British Sub-Aqua Club

A review of the nature of diving in the United Kingdom and of diving fatalities in the period 1st Jan 1998 to 31st Dec 2009

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The nature of diving in the United Kingdom

Types of dive site

The 17,000 km coastline of the United Kingdom (UK) is highly diverse with over 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 over 44,000 shipwrecks distributed around the coastline, a significant proportion of which are visited by UK divers. The wrecks from the WWI and WWII 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 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 (0-50m) 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 (>30m) 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 to 2°C higher than the east. 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 semi-dry 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 30m 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 necessary for almost all dives in the UK.

Weather conditions

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 sea-sickness and exposure and good judgement 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 means 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.

Nature and history 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 which qualifies over 3-400 instructors a year. The Instructor Trainers and the training of Instructor Trainers are all 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 ten 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 who 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 who 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) and ScotSAC (based in Scotland) and CFT (based in Ireland) which have a structure similar to BSAC but have a very 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 and to a lesser extent SSI. A number of different technical training agencies (IANTD, TDI, ANDI, ITDA etc 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 has 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 Dive Master. Such a system relies on the ability of the Dive Master 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 in Ireland) 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 Dive Master 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 where 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. In response to changing attitudes to diving and diver training, in part due to establishment of professional agencies in the late 1990’s, 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 a diver 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 an Ocean Diver student 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
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 towards 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 requires 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 say a typical coral reef. Consequently the ability to navigate underwater to locate and navigate around a dive site and importantly 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.

Table 1 Dive Management role for different BSAC diver grade

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 Manage dives to • Known locations • With a Charter Boat skipper
Advanced Diver	Dive Manage dives to unknown locations (exploration dives)
First Class Diver	Dive Manage major Expeditions and/or projects

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).

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 5-9m Rigid Hull Inflatables (RIBs) and even hardboats, compressors, oxygen equipment and more recently gas blending equipment & 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^{o}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 mins 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 tank’ dives.

Decompression

Two different features of UK diving contribute to the attitude towards decompression in UK diver training. With over 44,000 wrecks in UK waters it is unsurprising that a large proportion of diving takes place on wrecks either for the wrecks themselves or the marine life that inhabit 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 5-10m, temperate waters like 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 (12-30m depending on water clarity).

Before the advent of reliable dive computers in the late 1980’s 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 5 minute stops for simplicity and to add additional safety margins. This subsequently had a knock on effect with divers accepting substantial penalties in order 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 where 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 focussed 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 1980’s when a steady and significant growth in the range of commercial training organisations, usually US based, began and it has continued to increase since that time. Initially, the training programmes were

not specifically oriented towards 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 centres around a swimming pool where initial practical diver training takes place. Pool sessions are typically of 1 hour duration. As a result of this, initial training can take some time, not least 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 and requires less repetition and so 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 is taking place. This allows progression to complete Open Water training in the early part of the season, leaving the remainder of the season to enjoy diving.

Commercial diver training is orientated towards 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 demands 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 in the UK. 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 internet 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 'Safe Diving' booklet www.bsac.com/safediving, which is available free of charge from BSAC, is a summary of the key factors that a diver should consider to ensure a safe and event free 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 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 reporting 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.
- Reports from the Maritime and Coastguard Agency (MCA). The MCA is the UK agency responsible for coordinating the response to marine incidents (and some inland sites) and the MCA feed information on diving incidents to BSAC.
- Reports from the Royal National Lifeboat Institute (RNLI). The RNLI operate a lifeboat service around the UK in response to requests for

assistance from the MCA. The RNLI supply information on diving incidents to BSAC.

- Free-form reports gleaned from a number of sources such as ad-hoc statements sent to us directly or derived from credible internet sources.
- Press reports. 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; very 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 non-fatal diving incidents. However, we are confident that we gather enough information on non-fatal 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 (non judgemental) 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 country wide 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 just under 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.

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 1st Jan 1998 to 31st December 2009 – a period of 12 years.
BSAC uses a first level categorisation for incidents; these categories are 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. What this hides is the fact that 10 of these fatal incidents involved double fatalities, thus the total number of fatalities that occurred in this period is 197. It is this 197 that are analysed in more detail in the body of this paper.

