The Learning Curve: A Quantitative Analysis of Fatal British Cave Diving Incidents from 1980 to 2005

David Brock, 31st January

Abstract

A description is given of nine fatal cave diving incidents in the 26 years between 1980 and 2005. The overall fatality rate for all dives is estimated at 1 in 3,286 dives. Experience is identified as the main variable and an experienced diver is estimated to be 25 times more likely to survive a dive than an inexperienced diver. The most significant hazard to experienced divers is inadequate line management and the most frequent major hazard to inexperienced divers is lack of training. Cave diving safety has advanced considerably over the last 26 years for experienced divers. An experienced cave diver is 39 times more likely to survive a dive than his counterpart from 26 years ago. Unfortunately this improvement in diver safety has not been matched for inexperienced divers. There remains a lot of work to be done in understanding the safety issues for new cave divers and in developing suitable training programmes and education opportunities to get them up the learning curve safely and quickly.

Method

Data was collected in a standardized form to allow analysis of fatal incidents by divers who have deliberately entered into the overhead environment of the natural caves of Britain (excluding Ireland) using breathing apparatus. Fatalities from open-water training, breath-hold diving, diving in mines or diving in countries other than mainland Britain were not analysed. Information was obtained from published sources and by direct accounts from the people involved with the incidents.

The following information was collected for each incident:
Name:
Age:
Date of incident:
Location of incident:
CDG Qualified Diver: Yes/No
CDG member: Yes/No
Estimated to have previously completed more than 45 dives: Yes/No
Line management was a significant contributory factor: Yes/No
Equipment failure was a significant contributory factor: Yes/No
Training was a significant contributory factor: Yes/No
Something else was a significant contributory factor: Yes/No
Narrative: About 100 words summarizing the event and probable causes

Statistical Considerations

Although quantitative information is presented, a fair degree of caution must be exercised in interpreting their meaning. A major confounding factor is the timescale from the first to the last incident. Cave Diving technologies and practices have improved considerably from 1980 to 2005 and the probability

of a fatal incident has fallen considerably. The number of incidents is also very small. This can produce gross sampling errors so although incidents rates are presented, there is an unknown degree of accuracy. There is still value in producing these rates as they allow the Group to observe changes over time and to compare incident rates between sub-groups of divers. A word about incident rates; if the fatal incident rate is 1 in 3,286 dives then this does not mean that the 3,287th dive a person does will be fatal because the odds of survival improve with experience. It means that if 3,286 people dive once in identical circumstances, then the likely number of fatalities is one.

This analysis will also contain data sampling errors. Given the close nature of the cave diving community, it is highly unlikely that there have been any unreported deaths in natural caves. Deaths in artificial cave-like structures such as mines have not been included to maintain the completeness of the incident dataset. The information about the incidents is less complete and some of the contributory factors for some of the incidents remain unknown. Lastly, values for the quantity of diving have been drawn from estimates that contain an unknown margin of error. The restriction of scope to incidents from mainland Britain goes some way to reducing the scale of this estimation error.

Incident Data

Location	Date of incident	variables			Major Contributory Factors			
		CDG Qualified Diver	CDG Member	More than 45 dives	Line Management	Equipment failure	Training	Other
Bull Pot of the Witches, Cumbria	16/3/1980	Yes	Yes	Yes	Yes	No	No	No
Keld Head, North Yorkshire	23/11/1980	No	No	No	Yes	No	Yes	Yes
Wookey Hole, Somerset	14/11/1981	No	Yes	No	No	No	Yes	UNK
Hurtle Pot, North Yorkshire	6/1/1985	No	No	Yes	No	No	No	Yes
Unnamed Hole, Barbondale	23/4/1988	No	No	No	Yes	No	Yes	Yes
Joint Hole, North Yorkshire	17/6/1992	No	No	No	No	No	Yes	UNK
Birkwith Cave, North Yorkshire	9/7/1994	No	No	No	No	No	Yes	Yes
Ogof Pont Y Meirw, Merthyr Tydfil	30/12/1998	No	No	No	Yes	Yes	Yes	UNK
Low Birkwith Cave, North Yorkshire	13/3/2005	Yes	Yes	Yes	Yes	No	No	No

UNK = Unknown

Narratives

1980 - Bull Pot of the Witches

Ian Plant lost the line in sump 2 of Bull Pot of the Witches and ran out of air before finding his way out of a complicated area in poor visibility [CDG NL 56].

