ANNUAL DIVING REPORT

2012-2015 Edition

2010-2013 Diving Fatalities, Injuries and Incidents

DAN
YOUR DIVE SAFETY ASSOCIATION

DAN Annual Diving Report
2012-2015 Edition
A report on 2010-2013 data on diving fatalities, injuries, and incidents

Peter Buzzacott, MPH, PhD
Editor

Divers Alert Network
Durham, NC

Annual Diving Report 2012-2015 Edition

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EDITOR
Peter Buzzacott, MPH, PhD

AUTHORS

Peter Buzzacott, MPH, PhD (Sections 1, 2.2, 3)
Brittany M. Trout, BS (Sections 1, 2.1)
James L. Caruso, MD (Section 1)
Craig Nelson, MD (Section 1)
Petar J. Denoble, MD, DSc (Section 1, 2.1, Appendix E)
Daniel A. Nord, BFA, EMT-P, CHT (Section 2.1)
James Chimiak, MD (Section 2.1)
Stefanie D. Martina, BS (Section 2.1)
Matias Nochetto MD (Section 2.1, Appendix E)
Neal W. Pollock, PhD (Section 4, Appendix A and F)
John Lippmann, OAM, MAppSc (Appendix B and C)
Christopher Lawrence, MD (Appendix B)
Andrew Fock, MD (Appendix B)
Thomas Wodak, LLB(Appendix B)
Scott Jamieson, (Appendix B and C)
Richard Harris, MD (Appendix B)
Douglas Walker, MD (Appendix B)
Yasushi Kojima, MD (Appendix D)

CONTRIBUTORS

David Carver, EMT-P
Niles W. Clarke, EMT, DMT
Emily A. Davidson, BA
Mitchell N. Mackey, BS
Marty C. McCafferty, EMT-P, DMT-A
Jeanette P. Moore
Payal S. Razdan, MPH
Frances W. Smith, MS, EMT-P, DMT
Scott Smith, DMT
Lana P. Sorrell, EMT, DMT
Richard D. Vann, PhD

Cover Design: Rick T. Melvin

Layout: Jeanette P. Moore

Cover Photos: Mark Long, Craig Dietrich, Peter Buzzacott

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Worldwide DAN Offices

DAN is comprised of independent DAN organizations based around the world that provide expert emergency medical and referral services to regional diving communities. These local networks have pledged to uphold DAN's mission and to operate under protocol standards set by DAN. Each DAN organization is a nonprofit, independently administered organization. Each DAN depends on the support of local divers to provide its safety and educational services, such as emergency hotlines. In addition, each country has its own rules and regulations regarding insurance. Each regional DAN is cognizant of the insurance regulations of its territory.

DAN
DAN America serves as the headquarters for IDAN. Regions of coverage include the United States and Canada.
Diving Emergencies: +1-919-684-9111 (accepts collect calls)

DAN Brasil
Region of coverage is Brasil.
Diving Emergencies: +1-919-684-9111 (accepts collect calls)
0800-684-9111 (local number - Portuguese only)

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Regions of coverage include the Caribbean, Polynesia, Micronesia, Puerto Rico, Guam, Bahamas, British and U.S. Virgin Islands, Central and South America, and any other area not designated below.
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DAN Asia-Pacific
Diving Emergencies: 1-800-088-200 (toll free within Australia — English only)
+61-8-8212 9242 (from outside Australia — English only)

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Diving Emergencies: 0800-020-111 (within South Africa)
+27-11-254-1112 (outside South Africa — accepts collect calls)

Foreword

DAN has been monitoring underwater diving injuries for over 30 years and producing the Annual Report for the last 28 of those. Past reports presented four distinctive sets of data: compressed gas diving fatalities, compressed gas diving injuries, breath-hold diving incidents regardless of outcome, and data from a prospective study of dive exposure and dive outcomes (Project Dive Exploration). The sources of data, the process of data collection, and the format of published reports have changed over time. Many factors affected the change.

Injury data (compressed gas diving) was provided for decades by hyperbaric facilities treating recreational divers for decompression illness. In the past decade, many reporting chambers dropped out due to changes in regulations in health information privacy under the Health Insurance Portability and Accountability Act (HIPAA). Fear of litigation, decreasing number of hyperbaric facilities treating divers and changes in the business environment left less time for staff to spend on unpaid reporting. DAN has since come to rely more on data acquired directly through the DAN Medical Services Call Center (MSCC) when divers call for assistance or advice. The primary role of the MSCC is to fulfill the DAN Mission: to assist divers in need, to help them find and get into healthcare facilities that are best suited to diagnose and treat their conditions, and to provide consultation to healthcare providers when they lack experience and expertise with specific diving injuries. In this process, data collection is of secondary significance and may be is forfeited to concentrate on better care for the injured diver. We strive to streamline the functions of the MSCC and enhance interaction with callers and care providers. Over time, we have trialled several systems of data collection to make it more efficient and less cumbersome for the MSCC on-call staff without affecting the quality of services. Frequent compliments from people who have used MSCC services testify to their satisfaction with the high quality and standards of our services. Nonetheless, the quality of collected data varied over time and this report reflects those changes.

In 2014, we declared data collection to be an equally important function of MSCC. We added staff dedicated to follow up on data collection, quality assurance and customer satisfaction control. Injury data has much improved and this will be reflected in the next edition of this report.

In addition, DAN established a new position, Director of Injury Monitoring and Prevention, to emphasize the commitment to injury prevention and safety of diving. The Director of Injury Monitoring and Prevention coordinates diving incidents, injuries and fatality data collection, data analysis and development of preventive interventions.

This edition is a four year report covering 2010 - 2013 data. It has several new chapters, one about incidents reported by divers through the DAN online incident reporting system (DIRS), additional injury data from public health sources and more data from our worldwide partners. The PDE study was completed and data will be published in a scientific journal. Chapters on fatality and breath-hold incidents have strong quantitative components while the injury chapter provides more qualitative analysis. Each segment abounds with a summaries and vignettes of memorable cases that we hope may help divers adopt safer behaviors than just raw statistics would do.

For the pleasure of bringing this edition to you we thank the DAN Mission staff and the new editor, Dr. Peter Buzzacott.

Let this read help you to be a safer diver and enjoy diving for years to come.

Petar J. Denoble, MD, DSc
Vice President, Mission

Introduction

Since the DAN "Report on 1987 Diving Accidents" first appeared, DAN has monitored diving deaths, injuries and treatments. Data on diver demographics and diving practices have informed the diving community and identified at risk groups, unsafe behaviors and emerging hazards, for example the rise in lion fish envenomations. In recent years it has become apparent that our average age is increasing and, with that, DAN is receiving more reports of cardiovascular-related fatalities and questions to the Medical Services Call Center concerning cardiovascular matters. The majority of diving fatalities in this report were over 40 years of age and more than half were over 50. Today, perhaps more than ever, fitness to dive is critical in recreational diving. The average Body Mass Index of the fatalities within this year's report is in keeping with that of the average American, but that should not be grounds for complacency. The demands associated with scuba diving can increase rapidly and unexpectedly. It is when these unexpected demands occur that fit and healthy divers are better equipped to survive than out-of-shape divers or those in poor health.

In this report we consider differences between divers who died while hunting for game such as lobster or spearfishing, and recreational divers in the ocean who were not hunting when they died. It appears the two groups did not differ greatly in physique and that the activity itself may have something to do with the manner of death. Indeed, it appears the 'hunters' ran low on, or out of, gas more commonly than the non-hunters. Perhaps the thrill of the hunt distracts divers from checking their air pressure? We cannot say with certainty, but we urge every diver to regularly check their submersible pressure gauge and to monitor their gas reserves.

Rebreathers continue to gain popularity in recreational diving and reports of fatalities involving rebreather divers continue to flow steadily into DAN each year. Human error remains a target for improvement. Likewise, cave diving is another unforgiving diving niche where human error can be fatal. More commonly, however, a cave diving fatality occurs as the result of a collusion of circumstances, all of which conspired to turn a dive fatal. Rarely does a single mistake end a life in cave diving. Often it is a combination of factors, with human error among them.

Outside of caves, freshwater diving is enjoyed by many in the USA. A great number of divers learn to dive in dive parks, quarries, lakes or rivers and in this report we consider the nature of fatalities that occurred at freshwater dive sites. They are often colder at depth than ocean dives, with access to substantial depth relatively close to shore. Divers are reminded that even though freshwater dive sites may appear relatively safe, when there are no waves or current, every dive is made safer by prudent risk management and safe diving practices.

The DAN Medical Services Call Center have been as busy as ever, dealing with the full range of diving emergencies, often in far flung corners of the globe where medical resources may be scarce. Any diver planning a trip to a remote diving destination should consider the added consequences of an injury in such a location. The discomfort associated with a significant delay before evacuation and the costs of treatment should be reason enough to dive conservatively. Insurance can also prove invaluable when injury strikes. Whether a diver is insured or not, the DAN Emergency Hotline is here for you, 24 hours a day, 365 days a year.

In 2010-2013 there were an estimated 57,504,885 Emergency Department admissions in the US and US territories, and 4,368 of those (0.008%) were for scuba injuries, so it should be little surprise if scuba is not a high priority among other national injury monitoring and prevention organizations. DAN takes the lead in this effort. This year the Annual Report contains data on scuba-related Emergency Department admissions. These offer a snapshot of the variety of scuba injuries divers suffer. Future reports will explore additional sources of data from outside of DAN, to assist the reader build a picture of the annual burden of injury attributable to recreational scuba diving.

Also new to the DAN Annual Report this year is a collection of diving incident reports. This initiative collects data from divers who experienced something unexpected, and from these we learn more about the causes of common mishaps such as running out of gas, omitting decompression or unexpected encounters with marine life. We thank everyone who reported an incident and encourage all divers who read this report to visit the DAN website at https://www.diversalert-network.org/diving-incidents/ and report the last time you had an incident, whether it resulted in an injury or not.

Our research into the fast growing sport of breath-hold diving continues and this annual report documents the continuing rise in the number of breath-hold fatalities reported to DAN each year. The distribution of ages point to a younger crowd than in scuba diving, and the causes of death also differ. A read of the case summaries will reinforce to all breath-hold divers the value of a “spotter” at the surface and of limiting hyperventilation before diving. Widespread adoption of spotters and limited hyperventilation could significantly reduce the number of breath-hold deaths each year.

Our colleagues in Australia and Japan contribute data on the status in their respective countries and we hope to expand on this next year with an increased global perspective. Countries differ in their climate, sea conditions, regulations for diving, boating and hunting, in their near-shore bottom topography and, indeed, in the people that live there. Much can be learned by comparing diving practices and injuries between regions.

Peter Buzzacott, MPH, PhD
Director, Injury Monitoring and Prevention

Section 1. Dive fatalities

Peter Buzzacott, Brittany M. Trout, James L. Caruso, Craig Nelson, Petar J. Denoble

1.1 Introduction

According to the Centers for Disease Control and Prevention (CDC) National Center for Injury Prevention and Control (NCIPC), injury is the leading cause of death for persons ages 1 – 44 in the US and worldwide.[1] From age 45 onwards, heart disease accounts for more deaths in the US each year than unintentional injury, and this is reflected in the diving fatalities reported to DAN that occurred between 2010 and 2013.

1.1.1 The Data Collection Process

The data collection process at DAN starts by first identifying a scuba diving death through contact with the DAN Emergency Line, internet alerts, news, forums or reports from affiliated organizations such as County Coroners, Public Safety Divers, offices of Medical Examiners or members of the public. Each event is classified whether it is possible to be followed up to collect additional information or not. Recreational diving fatalities occurring in the US or Canada are tagged as follow-up cases and fatalities that occur overseas are tagged as no-follow up unless it appears likely additional details can be obtained beyond media reports, such as when an American diver dies overseas but is repatriated and an autopsy is conducted.

News reports, mostly online, are monitored constantly for keywords involving diving deaths and scuba. Other sources for notification regarding fatalities include notifications from families of DAN members and friends and acquaintances of the deceased who are aware of DAN's data collection efforts. The DAN Medical Services Call Center (MSCC) is also a valuable resource as the DAN Medical Services Department assists with the management of any scuba diving event that is called in, whether the patient is a DAN member or not.

1.1.2 Investigator and Medical Examiner Reports

Most of the scuba-related deaths in the US are investigated by local law enforcement agencies or the US Coast Guard (USCG) and are subjected to autopsies. The investigation reports and autopsies are integral in DAN's research into the cause of scuba-related fatalities. Without access to these reports, it would be virtually impossible to compile enough data for analysis.

Each state in the US has its own set of regulations regarding the release of information in addition to compliance with the federally mandated HIPAA (Health Insurance Portability and Accountability Act) Privacy Rule. Some states consider investigation and medical examiner's reports to be public information and are released easily while others are governed by more stringent privacy laws. In addition, within each state sometimes the regulations (hence, ease in procuring reports) can also vary from county to county. As presented in this chapter, the majority of diving deaths in the US occur in Florida and California. Luckily, these two states have straightforward protocols for requesting and obtaining copies of reports.

Local investigating agencies (sheriff and police departments) follow similar privacy laws in their respective states to medical examiners. However, since not all the information contained in their reports contains private medical information, often they are able to release reports under the Freedom of Information Act (FOIA).

Reports for cases that are investigated by the USCG can now be requested from one central location in Washington DC. However, it may take up to two years after an incident before any case is closed and copies released. The USCG follows FOIA protocols and will not release personal information contained in their reports. A redacted copy, removing all personal and identifying information, is usually requested.

1.1.3 Reports from Witnesses and Next-of-Kin
DAN uses the Fatality Reporting Form to collect data from witnesses and family. The form may be downloaded from the DAN website (http://www.diversalertnetwork.org/files/FATform.pdf) or may be requested from the research and medical services department. When necessary, the family of the decedent or next-of-kin may be contacted to assist in data collection. They may complete the Fatality Reporting Form and/or provide authorization for the release of their family members' autopsy reports.