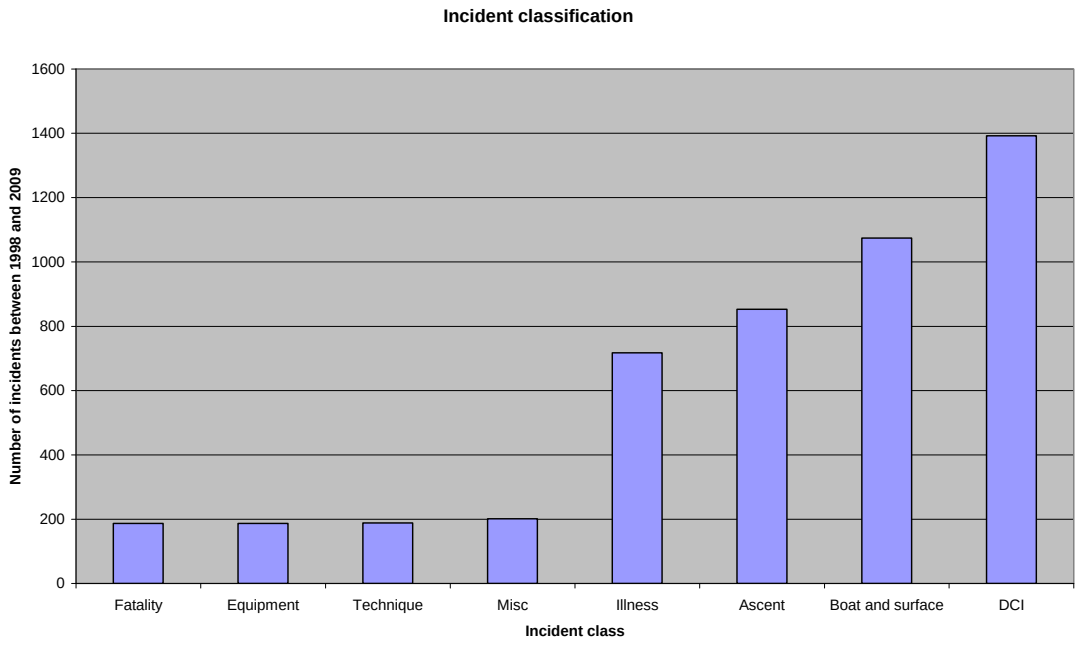

Figure 1 Distribution of Incident Classification for Incident data 1998-2009

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 are also included. In some cases it is very clear exactly what happened but in a number of cases there is insufficient evidence to be certain of the events; in some of these cases the Author has included 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%) 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 sub-divisions 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 as 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 where causal factors could be identified.
Table 2 charts these factors and their frequency.

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%**

Non-diving related medical problems
38 cases (of the remaining 140) are ascribed to non-diving 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.
2 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
27 cases (of the 197 fatalities) involved divers who were using rebreathers. However 7 of these fall within the 'insufficient information' category; this leaves 20 cases in the remaining group of 140 where it is possible to draw conclusions. In 5 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 4 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 'home made' 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 7 cases where there is 'insufficient information'; however there is no evidence available to prove this.
Overall 27 of the 197 fatal incidents involved divers who were using rebreathers (14%). Our 2007 survey indicated that only 4% 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 3 cases the event was initiated by a regulator free flow. In 3 cases a regulator fault occurred which led to a loss of gas supply. 2 cases involved weighting systems where the diver was unable to drop weight (in one case the belt was tied on). 2 cases involved buoyancy device (BCD) control failures; in one case the inlet valve jammed open and resulted in a rapid ascent; in the second case the inlet valve jammed in the closed position and the diver was unable to gain buoyancy. 1 case involved a direct feed hose failure. 1 case involved a cylinder pressure gauge which 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 semi-drysuit that was too big; the diver became very cold, resulting 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 re-entering 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).

Inadequate pre-dive briefing and/or equipment checks
12 cases fall into this category. 7 of these involved an incorrect equipment set up 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. 3 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 on in the dive. 1 case involved a double fatality where the divers entered the water and encountered difficult and unexpected conditions that led to their deaths; one reported finding of the inquest was that the 'dive brief was inadequate'.

