Invited commentary

The international safety record for scientific diving

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This issue sees the publication of two papers with a common element in that they review the safety records of scientific diving programmes undertaken in Australia and the United States.[1,2] Earlier this year, an analogous review was made of a single institution's scientific diving operations in the UK and the abstract of that paper is also reproduced.[3] Such detailed published appraisals of a specific sector of the diving-at-work industry are rare, especially for three comparable reviews to have been conducted in similar depth in different national programmes. In this commentary I will contrast the safety trends of the three studies in a way that presents an international evaluation of the relative risk levels for the scientific diving sector as a whole.

As with any meta-analysis of data sets that have been developed in isolation, there will be difficulties in making exact comparisons or when trying to combine the information into single estimates. At least Carter et al and Sayer and Barrington had the relatively straightforward task of examining records from single institutes. Lang's work has had to make some assumptions because of a lack of consistency in some of the reporting phraseology made during two long-term, multi-institute assessments.

In their inter-sectorial comparisons, Sayer and Barrington argue that the unit of 'a dive' does not necessarily convey the true risk to the individual as differences in diving practices will produce varying ratios of person dives to dives. For the UK study that ratio was just over 1.8 but this value could potentially vary considerably within and between the other studies. Conceivably, the US data expressed as 'dives' could refer to the number of divers per person. The study of Carter et al does relate their findings to the 'person dive' level. However, the overall lack of clarity in the reporting terminology between the three studies does influence the levels of certainty in some of the joint incident rates calculated below.

The Australian study does not give a detailed breakdown of the actual maximum depths dived to but the diving was restricted to depths shallower than 30 metres' sea water (msw) or 15 msw depending on the level of qualification because of the statutory limits for scientific diving in that country. The UK study does not discriminate between depth classes deeper than 30 msw but the statutory maximum for diving on scuba at work in the UK is 50 msw. The maximum depths reported from the US were in excess of 50 msw. Looking at dive numbers only, and making some allowance for conversions of depths from feet to metres, indicates that the types of diving being undertaken by the scientific sectors in the US and UK are remarkably similar (Table 1). The only major difference is in depths shallower than 19 msw, where the majority of US diving is performed shallower than 9 msw whereas most of the UK diving is done between 10 and 19 msw. Summing the dives performed shallower than 19 msw produces a very similar trend, with 87% of the US dives and 88% of the UK dives being in this depth range. This similarity in trend is also shown in the proportion of dives undertaken in the depth ranges of 20–29 msw (10% in both) and 30+ msw (3% and 2% by US and UK scientific divers respectively). By subtraction, this means that the proportion of scientific dives performed shallower than 30 msw is 97% in the US, 98% in the UK and 100% in Australia.

This overview examines both the rates of decompression illness (DCI) and those of serious diving incidents. Lang questions whether some of the incidents reported as "pressure accidents" in his pre-1981 data set refer specifically to incidents of DCI or not. I have assumed here that they do but they are also grouped, along with the deaths, within the "serious accidents" category. The relative sizes of the three studies means that any 'international' risk factor that is constructed will be heavily influenced by the US study. The lack of any incidents in the Australian account and only a single incident in the UK study produce their own statistical problems when attempting to apportion risk rate. That notwithstanding, combining the three data sets produces a total of 508,771 dives in which there were 7 deaths, 21 cases of DCI and, by summation, 28 serious diving incidents. This produces rates of 0.06 and 0.04 respectively for serious incidents and DCI cases per 1,000 dives. The incident rates from this analysis for scientific diving are lower than those previously reported for military personnel (0.14 serious incidents per 1,000 dives),[4] amateur recreational divers in the UK (DCI only, 0.07),[5] recreational divers in the Caribbean (DCI only, 0.09),[6] recreational divers in western Canada (serious incidents, 0.12)[7] and wreck divers in cold water (serious incidents, 0.25–0.49).[8]

Table 1. A comparison by maximum depth of the types of scientific diving undertaken in the US (Lang)[2], UK (Sayer and Barrington)[3] and Australia (Carter et al)[1]

Depth range (msw)	US (%)	UK (%)	Australia (%)
0–9	49.20	31.90	
10–19	37.93	56.40	
0–19	87.13	88.30	
20–29	10.10	9.60	
0–30	97.22	97.90	100.00
30+	2.78	2.10	0.00

The assumption made from all three studies is that the vast majority of scientific diving operations are performed using scuba equipment and equipment configurations that have, in general, been developed for and employed by the recreational diving sector. Although scientific diving may have been a driving developmental sector during the advent of scuba, the massive expansion of the recreational sector in recent decades has accelerated development and, as a consequence, made scuba equipment inexpensive and easily accessible. So the question raised by these studies is that if the diving techniques and equipment are common to both sectors, why is the scientific safety record better than the recreational one? There are a number of possible explanations for this that are consistent from the three studies, any one of which may be the most significant.