The online incident reporting form on the DAN website (https://www.diversalertnetwork.org/research/incidentReport/) can also be used by family and witnesses to report a fatality and provide additional details regarding any scuba diving fatality.

1.1.4 Data Entry and Analysis
DAN research maintains the scuba diving fatality data in a secure server. Once all pertinent information have been gathered and entered into the database, results are analyzed and published in the DAN Annual Diving Report.

1.2 Geographic and Seasonal Distribution of Fatalities

Worldwide, DAN received notification of 561 deaths involving recreational scuba diving during 2010-2013. This is shown in Table 1.2-1. Only the deaths of 334 US and Canadian recreational divers were actively investigated by DAN. Reports of dive-related deaths from other regions were recorded when available but were not actively pursued or investigated.

Table 1.2-2 shows the geographic distribution of Canadian or US fatalities by state or province over the ten year period 2004-2013. Year after year Florida leads in the number of diving fatalities reported to DAN, followed by California and then Washington. These three states accounted for 369 (55%) of the 665 Canadian or US diving fatalities reported to DAN over this decade.

Table 1.2-1 DAN-received notifications about fatalities by country and region, 2010-2013 (n=561)

Region	Country	2010	2011	2012	2013	Total
Africa	Egypt	4	1	2	1	8
	South Africa	1	0	1	3	5
	Cape Verde	0	0	1	0	1
	Seychelles	0	1	0	0	1
Africa Totals		5	2	4	4	15
Asia	Philippines	3	6	5	0	14
	Indonesia	2	3	4	0	9
	Malaysia	1	1	0	3	5
	Japan	2	1	1	0	4
	Maldives	1	0	2	0	3
	Thailand	0	1	0	2	3
	Vietnam	0	0	0	1	1
	China	0	0	1	0	1
	Taiwan	0	1	0	0	1
	Papua New Guinea	0	1	0	0	1
Asia Totals		9	14	13	6	42

Table 1.2-1 (cont.) DAN-received notifications about fatalities by country and region, 2010-2013 (n=561)

Region	Country	2010	2011	2012	2013	Total
Caribbean	Cayman Islands	1	4	5	2	12
	Netherlands Antilles	1	2	5	2	10
	Turks and Caicos Islands	0	1	2	0	3
	Cuba	1	0	1	0	2
	Bahamas	1	0	0	1	2
	Virgin Islands (British)	0	0	0	1	1
	Barbados	1	0	0	0	1
	Dominican Republic	1	0	0	0	1
	French West Indies	0	0	1	0	1
	Jamaica	0	1	0	0	1
	Puerto Rico	0	0	1	0	1
	Virgin Islands (U.S.)	0	0	0	1	1
	Trinidad and Tobago	0	1	0	0	1
Caribbean Totals		6	9	15	7	37
Central America	Honduras	1	2	3	0	6
	Belize	1	2	1	2	6
Central America Totals		2	4	4	2	12
Europe	United Kingdom	5	8	8	7	28
	Italy	4	1	4	2	11
	Scotland	2	2	4	2	10
	Spain	1	0	5	1	7
	Malta	1	1	3	0	5
	Great Britain (UK)	3	1	0	0	4
	France	1	0	1	2	4
	Ireland	0	1	2	1	4
	Switzerland	0	1	2	0	3
	Finland	0	2	0	1	3
	Norway	1	0	0	1	2
	Greece	1	0	0	1	2
	Russian Federation	0	0	2	0	2
	Denmark	0	1	0	0	1
	Belgium	0	0	1	0	1
	Croatia (Hrvatska)	0	1	0	0	1
	Bulgaria	0	0	1	0	1
	Portugal	0	0	0	1	1
	Poland	1	0	0	0	1
	Montenegro	0	0	1	0	1
	Netherlands	0	0	0	1	1
	Latvia	0	1	0	0	1
	Austria	0	0	1	0	1

Table 1.2-1 (cont.) DAN-received notifications about fatalities by country and region, 2010-2013 (n=561)

Region	Country	2010	2011	2012	2013	Total
Europe Totals		20	20	35	20	95
Middle East	United Arab Emirates	0	0	1	0	1
Middle East Totals		0	0	1	0	1
North America	United States	56	74	56	48	234
	Canada	4	6	7	10	27
	Mexico	1	9	9	8	27
	Bermuda	0	1	1	1	3
	Greenland	1	0	0	0	1
North America Totals		62	90	73	67	292
Oceania	Australia	6	11	7	11	35
	New Zealand (Aotearoa)	2	7	0	4	13
	Fiji	3	0	0	1	4
	Tonga	0	0	3	0	3
	Guam	0	0	0	2	2
	Micronesia	1	0	1	0	2
	Vanuatu	0	0	0	1	1
Oceania Totals		12	18	11	19	60
South America	Brazil	0	0	4	1	5
	Ecuador	1	0	1	0	2
South America Totals		1	0	5	1	7
Overall Total		**117**	**157**	**161**	**126**	**561**

Table 1.2-2 Number of recreational fatalities in US and Canada by state or province in 2004-2013 (n=665)

State/Province/Territory	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
Florida	17	18	17	32	29	22	12	25	18	16	206
California	9	10	11	13	8	10	15	17	14	14	121
Washington	4	5	7	4	5	4	2	5	3	3	42
Hawaii	3	3	1	5	4	4	8	4	5	2	39
Ontario	7	4	4	5	2	0	1	0	1	3	27
British Columbia	2	5	2	1	2	3	2	0	2	4	23
New York	2	4	2	2	1	0	1	4	1	2	19
Massachusetts	1	3	1	3	3	3	2	1	1	0	18
Michigan	2	0	4	2	1	0	2	2	1	3	17
New jersey	1	1	2	2	1	4	3	1	2	0	17
North Carolina	3	3	1	2	1	0	1	5	0	0	16
Pennsylvania	0	2	0	2	0	3	1	1	1	2	12
Wisconsin	0	0	0	0	2	2	3	0	0	2	9
Nova Scotia	1	3	0	0	1	0	0	0	2	1	8
Illinois	0	2	1	1	0	0	2	1	0	0	7

Table 1.2-2 (cont.) Number of recreational fatalities in US and Canada by state or province in 2004-2013 (n=665)

State/Province/Territory	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
Ohio	0	0	0	4	0	1	0	2	0	0	7
Texas	1	3	0	2	1	0	0	0	0	0	7
Maine	0	1	2	0	2	0	0	0	0	0	5
Virginia	1	0	0	0	1	0	0	1	2	0	5
Alberta	0	0	0	1	0	0	1	0	1	1	4
Minnesota	1	0	1	0	0	0	1	0	1	0	4
Nevada	0	0	0	0	1	1	0	0	1	1	4
Oregon	0	1	0	0	0	1	1	0	1	0	4
Rhode island	0	1	0	1	2	0	0	0	0	0	4
South Carolina	1	1	0	0	1	0	0	0	1	0	4
Alaska	0	0	0	2	0	0	0	1	0	0	3
Alabama	0	0	0	0	0	0	0	1	1	1	3
Arizona	1	0	0	0	0	1	0	0	1	0	3
Georgia	1	0	0	0	1	1	0	0	0	0	3
Missouri	1	0	0	0	0	0	1	1	0	0	3
Arkansas	1	0	0	0	0	0	0	0	0	1	2
Louisiana		0	1	0	0	0	0	1	0	0	2
New Hampshire	1	0	0	0	1	0	0	0	0	0	2
Newfoundland and Labrador	0	0	1	1	0	0	0	0	0	0	2
Quebec	0	0	1	0	0	0	0	0	1	0	2
Utah	1	0	0	0	0	0	0	1	0	0	2
Connecticut	0	1	0	0	0	0	0	0	0	0	1
Kansas	0	0	0	0	0	0	0	0	0	1	1
Manitoba	0	0	0	1	0	0	0	0	0	0	1
Montana	0	0	0	0	0	0	0	1	0	0	1
New Brunswick	1	0	0	0	0	0	0	0	0	0	1
Puerto Rico	0	0	0	0	0	0	0	0	1	0	1
Tennessee	0	0	0	0	0	1	0	0	0	0	1
Vermont	0	1	0	0	0	0	0	0	0	0	1
Wyoming	0	0	0	0	0	0	1	0	0	0	1
Overall total	**63**	**72**	**59**	**86**	**70**	**61**	**60**	**75**	**62**	**57**	**665**

Figure 1.2-1 shows the occurrence of recreational diving fatalities in 2010-13 by month. Figure 1.2-2 shows the average number with a trend line showing that in general the number of fatalities reported to DAN increases as summer approaches, peaks around July and then diminishes with the approach of winter. Figure 1.2-3 shows the occurrence of diving fatalities in Florida, California and Washington, by month.

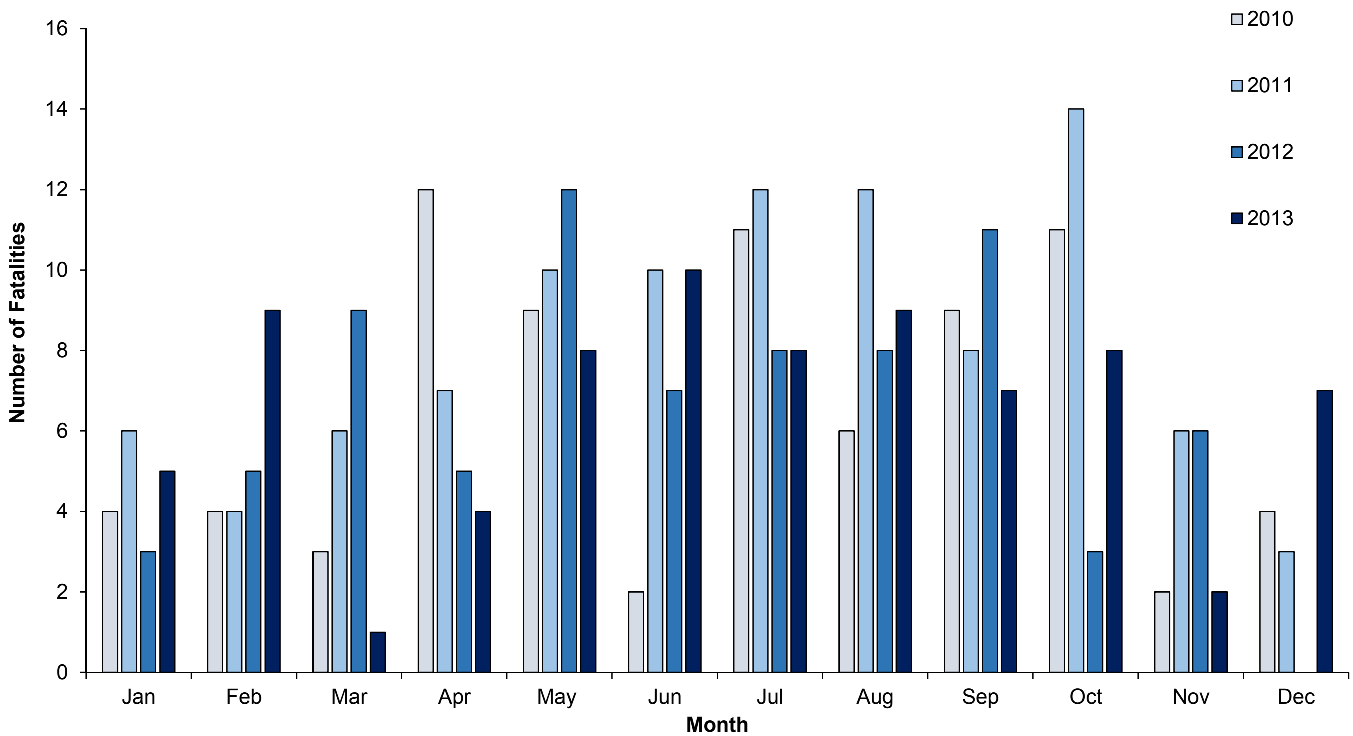

Figure 1.2-1 Monthly distribution of recreational diver deaths 2010-2013 (n=334)

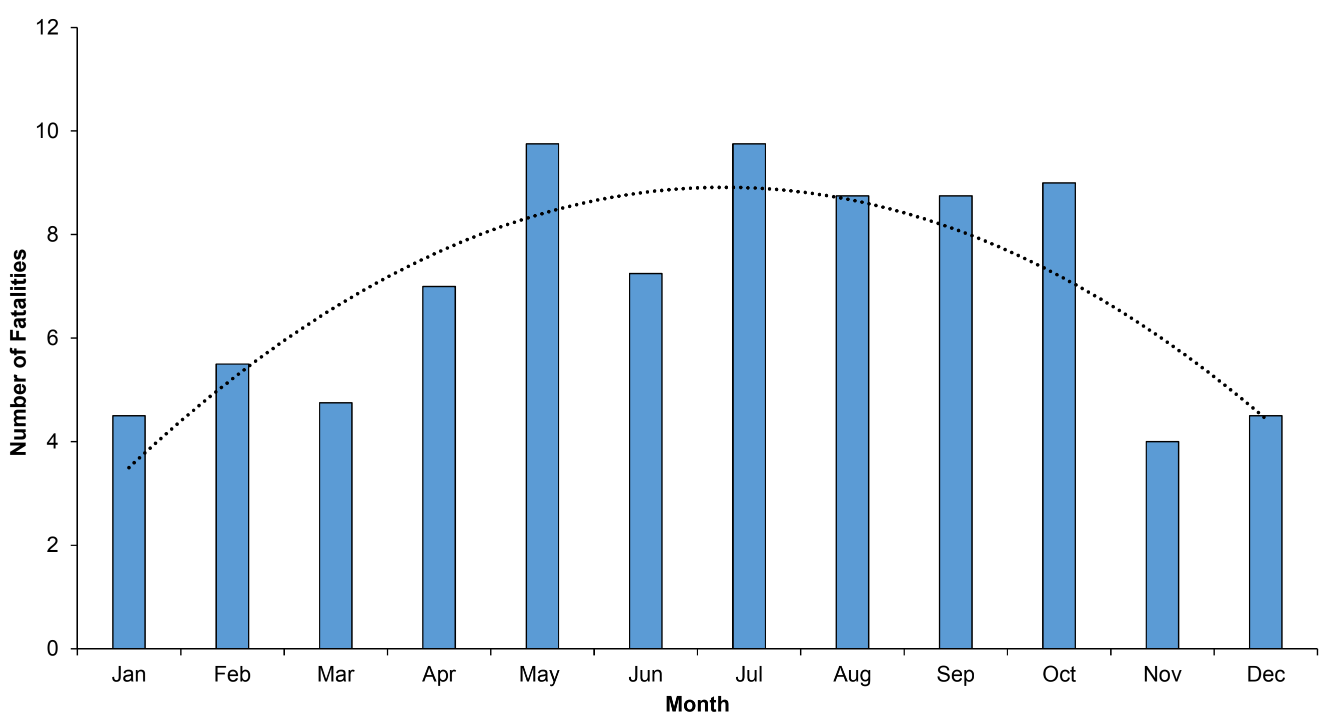

Figure 1.2-2 Average number of fatalities 2010-2013 by month (n=334)

