Pressure-Related Injury Incidence in Scientific Diving 2008 – 2017

REPORT

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AUTHORS:

Jay V. Haigler

Lizzie McNamee

Ross Whippo

American Academy of Underwater Sciences
PO Box 9067
Mobile, AL 36691-9067

Jay V. Haigler[1], Lizzie McNamee[1], Ross Whippo[1*]

[1]American Academy of Underwater Sciences, PO Box 9067, Mobile, AL 36691-9067, USA

*corresponding author: statistics@aaus.org

Abstract

In 2007 the American Academy of Underwater Sciences (AAUS) examined the AAUS database to calculate an incidence rate for pressure related injuries for each year from 1998 to 2005. This analysis was done to determine if the original reasoning behind the partial exemption from the US Occupational Safety and Health Administration (OSHA) standards for commercial diving as established by (29 CFR Part 1910, Subpart T – Commercial Diving Regulations) was still valid. A subsequent paper published in 2012 in Diving and Hyperbaric Medicine performed an analysis on rates of decompression illness from the AAUS database between 1998 and 2007. The current report analyzes 10 years of scientific diving statistics from 2008 to 2017 and compares the 10-year periods (1998-2007 and 2008-2017) to determine the continued validity of the OSHA partial exemption. The reduction in the total number of incidents reported and pressure related injuries from one period to the other period reinforces the on-going validity for the exemption.

Introduction

In 2007, a retrospective evaluation of the American Academy of Underwater Sciences (AAUS) scientific diving statistics from 1998 to 2005 was undertaken in order to determine if the original reasoning behind the partial exemption to the established mandatory occupational safety and health standards for commercial diving (29 CFR Part 1910, Subpart T – Commercial Diving Regulations, U.S. Occupational Safety and Health Administration, 1985) given by the U.S. Occupational Safety and Health Administration (OSHA) was still valid (Dardeau et al. 2007). A subsequent evaluation was done to examine the incidence of decompression illness in 10 years of scientific diving, which examined all diving records for the period between January 1998 and December 2007 (Dardeau et al., 2012). Building upon these evaluations, this report examines pressure related incidence rates in scientific diving between January 2008 and December 2017. We compare 2008-2017 incidence rates with the 2007 report using the same methodology as Dardeau and McDonald 2007 and Dardeau et al. 2012, and present additional analyses that frame incident metrics in a variety of ways.

Methods

Dive Statistics

AAUS statistics and incident reports, which are required annually from all AAUS Organizational Members, were used to calculate the overall injury and pressure-related injury annual incidence rates each year from 2008 to 2017. Incidents were filtered in a step-wise fashion using self-reported categories of incident type and incident reports, and separated into categories guided by the structure found in Dardeau et al. 2012. Overall injury included pressure-related and non-pressure-related incidents, pressure-related included barotrauma and DCI, and suspected or confirmed DCI was also considered alone.

Incidence Rates

Incidence rates were calculated in several ways to allow for direct comparison to previous reports and OSHA methods, to provide intuitive measures of incident rates, and to compare pressure and non-pressure related injury incidence rates. To relate current incidence rates to Dardeau and McDonald 2007 and Dardeau et al. 2012, scientific diving safety was evaluated in line with OSHA annual incidence rates for pressure related injuries (Federal Register, 1982), that are calculated with an equation used by the Bureau of Labor Statistics (BLS):

$$(\frac{N}{EH}) \times 20,000 = IR \quad (1)$$

where N = number of pressure-related incidents, E = total estimated number of divers, H the estimated full-time annual hours worked for a single full-time employee (2000 hours), with 20,000 representing the estimated full-time annual hours worked for 100 employees (40 hours per week, 50 weeks per year), and IR as the calculated annual incidence rate per 100 employees. For the purpose of this analysis the equation can be simplified to:

$$\frac{N}{E} \times 100 = IR \quad (2)$$

Additional summaries found in Dardeau et al. 2012 were also calculated including the incidence rate per 10,000 dives, and inter-annual differences in mean incidence rates with t-tests ($p < 0.05$). A suite of exploratory statistics are also presented including overall (all injury types) incidence rates and incidence rates by diving hours. Rates of injury incidence in other industries for comparison to AAUS statistics were drawn from the Bureau of Labor Statistics (www.bls.gov).