1980 - Keld Head

Four divers embarked on a training dive. Mark Woodhouse, a relatively inexperienced diver became entangled in the line just before a kicking water airbell 100m from the entrance. On freeing himself he surfaced in the 100m airbell in a state of panic. A second diver was nearby but had to adjust his own buoyancy before offering help. By the time his buoyancy was sorted, the first diver had descended back in to the sump and was presumed to be making an exit. A few minutes later the second diver found the first diver laid on his back without his mouth- piece in place. The second diver recovered the first diver some 50m towards the entrance but was unable to save him. The body was recovered later that day [CDG NL 58].

1981 - Wookey Hole
Keith Potter, a trainee diver, died during a training dive in Wookey Hole. He appears to have lost his mouthpiece a short distance from the surface in chamber 20 [CDG NL 62].

1985 - Hurtle Pot
Derek Crossland, an experienced diver drowned 14m from the surface during a routine dive. Subsequent tests of the equipment found no defects and the cause of the accident is uncertain [CDG NL 75].

1988 - Barbondale
Nick Whaite, an inexperienced 18 year old diver became physically wedged whilst trying to push a tight, unexplored sump with a base fed line. The sump was pumped out and the body recovered with much effort [CDG NL 80].

1992 - Joint Hole
Martin McMahon failed to return from a routine dive to the first airbell. He was later found dead near the entrance on the line with air available. There was nothing obviously wrong with the equipment on later inspection [CDG NL 105 & 118].

1994 - Birkwith Cave
Trevor Kemp, an inexperienced diver, disappeared in the final 20m sump whilst on the through trip from Old Ing to Birkwith with a less experienced diver. The diver was found dead the next day some 3m from the line and about halfway through the sump near a “letter box” constriction. The diver’s equipment was old but was working correctly when checked after the incident. The contents gauge was connected directly to the first stage and not via a hose so it would not have been possible to read the cylinder pressure whilst in the sump [CDG NL113].

1998 - Ogof Pont Y Meirw
Peter Fowler drowned whilst returning from exploring beyond the first sump with another diver. The line had become fouled in undercuts and the diver was found drowned a short distance from surface with no air left in his cylinders. Later examination of his equipment showed one of the demand valves to have a fault [CDG NL 134].

2005 - Low Birkwith Cave

Colin Pryer, an experienced diver, was engaged in a project to revisit a low, silty cave last extended in the 70's. The diver became entangled in old, loose line and ran out of air before he could free himself [CDG NL 155].

Amount of Diving

The amount of diving was investigated earlier this year and the details are reported elsewhere in this Newsletter [Brock & Cordingley, 2006]. The following estimates are taken from that work.

The estimated total amount of diving performed between 1980 and 2004 is 29,149 man-dives of which 1,140 were conducted in 1980. Information for all dives in 2005 was taken from CDG Newsletters 154 to 157 which reported a total of 335 man-dives for the year. Using the reporting rate estimate of 78%, the estimate for the total amount of diving in 2005 is 429 man-dives. The total amount of diving for 1980 to 2005 is 29,578 man-dives. The total amount of diving for 1981 to 2005 is 28,438 man-dives.

It has been estimated that new cave divers performed 6,750 man-dives between 1980 and 2004. The full estimate from 1980 to 2005 would therefore be 7,020 man-dives. The estimate from 1981 to 2005 would therefore be 6,750 man-dives.

Analysis of Incident Rates

Incident rates have been calculated and are presented below.

The time between the first and the last incident has been identified as a confounding factor. Line management was identified as a major problem in 1980 and a Technical Review was published to address this issue [Yeadon, 1981]. Since then the quality of line management has improved and a sub-group of dives from 1981 to 2005 has been analysed to give an incident rate that may be more appropriate to modern circumstances.

Experience has been identified as a variable. Three interpretations of experience were collected during the data collection phase. Membership of the CDG is not used as a definition of experienced for the purposes of this analysis. Both being a Qualified Diver and having completed an estimated 45 dives are analysed as being an experienced diver.

Previous work [Brock, 2005] has identified that line management, equipment failure and training are the three most important hazards faced by British cave divers. Incident rates are reported for these three factors.

