 70 minutes after their dive in very rough sea conditions, and the casualty lost consciousness and drowned during this time despite efforts by her buddy to resuscitate her in the water.

Separation occurred in a total of 55 of the 140 analysed fatalities (39 percent), but in all cases, except the one recorded above, it was as a result of some prior perturbing event(s). Separations are caused by divers being too buoyant or too heavy, divers losing contact with each other in low visibility, divers distracted by problems with equipment and many other causes. While separation is not a key primary causal factor, it is clear that if separations could be avoided once an incident has started, the possibility for assistance from the casualty's buddy remains and a death might be avoided. Once separation has occurred, the potential for assistance from the buddy is gone. It is very plausible that actions to reduce the chances of divers becoming separated from their buddies will reduce the number of fatalities.

Exacerbating Factors

In addition to the major causal factors identified above, a number of exacerbating factors have also been identified. These factors are believed to have increased the opportunity for the initiating factor to occur and/or reduced the ability of those present to resolve the incident once it had started.

Nonpair diving

Nonpair diving includes solo divers and divers in groups of three or more. Twenty-six of the total of 197 fatalities involved solo divers who had deliberately chosen to dive alone, either entering the water alone or deliberately separating from other divers and continuing alone once underwater. This represents a fatality rate of 13 percent for solo divers. We currently do not have any data to put this number into perspective, but it is thought that the number of solo dives that take place in the UK is significantly less than this. Intuitively, solo diving is likely to be more hazardous since the absence of the possibility of buddy assistance must increase the chances of a negative outcome in the event of an incident.

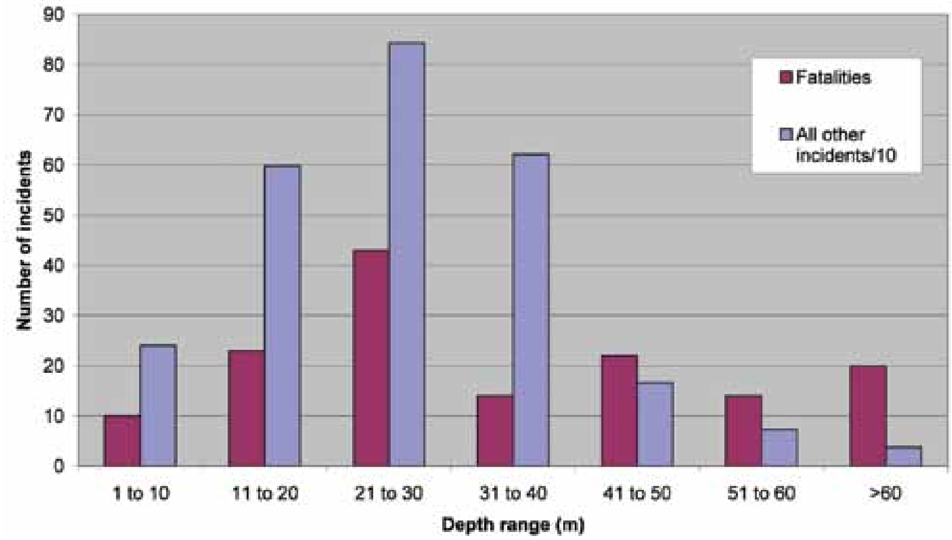
"It is very plausible that actions to reduce the chances of divers becoming separated from their buddies will reduce the number of fatalities."

Thirty-eight cases of the 197 total involved divers diving in groups of three or more. Very often this was in a training situation in which a single instructor was with a group of two or more students. The drawback with this configuration comes when there is a problem. One diver (often the instructor) assists another diver who is experiencing a problem, and the other diver(s) are left unattended and then get into serious difficulties. Of these 38 cases, 28 resulted in a separation (74 percent), significantly more than the background level of cases of separation, which is about 40 percent. Clearly separation is much more likely when groups of divers are diving together and, as discussed above, separation is a factor that contributes to a negative outcome.

Depth

Figure 2 shows a comparison of the maximum depth (where known) of dives during which an incident occurred. The darker bars show the number of fatal incidents that occurred in the depth ranges defined, and the lighter bars show the number of the nonfatal incidents recorded in the database during the 12-year period of this study. The nonfatal incidents have been divided by 10 to enable a visual comparison to be made more readily. For clarity, if one looks at the 21-30 m depth range, the chart shows that the number of fatalities occurring in this range was 43, while the number of nonfatal incidents occurring in this range was 843.

Figure 2: Maximum depths of dives in which incidents occurred



"Deep depths bring significant problems such as narcosis, greater gas consumption and long decompression, and when problems do occur the diver is much further away from safety and the support of his surface party."