Inexperience
Arguably inexperience is a root cause of the great majority of fatal incidents; if the diver was 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 very clearly significantly beyond their current level of ability. One clear example of this is where a diver is diving to a depth way beyond the maximum defined by their 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. 3 cases involved an instructor with 2 or more trainees; 2 of these involved students struggling with their air supplies and 1 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 being water in face mask, water in mouthpiece or difficulty clearing ears. However, an inability to control these events often led to panic and subsequent drowning. 1 case involved a diver on their first UK dive, their 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. 4 cases involved divers losing control of their drysuits and making rapid ascents (inverted in 3 of these cases). 2 cases involved weights; one diver diving without any weights and another who accidentally lost his weights at depth. 2 cases involved divers simply failing to maintain adequate buoyancy control. 1 case involved a diver having problems deploying a delayed surface marker buoy and 1 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.
6 of these cases resulted in a death through some pressure related injury (pulmonary barotrauma or embolism). In 1 case an inverted diver drowned, in 1 case the casualty ended up sinking and drowning and in 2 cases the actual cause of death is not known.

Buoyancy – diver too heavy
8 cases have diver over-weighting as their primary causal factor. 4 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). 2 cases involved divers who had completed their dives but sank from the surface. 1 case involved a diver who surfaced rapidly, dived again to conduct his decompression but failed to stop at the required stop depth. 1 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 8 cases have this problem as their primary causal factor it is important to note that this issue is also present as a non-primary factor in 25 of the total of 140 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 5 cases. All cases relate to divers using air and the depths were 60m, 60m, 57m, 55m and 51m. All cases involved divers making poor decisions and becoming confused at depth. 3 cases involved divers failing to follow depth and time constraints. 1 case involved a diver becoming confused and unable to deal with a tangled rope and in 1 case the diver appears to have simply lost consciousness.
BSAC has always stated that the limit for air diving is 50m (and then only for suitably qualified divers), it also recommends the use of helium mixtures for depths deeper than 30m (with a maximum limit of 80m – again only with suitable training).

Tangled
5 cases involved divers who became tangled in rope and lines. 2 cases involved incidents in which divers became tangled in delayed surface marker buoy lines, 2 cases involved divers who became tangled in lines laid on the

bottom (one of these was a solo cave diver) and 1 case involved a diver who became tangled in a shotline.

Trapped in shipwreck
5 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 4 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
3 cases involved divers who received non-pressure related physical traumas. 1 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 non-diving, but it occurred during an action directly connected to diving activities and is therefore reported for completeness.

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

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

Unconsciousness
1 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 oedema due to immersion. It is not clear why she lost consciousness in the first place.

Separation
1 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%), 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. Whilst 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.

Non-pair diving

Non-pair diving includes solo divers and divers in groups of three or more.

26 of the total of 197 fatalities involved solo divers; 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% 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 takes 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.

38 cases, out of the total of 197, involved divers diving in groups of three or more; very often this was in a training situation where 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 they then get into serious difficulties. Of these 38 cases 28 resulted in a separation (74%); this is significantly more than the background level of cases of separation which is about 40%. 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 non-fatal incidents recorded in the database during the 12 year period of this study; the non-fatal incidents have been divided by ten to enable a visual comparison to be more readily made. For clarity, if one looks at the 21 to 30m depth range the chart shows that the number of fatalities occurring in this range was 43 while the number of non-fatal incidents occurring in this range was 843.

The non-fatal 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%) of diving taking place in depths shallower than 41m. This picture is probably somewhat biased towards the deeper depths since it includes 975 cases of DCI and it is very likely that such incidents will involve

deeper depths. Never-the-less 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 towards the deeper depths. In the fatalities only 62% occurred in the '40m or less' depth ranges; 38% occurred deeper than 40m whereas only 11% of the diving takes place in this range.
This finding is not unexpected; deep depths bring significant problems, for example 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 120m.
Note; this chart shows a total of 146 fatalities and 2,578 non-fatal incidents; in many cases the maximum depth is not known and thus these incidents are not included in this chart.