Results

Dive Statistics

The AAUS database contained records of 1,433,523 dives (annual mean = 143,352, median = 144,070, standard deviation = ±18,033) between January 2008 and December 2017 from 172 organizational members (Figure 1a). The annual number of total divers per year ranged from

4,184 to 7,434 (mean = 5,325; median = 5,158; standard deviation = ±930, Figure 1b). The total number of dive minutes per year ranged from 4,959,357 to 7,045,333 (mean = 5,988,661, median = 6,037,928, standard deviation = ±725,459, Figure 1c).

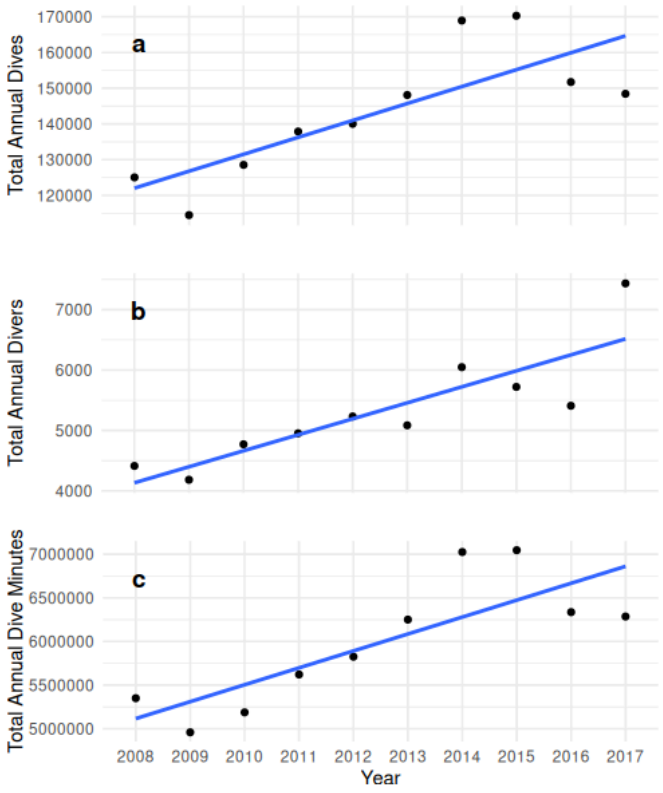

Figure 1: Total annual number of dives (a), divers (b), and dive minutes (c) reported between 2008 and 2017 in the AAUS statistical database. Linear regression is shown for each panel (y = mx + b).

Incidence Rates

For the years 2008-2017 a total of 83 dive incidents were reported in the AAUS statistics database (Table 1). This included 45 barotrauma and hyperbaric injuries, and 21 cases of decompression illness (DCI).

Table 1: Reported dive incidents from AAUS statistical reporting between 2008 and 2017.

Total reported incidents	83
Pressure-related (DCI/Barotrauma)	45
DCI	21

Pooled rates of all injury types (hyperbaric, barotrauma, injury, other) show a decreasing trend from 1998 to 2017, however this trend was not statistically significant. Pressure-related injuries did show a significant decrease from 1998 to 2017, and cases of DCI also decreased with an increasing number of dives and divers (Figure 2a-i).