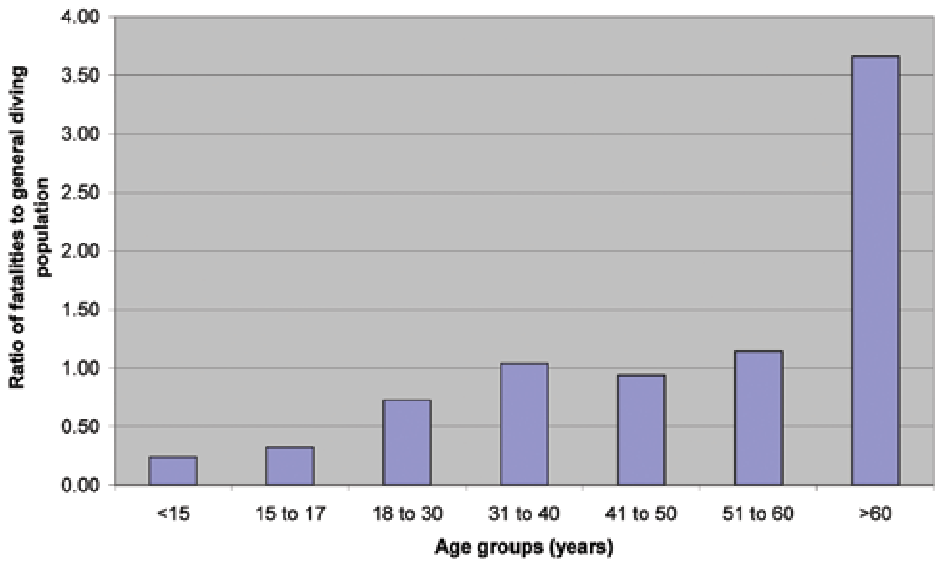
The nonfatal incidents are included to give an indicator of the "normal" distribution of diving depths, and the picture is, as might be expected, with the great majority (89 percent) of diving taking place in depths shallower than 41 m. This picture is probably somewhat biased toward the deeper depths since it includes 975 cases of DCI, and it is very likely that such incidents will involve deeper depths. Nevertheless, it is thought to give a good indication of the background of diving depths.

An examination of the depths of the fatalities, however, shows a clear bias toward the deeper depths. Among fatalities only 62 percent occurred in the "40 m or less" depth ranges, 38 percent occurred deeper than 40m, whereas only 11 percent of the diving takes place in this range. This finding is not unexpected. Deep depths bring significant problems such as narcosis, greater gas consumption and long decompression, and when problems do occur the diver is much further away from safety and the support of his surface party. The deepest depth recorded in this analysis involved a solo dive to 120 m. Note: This chart shows a total of 146 fatalities and 2,578 nonfatal incidents; in many cases the maximum depth is not known, and thus these incidents are not included in this chart.

Age

A recently identified trend is that the age of divers suffering fatal incidents seems to be higher than the age range of the general diving population, shown clearly in Figure 3. This chart compares the age grouping of divers who suffered fatal incidents compared to the age range of the general diving population derived from the 2007 diving survey. In each age range the percentage of fatalities in that group was divided by the percentage of divers in that group in the background survey. If the age range of fatalities exactly matched that of the background then each column would be unity, which, as can be seen, is not so. In the younger age groups it is less than 1, and in the over-60 group it is much higher than 1.

Figure 3: The effect of age on diving fatalities



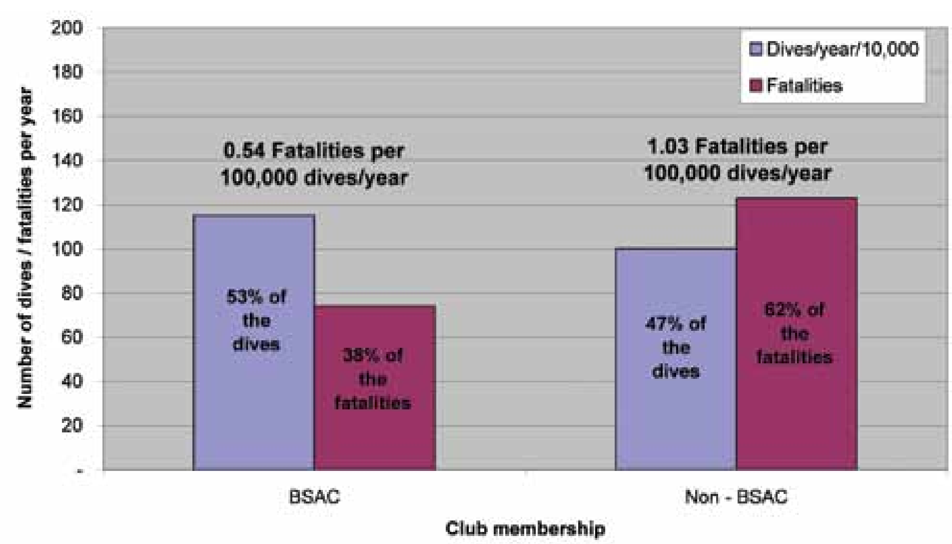
It is easy to speculate why this might be and very probable that much greater care is taken of young people in the <15 and the 15- to 17-year-old categories (depth limitations, pairing them with attentive elders and probably less susceptibility to nondiving medical problems). In the over-60 group the possibility for medical problems becomes more likely. The oldest fatality in the study involved a diver who was 78 years old.

