American Cave Diving Fatalities 1969-2007

Peter L. Buzzacott, Erin Zeigler, Petar Denoble, and Richard Vann

Fatality records for American cave-diving fatalities (n = 368) occurring between 1969 and 2007 were examined and circumstances preceding each death categorized. Safety rules breached were noted in each case. The number of deaths per year peaked in the mid-1970s and has diminished since. Drowning was the most frequent cause of death, most often after running out of gas, which usually followed getting lost or starting the dive with insufficient gas. Compared with untrained divers, trained divers tended to be older, died at deeper depths and further inside caves, carried more cylinders of gas and more often died alone. Untrained divers were more likely to have dived without a guideline, without appropriate number of lights, and/or without adequate gas for the planned dive. Since running out of gas was associated with the greatest number of fatalities for trained divers, we recommend that gas management rules should receive the greatest emphasis in cave diving courses.

Cave divers visit environments with inherent hazards that include flowing water, low or no visibility, a confusing number of possible exits, restrictions, entanglement in a guideline, and, by definition, a physical overhead barrier preventing divers from ascending to the surface when desperately low on air. The first recorded scuba dive within a flooded cave occurred in August 1946, described in detail in the best-seller, *The Silent World* (Cousteau & Dumas, 1953). The first cave dives in America using scuba were made in 1952 by the Florida Speleological Society (FSS), and one year later, the FSS established the first cave-diving training program in the United States (Exley, 1994). The first known English-language text on the exploration of "sumps and vauclusian springs" was a translation of *Caves and Cave Diving* by Guy de Lavaur, published in 1957 (DeLavaur, 1957). The first American known to have died while cave diving was Connie Limbaugh, who died in 1958 while diving a cave in France, and by 1966 a report on 86 American skin and scuba deaths included 11 deaths in caves or springs (Webster, 1966). This report identified likely contributory causes, such as diving alone or failing to use a lifeline, suggesting "In virtually all of the accidents, the victims' disregard of one or more of the recognized rules or procedures for safety was found to be a contributory cause" (Webster, 1966, p. 5).

The authors are with Divers Alert Network in Durham, North Carolina. Peter Buzzacott is also with the University of Western Australia, School of Population Health in Crawley. Petar Denoble and Richard Vann are also with Duke University, Department of Anesthesiology in Durham, NC.

Cave Diver Training in America

The first American cave diving instructional text was published in 1969, when Sheck Exley wrote the *Dixie Cavern Kings Cave Diving Manual*, the same year the National Association for Cave Diving (NACD) was established by David Desaultels (Exley, 1994). Today the NACD has over 1,000 current members who have completed cave diver training (Bauer, 2007). The *Cave Diving Manual* appeared in 1972 (Mount, 1972) followed by *Safe Cave Diving* in 1973 (Mount, Dickens, & Exley, 1973). This period of American cave diver training material production was concurrent with a series of diving safety seminars in which annual fatality reports and possible risk factors were presented (Desautels, 1970, 1972; Desautels & Briel, 1968). At this time, Desautels added details of 155 known cave and sinkhole diving fatalities to the Rhode Island University diving fatality database (Schenck, McAniff, Schenck, & Schenck, 1972). The subsequent report noted the high incidence of multiple fatalities in Florida caves, that cave and sink divers were dying at deeper depths than other American divers and that the proportion of cases involving untrained divers had actually risen in recent years.

In 1973, Sheck Exley formed and became chairman of the National Speleological Society (NSS) Cave Diving Section (CDS), to date the largest cave diver training organization in the world (Exley, 1994). In 1979, Exley published *Basic Cave Diving: A Blueprint for Survival*, with descriptions of safe diving practices and brief case narratives where these practices were not followed and divers died as a result (Exley, 1979). This close relationship between case review and safe practice has been repeated in cave diver training materials since. In 1991, the method was adapted to examine diving practices at shipwrecks (Chowdhury, 1991), where human-created overhead environments present challenges and hazards that are similar to cave diving. That same year, Martyn Farr published a case series of cave diving fatalities with potential root causes as an appendix (Farr, 2003). Today, many cave-diver training texts review cave-diving fatalities as part of the cave-diving course (Harrison, Bulling, & Richardson, 1998; Wohlers, 1993). The NSS-CDS continued to produce American cave diver training texts throughout the 1980s. Other training agencies followed suit in the 1990s and gradually as landowners became aware of the availability of training, untrained divers found it increasingly difficult to access popular caves (Farr, 2003).

When *Blueprint for Survival* was published in 1979, cave diver training agencies accepted that most cave diving accidents involved three initial common risk factors (Zumrick, Prosser, & Grey, 1988):

- Failing to dive with a continuous guideline to the surface;
- Failing to limit the dive's penetration to 1/3 of the starting air volume; and/or
- Diving beyond a safe depth for the type of gas being used.