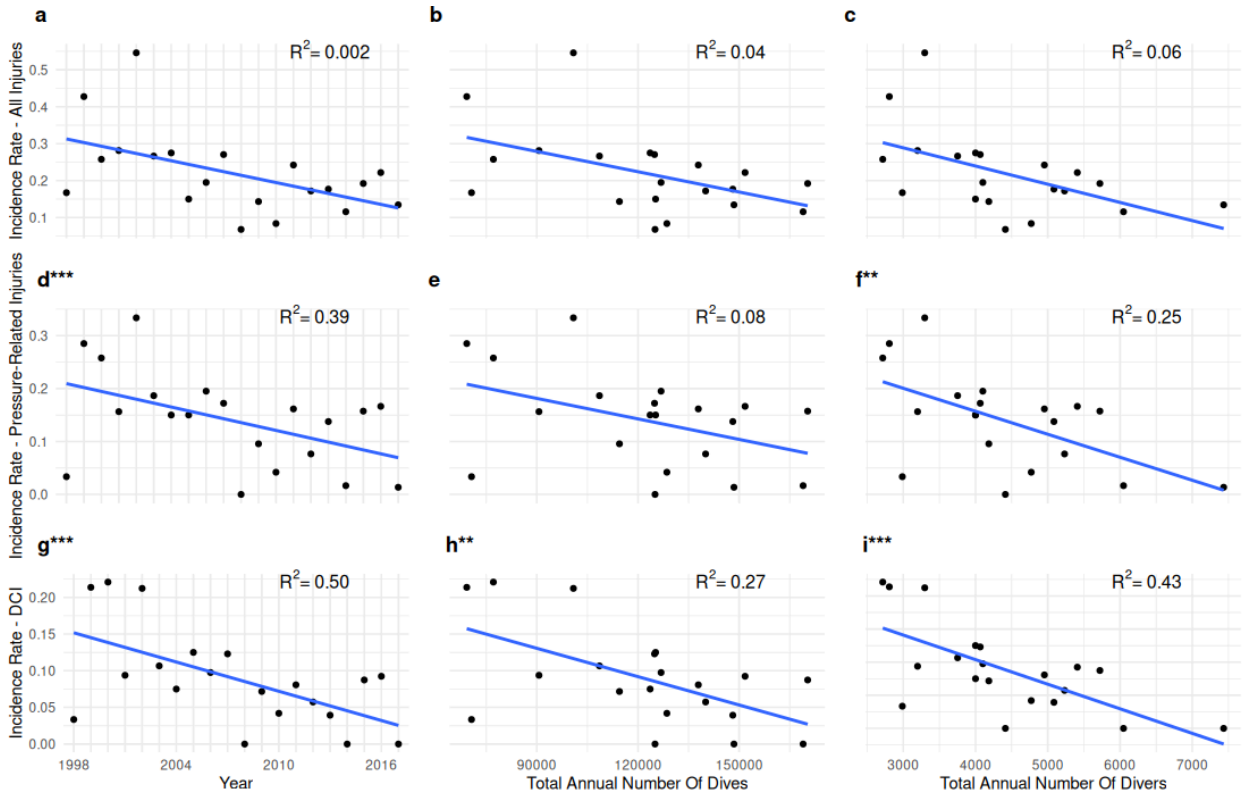

Figure 2: Rates of all incidents (a-c), pressure-related incidents (d-f), and DCI (g-i) across years (a, d, g), number of dives (b, e, h), and number of divers (c, f, i). All measures indicated decreasing incidence rates for all injury types (lm, sig. code * < 0.05, ** < 0.01, *** < 0.001).

When considering the 10-year periods from 1998-2007 (first report and publication) and 2008-2017 (current report), rates of pressure-related injury and DCI-incidence did not decrease significantly within each time period. However, when the two time periods were compared to each other there was a significant decrease of 55% for pressure-related injuries overall (t-test, t = 3.1147, df = 17.082, p-value = 0.006276), and a 68% decrease in DCI (t-test, t = 3.8806, df = 13.296, p-value = 0.001821; Table 2).

Table 2: Mean incidence of pressure-related and DCI only from 1998-2007 (first report/publication) and 2008-2017 (this report). Pressure-related incidence rates include barotrauma and DCI and are calculated using equation 2 above.

Period	Category	Mean Incidence
1998-2007	pressure-related	0.192
	DCI	0.130
2008-2017	pressure-related	0.087
	DCI	0.042

Incidence of all injury types also tended to decrease with increasing annual minutes of diving (Figure 3).