A theme common to all three accounts is that the scientific diving programmes are conducted under some form of centralised regulation. In the US, this is defined by the Department of Labor's Occupational Health and Safety Administration but implemented through the American Academy of Underwater Sciences. Australia and New Zealand have an Occupational Diving Standard with a sector-specific Scientific Diving Standard, while in the UK scientific diving has a sector-specific Approved Code of Practice under the Diving at Work Regulations. There are many regulatory differences between each of the national approaches but the aim in each case is to ensure that all scientific diving is conducted to standards that minimise the potential for accidental injury and/or illness and to set minimum training and operational competencies. Of course, it could be argued that these aims are also common to the recreational sector. However, it is the level of post-training dive management that is significantly different to that for recreational diving. Sayer has previously detailed how risk is managed in UK scientific diving operations,[9] and although the same level of formalistic risk analysis may not be required in the other two national programmes, the basic control mechanisms are similar for all three countries. That is: there are defined management structures for diving operations, usually with a distinct level of supervision; dive depth may be limited totally and additionally restricted depending on experience; the method of managing decompression may be prescribed; and there will be an age-determined medical requirement.

In general, the type of diving required by science rarely involves excessive physical exertion and it will usually not be dominated by the same commercial demands that other diving-at-work sectors may have. Although it is tempting to suggest that dive duration does not need to be maximal for the depths being dived this may not be the same for all three nationalities. There was some variation in average dive times, from about 32 minutes in the UK, to 41 in the US, and 52 in Australia. This could be explained by the predominate depth range being deeper in the UK but is much more likely caused by the types of science being done and the clarity and temperature of the water being worked in. Although much of the Australian scientific diving was classified as multi-day this may not be true for the US and UK. However, it is possible that the near-total proportion of dives being shallower than 30 msw in all three programmes is not typical of recreational diving.

In all three cases there was a high use of tables to control decompression, from 100% in the UK and Australian programmes to about 50% usage in the US. The Australian programme employed DCIEM tables and the UK the RNPL 11 up to 2002 and Bühlmann 1986 tables since then. The theories that drive decompression-table and computer development are evolving constantly and both approaches will have their relative merits. However, the use of tables does force divers to plan further in advance with pre-agreed depth and duration schedules. This should reduce factors such as unplanned staged decompression and problems with gas supply. The counter-argument is that the vast majority of scientific dives involve returning to the same location to perform the same task in order to increase the levels of statistical acceptance. In these cases, maximum depths are often planned in advance, the dive profile is inevitably square-wave and so decompression management could be controlled by either table or computer. Whatever the method of control, the rates of no-stop dives are very high in scientific diving: greater than 99.5% in the US, 95.6% in Australia and, although not reported, probably close to 100% in the UK. In addition, there are obvious attempts to increase the safety margin through statutory safety stops, employing more conservative decompression tables and increasing the surface-interval durations.

The final comparison to make between the scientific and recreational diving sectors is demography. Lang's is the only study that mentions age and suggests that the majority of scientific diving in the US is performed at the under- and post-graduate levels making the predominant age group 18–34 years. Increasing age has been identified as a DCI risk factor as Carter et al point out, with the physical and physiological consequences of getting older being, of course, multi-factorial. But, irrespective of age, all three programmes are based on rigorous levels of medical examination of the divers that may intensify with increasing age. Conversely, the recreational sector appears now to have adopted self-certification as the predominant method of medical supervision.

In conclusion, the close timing of publication of these three accounts has delivered a special opportunity to appraise a whole sector of the diving industry at a pan-national scale. In general, the safety record for scientific diving in all three programmes is extremely good and is much higher than would have been anticipated considering a near-total use of scuba. It is not clear as to whether the often-quoted incident rate of 1 in 100,000 dives for the scientific sector refers to the number of dives *per se* or the number of person dives. In either case, however, the rate appears to be too low compared with the evidence provided here. In future, anyone wishing to be conservative could employ rates of 1 in 18,000 dives for serious incidents and 1 in 25,000 dives for DCI for the sector. Alternatively, if the UK value of 1.8 person dives per dive is used, then rates of 1 in 32,400 and 1 in 45,000 dives for serious incidents and DCI respectively would be generated.

There is great importance attached to incident rates as they can influence insurance premiums as well as be useful for informing employers as to what the acceptable levels of risk are for a specific at-work activity. Whereas there may be national schemes to collate data, these may be incomplete, or even if they are complete they are obviously infrequently published. Collectively assessing the three reports has demonstrated the potential value of evaluating national trends within an international context. Perhaps it may be too optimistic to believe that this approach could lead to an international database for scientific diving with a standard reporting format. But then, when you consider the statistic-driven mentality of the scientist, who knows?

References

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The Editor's offering

One of the problems that has dogged epidemiological studies of diving safety is knowing accurately the incidence or prevalence of the matter at hand, be it fatalities, decompression sickness, etc. Assembling such data for scientific diving from three international sources in a single issue of the Journal was a unique opportunity. In place of my usual, frivolous editorial, Martin Sayer has provided commentary on the papers from the Australian Institute of Marine Sciences and the Smithsonian in the USA as well as his own UK data.

Michael Davis

Front cover photograph by George Steinmetz, courtesy of Smithsonian Institution