In 1984, two additional rules were added: that all divers entering caves should have cave diving training, and each diver should have three sources of light, each capable of outlasting the dive (Jablonski, 2001). These five rules now form the core of many cave diver courses (Bozanic, 1997; Harrison et al., 1998; Jablonski, 2001).

Cave Diving Fatality Reviews

A case series of 11 British diving fatalities was published in 1980 (Churcher & Lloyd, 1980) in which overrunning the air margin was implicated in eight of those deaths. This review was soon followed by a descriptive case series of 11 cave and sinkhole diving fatalities occurring in South Australia between 1950 and 1980, published in 1981 (Horne, 1981) and revised in 1987 to include a further three cases (Horne, 1987). Horne found the majority of cave-diving fatalities (91%) involved running out of air as a result of either deep-diving with inadequate gas reserves or getting lost in silty, low visibility conditions. Horne concluded " . . . it is absolutely essential for all prospective cave divers to learn about the special hazards and techniques involved in the activity, before they enter water filled caves" (Horne, 1987, p. 64). Australian cave diving fatalities were included in annual diving fatality reports between 1972 and 1998 and in compendiums of these reports (Walker, 1998, 2002). Interestingly, cave diving deaths virtually ceased altogether in Australia after the Cave Divers Association of Australia was formed in 1973, following a number of high profile cave diving deaths (Bulling & Harrison, 1998) and access to popular caves became restricted to trained cave divers only (Farr, 2003).

Since 1992 through the present day, the NSS have published case narratives of recent cave diving fatalities, in the hope that future cave divers will not repeat contributory errors of judgment (Grey, 1992). In 1997, an analysis of 287 cave diving fatalities that had occurred within Florida was conducted and, where information was sufficient to suggest likely circumstances preceding each case, potential causal factors were proposed (Byrd & Hamilton, 1997). The authors noted that drowning accounted for the majority of causes of death (93%) and that a lack of cave diver training was the leading contributing factor, followed by the failure to use a continuous guideline back to safety.

In the United Kingdom, cave diving fatalities are included within the British Cave Rescue Council (BCRC) annual incident reports (Allwright, 2006) and also within the British Sub-Aqua Club's annual incident reports (Cumming, 2005, 2006). In 1999, the BCRC published an analysis of British cave rescues (Allwright, 1999), including seven cave diving incidents, modeled on an earlier analysis of 25 French cave diving fatalities (Dodelin, 1997).

In 2005, the NSS published a summary and analysis of ten American cave diving fatalities (Gooking, Green, & Burns, 2005), identifying likely contributing factors. In 2006, a British analysis (Brock, 2006) compared nine cave diving fatalities occurring within the previous 25 years to 11 that had occurred in the 34 years before that period (Churcher & Lloyd, 1980). The latter report concluded, "the most significant hazard to experienced divers is inadequate line management and the most frequent major hazard to inexperienced divers is lack of training" (Churcher & Lloyd, 1980, p. 1).

The work summarized above identified events that may have contributed to cave diving deaths and led to training programs with rules to make these events less likely. The effectiveness of these programs is suggested by a decline in the proportion of deaths involving untrained divers. We reviewed 368 cave diving deaths to identify the rules most frequently violated by either trained or untrained divers. We hypothesize that different circumstances apply to fatalities in these groups and argue that for trained divers, the most important rules are associated

with the most frequent incidence of deaths. We further propose that greater emphasis given these rules during training might make cave diving even safer with fewer cave diving fatalities.

Method

Data Sources

American diving fatalities were investigated by John McAniff of the University of Rhode Island between 1970 and 1989 (McAniff, 1970, 1989) in conjunction with the Divers Alert Network (DAN) from 1989 until his retirement in 1995 (Dovenbarger, 1991) and by DAN since 1995 through the present day (Vann et al., 2005). Cave diving fatality records contained within the collection at DAN were reviewed and the circumstances surrounding each death were classified according to a system similar in practice to one used in 1997 to classify factors relating to cave diving fatalities in Florida alone (Byrd & Hamilton, 1997) and to the method employed when classifying 103 shipwreck diving fatalities in 1992 (Chowdhury, 1992). Up to four stages in the chain of events leading up to each case were classified using a process of root cause analysis. Root cause analysis is defined by the USA Department of Veteran's Affairs as "a process for identifying the basic or contributing causal factors that underlie variations in performance associated with adverse events or close calls"(NCPS, 2008). The four stages were the *cause of death*, the *preceding event* immediately before the death, the *harmful action* known to have occurred immediately before the preceding event, and the event that led to, or *triggered*, the harmful action.

Causes of death were taken from autopsy, medical examiner reports, or death certificates. Circumstances preceding each death were classified according to evidence contained within each file, such as witness statements, police reports, equipment examinations, gas analysis reports, and other documents. As each new classification was identified and added to the instrument, the sequential number of cases reviewed was recorded and growth of the instrument was charted (see Figure 1).