"It is … very probable that much greater care is taken of young people in the <15 and the 15- to 17-year-old categories (depth limitations, pairing them with attentive elders and probably less susceptibility to nondiving medical problems)."

Club diving versus nonclub diving

One of the factors that was investigated as a result of the 2007 survey was the fatality rate of BSAC members versus non-BSAC members when compared to the amount of diving conducted by people in these groupings (Figure 4).

Figure 4: Fatality risk comparison



The 2007 survey indicated that slightly more than half the diving that takes place in the UK is conducted by BSAC members. A study of the fatal incidents in the 12-year period of this study shows that 38 percent were BSAC members (this includes individuals with multiple agency memberships), and 62 percent were not

BSAC members. A reduction of these two factors reveals that the fatality rate for BSAC members is 0.54 fatalities per 100,000 dives per year, whereas it is almost twice this at 1.03 fatalities per 100,000 dives per year for non-BSAC members.

While this may seem to be a strong advertisement for BSAC and its training programme (and it probably is), it is the authors' contention that more lies behind these numbers. It is our belief that any "good" club-based organisation improves diver safety for the following reasons:

- In a diving branch environment there are no commercial pressures to increase the speed at which training takes place. In fact, one criticism often leveled at the BSAC branch system is that it can be too slow. Typically branches hold weekly pool sessions and train new divers during the winter months, allowing for plenty of time for a sound basis of diving skills to be built.

- There are no commercial pressures to encourage instructors to take groups of trainees into the water. Usually diving clubs have a good ratio of experienced divers to trainees, and one-to-one training is normal, especially in open-water diving/training.

- Third, and perhaps most important, when trainees have finished their training and are ready to undertake "nontraining" diving, they are very likely to be accompanied by an experienced diver in a diving party that also has a lot of experience. This environment is able to avoid potential problems through the application of their knowledge and understanding and to nurture the ongoing development of the trainee diver. In nonbranch situations divers who have completed a training course usually lack this access to a supportive network and often take themselves diving with a similarly skilled buddy, sometimes with serious consequences. One of the reasons that a number of our inland sites have had significant numbers of fatalities is that relatively inexperienced divers can reach the site without any infrastructural support (they simply drive there) and have direct access to very deep water and challenging conditions. For this reason many of the better run sites insist on monitoring the skill level of their visitors.

"In a diving branch environment there are no commercial pressures to increase the speed at which training takes place."

SUMMARY AND CONCLUSIONS

Many of the conclusions from this study have already been highlighted in the paper, and there are no new "revelations." Earlier in the paper BSAC's "Safe Diving" booklet was mentioned, and in the great majority of fatal incidents it is possible to highlight a number of places where those involved diverged from the advice given in this booklet (also reflected in the advice given by other respected sports diving agencies). The only fatalities that are arguably unavoidable are those where some nondiving medical event takes place since it is very difficult to screen divers for potential serious medical conditions, and it would be unacceptable to place barriers to diving based simply on factors such as age or body mass index.

Key points to note for the "avoidable" incidents are as follows:

- Spend time in dive preparation. Time spent in this area could have prevented 29 percent of the analysable fatalities in this study.

  — Ensure that diving equipment is properly serviced.

  — Ensure that diving equipment is correctly prepared.

  — Ensure that diving equipment is properly fitted.

  - Conduct rigorous buddy checks; don't let familiarity lead to cursory checks.
  - Plan the dive, and follow the plan.
  - Ensure that all divers understand the dive plan and actions to take if things start to go wrong.
  - Buddy inexperienced divers with experienced divers.
  - Avoid "nonpair" diving.