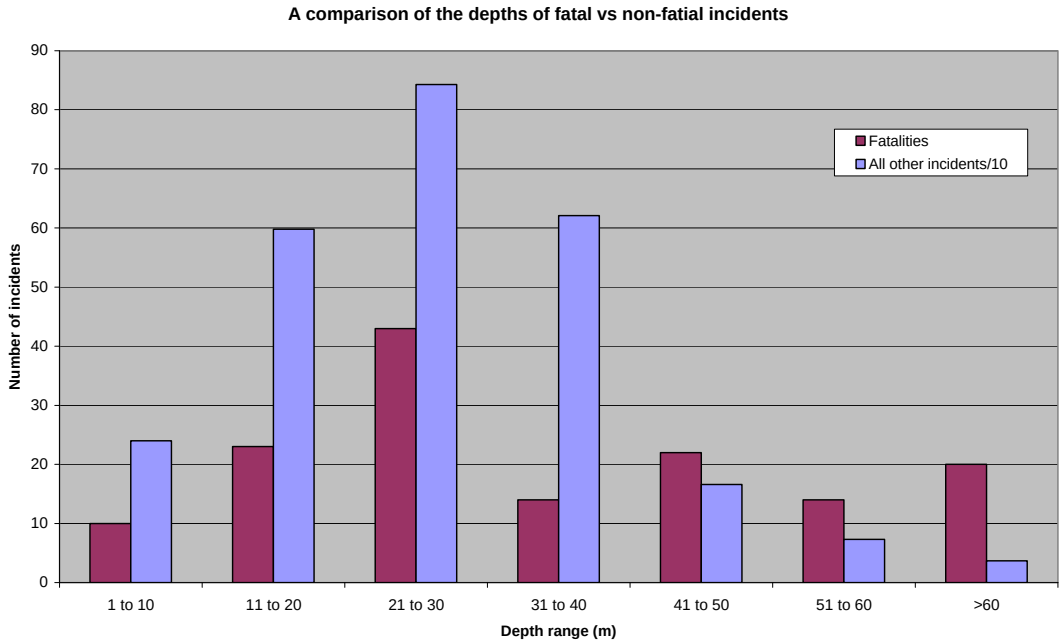

Figure 2 Maximum depths of dives in which incidents occurred

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. This is 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; as can be seen, this is not so. In the younger age groups it is less than 1 and in the over 60 group it is very much higher than 1.
It is easy to speculate why this might be; it is very probable that much greater care is taken of young people in the <15 and the 15 – 17 year categories; for example depth limitations, pairing them with attentive elders and they are

probably less susceptible to non-diving 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.