We also noted cave diving safety rules that were broken in each case and then, when a broken rule directly affected the chain of events, breaking that rule was classed as relevant. Breaking the training rule was deemed relevant only when a diver was known to be untrained and known to have broken at least one other rule classed as relevant to the death. Merely being untrained was not deemed relevant if no other rules were broken and classed as relevant.

Each case was then again reviewed and the chain of events classified by a second reviewer. The two initial classifications were compared and overall interrater agreement calculated for up to four stages classified by the reviewers. Exact or proportion of agreement was measured for rules classed as broken or relevant. Disparate classifications were reexamined and the disparity resolved between reviewers. Raw initial agreement between raters during the first 316 cases measured just 52% when classifying which of the five rules had been broken (344/666 rules classed as broken), and 61% when classifying which of any broken rules had been directly relevant to the death (211/348 rules classed as broken *and* relevant).
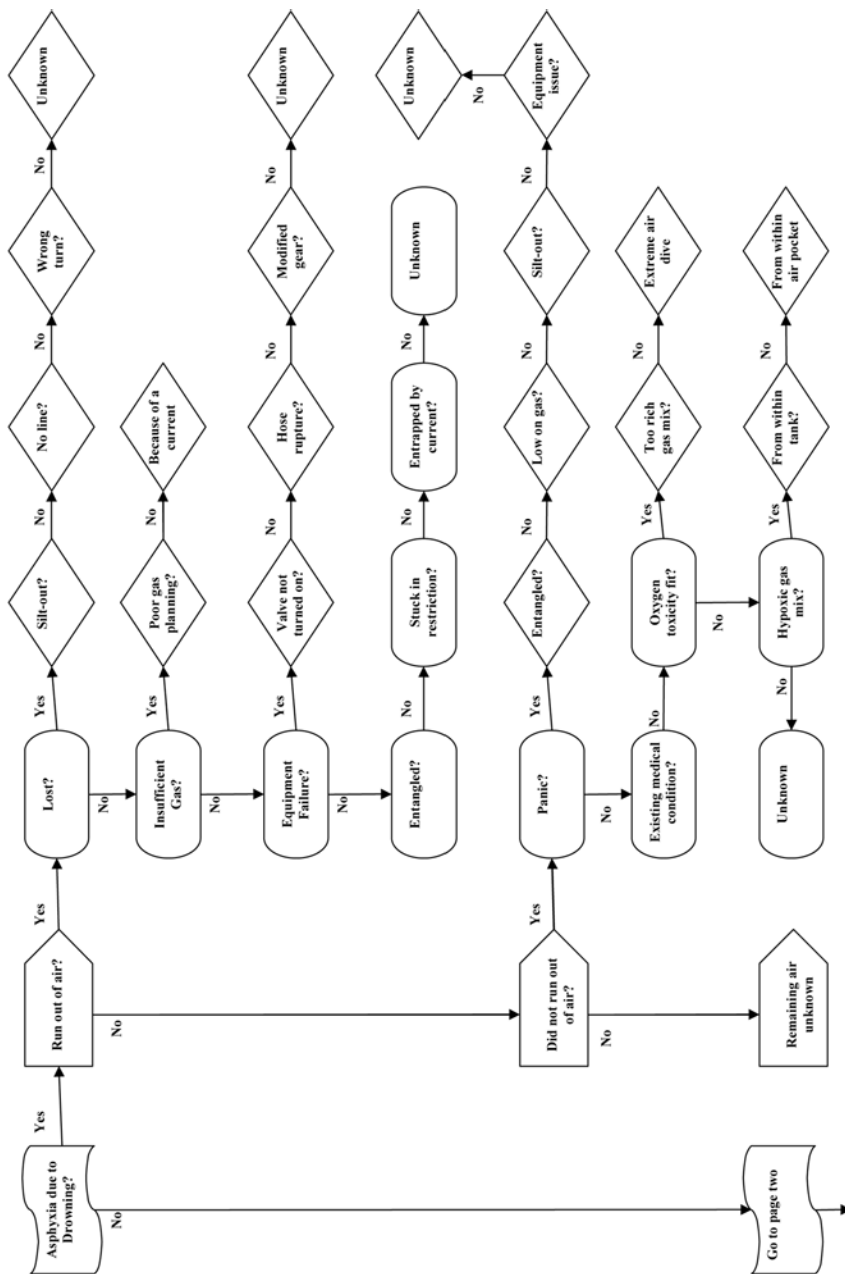
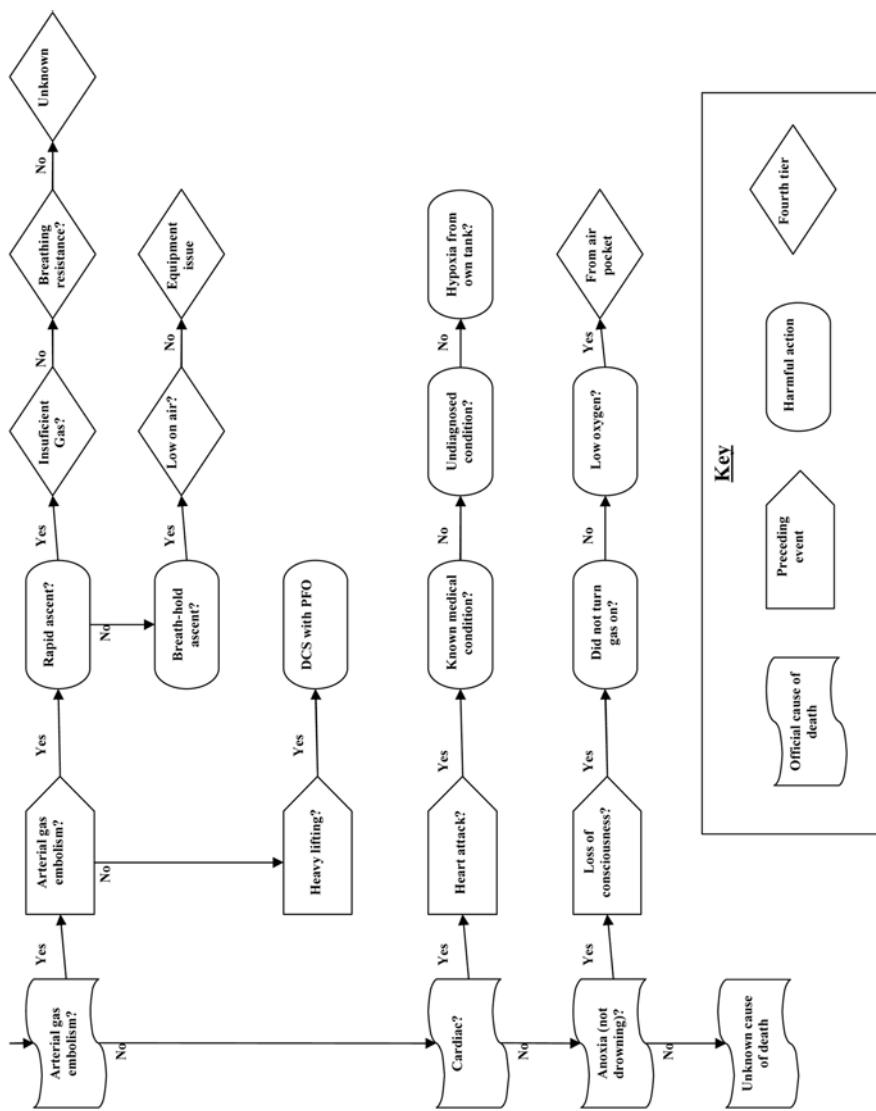**Figure 1** — Cases reviewed and growth of the instrument.