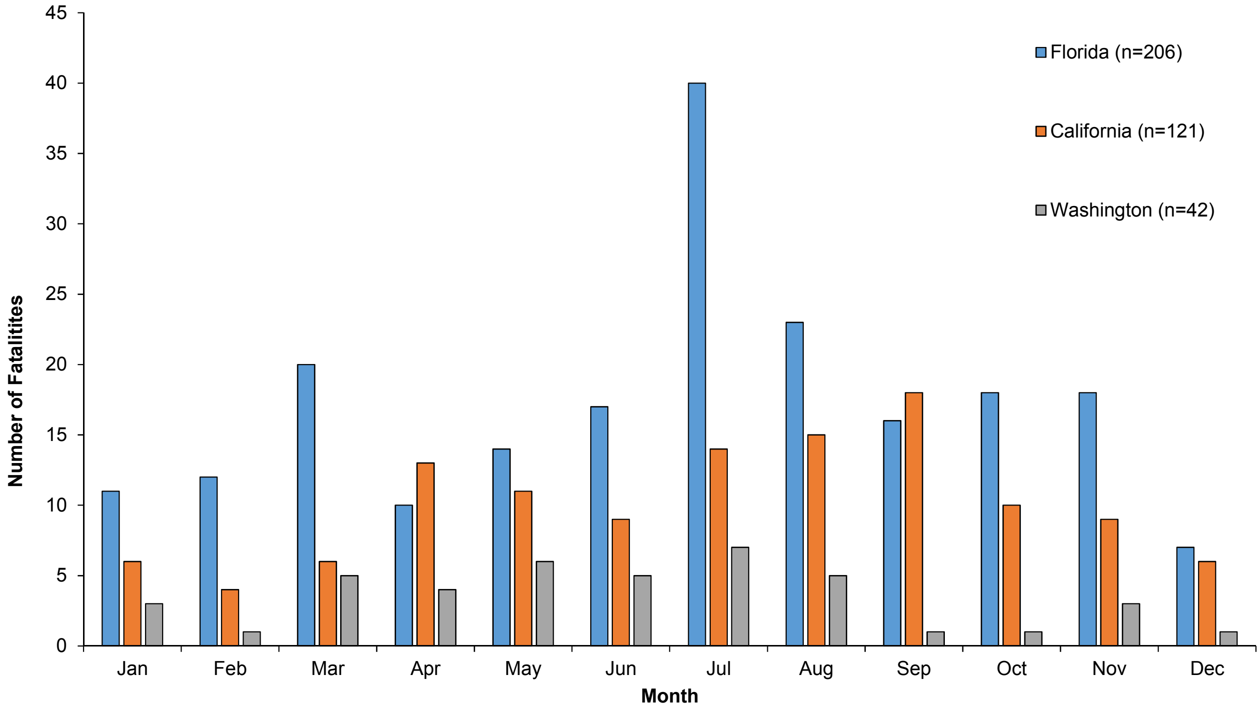

Figure 1.2-3 Month of death by three states with the most diving fatalities in 2004-2013 (n=369)

1.3 Source of information

Autopsies were made available in 161 out of 334 (48%) US and Canadian citizens. Coroner summaries/death certificates were available for a further 14 cases (4%) as shown in Table 1.3.1. The body of the decedent was not recovered in six cases (2%).

Table 1.3.1 Medical examination data (n=334), by year 2010-2013

Autopsy Information	2010	2011	2012	2013	Total
Unknown	30	31	25	35	121
Included	32	52	40	37	161
Autopsy report not available	7	10	7	1	25
Death certificate	1	1	5	1	8
No autopsy	3	1	1	2	7
Body not recovered	3	1	1	1	6
Coroner summary	1	2	2	1	6
Total	**77**	**98**	**81**	**78**	**334**

1.4 Age and Health of Decedents

Figure 1.4-1 shows the age distribution for dive fatalities. In 82% of cases, the victims were males (n=274), and in 18%, females (n=59). Seventy-eight percent of males and 90% of females were 40 years or older. Fifty-eight percent of male and 59% of female victims were 50 years or older. Age was unknown in just one case.

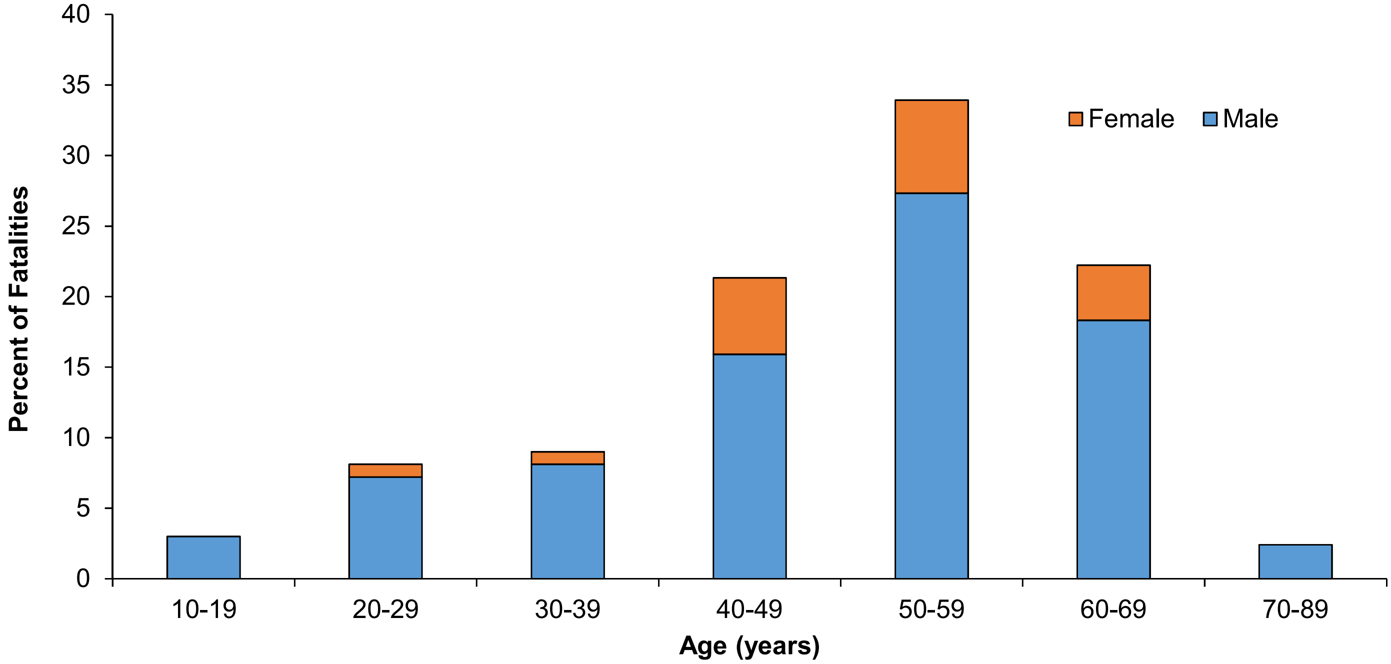

Figure 1.4-1 Overall distribution of fatalities by age and sex 2010-2013 (n=333)

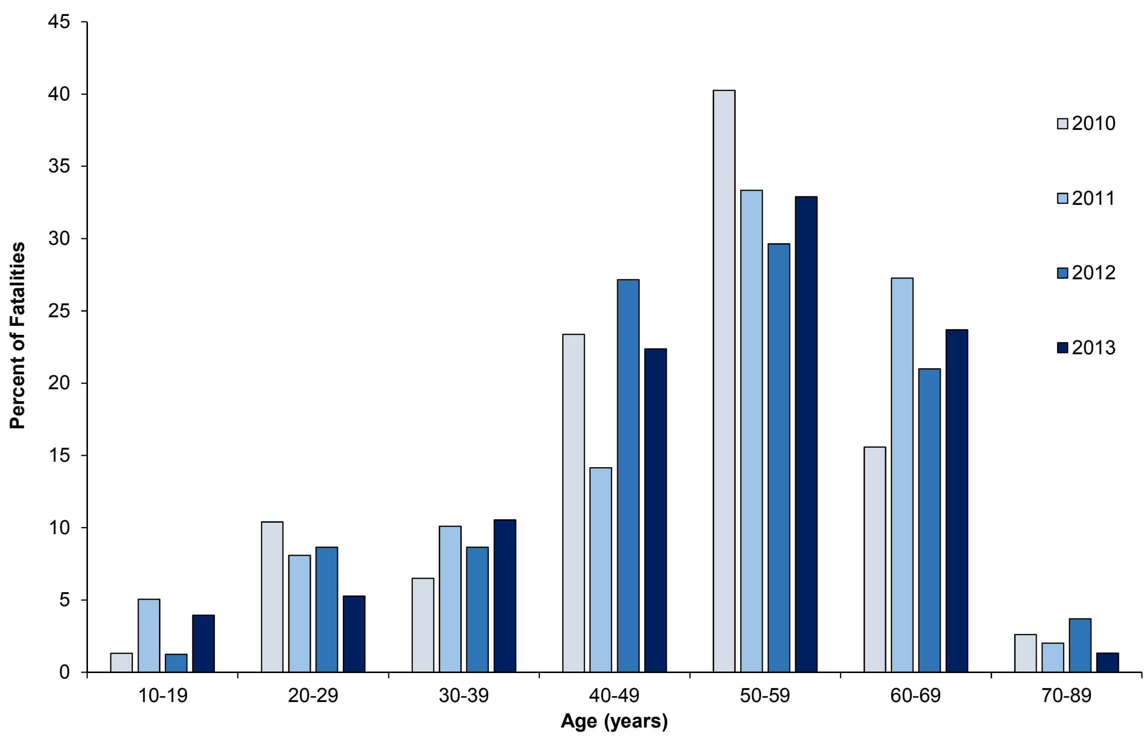

Figure 1.4-2 Distribution of fatalities by age, by individual year 2010-2013 (n=333)

Among the decedents, there were six divers aged sixteen years old or less.

Case 11-13: Inexperienced diver with cardiovascular health issues
This 16-year-old male had only been certified for four months when he made a navigational dive in a quarry with a group of other divers. The diver did not return with the group and he was found unresponsive 30 minutes later. The medical examiner ruled the death to be due to an air embolism but there is no evidence that the diver had ascended. The autopsy disclosed cardiomegaly and the diver was markedly obese with a BMI of 39. A cardiac event may have resulted in this drowning.

Medical history was, in most cases, incomplete or unknown. In 18 cases (5%), it was explicitly reported that there were no known medical conditions. The most frequently reported medical conditions in decedents were high blood pressure (n=40; 12%) and heart disease (n=18; 5%).

Table 1.4-1 Known medical history on decedents by year, 2010-2013 (n=334)

	2010	2011	2012	2013	Total (%)
Hypertension	12	12	11	5	40 (12)
None	10	4	2	2	18 (5)
Cardiovascular disease	2	7	7	2	18 (5)
Diabetes	3	6	5	1	15 (4)
Asthma	3	0	4	1	8 (2)
Back Pain	0	3	1	1	5 (1)
Allergies	1	0	1	1	3 (1)
Pulmonary	0	2	1	0	3 (1)
Flu/Cold	2	0	0	0	2 (1)
Nervous	0	1	1	0	2 (1)
Depression	1	1	0	0	2 (1)
Ear/Sinus	1	0	0	0	1 (0)

The true prevalence of high blood pressure and cardiovascular diseases among victims is not known. The numbers in Table 1.4-1 represent only the number of cases with known medical conditions. The medical history was not known for many cases and some of those who were reportedly healthy may have had undiagnosed hypertension, heart disease or diabetes, as is often the case in the general population.

Case 10-14: Sudden cardiac death followed by drowning
This 49-year-old male was a certified diver with an unknown amount of experience who was diving with five other divers in a reservoir. The decedent gave an “OK” signal prior to ascending but he never ascended. The decedent’s body was recovered at 115 fsw (35 msw) the next day. The medical examiner concluded the cause of death to be drowning and stated an air embolism could not be excluded. Without an ascent, the possibility of air embolism is excluded. However, the decedent did have hypertensive cardiovascular disease with cardiomegaly at autopsy and this may have contributed to the death.

Case 13-69: Sudden cardiac death due to coronary atherosclerosis
This 67-year-old experienced diver had a medical history of hypertension. He was diving from a boat in tropical waters and ascended from approximately 100 fsw (61 msw) to a safety stop at 15 fsw (5 msw). During the stop, he became unresponsive. He was brought onto the boat where resuscitative efforts were administered and he was then transported to a nearby hospital. Death was pronounced in the emergency department. The autopsy documented changes of hypertensive cardiovascular disease. His death appeared to be due to a sudden cardiac arrest while underwater.