Rates of Fatal Incidents			Time Period	
			1980 - 2005	1981 - 2005
Divers	**Variable**	**Factors**		
All Divers		**All Factors**	1 in 3,286	1 in 4,063
Experienced Divers	Qualified Divers	All Factors	1 in 14,789	1 in 28,438
		Line management	1 in 14,789	1 in 28,438
		Equipment Failure	0	0
		Training	0	0
	Over 45 Dives	All Factors	1 in 9,859	1 in 14,219
		Line management	1 in 9,859	1 in 28,438
		Equipment Failure	0	0
		Training	0	0
Inexperienced Divers	Not Qualified Divers	All Factors	1 in 1,003	1 in 1,125
		Line management	1 in 2,340	1 in 3,375
		Equipment Failure	1 in 7,020	1 in 6,750
		Training	1 in 1,170	1 in 1,350
	Less than 45 Dives	All Factors	1 in 1,170	1 in 1,350
		Line management	1 in 2,340	1 in 3,375
		Equipment Failure	1 in 7,020	1 in 6,750
		Training	1 in 1,170	1 in 1,350

Discussion

The overall fatal incident rate is 1 in 3,286 dives but the rates for the sub-groups show a more complex picture.

Clearly there is a major confounding effect with time and removing 1980 from the analysis reduces the overall incident rate to 1 in 4,063 dives. The accuracy and applicability of the rates to modern cave diving activities is questionable. Robust incident statistics are available for current open water diving [BSAC, 2005] however the confounding of the cave diving data renders it inappropriate to compare the two sets of incident rates. It is however possible to make observations about the relative rates within the cave diving incident rates. The differences are perhaps best observed by looking at the data from 1981 to 2005.

The greatest difference is seen between experienced and inexperienced divers. The difference in defining experience as either a Qualified Diver or having completed more than 45 dives is not extreme. Taking Qualified Diver status as the most precise and documented determinant of experience then the picture is clear.

CDG Qualified Divers have an overall incident rate of 1 in 28,438 dives whereas unqualified divers have an incident rate of 1 in 1,125 dives. It appears that Qualified Divers are 25 times more likely to survive a cave dive than an inexperienced cave diver. A similar effect was found by the HSE

[Paras, 1997] when examining open water diving. They found that "*There are a small number of repeated causes associated with the majority of fatalities. If these causes are eliminated then the number of fatalities would have fallen from 286 to 8*". This equates to a 36- fold difference in the incident rates between true accidents and fatal incidents involving repeat causes.

The last quantitative analysis of fatalities conducted by the CDG covered the period 1957 to 1978 and indicated an overall fatal incident rate of 1 in 620 dives [Churcher & Lloyd,1980]. Excluding the non- cave and non- British dives there were 6 fatalities from 4338 dives, of which 3 were experienced divers and 3 were inexperienced divers. The overall fatality rate was therefore 1 in 723 dives. There was no obvious difference between the number of fatal incidents for experienced and in- experienced divers. The analysis did not report the proportion of the 4338 dives that were conducted by inexperienced and experienced divers so the assumption is made that an equal number of dives were performed by both subgroups.

In the 26 years between the two analyses of cave diving figures there has been a great step forward in the safety of experienced divers. The fatal incident rate of 1957 to 1978 was 39 times higher for experienced divers than for their counterparts 26 years later. Unfortunately the same improvements for safety have not been made for inexperienced divers for whom the fatal incident rate improved by only a factor of 1.6. Although there are sampling and assumption errors, there is no evidence of a significant improvement in the safety of inexperienced cave divers over the last 26 years.

Three main causal factors were analysed; line management, equipment failure and training. Equipment failure and training were not major factors in either of the recorded incidents for experienced divers whereas line management figured in both. Experienced divers clearly need to take account of all hazards affecting cave diving but should pay particular attention to line management.

All factors contributed to the incidents for inexperienced divers and it comes as no surprise that training was the predominant factor. The take home message for inexperienced divers is to get trained and become qualified. As this group of divers is at a significantly higher risk of a fatal incident, the training should be controlled by very stringent safety standards. There was also a high incidence of uncategorized contributory factors recorded as "other" affecting inexperienced divers. A number of factors fell into this category such as panic or irrational decisions. Brandt claims that anxiety or other psychological problems affect 12% of non- fatal incidents [Brandt, 1980]. It is probable that inexperienced divers are far more susceptible to these issues than experienced divers and more work should be done in this area.

Conclusions

Fortunately there have been too few fatal cave diving incidents for robust fatality rates to be calculated. It is not possible to make meaningful comparisons between the risks faced by cave divers and the risks faced by other kinds of divers. It is clear that cave diving safety has advanced

considerably over the last 26 years for experienced divers. It is also probable that this improvement in diver safety has not been matched for inexperienced divers. There remains a lot of work to be done in understanding the safety issues for new cave divers and in developing suitable training programmes and education opportunities to get them up the learning curve safely and quickly.

No activity is without risk but it is important to balance the risks of any activity against the benefits of that activity. There are multiple health and happiness benefits derived from participating in an intellectually, socially and physically challenging pastime like cave diving.

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