Figure 1 *(continued)*

Statistics

Data were managed using Microsoft Access and analyzed using SAS version 9.1 (SAS Inc, Cary, NC). Interrater agreement was measured using simple kappa, proportion of agreement adjusted for chance occurrence. Scores between 0.41–0.60 indicate fair agreement, 0.61–0.80 good agreement, 0.81–0.90 very good agreement, and between 0.91 and 1.00 excellent agreement (Byrt, 1996). Differences in means were tested using Student's T-tests for normally distributed continuous variables and by Wilcoxon Rank-Sum test for data with skewed distributions (depth and distance inside cave). Odds ratios are reported with 95% confidence intervals. Variables of interest were then fitted to a logistic model. Nonsignificant variables ($p \leq .05$) were removed by backward elimination.

Results

Initially, the classification instrument started with just two possible causes of death (drowning and unknown), three possible preceding events, eight possible harmful acts and 14 possible triggers (the fourth tier). These were selected as a starting point by reviewing 50 pilot cases before the commencement of the classification phase. The subsequent growth of the instrument over the review of the first 373 cases is shown in Figure 2. The finished instrument contained five causes of death, seven preceding events, 21 harmful acts, and 25 triggers. The last addition to the instrument occurred while reviewing the 244th case, and there were no further categories needed to classify the remaining 129 cases. Of the 373 cases co-reviewed, 316 occurred between 1969 and 2007 inclusive, and of the last 129
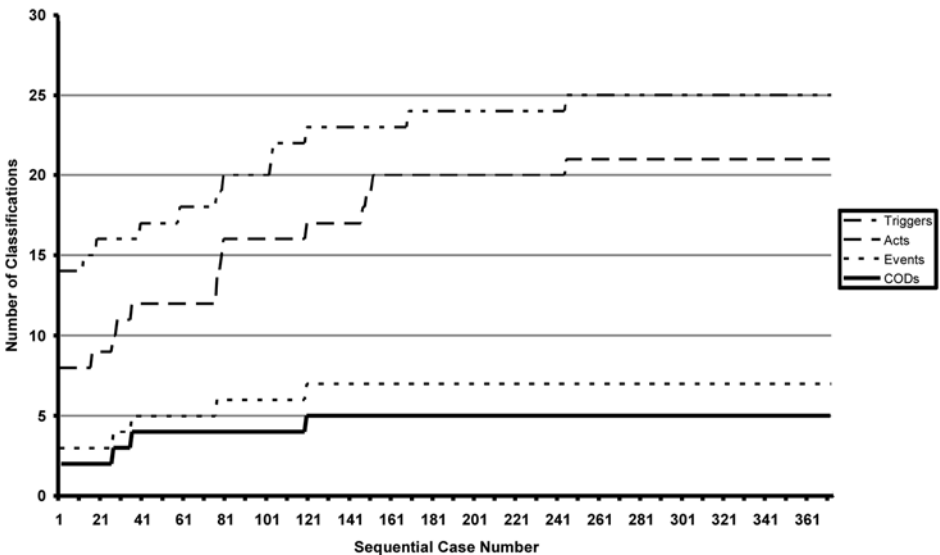