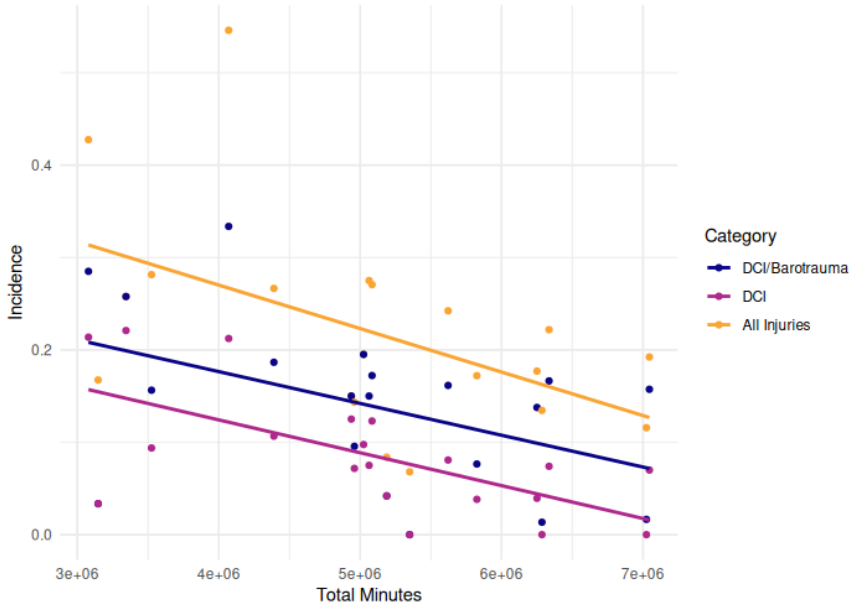

Figure 3: Incidence rates of three injury types for total annual minutes of diving that are recorded in the AAUS statistics database.

When considering other major industries, AAUS incidence rates were typically an order of magnitude lower consistently across the reporting period (Figure 4). While injury incidence rates for AAUS diving is significantly lower than the injury incidence rates for various BLS industries, it should be noted that the basic premise of OSHA's model assumes that scientific divers spend their entire workday in or under the water.

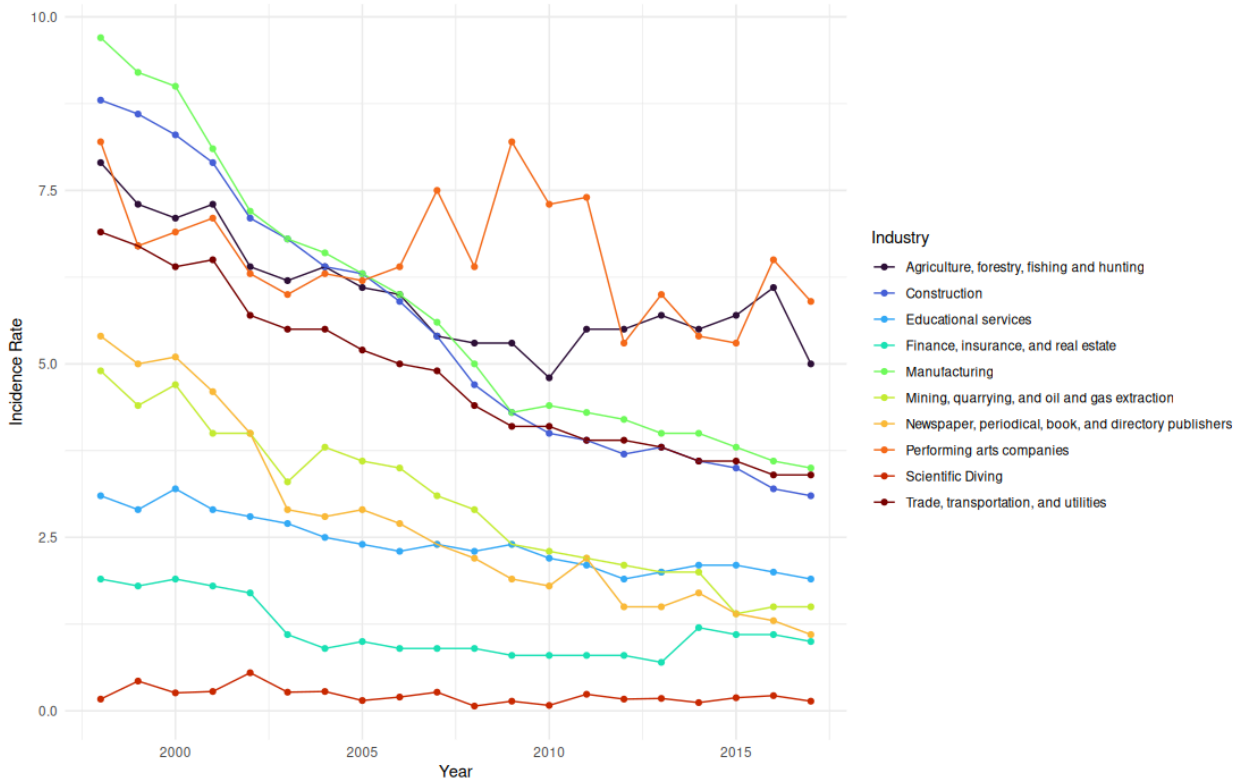

Figure 4: Rates of industry injury incidence from 1998-2017. Scientific diving rates are drawn from the AAUS dive statistics database and include all types of injury.