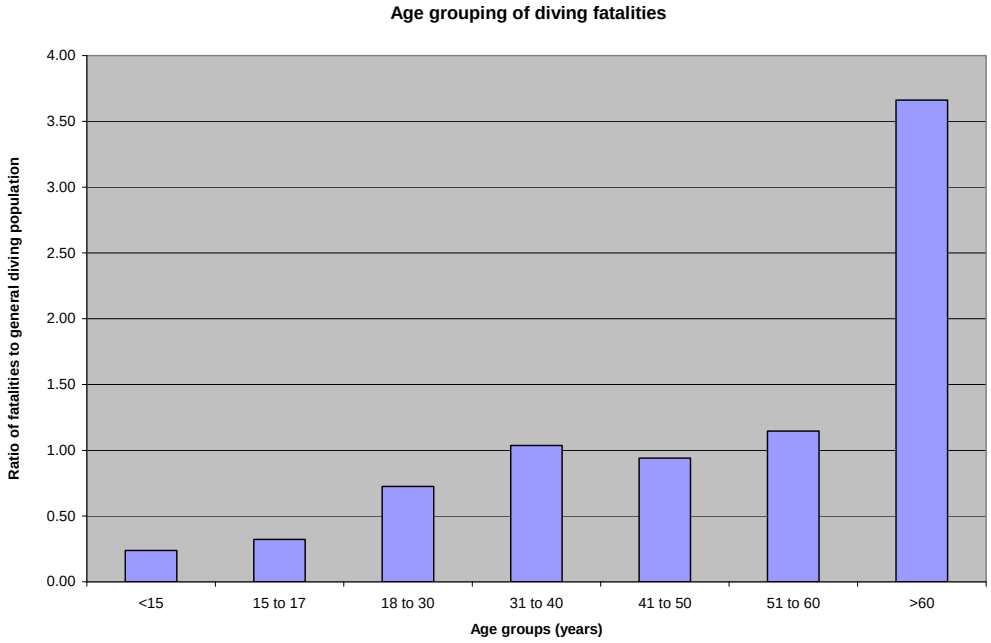

Figure 3 The effect of age on diving fatalities

Club diving vs. non-club diving

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

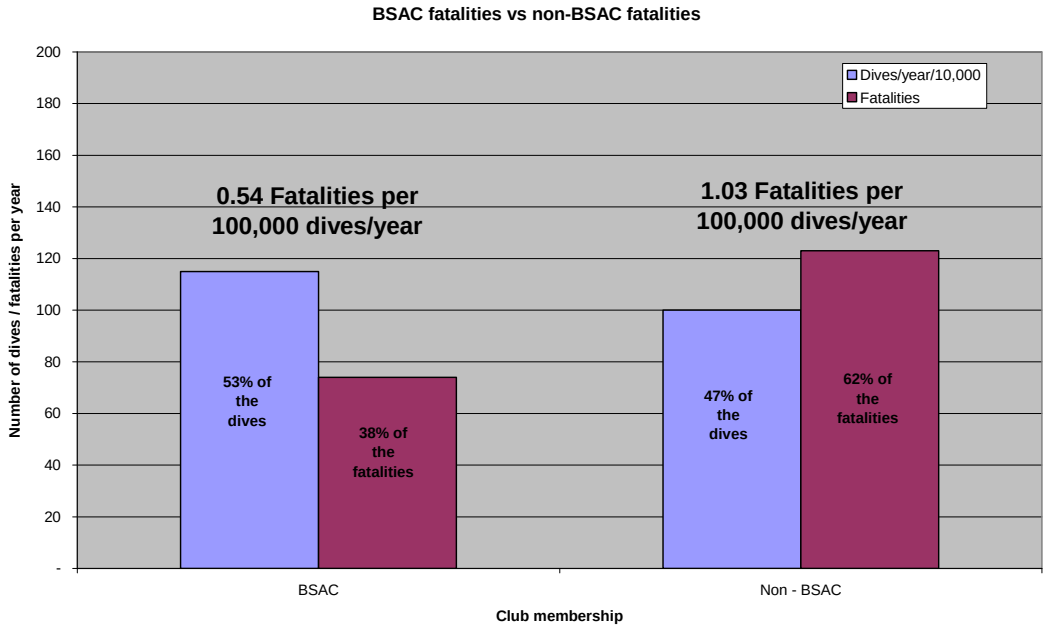

Figure 4 Fatality risk comparison

The 2007 survey indicated that just over 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% were BSAC members (this includes individuals with multiple agency memberships) and 62% 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.

Whilst this may seem to be a strong advert 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 and this is 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 levelled 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; this gives 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.
- Thirdly, and perhaps most importantly, when a trainee has finished their training and is ready to undertake 'non-training' diving they are very likely to be accompanied by an experienced diver in a diving party which 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 non-branch 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.

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 (and this advice is reflected in the advice given by other respected sports diving agencies); the only fatalities that are arguably unavoidable are those where some non-diving 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 BMI.

Key points of note for the 'avoidable' incidents are as follows:-

- Spend time in dive preparation – time spent in this area could have prevented 29% 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 'non-pair' diving
- Monitor the progress of a dive effectively. Care in this area could have prevented or arrested 18% 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, 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% 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 that they can secure themselves at the surface in an emergency situation.
  - Practice 'out of gas' procedures so that they are second nature.
- Stay well within your personal 'comfort' zone and be ready to call off or abort a dive if necessary; don't adopt a brave stance and assume that the dive must go ahead. Awareness of this point could have prevented 9% 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 re-build this experience after a lay off from diving; don't 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 too. On this basis it is probably fair to conclude that, if the guidelines laid out 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.