Figure 2 — Growth of classification categories by number of cases reviewed.

cases reviewed by both reviewers, 127 occurred during this same time period, which is when cave-diver training was available, as described earlier. For each of the four stages classified, interrater agreements are presented in Table 1. Measurement of initial agreement was completed with case number 316 and the remaining 52 cases were reviewed by single reviewers. As indicated by the last row of Table 1, at that stage initial agreement was generally good.

At the completion of the study, the final dataset comprised 368 divers who died while diving in caves between 1969 and 2007. Males accounted for 95% (n = 350) of all fatalities. Of the 368 cave diving fatalities, 329 (90%) died in caves within the USA, 14 (4%) in Mexico, and 9 (2%) in the Bahamas. The remaining 16 divers (4%) were distributed between 10 other countries. Most of the deaths (n = 287) within America occurred in Florida (87%), 6 (2%) died in Texas, 6 (2%) in Missouri, 4 (1%) in Georgia, 4 (1%) in Hawaii, and the remaining 22 divers (7%) were distributed across 16 other states. In Florida, three caves accounted for 111 of the 287 deaths (39%). They were Peacock Slough (n = 46, 16%), the Devil's System (n = 34, 12%), and Little River Spring (n = 31, 11%).

Of the 275 divers whose occupation was known, the two most common were student (n = 89, 32%) and U.S. Military (n = 34, 12%). Professional divers and/or diving instructors accounted for 15 of the 275 (5%). Of 199 divers for whom the level of recreational diving certification was known, 26 (13%) were rated diving instructors. Marital status was known for 262 divers; 96 were single (37%), 154 married (59%), and 12 were divorced/widowed (5%).

Seventy-four divers (20%) were known to have been trained in cave-diving techniques, while 208 (57%) were reported to have not completed any cave diving training. The training status of the remaining 86 (23%) divers could not be determined from information contained within the records. The number of deaths per year within the dataset appears to diminish over time, as shown in Figure 3, while the proportion of divers who were trained appears to have increased over the same period, as shown in Figure 4.

As shown in Table 2 binary tests indicated that compared with untrained divers, trained divers tended to be older ($p < .01$), to die at deeper depths ($p < .01$), further into the cave ($p < .01$), to carry more cylinders ($p < .01$), and to die alone ($p < .01$). Table 2 also illustrates the proportion of deaths where divers were known to have broken any of the five rules and when breaking those rules directly contributed to each death.

Table 1   Measures of Interrater Agreement

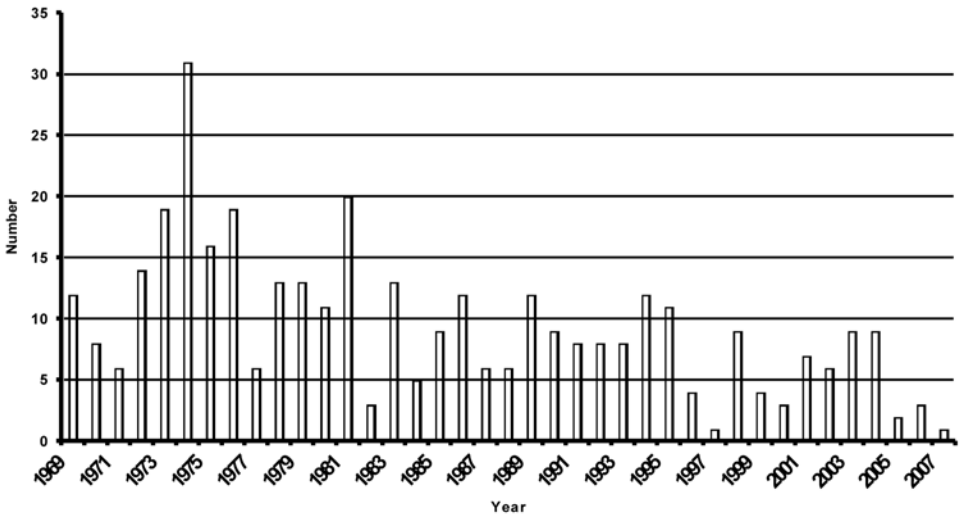|	Cause of Death	Preceding Event	Harmful Action	Trigger
Proportion of agreement (n = 316)	94%	91%	72%	89%
Proportion of agreement (last 127)	90%	98%	90%	93%
kappa (n = 316)	0.77	0.61	0.32	0.65
kappa (last 127)	0.76	0.88	0.68	0.57