- Monitor the progress of a dive effectively. Care in this area could have prevented or arrested 18 percent of the analysable fatalities in this paper.
  - Regularly check gas supplies and take action early to avoid running low.
  - Don't progress the dive into unplanned directions, for example, going deeper than planned, or wreck penetration without appropriate equipment.
  - Avoid becoming separated from your buddy, especially likely during ascent and descent. Use a datum (shotline, delayed surface marker buoy) to assist with this.
  - Be alert to developing problems with yourself and your buddy, and be ready to act early and effectively, for example, avoiding and assisting with tangled ropes.

- Practice the key diving skills, and keep this practice up-to-date. Good diving skills could have prevented or arrested 16 percent of the analysable fatalities in this paper.
  - Ensure that proper ascent rates can be achieved with ease.
  - Ensure that divers are able to achieve surface buoyancy easily and quickly so they can secure themselves at the surface in an emergency situation.
  - Practice out-of-gas procedures so they are second nature.

- Stay well within your personal comfort zone, and be ready to call off or abort a dive if necessary. Do not adopt a brave stance and assume that the dive must go ahead. Awareness of this point could have prevented 9 percent of the analysable fatalities in this paper.
  - When diving with trainees or less experienced divers beware of this point from their perspective, and advise and guide them accordingly.
  - Build up your experience gradually, progressing to more challenging environments at an acceptable pace and in the company of more experienced divers.
  - Be prepared to rebuild this experience after a layoff from diving. Do not assume that you can start from where you left off.

As stated earlier in this paper, 57 of the total of 197 fatalities that occurred in the 12 years analysed relate to incidents where there is little or no evidence to glean information on any causal factors. However, there is no reason to believe that anything other than the factors identified in this paper applied to these 57 as well. On this basis it is probably fair to conclude that, if the guidelines presented in the above summary had been followed by those involved in these 197 fatal incidents, only those with a medical root cause would remain, and probably another 140 UK divers would be alive today.

"Stay well within your personal comfort zone, and be ready to call off or abort a dive if necessary."

Discussion

CRAIG JENNI: You just mentioned the 27-percent medical statistic, and so approximately a third of the divers had a nonmedical-related incident that led to their death. What does BSAC do in regard to medical screening and/or fitness to address that issue?

BRIAN CUMMING: Basically it is self-certification. You are asked to fill out a medical form and declare any preexisting conditions. That is what we do. One of the issues — and I am not a medical physician, so there are people in the room more qualified to answer this question than me — but my understanding is the ability to effectively screen for these conditions is quite full. You have to go through an extensive process to screen people out who are potentially going to suffer from these problems. It is something that we as an organization are starting to look at. There is a consultant cardiologist in the UK, one of our members, who has started to get very interested in this. One of the problems we have in the UK is that the coroner process is very much uncontrolled nationally. We do not have automatic right of access to coroner findings. We cannot demand that information. So a lot of the information that could come out of some of these fatal analysis is quite hard to come by, but it is something we feel we need to investigate a lot more.

DAN CALLAHAN: You seem to have a lot of information on deaths related to people who are diving solo. Do we have any information as to whether those people were actually trained in solo diving techniques or if they were untrained, and that is not necessarily a solo-diving death but something that leads back to a lack-of-training death?

CUMMING: I do not believe they were trained in solo diving. My guess would be these are people who have some diving certification of some type but then choose to go dive on their own. I don't think they have had specific training for solo diving, no.

GREG STANTON: You mentioned that many individuals might look at your database and make corrections, but did BSAC make any corrections in their training standards or activity standards based on this data?

CUMMING: The thing we have had a really big push on recently, perhaps not related to fatalities in a big way, but one of the major issues that has come out of the incident analysis is buoyancy control. A huge amount of other incidents were being caused by poor buoyancy control. That is something that we have worked on quite hard over the last two or three years, introducing new training processes for buoyancy control, and the data seem to be suggesting that it is having an impact on those sorts of incidents coming down. So, in general, yes, if there are major concerns that we can identify, yes, we do push toward it. The sad thing about this to me is I have been writing this incident report that we have produced for about the last 13, 14 years, and I found myself writing the same thing again and again. We continually reissue the same advice, do this, do not do this. It does not always happen. So other people were expressing it earlier today, what can you actually do? If someone is determined to say, I am not going to listen to any of that, I am going to do my own thing, majority rules. Does anybody want advice on computer maintenance?

DR. PETER BENNETT: You have many regional differences on Scapa Flow regarded as deep, technical diving, so on. Is it more there than anywhere else?

CUMMING: There are a lot of incidents at Scapa Flow, yes. I cannot give you numbers, but, yes, there are. It is a very popular site, dark, deep. We do get a fair share of incidents there.

UNIDENTIFIED SPEAKER: It is reasonably deep at Scapa Flow. It's quite good visibility most of the time.