Body mass index (BMI) was available in 163 victims (49%) as shown in Figure 1.4-3. According to the Center for Disease Control (CDC) classifications, 17% of victims' BMI classified as normal weight (18.5-24.9 $kg \cdot m^{-2}$), 47% as overweight (25.0-29.9 $kg \cdot m^{-2}$) and 35% as obese (30.0-39.9 $kg \cdot m^{-2}$). This prevalence of obesity among scuba fatalities concords with that found in the wider US population, at 35%.[2] Data for the wider scuba diving population is not available however, therefore we cannot know if obese divers drop out of diving and are less common in diving than in the wider population, and/or if obesity is linked with an increased risk of dying while scuba diving.

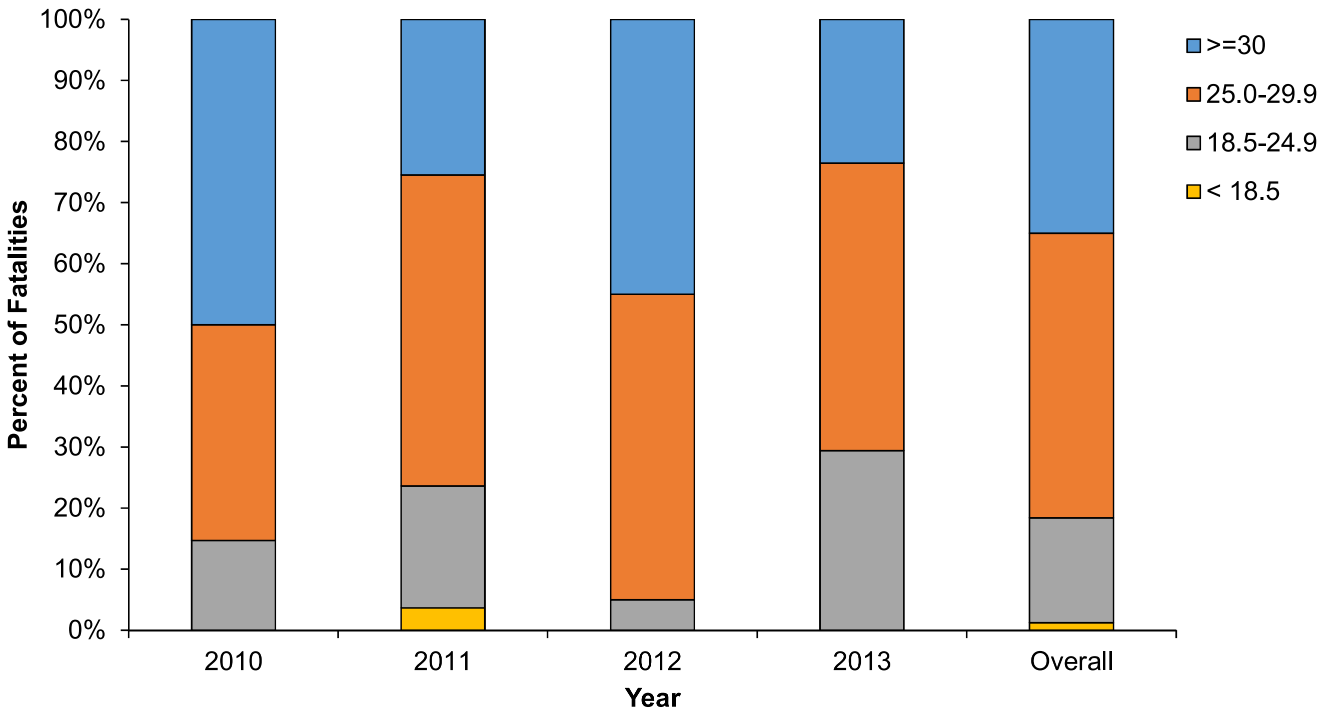

Figure 1.4-3 Classification of fatalities by BMI, 2010-2013 (CDC classifications) n=163

Case 10-25: Out of practice and out of shape diver suffers arterial gas embolism
This 51-year-old male was an experienced, certified diver who had not made a dive in over 3 years. He also admitted to being somewhat of an 'air hog'. The diver was diving in a group but without a designated buddy. He made a dive to 94 fsw (29 msw) for 23 minutes, losing consciousness after surfacing from the dive. The decedent was obese with a BMI of 39 and he had an enlarged heart with a thickened left ventricle. There was intravascular gas present at autopsy and the cause of death was determined to be air embolism.

1.5 Diving Certification and Experience

Information about certification was available in 147 cases (44%) as shown in Figure 1.5-1. Eighteen victims were students during their fatal dive. The youngest student was a 17-year-old in an open water course. The age of the other students who died were between 22 and 61 years old.

Most victims had basic open water diving certification (n=39) but there were also 11 instructors, 18 dive leaders or assistant instructors and 26 divers with technical certifications. Seven divers died while instructing other divers.

Table 1.5-1 Diving certifications of fatality cases by year, 2010-13 (n=147)

Certification	2010	2011	2012	2013	Total
Unknown/Missing	48	60	33	46	187
Student	8	3	6	1	18
Basic/OpenWater	8	12	13	6	39
Advanced/Specialty	1	10	9	4	24
Rescue	2	0	2	1	5
Leader/Asst Instructor	4	1	7	6	18
Instructor and Above	1	2	3	5	11
Technical	5	8	5	8	26
None	0	2	3	1	6

The experience of divers as indicated by the number of years since certification was known in only 147 cases. The details are shown in Figure 1.5-1.

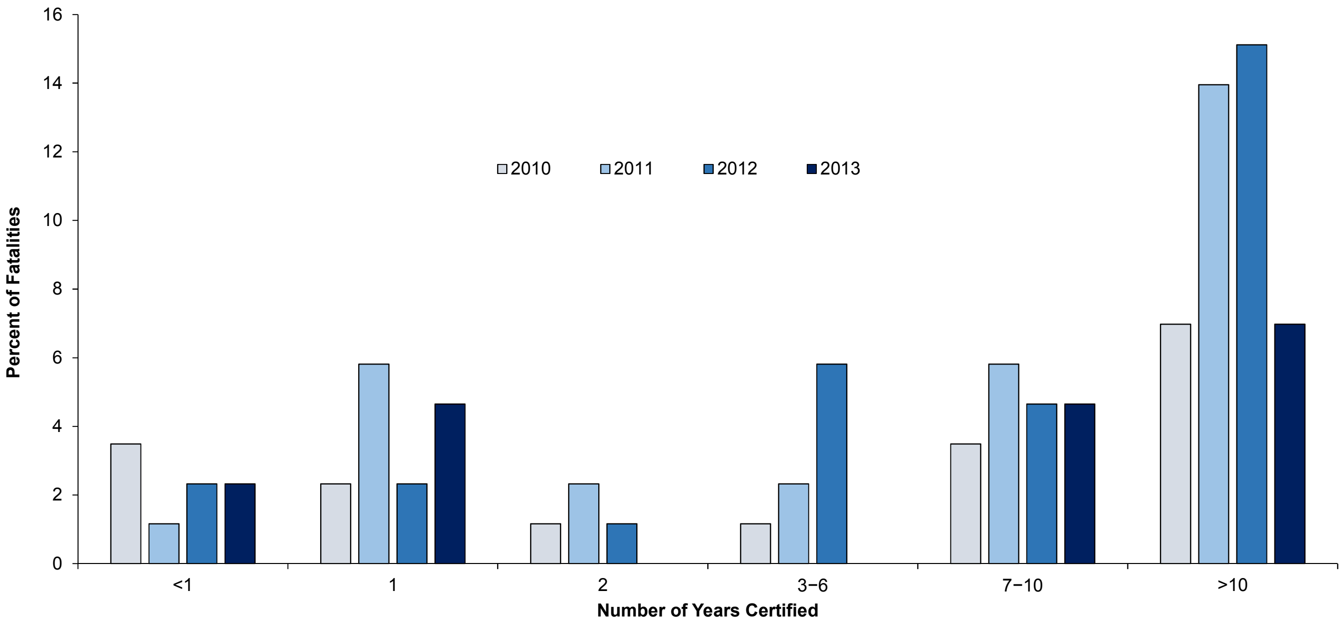

Figure 1.5-1 Number of years since initial certification for divers who died, by year 2010-13 (n=147)

Case 10-86: Equipment issues and a lack of experience lead to panic
This 23-year-old male was not a certified diver and this was his first time using scuba equipment. He made a shore entry dive with a group of other divers and was using too much weight as well as a regulator that had been free-flowing when he entered the water. The diver immediately panicked and struggled before submerging. His body was pulled from the bottom, at a depth of 13 fsw (4 msw). The death was determined to be due to drowning with panic as a contributing factor.

1.6 Characteristics of Dives

Figure 1.6-1 shows the type of diving activity during the fatal dive. Information was available for 300 cases (90%). Two hundred and twelve (64% of cases) of the fatal dives involved pleasure or sightseeing, 35 cases (11%) involved spear fishing, hunting or collecting game, 27 cases (8%) involved training.

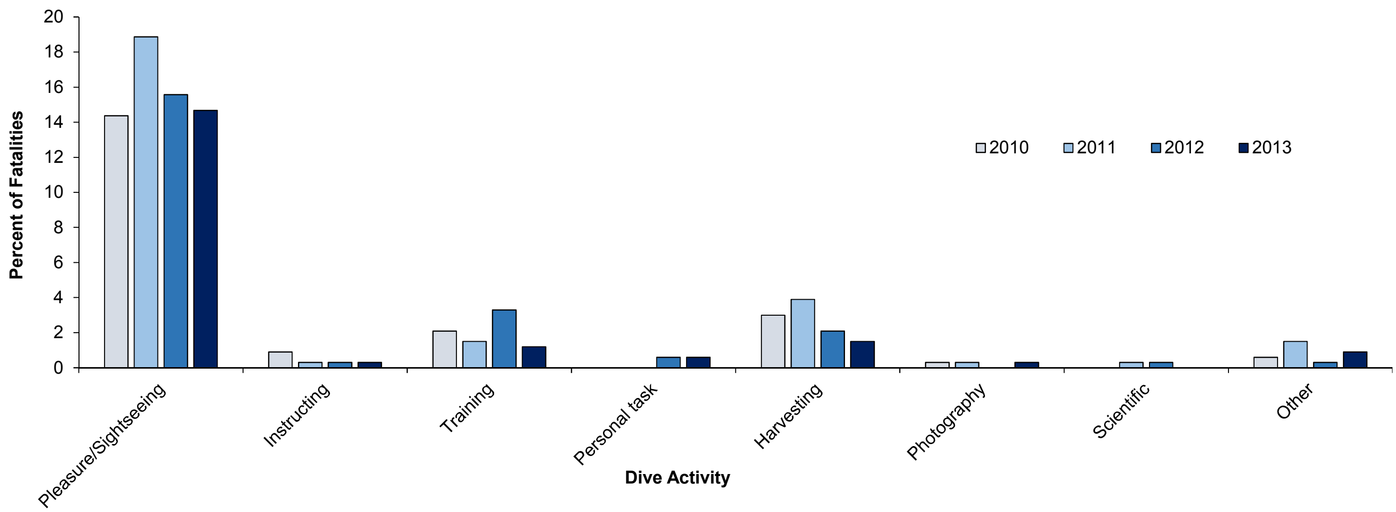

Figure 1.6-1 Diving activity 2010-13 (n=300)

Figure 1.6-2 shows the platform from which the fatal dives began. In most cases, the dive began from a charter boat or private vessel (n=164; 59% of known cases). Dives began from beach or pier in 104 cases (38% of known cases).

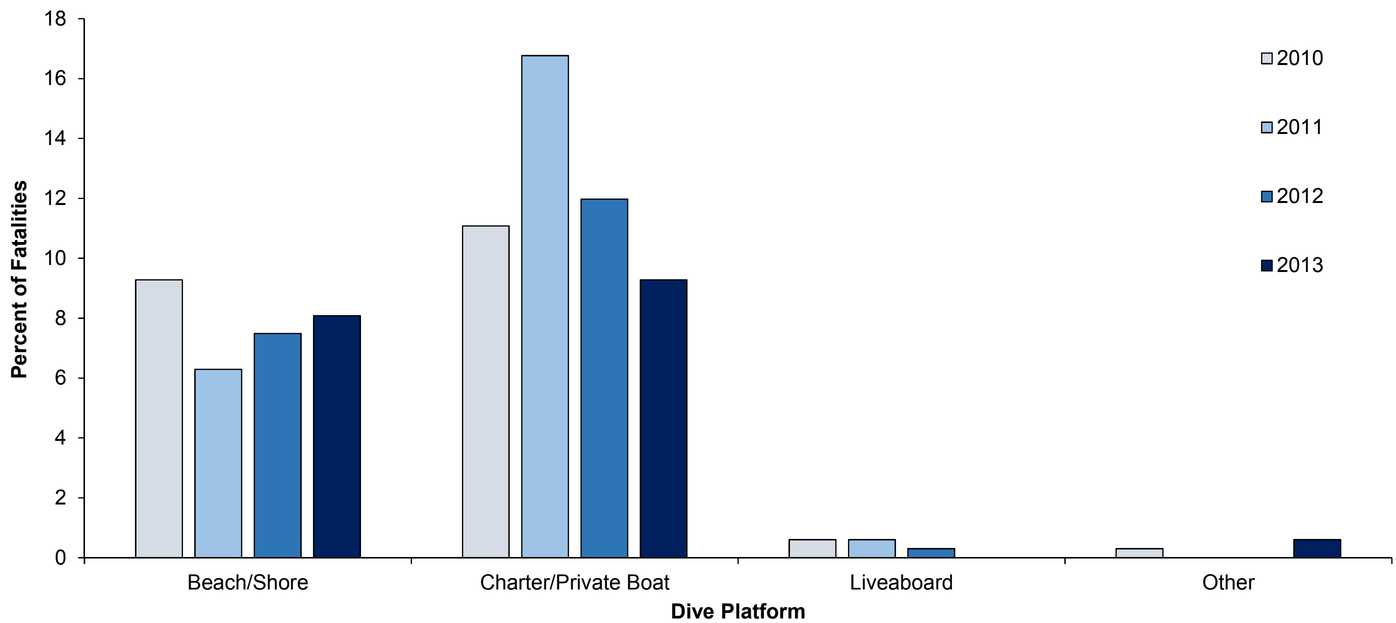

Figure 1.6-2 Dive platform by year, 2010-13 (n=276)

Most dives occurred in an ocean/sea environment (n=206, 62%) with a significant number occurring in stationary fresh water (n=54, 16%) and rivers (n=16, 5%).