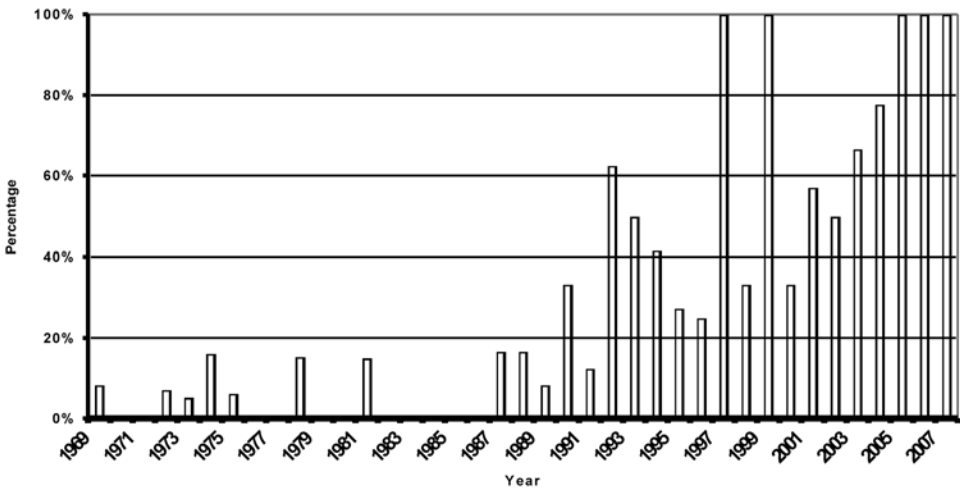**Figure 3** — Number of reported cave diving deaths by year.

Figure 4 — Proportion of cave diving deaths by trained divers, by year.

In addition to breaking the training rule, untrained divers were significantly more likely than trained divers to have broken the continuous guideline rule (OR 10.9, 95% CI 5.1, 23.0), the three lights rule (OR 15.6, 95% CI 6.8, 35.7), and the thirds rule (OR 2.8, 95% CI 1.6, 5.1). Among untrained divers, it was significantly more likely that breaking the rule of thirds would be relevant (OR 2.0, 95% CI 1.1, 3.7) and that breaking the continuous guideline rule would be relevant (OR 6.9,

Table 2   Characteristics of Cave Divers by Training Status

	Trained (n = 74)	Untrained (n = 208)	Overall (n = 368)
Age in years ū (*SD*, n)	37.5 (11.4, 72)	26.7 (8.9, 205)	28.8 (10.3, 363)
Depth in feet ū (*SD*, n)	155 (127, 49)	74 (37, 170)	91 (71, 268)
Distance in feet ū (*SD*, n)	750 (817, 41)	258 (406, 133)	374 (544, 210)
Number of cylinders n (%)			
Single cylinder	5 (7)	143 (69)	181 (49)
More than one cylinder	37 (50)	17 (8)	65 (18)
Total	42 (57)	160 (77)	246 (67)
Single or multiple n (%)			
Single deaths	58 (78)	89 (43)	188 (51)
Multiple deaths	16 (22)	119 (57)	180 (49)
Rules Broken n (%)			
Thirds Rule	19 (26)[a]	103 (50)[a]	152 (41)[a]
Training Rule	0 (0)[a]	208 (100)[a]	208 (57)[a]
Line Rule	9 (12)[a]	125 (60)[a]	162 (44)[a]
Gas Rule	12 (16)[a]	6 (3)[a]	25 (6.8)[a]
Lights Rule	7 (9)[a]	129 (62)[a]	167 (45)[a]
Broken *and* Relevant n (%)			
Thirds Rule	16 (84%)[b]	74 (72%)[b]	109 (72%)[b]
Training Rule	—	127 (61%)[b]	127 (61%)[b]
Line Rule	5 (56%)[b]	69 (55%)[b]	87 (54%)[b]
Gas Rule	3 (25%)[b]	2 (33%)[b]	8 (32%)[b]
Lights Rule	0 (0%)[b]	2 (2%)[b]	3 (2%)[b]

Note. ū = Mean, *SD* = standard deviation, n = number of cases. [a] = percentage of divers who broke rule, by training status; [b] = percentage of times broken rule deemed relevant, by training status.