To account for this we also present standard dive injury incidence reported as occurrence per 10,000 dives to allow for comparison across diving industries (Table 3).

Table 3: Mean incidence of pressure-related and DCI only from 1998-2007 (first report/publication) and 2008-2017 (this report). Pressure-related incidence rates include barotrauma and DCI and are calculated as incidents per 10,000 dives.

Period	Category	Mean Incidence (per 10,000 dives)
1998-2007	pressure-related	0.665
	DCI	0.454
2008-2017	pressure-related	0.309
	DCI	0.148

Discussion

AAUS was chartered in California in 1983, one year after OSHA Scientific Diving Exemption was published. While not identified by OSHA as the standard setting agency for scientific diving at that time, AAUS created manuals and standards that fit the needs of the community. Decades of safe practices, supported by data, set AAUS up for recognition by OSHA in 2022 with an official memo naming AAUS as the standard setting organization for scientific diving best practices (Kampert & Hayward, 2022). The data published in this report continues to support AAUS's role as a leader in safe diving practices.

Overall pressure-related injury decreased from 1998-2017 in reported AAUS statistics. The prevalence also decreased with an increasing number of recorded dives, divers, and dive minutes. When looking at the history of AAUS scientific diving, the annual injury incidence rate decreased even as more technical diving modes such as closed-circuit rebreathers (CCR) and decompression diving are being utilized by the scientific diving community. Monitoring the change of technology is important when determining if the standards are appropriate. Further investigation may be warranted to monitor how the use of new technologies may impact the AAUS diving incidence rate.

As the membership grows at both the Organizational Member level and the Individual Member level, the American Academy of Underwater Sciences has emphasized the importance of reporting incidences, pressure related or not, in order to better understand how our members utilize SCUBA as a tool in their work. It is imperative to continue to gather and analyze data to make informed decisions in regard to training and operational standards for scientific diving as AAUS diversifies in tasks, tools, and modes of diving to include the whole scope of AAUS programs. While this emphasis on reporting means that the incidence rate may increase in the short term, this information will only continue to improve the fit of the standards to meet the community's needs; it confirms that AAUS continues to be the standard for safety in scientific diving.

It is clear that the training and operational standards created by the American Academy of Underwater Sciences has maintained a low incidence rate for AAUS scientific diving, well below the average considered acceptable by OSHA for other industries. The measurable reductions in both the number of incidents and the number of pressure related incidents over consecutive 10-year periods show that the AAUS scientific dive community has made marked improvements to scientific dive safety through self-regulation, oversight, and reporting.

Acknowledgments

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Appendix A - Injury incidence rates from the AAUS statistics database 1998-2017

Rates calculated using Eq. 2

Year	All Injury	Pressure-related	DCI
1998	0.16739203	0.03347841	0.03347841
1999	0.42750267	0.28500178	0.21375134
2000	0.25773196	0.25773196	0.22091311
2001	0.28142589	0.15634772	0.09380863
2002	0.54595086	0.33363664	0.21231423
2003	0.26652452	0.18656716	0.10660981
2004	0.27500000	0.15000000	0.07500000
2005	0.15003751	0.15003751	0.12503126
2006	0.19507437	0.19507437	0.09753719
2007	0.27060271	0.17220172	0.12300123
2008	0.06798097	0.00000000	0.00000000
2009	0.14340344	0.09560229	0.07170172
2010	0.08383987	0.04191993	0.04191993
2011	0.24227741	0.16151827	0.08075914
2012	0.17201835	0.07645260	0.03822630
2013	0.17699115	0.13765978	0.03933137
2014	0.11574074	0.01653439	0.00000000
2015	0.19227408	0.15731515	0.06991785
2016	0.22185247	0.16638935	0.07395082
2017	0.13451708	0.01345171	0.00000000