Visibility was reported in 106 cases (32%). It was excellent (>50 ft [15 m]) in 32 cases (30% of the 106 cases where it was known), moderate (10-50 ft [3-15 m]) in 51 (48%) and poor (<10 ft [<3 m]) in 23 cases (22%).

Sea condition (sea state) was reported in 114 cases (34%). Calm seas were noted in 69 (21%), moderate seas in 30 (9%) and rough seas were reported in 15 cases (4%).

Currents were described in 113 cases (34% of total). Currents were strong in 34 cases (30%), slight in 39 cases (35%) or none in 40 cases (35%).

Information about protective suits worn by divers was available in 162 cases (49% of total). One hundred and twelve of the victims (34%) wore wetsuits, 12 (4%) wore swimsuits or dive skins and 38 (11%) wore drysuits.

Figure 1.6-3 shows the maximum dive depth reported for known cases (n=199; 60% of total). Fifty fatal dives (15%) occurred in water up to 30 feet deep, 55 (16%) in the depth range 31-60 feet, 36 (11%) in the depth range 61-90 feet, 24 (7%) in the depth range 91-120 feet, and 34 (10%) occurred in water deeper than 120 feet. Data were not available for 135 cases (40%).

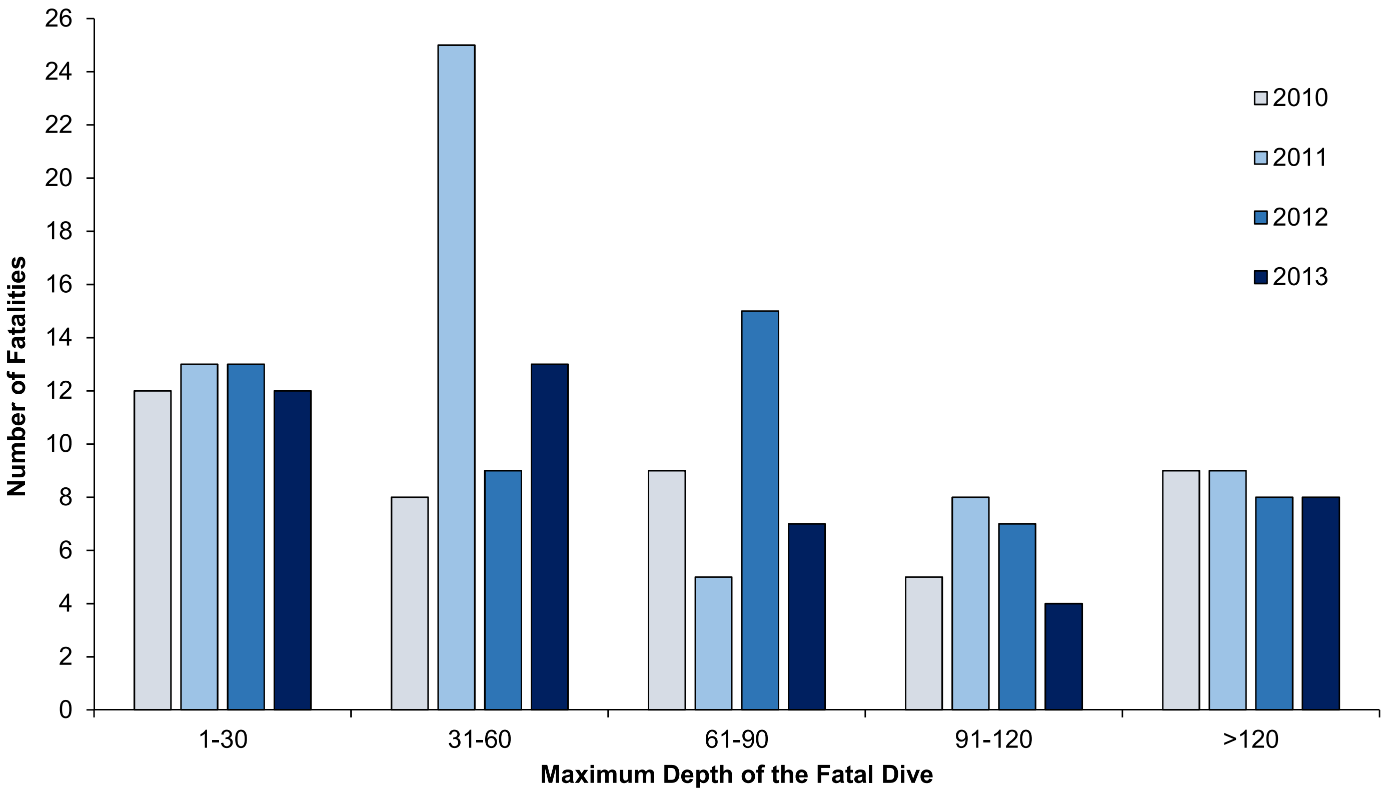

Figure 1.6-3 Maximum depth of the fatal dive, 2010-2013 (n=199)

While at least 12% of the fatal dives were intended as solo dives, as shown in Figure 1.6-4 most dives started with a dive buddy. Adherence to buddy system diving is difficult to establish retrospectively. When survivors notice that their buddy is missing it does not necessarily mean that the buddy intentionally separated; it may rather mean that nobody noticed the diver having problems that eventually led to them dying.

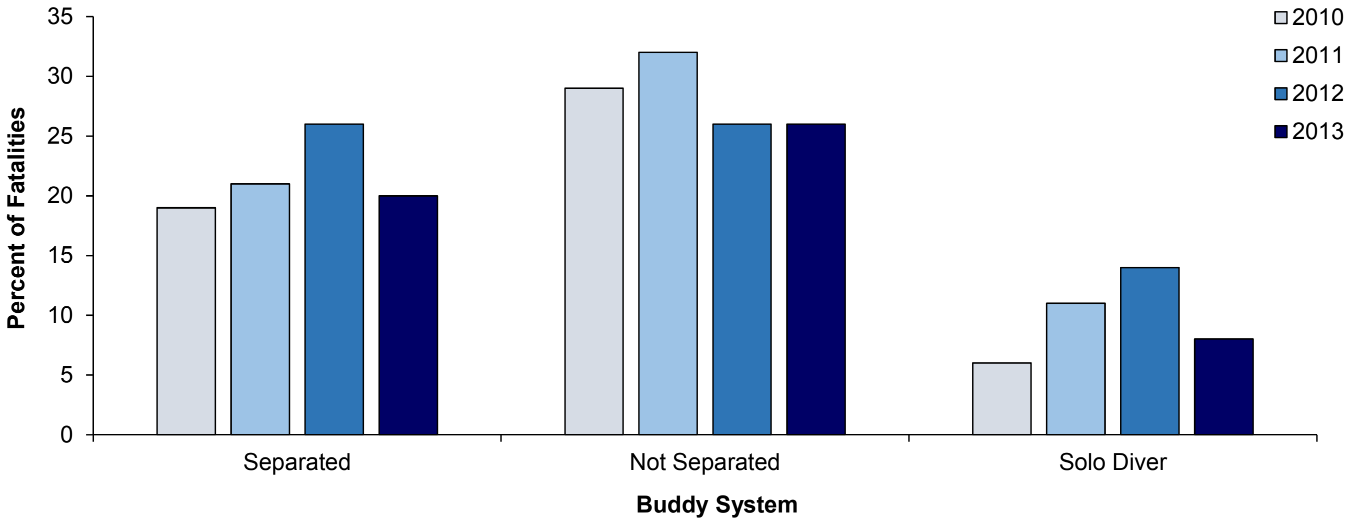

Figure 1.6-4 Buddy status during the fatal dive, 2010-2013 (n=238)

Open-circuit scuba was used in 218 cases (65%), rebreathers in twenty-six (8%) and surface-supply in four cases (1%), as shown in Figure 1.6-5. The source of the breathing gas was not specified in 86 cases (26%).

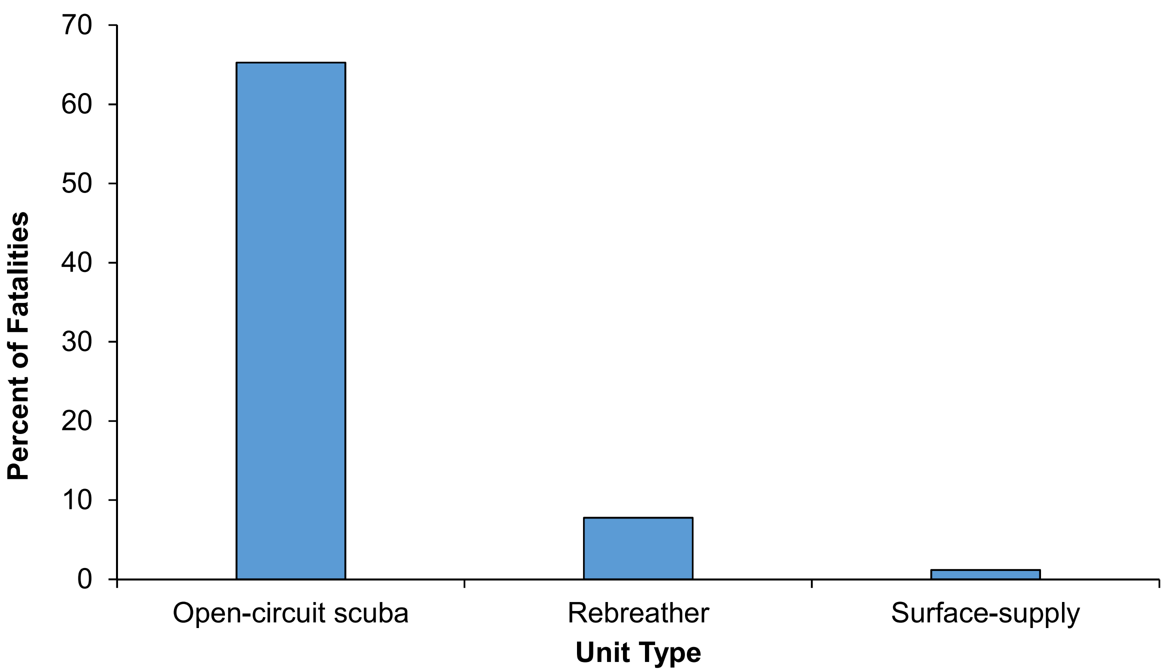

Figure 1.6-5 Type of breathing apparatus used (n=248)

Breathing gas, (Figure 1.6-6) was compressed air in 138 cases (41%), enriched air nitrox was used with scuba in 25 cases (7%), and trimix in seven cases (2%). In four cases (1%) oxygen was used and in a further seven cases (2%) a combination of gas mixes were used. In 153 cases (46%), information was not available.

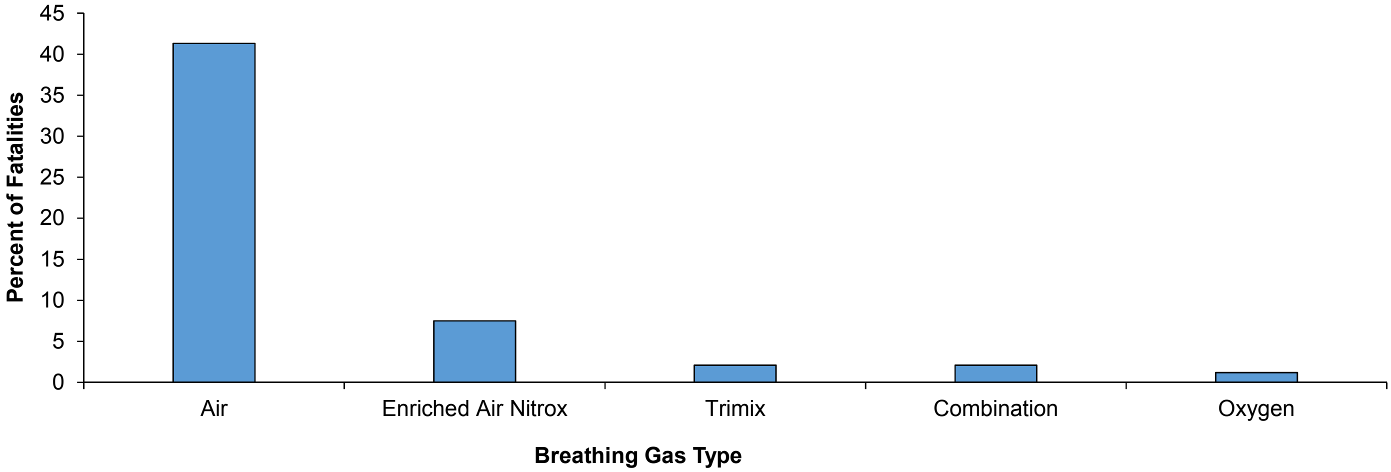

Figure 1.6-6 Breathing gas used (n=181)

1.7 Analysis of Situations and Hazards

We explored each case according to the phase of the dive in which the incident occurred, and the chronological chain of events ending in death.

1.7.1 Fatalities by dive phase

Dive phases included: a) on the surface before diving, b) descent/early dive, c) on the bottom, d) ascent, e) on the surface after diving and f) upon exiting the water. This information was available in 228 cases (68% of total). Table 1.7.1-1 shows the distribution of fatalities by dive phase when the problem became apparent and Figure 1.7.1-1 shows the phase of the dive whereupon the deceased lost consciousness. As can be seen, the majority of fatalities commenced while the diver was underwater and that is where the diver lost consciousness.