95% CI 2.6, 17.8). Trained divers were more likely to dive with a gas that was inappropriate for the depth, such as deep-air diving (OR 6.5, 95% CI 2.3, 18.2), but breaking that rule was not more likely to be relevant.

Training did not appear to significantly change the likely cause of death. Causes of death among trained and untrained divers are presented in Table 3. For those divers who drowned (*n* = 294), the event that immediately preceded death is presented in Table 4. Untrained divers were more likely to have run out of air before drowning (OR 3.3, 95% CI 1.7, 6.3). For those divers who ran out of air (*n* = 211), the harmful actions that immediately preceded running out of air are shown in Table 5. Getting lost or making a dive with insufficient air preceded 76% of divers running out of air. Circumstances that preceded getting lost (*n* = 93) are presented in Table 6 and circumstances preceding insufficient gas (*n* = 67) are presented in Table 7.

Fitting the main effects to a logistic model, and removing least significant effects by backward elimination, the remaining differences between trained and untrained divers were that older divers who died in caves were more likely cave

Table 3 Cause of Death by Training Status

Cause of Death	Trained (n = 74)	Untrained (n = 208)	Overall (n = 368)
Drowning	47 (64%)	180 (87%)	294 (80%)
AGE	7 (9%)	1 (0%)	11 (3%)
Cardiac	3 (4%)	1 (0%)	4 (1%)
Anoxia	1 (1%)	1 (0%)	2 (1%)
Unknown	16 (22%)	25 (12%)	57 (15%)

Table 4 Preceding Events by Training Status for Drowning

Preceding Event	Trained (n = 47)	Untrained (n = 180)	Overall (n = 294)
Ran out of air	31 (66%)	134 (74%)	211 (72%)
Did not run out of air	15 (32%)	31 (17%)	56 (19%)
Unknown	1 (2%)	15 (8%)	27 (9%)

Table 5 Harmful Actions Preceding Air Depletion by Training Status

Harmful Action	Trained (n = 31)	Untrained (n = 134)	Overall (n = 211)
Lost	14 (45%)	62 (46%)	93 (44%)
Entangled	5 (16%)	9 (7%)	20 (9%)
Stuck in restriction	1 (3%)	3 (2%)	4 (2%)
Entrapped	1 (3%)	1 (1%)	2 (1%)
Equipment failure	1 (3%)	3 (2%)	7 (3%)
Insufficient gas	8 (26%)	49 (37%)	67 (32%)
Unknown	1 (3%)	7 (5%)	18 (9%)

Table 6 Circumstances Preceding Getting Lost

Preceding Getting Lost	Trained (n = 14)	Untrained (n = 62)	Overall (n = 93)
Silt-out	5 (36%)	33 (53%)	41 (44%)
No line	4 (29%)	27 (44%)	44 (47%)
Wrong turn	4 (29%)	2 (3%)	7 (8%)
Unknown	1 (7%)	0 (0%)	1 (1%)

Table 7 Circumstances That Preceded Diving With Insufficient Gas

Preceding Insufficient Gas	Trained (n = 8)	Untrained (n = 49)	Overall (n = 67)
Poor gas planning	8 (100%)	48 (98%)	65 (97%)
Current	0 (0%)	1 (2%)	2 (3%)
Unknown	0 (0%)	0 (0%)	0 (0%)

diving trained (OR 1.08 per year, 95% CI 1.05, 1.12) and that cave diving trained divers were less likely to have died in a manner where breaking the continuous line rule was relevant (OR 8.99, 95% CI 4.00, 20.20) and more likely to have died alone, rather than in a multiple fatality (OR 3.49, 95% CI 1.69, 7.18). Dividing the dataset chronologically into two equal halves, early and late, and running a similar regression analysis, the differences between early and late divers were almost identical to the differences between trained and untrained cave divers.

Discussion

Fatality investigations aim to improve practice through analysis of the chain of events preceding each fatality. Causality is implied in order for a process of root cause analysis to yield results with bearing on practice. Temporality alone, however, does not prove causality and the results of this study should be interpreted with this in mind. Nevertheless, the final version of the classification instrument attached as an appendix when used with defined inclusion criteria, produced substantial agreement between raters. Of course, rater agreement diminished the further back the reviewers tried to peer. The authors intend for this instrument to be used to classify other diving fatality datasets, thus enabling direct comparison(s). This is the first such instrument developed for diving fatality classification with established interrater objectivity and, as such, it represents an advancement in the field of diving fatality investigation.

It is encouraging that fewer cave diving deaths are recorded in the U.S. each year. Without knowledge of the total number of participants or number of dives made per year, one cannot say whether the overall situation has improved in recent years, other than to say recently fewer cave diving deaths are recorded annually by DAN than has been recorded in previous years. From an epidemiological point of view, these data are far from conclusive. From a public health perspective, however, decisions regarding public safety are often made with less than complete information, and we are confident this study adds significantly to knowledge of cave diving fatalities.