Table 1.7.1-1 The distribution of fatalities for each year by the phase of the dive in which the cascade leading to the fatality commenced (n=228)

	2010	2011	2012	2013	Total
Surface pre-dive	6	5	4	3	18
Descent/Early Dive	4	6	6	2	18
Bottom	18	31	33	29	111
Ascent	6	5	5	4	20
Surface post-dive	22	13	10	9	54
Out of water	4	2	1	0	7

The point at which the victim lost consciousness was reported in 156 cases (47% of total). Most victims (n=105; 31%) lost consciousness underwater. The victims were reported to have lost consciousness upon surfacing in 80 cases (24%), at the surface before they submerged in 10 cases (3%), and after exiting the water post-dive in 17 cases (5%).

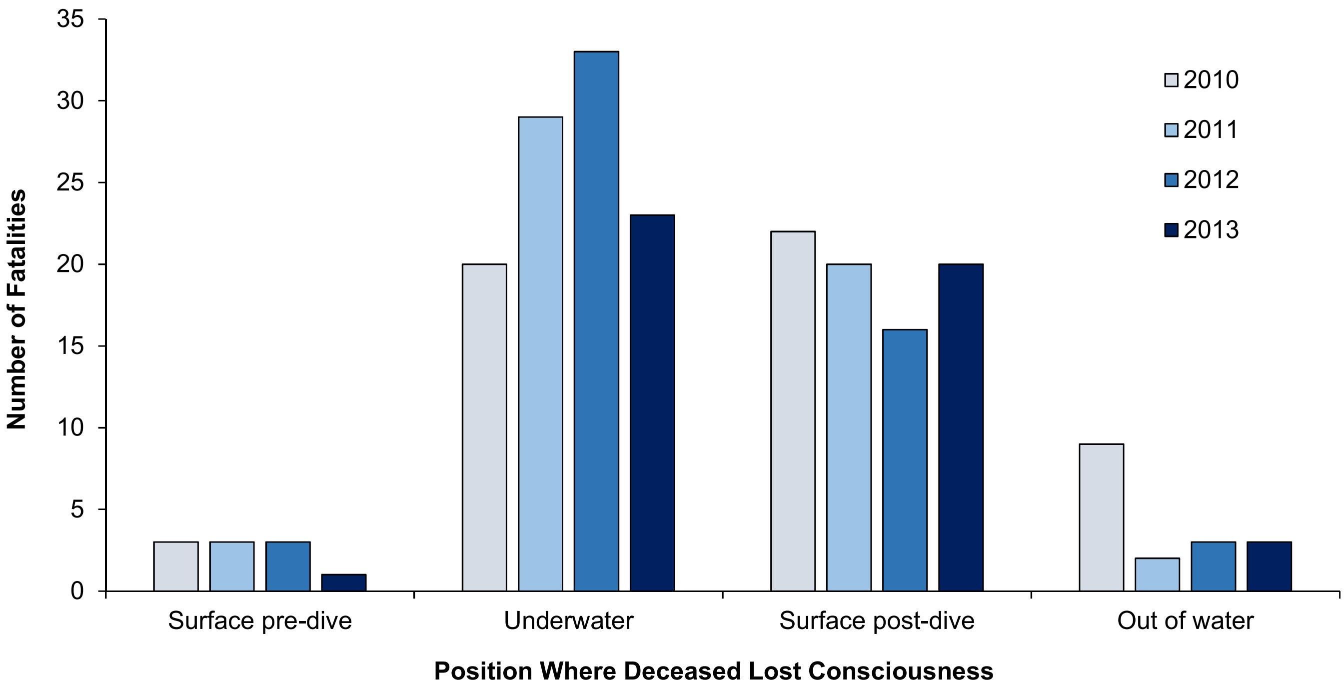

Figure 1.7.1-1 Phase of the fatal dive when the deceased lost consciousness, 2010-2013, (n=156)

1.7.2 Causes of injuries and deaths

Determination of the causes was based on: a) autopsy findings and the underlying cause of death reported by the medical examiner; b) dive profile; c) reported sequence of events; d) equipment and gas analysis findings and e) expert opinion of DAN reviewers. The process is described in further detail in a published paper.[3]

Root causes, mechanisms of injuries and causes of death were not established in a large number of cases mostly because of missing information and inconclusive investigation. Eleven case files (3%) were not included in this analysis because information from external bodies had not yet been received. Based on the available data and where triggers were identified (n=126), the most common known triggers were underlying health problems (15%) or running out of breathing gas (14%) (Table 1.7.2-1).

Table 1.7.2-1 Common triggers by year and overall, 2010-2013 (n=323)

Trigger	2010	2011	2012	2013	Total
Unknown	10	73	51	63	197
Health problem	19	0	0	0	19
Breathing gas management	6	9	3	0	18
Equipment	7	4	3	2	16
Entrapment	1	1	5	4	11
Weather/Environmental factor	4	2	4	1	11
Entanglement	3	2	5	0	10
Rapid ascent	10	0	0	0	10
Panic	2	0	2	1	5
Inappropriate breathing gas	0	1	1	2	4
Other	4	0	0	0	4

Table 1.7.2-1 (cont.) Common triggers by year and overall, 2010-2013 (n=323)

Trigger	2010	2011	2012	2013	Total
Exertion while swimming	0	1	3	0	4
Alcohol	0	0	1	2	3
Cardiac event	1	0	2	0	3
Ear squeeze	0	0	1	1	2
Inexperience	0	2	0	0	2
Buoyancy problem	1	0	0	0	1
Instructor pressed regulator purge	0	1	0	0	1
Omitted decompression	0	1	0	0	1
Water aspiration at surface post dive	0	1	0	0	1
Total	**68**	**98**	**81**	**76**	**323**

The most common known mechanisms leading to injury, among those identified (n=97), were rapid ascent (31%), running out of gas (31%) or panic (30%) (Table 1.7.2-2). Together, these three mechanisms accounted for two thirds of all identified events that led to injury.

Table 1.7.2-2 Harmful events by year and overall, 2010-2013 (n=323)

Mechanism	2010	2011	2012	2013	Total
Unknown	12	73	50	60	195
Other	29	0	2	0	31
Rapid ascent	19	6	4	1	30
Out of gas	5	8	6	10	29
Panic	0	2	5	0	7
Oxygen toxicity	0	1	2	1	4
Breathing gas contamination	0	2	1	0	3
Hypertension/cardiovascular disease	0	0	4	0	4
Weight not dropped	0	0	1	1	2
Equipment	0	1	1	0	2
Alcohol intoxication	0	0	1	1	2
Asphyxia	1	0	1	0	2
Exertion/exhaustion	0	0	1	1	2
Inhalation of water	1	1	0	0	2
Entangled	0	1	0	0	1
Ascent from deep dive	0	1	0	0	1
Deep dive	0	1	0	0	1
Marine life attack	0	1	0	0	1
Possible breath hold ascent	0	0	0	1	1
Struck head	0	0	1	0	1
Buoyancy	1	0	0	0	1
Water movement	0	0	1	0	1
Total	**68**	**98**	**81**	**76**	**323**

It can be seen that the leading causes of death over these four years, where known, were closely tied to the leading disabling injuries that led to each death. The great majority involved drowning, cardiovascular disease, arterial gas embolism, or immersion pulmonary edema. After these both the causes of death and disabling injuries were prevalent in only single figures though, of course, many causes of death remain unknown. Even so, preventive interventions have four clear targets if they are to make the greatest difference.

Table 1.7.2-3 Disabling injuries by year and overall, 2010-2013 (n=323)

Disabling Injury	2010	2011	2012	2013	Total
Unknown	15	38	39	48	140
Cardiovascular disease	13	25	16	8	62
Drowning	14	15	13	13	55
Arterial gas embolism	19	4	4	2	29
Immersion pulmonary edema	0	6	2	2	10
Loss of consciousness	1	3	1	3	8
Decompression sickness	0	3	1	0	4
Other	4	0	0	0	4
Seizure	0	1	2	0	3
Alcohol intoxication	0	1	1	0	2
Carbon monoxide poisoning	0	0	1	0	1
Lung overexpansion	0	0	1	0	1
Water aspiration	0	1	0	0	1
Asphyxia	1	0	0	0	1
Hypoxia	1	0	0	0	1
Shark bite	0	1	0	0	1
Total	**68**	**97**	**81**	**76**	**323**

Table 1.7.2-4 Causes of death by year and overall, 2010-2013 (n=323)

Cause of death	2010	2011	2012	2013	Total
Drowning	36	26	28	21	111
Unknown	9	28	31	42	110
Cardiovascular disease	5	23	13	8	49
Arterial gas embolism	14	4	2	2	22
Immersion pulmonary edema	1	7	2	2	12
Decompression sickness	1	4	1	0	6
Unspecified, body not recovered	0	4	1	0	5
Myocaridal infarction	1	0	1	0	2
Carbon monoxide poisoning	0	1	1	0	2
Anoxic brain injury	1	0	0	0	1
Gunshot wound to the head	0	0	0	1	1
Pulmonary barotrauma	0	0	1	0	1
Shark bite	0	1	0	0	1
Total	**68**	**98**	**81**	**76**	**323**

Plotting the leading causes of death and disabling injuries, where known, we are able to identify clear targets for injury prevention initiatives (Figure 1.7.2-1). Drowning remains the most common cause of death but falls to second place behind cardiovascular disease as the leading disabling injury. The diving community is aging steadily as those of us who learned to dive some decades ago continue to dive, and as the average age of newly certified divers has also increased since the early days of recreational scuba. With these changes comes an increased prevalence of health problems, with cardiovascular problems leading. Attaining and maintaining adequate fitness for diving should be the goal of every diver. Survival from acute cardiac events will always be lower among divers in the water compared with people on land, simply because the circumstances are less forgiving. That is why divers should pay extra attention to health and fitness, to counterbalance the added hazards associated with the environment we dive in.

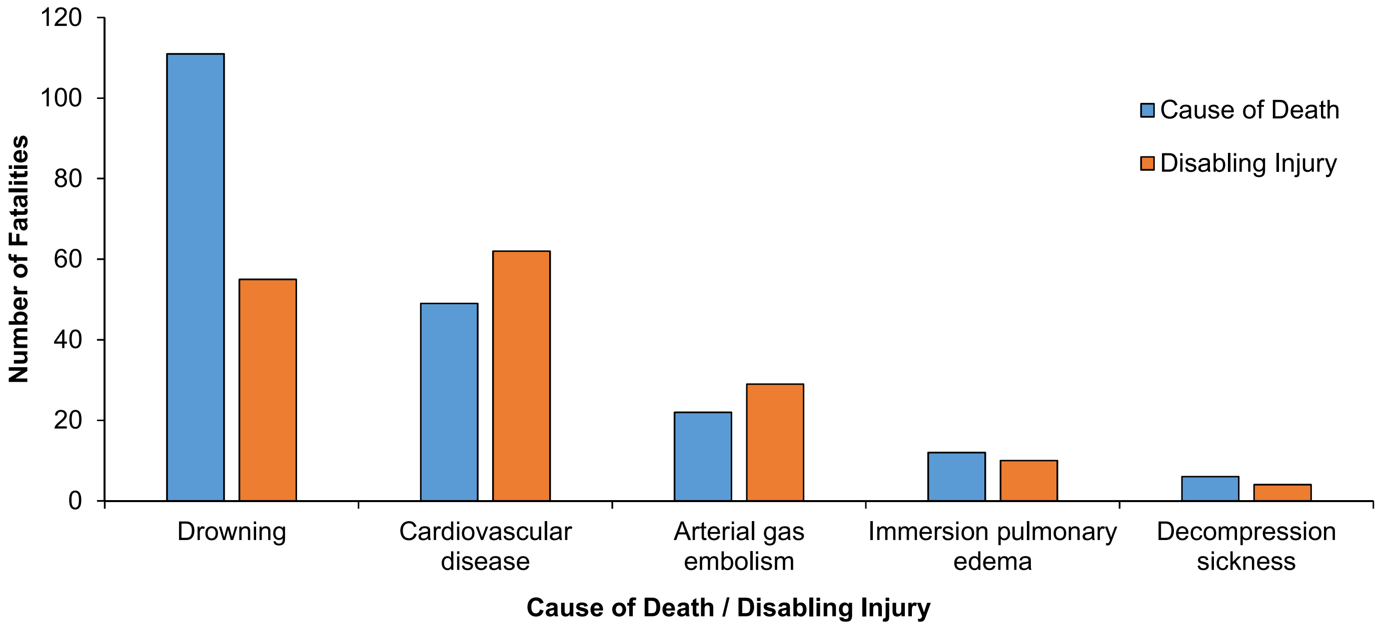

Figure 1.7.2-1. Distribution of disabling injuries (n=200)

1.8 Fatalities involving harvesting and spearfishing

Hunter/Harvesters

Recreational harvesting may be defined as catching marine animals such as lobster, abalone or fish for personal use while diving within recreational diving limits. Harvesting marine animals for personal use is popular in Canada and the USA among mainly male recreational divers. Legal harvesting occurs within designated locations and at specified times of the year. In Florida there is a 'sport season' which lasts just two days, ahead of the regular season, which lasts eight months.

There were 28 male recreational diver hunting fatalities in Canada and the US during 2010-2013. To identify characteristics specific to hunting we compared these hunters with a control sample of 105 non-hunter male recreational diving fatalities from the same period. Non-recreational divers and trainees were excluded from this sample, as were divers in freshwater lakes, quarries and dive parks.

Divers engaged in harvesting (hunters, n=28, 21%) were compared with non-hunters (n=105, 79%). Of the 133 fatalities, 15 (11%) were in Canada and 118 (89%) the US. Florida (n=39, 33%) and California (n=31, 26%) accounted for the majority of fatalities (n=70, 59%). There was a mean of seven hunting fatalities per year (Table 1.8-1).

Table 1.8-1 Number of male recreational diving fatalities per year 2010-2013, by hunting status

	2010 n (Col %)	2011 n (Col %)	2012 n (Col %)	2013 n (Col %)	Total n (Row %)
Hunters n (Row %)	9 (29)	10 (23)	6 (21)	3 (10)	28 (21)
Non-hunters n (Row %)	22 (71)	34 (77)	22 (79)	27 (90)	105 (79)
Overall n (Row %)	31 (23)	44 (33)	28 (21)	30 (23)	133 (100)

Anthropometry and dive history of hunters and non-hunters are shown in Table 1.8-2. Hunters were younger, on average (44 vs. 51), and yet had more dive experience but they had the same body mass index and died in water of the same depth as non-hunters.

Table 1.8-2 Recreational divers (n=133) anthropometry and dive history by hunting status

	Hunters (n=28)	Non-Hunters (n=105)	Overall (n=133)
Anthropometric			
Age years (SD)	44 (15)	51 (12)	49 (13)
BMI (kg·m-2) x̄ (SD)	29 (6)	29 (5)	29 (6)
Marital status n (% single)	10 (36)	50 (48)	160 (45)
Dive History			
>61 dives experience n (%)	9 (32)	23 (22)	32 (24)
Divers in team x̄ (SD)	2.0 (0.5)	2.3 (0.7)	2.2 (0.6)
Max depth fatal dive fsw x̄ (SD)	69 (57)	79 (71)	76 (68)
msw x̄ (SD)	21 (17)	24 (22)	23 (21)

Compared with non-hunters, the following were more common among hunters:

- boat diving (n=21/28, 75% vs. n=57/105, 54%)
- solo diving (n=8/28, 29% vs. n=13/105, 12%)
- night diving (n=5/28, 18% vs. n=1/105, 1%)

Of the divers who were low-on or out-of breathing gas, n=6/28 (21%) were hunters and n=7/105 (7%) non-hunters. Causes of death are shown in Table 1.8-3. As shown, hunters account for 21% of the dataset and yet they represent only 17% of cardiac deaths but 50% of the arterial gas embolisms.

Table 1.8-3 Cause of death by hunting status

Cause of Death	Hunters n (Row %)	Non-Hunters n (Row %)	Overall n (Col %)
Drowning	7 (22)	25 (68)	32 (24)
Missing	13 (19)	55 (81) .	68 (51)
Arterial gas embolism (AGE)	2 (50)	2 (50)	4 (3)
Cardiac	4 (17)	19 (83)	23 (17)
Immersion Pulmonary Edema	1 (33)	2 (67)	3 (2)
Decompression sickness	1 (33)	2 (67)	3 (2)
Overall	28 (21)	105 (79)	133 (100)

Discussion

Hunters were younger on average, compared with non-hunters. Hunters more commonly ran low-on or out-of breathing gas and hunters had slightly more AGE related causes of death than expected. Solo diving was also more common in hunters than in non-hunters. A picture emerges of a young, male diving hunter not paying attention to his submersible pressure gauge until it is too late.

Fatalities involving hunters showed a higher prevalence of the fatal dive being at night than among non-hunting fatalities. This is the converse to what is found in other parts of the world where lobster are permitted to be hunted only during daylight hours.

No denominator has yet been established in order to estimate the absolute risk of dying while hunting underwater. Compared with non-hunters, however, some relative indicators suggest possible targets for safety interventions, specifically the need to monitor one's gauge while hunting. Most fatalities involving hunters occurred in Florida and California, therefore safety interventions should target those two states.

In addition to fatality data collection, in the future more injury data (incident reports, diver surveys, Emergency Department admissions, etc) should be collated, both to better identify hazards particular to hunting and to quantify the burden of diving injuries attributable to underwater hunting.

Case 13-94: Spearing fish leads diver to run out of air

This 43-year-old man had an unknown certification and experience level. He and his buddy were spearfishing in warm water in the daytime (conditions not otherwise reported). The diver signaled that he was ascending; his buddy went to chase a fish. Shortly after, the diver approached the buddy in a panic signaling that he was out of air. The diver and buddy struggled over the buddy's regulator. The buddy pulled away and ascended via a line. The diver's body was recovered on the bottom with an empty tank. The cause of death was listed as drowning.

1.9 Freshwater diving fatalities

Each year, as the sun heads north and many divers prepare for the summer season, attendance at freshwater dive parks, quarries, lakes and rivers steadily increases. These sites often have no current, they do not involve a boat trip, the entry-exit may be diver-friendly and, as an added bonus, if a diver can stay off the bottom then the dive gear may not even need washing afterwards.

But appearances can be deceptive and each year DAN receives reports of divers suffering diving injuries and even deaths in sites that might otherwise appear relatively safe. Over the period 2010-2013 DAN received reports of 51 US and Canadian freshwater diving fatalities, 22 of those in what are commonly known as dive parks, scuba parks or underwater parks. In the rest of this section we will refer to them as dive parks and the definition we used to classify a dive park, or a non-dive park, was that a dive park had underwater attractions deliberately placed to attract divers, whereas any objects in non-dive parks visited by divers were not placed there for that purpose. A 'typical' dive park might be a local quarry with steps into the water or a dock for stepping off, buoys and descent lines down to a platform at 10-20 feet depth for practicing dive skills, with horizontal ropes for navigation between one attraction and another. A survey of mines converted into dive parks noted such attractions included sunken aircraft, small boats, cars, buses, exercise equipment and various other man-made objects to offer divers more novelty underwater than they might find in non-dive park quarries. Non-dive park sites may well still include stolen cars, old mining equipment and other objects that divers might find interesting enough to visit.

Many US dive parks also offer above-ground facilities such as on-site air-fills, picnic tables, toilets, sun-shelters, large signs showing a map of the quarry and more. A perception exists that dive parks may attract students participating in open water diver classes and divers who have not dived for some considerable time, possibly following a change in medical fitness for diving. Accordingly, given the relatively significant number of freshwater diving fatalities between 2010 and 2013 inclusive, we decided to look back over ten years of data to identify if diving fatalities in dive parks differed in any substantial way to fatalities in other freshwater sites. It should be remembered though that how many divers visit dive parks and non-dive parks each year remains unknown, as does how many dives are made in each type of dive site.

Of the diving fatalities in the DAN Diving Fatality Database, we excluded all sea/ocean dives, military and commercial divers, dives from charter-boats, cave dives, dives collecting golf-balls and dives in swimming pools. Finally, our dataset for 2004-2013 contained 47 diving fatalities in known dive parks and 63 more in other freshwater quarries, lakes and rivers, a total of 110 diving deaths in ten years.

There were 47 fatalities in dive parks and 63 in similar sites that weren't dive parks. The mean number of diving fatalities per year between 2005 and 2014 was 6.3 for non-dive parks and 4.7 per year for dive parks. Figure 1.9-1 shows the number per year by dive park status.

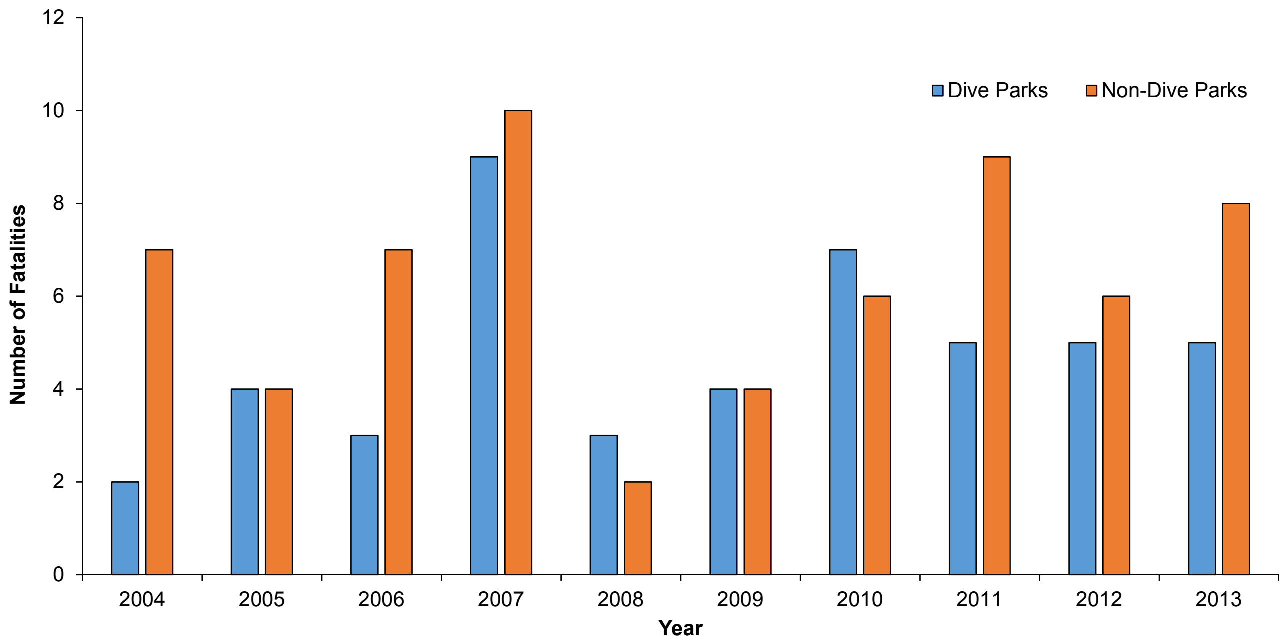

Figure 1.9-1: Number of freshwater deaths by year and dive park status, 2004-2013 (n=110)

Plotting deaths by month by dive parks and non-dive parks (Figure 1.9-2) suggests that deaths in non-dive parks climb over the summer and peaks in August, but that deaths in dive parks peak in the month that many consider as the start of the dive season, May.

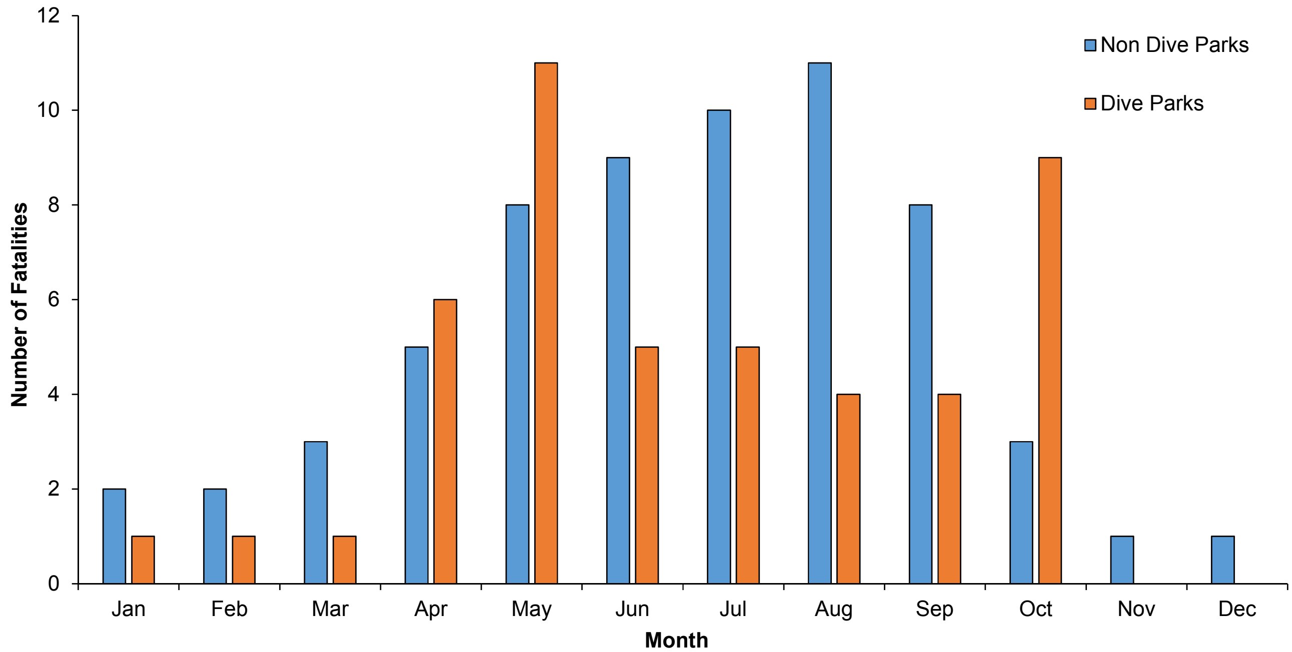

Figure 1.9-2: Number of dive park and non-dive park fatalities 2004-2013, by month (n=110)

The citizenship of the divers was 26 Canadian (24%) and 84 US (76%). The most frequent states for dive park fatalities were Pennsylvania (n=10, 21%), Ohio (n=8, 17%), Texas and Illinois (n=5 each, 11%). The remaining 11 states had three or less dive park fatalities each over the ten year period.

Characteristics of divers are shown in Table 1.9-1.

Table 1.9-1: Characteristics of freshwater diving fatalities 2004-2013

Characteristic	Dive Parks (n=47)	Non-Dive Parks (n=63)	Overall (n=110)
Males : Females n (%)	39 (83) : 8 (17)	54 (86) : 9 (14)	93 (85) : 17 (15)
Age x̄ (SD)	46 (14)	44 (12)	45 (13)
BMI x̄ (SD)	30 (7)	29 (4)	30 (6)
Divers in team x̄ (SD)	2.6 (1.0)	2.2 (0.8)	2.4 (0.9)
No dives last day x̄ (SD)	1.3 (0.5)	1.2 (0.5)	1.3 (0.5)
Max depth (feet) x̄ (SD)	76 (60)	39 (44)	56 (55)

The marital status of diving fatalities is shown in Table 1.9-2, by dive park status. While it might be tempting to suggest perhaps married divers are more likely to dive in dive parks, we cannot say without knowing how many dives are made in dive parks each year, and in non-dive parks.