With tougher access conditions, negative publicity following cave diving deaths and/or the rising expense of cave diver training and equipment, it could be argued that fewer divers are diving caves than were in previous years. Fewer untrained divers are reported to be dying in caves in recent years, and the three caves accounting for the most deaths now each have access restricted to trained divers only, so it is possible these access restrictions could be, at least in part, responsible for the drop in number of annual cave diving fatalities. This would be in keeping with the Australian experience, as described earlier in the background. So too, specialized equipment has become more available over time. This study does not claim to prove that existing cave diver training is responsible for the decline in number of cave-diving deaths recorded annually in the U.S. Improved equipment and restricted access might equally explain why the differences between trained and untrained divers are the same as the differences between early and late divers.

The most common cause of death in flooded caves remains drowning, itself a diagnosis of exclusion and of little use to the design of safety initiatives. Immediately before drowning, the majority of divers ran out of air, and this was more

likely among untrained divers. We observed that 76% of divers who ran out of air did so after either getting lost or starting the dive with insufficient gas for the planned excursion. How to avoid getting lost and how to plan one's gas needs are covered by most, if not all, cave diver training courses. This could explain, at least in part, why untrained divers were more likely to have run out of air.

Of the 67 divers known to have run out of gas after poorly planning their gas needs, only two were known to have had insufficient gas for dives in the strong currents they encountered. The remaining 65 (97%) should have had sufficient gas to escape the cave if they had turned back at one-third of their gas usage. In this sample at least, training appears to have made no difference to the consequence of poor planning. Put simply, regardless of training status, failing to plan adequately for one's gas needs leads to running out of air and drowning.

Training does appear to be associated with the circumstances that preceded getting lost. Untrained divers were significantly more likely to have dived without a guideline, thus breaking one of the five "golden rules" and were also more likely to have gotten lost after a silt-out was recorded. Trained divers were more likely to have taken a "wrong turn," perhaps a consequence of the increasing complexity of long cave systems, now often with multiple guidelines and marked routes.

Raters initially agreed which rules were broken only half of the time (51%), which illustrates how difficult it is to find obvious evidence of rule breaking from data contained within the files. Half of the classifications needed a third, joint review. The importance of each of the five rules was implied by the proportion of times breaking them was relevant to the outcome. The "gas-thirds" rule was the most likely to become relevant when broken, followed by the failure to have received training rule. Trained divers broke the continuous guideline rule far less often than untrained divers (12% vs. 60%), although when they did it became relevant just as often (56% of the time), which should reinforce the importance of this rule to all who dive in caves. Using the wrong blend of gas for the depth, for example diving with air deeper than 40 m, did not commonly precede death. Rarely was there evidence that taking fewer than the recommended three lights contributed to a death. That is not to say breaking the lights rule did not more often play a part in the outcome, but merely that the evidence did not clearly show that carrying an additional light would have prevented a diver from running out of air, the most common event to precede drowning.

Worldwide, both diving and nondiving populations alike are known to be growing older, and, as the proportion of trained divers among the dead has risen over time, it is no surprise then the mean age for trained divers (37.5 years) would be greater than for untrained divers (26.7 years).

Conclusions

Table 2 suggested that the fatal exposures were greater for trained than untrained divers as indicated by depth (155 feet trained, 74 feet untrained), distance traveled (750 feet trained, 258 feet untrained), cylinders carried (50% more than one cylinder for trained, 69% only one cylinder for untrained), and diving alone (78% trained, 43% untrained). When a broken rule was relevant, the most critical broken rules were the *thirds* (84% trained, 72% untrained) and *line* rules (56% trained, 55% untrained). Being untrained was relevant for 61% of untrained divers.

The most important preceding event was running out of air (66% trained, 74% untrained), while the most important harmful actions were becoming lost (45% trained, 46% untrained) and having insufficient gas (26% trained, 37% untrained). The circumstances that preceded getting lost were silt-out (36% trained, 53% untrained), no use of a guideline (29% trained, 44% untrained), and wrong turn (29% trained, 3% untrained). The circumstance that most often preceded a dive with insufficient gas was poor gas planning (100% trained, 98% untrained).

Regarding untrained divers, one need conclude no more than they ought not dive in caves. For cave trained divers, however, there might be fewer fatalities if training placed greater emphasis on closely observing all five rules, especially the rule of thirds and using a continuous guideline. Engaging in deeper and longer dives as well as diving alone also were strongly represented among trained divers, but dives of this nature represent personal choice and are not covered by rules. We suggest cave divers remember the Pareto principle (Juran, 1945; Steindl, 2008): the majority of accidents are associated with relatively few potential causes. In this study of cave diving fatalities, the potential causes preceding death were a failure to use a continuous guideline to the surface and bringing inadequate gas for the intended dive. We recommend every cave diver give additional consideration to the use of a guideline and turn around after using one third of the gas rules above all others.

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