Table 1.9-2: Marital status of freshwater diving fatalities 2004-2013

Marital status	Dive Parks (n=47)	Non-Dive Parks (n=63)	Overall (n=110)
Single	17 (36)	26 (41)	43 (39)
Married	16 (34)	12 (19)	28 (25)
Divorced/widowed	3 (6)	3 (5)	6 (5)
Unknown	11 (23)	22 (35)	33 (31)

The majority of fatalities in either dive parks or non-dive parks were recreational divers (77% overall), but there were twice as many technical divers in dive parks (n=8, 17%) as there were in non-Dive Parks (n=4, 6%). Students accounted for at least 10% of all fatalities and basic open water certification accounted for at least 12%, though it should be noted that certification status was not positively known in 55% of fatalities. While most divers (n=62, 56%) were simply diving for pleasure or sightseeing, 25% (n=28) were involved somehow in training.

The majority of dive sites were at sea-level (n=84, 95%) and the majority of divers (n=81, 74%) entered the water from the beach/shore, rather than from a dock or jetty. Only a minority were thought to be solo diving, 4/48 (17%) in non-dive parks and 4/44 (9%) in dive parks. Where each diver's equipment was obtained was known in only 47/110 cases (43%). Of those 47 the equipment was rented or borrowed in 36% of fatalities in dive parks, and also 36% of cases in non-dive parks. Clearly, with such high percentages, unfamiliarity with one's equipment must be more common among freshwater diving fatalities than among American recreational divers in general. Drysuit use may be less common than some divers might imagine. Among the 61 fatalities in which dive dress was known, only 21 (34%) were in drysuits whereas 37 (61%) were in wetsuits. There was no difference in diving dress between dive parks and non-dive parks. At least 12% of the 110 divers (n=13) were known to have ran out of gas. Causes of death are listed in Table 1.9-3.

Table 1.9-3 Causes of death for freshwater diving fatalities 2004-2013

Cause of Death n (%)	Dive Parks (n=47)	Non-Dive Parks (n=63)	Overall (n=110)
Air embolism	5 (11)	0 (0)	5 (5)
Asphyxia/drowning	20 (43)	19 (31)	39 (35)
Cardiac	3 (6)	9 (14)	12 (11)
Others	1 (2)	2 (3)	3 (3)
Unknown	18 (38)	33 (52)	51 (46)
Total	**47 (100)**	**63 (100)**	**110 (100)**

Discussion

Regardless of whether a diver dives in a dive park with buoys and training platforms, descent/ascent ropes and stairs into and out of the water, the most common cause of death is asphyxia/drowning. The maximum depth of fatal freshwater dives was deeper in dive parks than in other freshwater sites, and the proportion of fatalities involving technical divers was higher in dive parks. Solo diving was less common in dive parks which might be as expected, given that many dive parks forbid diving alone.

Dives involving diver training accounted for 25% of freshwater diving fatalities and, of the 47 fatalities where the provenance of the dive equipment was known, it was as common for the dive gear to have been rented or borrowed in either dive parks or other freshwater sites (36%).

1.10 Cave diving fatalities

There were twelve cave diving fatalities in the US during 2010-2013, five involving divers who were not trained in cave diving techniques and seven who were. Little can be learned from the untrained cases except to say that the need for cave diver training is well known and these five lives were lost merely reinforcing this well-known maxim. The two untrained divers who died in the Eagle's Nest on Christmas Day provided such a tragic example of what not to do that if anyone had any doubts that untrained divers do not belong in caves then those doubts must certainly now have been erased.

Proper training is needed to cave dive!

This year, DAN invested in an extensive analysis of the last three decades of trained US cave diving fatalities and we recommend interested readers locate our future paper on the full dataset of 67 trained US cave diving fatalities. Looking at the seven trained cave diving fatalities 2010-2013 is still instructive, both because the majority of cave diving fatalities in the US today involve trained cave divers but also because the information may assist training agencies monitor the effectiveness of cave diver training, especially in the face of widespread technological change such as adopting rebreathers, scooters, long-life torches, undersuit heaters and other advances.

Case vignettes often provide reminders of what is known to be safe and describe circumstances that lead to discussion in the cave diving community. Case summaries now follow.

13-CT01: Oxygen toxicity - confused oxygen for air tank despite proper labeling
40-year-old male was diving in a team of three, with two steel 130 cu ft back-mounted primary tanks and one stage-mounted aluminium 80 cu ft tank marked “O2” (oxygen) and “MOD 20”. The diver at the rear of the team reports that at approximately 10 minutes into the dive, the lead diver started waving his light. When the rear diver approached the victim he found him unconscious with arms outstretched and the stage mounted (oxygen) tank regulator in his mouth. The surviving divers replaced the oxygen regulator in the divers mouth with a regulator from the primary tank. The depth at this point in the cave is clearly beyond the accepted 20 fsw (6msw) Maximum Operating Depth (MOD) for oxygen, at around 85 ffw (26 mfw).

Efforts to provide gas to the victim may have re-started breathing though consciousness was not regained and breathing ceased before the victim could be extricated from the cave.

Prior to the fatal dive the victim had been asked about the markings on the stage tank which indicated the contents were oxygen but he had explained that the tank was actually filled with air (21% oxygen, 79% nitrogen). The victim had his own mixing and filling station at his home. No one reported seeing the victim analyse his gas prior to the dive and the victim’s dive computer was set for air. The stage bottle was analysed post-mortem and found to contain 98% oxygen, which would have given a partial pressure at the point in the cave where the victim first indicated distress of 3.5 ATA. The back-mounted primary tanks contained just 30% oxygen.

11-CT06: Handling gas tanks without checking labels led to oxygen seizures
50-year-old male, highly experienced cave diver diving as part of group of three. Other divers in the group observed the victim having what appeared to be a seizure at 220 ffw (67 mfw) after around 1 hour and 45 mins since he was last seen at the surface. While the other divers in the group completed decompression two divers from another diving party arrived onsite and recovered the body to the custody of waiting law enforcement.

It appears that the victim may have inadvertently staged at 70 ffw (21 mfw) the tank of gas he needed for the deep part of the dive and then later, at depth, switched to a gas mix that was intended for the shallow stage instead. The team the victim was diving with at the time usually utilize a procedure whereby each diver verifies the gas mixture label on the side of a tank before switching to it, and other divers in the team often verify that a safe mixture is being switched to. In this case the victim was last in the order of divers dropping tanks and switching gas, and three key factors colluded:

- the victim apparently did not check the labeling of the tank being dropped at 70 ffw (21 mfw)
- the victim did not check the labeling of the tank switched to at 220 ffw (67 mfw) depth
- the victim’s buddies did not notice either error.

The victim then breathed the wrong gas mix for nearly one hour at depth, inhaling a higher partial pressure of oxygen than is generally considered safe by the cave diving community, before apparently suffering an oxygen toxicity fit. The official cause of death was ruled a drowning.

12-CT02: Out of gas drowning
43-year-old male, full cave diver, was diving alone with two dive tanks. When he did not re-surface two hours later at the prearranged time his girlfriend raised the alarm. The site manager then entered the water and reportedly found the victim at 1200 ft (366 m) inside the cave although the recovery diver estimates the distance penetration may have been as much as 1700 ft (520 m). The cave starts with an entry area in which open water divers are permitted to dive but then at 300 ft (90 m) penetration there is a gate with a lock on it and the key is made available to trained cave divers only. As divers progress into the cave the depth increases steadily to around 160 ffw (50 mfw) where the victim was found. On this occasion the victim was the only diver in the water and a tank for decompression was left outside the gate. The contents of that tank are unknown. After recovery of the body (the following day) the two primary tanks worn by the diver were noted to have been empty and the valves open. What caused the diver to run out of gas remains unknown however

an unconfirmed report suggests the diver was using a single scooter which became entangled in the guideline. Certainly an unexpected delay at such depths can rapidly result in significantly greater gas consumption than planned for.

12-CT03: Possible panic after entrapment
29-year-old male, full cave diver engaged in a scientific dive. The victim was diving with a buddy and two additional divers were in support. The victim and his buddy passed through a restricted passage where divers must keep to the right since the left side pinches into a low trap. The buddy and two support divers saw the victim taking the incorrect route towards the impassable section and reported waving their lights to attract his attention. The victim got stuck in the restriction at ~90 ffw (27 mfw) and the buddy was prevented from rendering assistance because he was wearing his primary gas tanks on his back, whereas the victim's 108 cu ft tanks were on his side and thus he had entered a much lower space than the buddy was able to.

One of the support divers was also wearing sidemounted tanks and managed to reach the victim's fins in an attempt to pull him backwards. Suddenly free the victim ascended rapidly, swimming towards daylight instead of following the guideline to safety, where four additional tanks of gas were staged for emergencies at various depths. His buddies lost sight of him at this time. Later, the recovery divers found the victim wedged so firmly into a crevice that his equipment needed cutting off to recover him.

The equipment was recovered the following day. Both tanks still contained over 1500 psi (>100 bar) and tests of the gas in the tanks confirmed it was trimix 16/33 in the left and 21/29 in the right. After autopsy the medical examiner ruled the death a result of Arterial Gas Embolism.

11-CT05: Possible cardiovascular event after cave diving
68-year-old male unexpectedly left the decompression stop early and collapsed at the surface.

11-CT04: Decompression sickness
58-year-old male diving a rebreather had given up diving after diagnosis with various cardiovascular health problems but after valve replacement surgery he returned to cave diving. On this day the victim surfaced from a dive to 285 ffw (56 mfw) and while loading the van shortly after the dive he suffered symptoms compatible with decompression sickness (weakness, shortness of breath, headache, pains). The victim was admitted to an emergency department then transferred to a hyperbaric chamber where he died.

10-CT07: Possible panic disorientation induced drowning
67-year-old female diver signaled her buddy while heading out of the cave, appeared to her buddy to show signs of panic, then inexplicably turned around and swam back into the cave. The victim was found 830 ft (250 m) into the cave at a depth of 53 ffw (16 mfw). Following autopsy the cause of death was determined to be drowning.

1.11 Rebreather Fatalities

DAN is aware of 64 rebreather cases between 2010-13 that occurred worldwide. Nineteen of those (30%) were in the US, where follow-up inquiries often lead to obtaining further detailed information. The distribution of rebreather fatalities by country is shown in Table 1.11-1. Case vignettes from 13 of the US cases follow.

Table 1.11-1 Number of rebreather fatalities by countries (2010-13) n=64

Accident Country	2010	2011	2012	2013	Total
United States	3	9	3	4	19
Italy	4	1		1	6
Egypt	3	1		1	5
Spain			3		3
Finland		2		1	3
South Africa	1			2	3
Australia	1			1	2
Bermuda			1	1	2
France	1			1	2
Norway	1			1	2
United Kingdom	1	1			2
Netherlands Antilles			1		1
Brazil				1	1
Canada				1	1
Switzerland			1		1
Germany				1	1
Ecuador			1		1
Micronesia	1				1
Greece				1	1
Croatia		1			1
Ireland		1			1
Mexico				1	1
Malaysia	1				1
Oman		1			1
Poland	1				1
Sweden				1	1
TOTAL	**18**	**17**	**10**	**19**	**64**

11-01: Death with severely modified rebreather - final cause of death unknown
52-year-old male, unknown experience and/or certification level. Victim was using a heavily modified rebreather unit for the first time while diving in a quarry. On his second dive of the day, the victim started coughing and spluttering. Victim signaled to his buddy that he was in distress and started ascending. Buddy followed him and made a safety stop, where he became separated from the victim. Buddy located victim on the bottom, unconscious and with the mouthpiece out of his mouth. Buddy was unable to bring victim to the surface. He ascended to the surface to get help, instead. Buddy then returned to the victim and removed the victim's weights and was able to bring him to the surface. According to the buddy the victim surfaced 41 minutes into the dive before sinking again. The victim's unit was heavily modified according to the investigator's equipment report. If/how the modifications affected the outcome of this dive remains undetermined at this stage.

12-44: Oxygen sensor failure – drowning due to seizures caused by oxygen toxicity
52-year-old male, experienced technical diver and instructor, was supervising another diver who was working towards his trimix technical diver certification. Dive buddies witnessed victim experience a seizure at about 17 minutes into the dive at 160 fsw (48 msw), drop his mouthpiece and lose consciousness. Buddies brought the victim to the surface and tried to resuscitate him but without success. The investigation report suggests failure of the oxygen sensors as a probable cause of seizures. The report also indicated the decedent neglected to pre-breathe his CCR unit prior to the dive.

13-11: Regulator free flow and failed gas donation led to asphyxia at depth
55-year-old male, Master Diver certification and experienced. He was diving a shipwreck with a group. His dive buddies noticed the victim swimming with a free flowing regulator out of his mouth. The victim approached the dive buddies and signaled towards the bubbles by his chest and pointed over his left shoulder to turn off the valve for the free flowing regulator, after which one buddy shut off the valve to stop bubbles flowing from the regulator. One of them offered the victim their primary regulator which the victim attempted to use then returned. The witness described the victim as "acting like it did not work". Then the victim stopped moving and the buddies attempted to again put the regulator in his mouth. When that did not work, and it became clear he was unconscious, they send him to the surface alone from the depth of 200 fsw (60 msw). First, they tried to inflate his BCD, but then discovered the power inflator was not connected. They inflated his dry suit instead and sent him to the surface. All other equipment was examined and found to perform as designed, except for the unattached power inflator. Gas analysis findings came back within standard specifications.

13-78: Drowning (poorly maintained rebreather but unknown why he became unconscious)
38-year-old male, advanced certification and experienced diver. During descent, at 50 fsw (15 msw), victim signaled to his dive buddies to stop. The victim started to ascend but then lost consciousness and began to sink after a few seconds, hit his head on a platform and continued to sink. Victim was recovered by his buddies, pulled to the surface and taken to the hospital where he was pronounced dead. An equipment inspection by the investigating team determined the decedent's equipment had multiple deficiencies, including a mechanically non-functional alternative rebreathing device. The diluent tank had a 39.8% oxygen mixture and it should have been 50% mixture. The system was described as poorly maintained, O-rings were dry and the oxygen tank may not have been turned on, which could have caused hypoxia leading to unconsciousness. The victim was known to service his own equipment and a witness statement indicated the decedent had experienced some O-ring problems a month prior to the incident. How this could have affected the safety of the rebreather is not clear.

10-77: Unexplained death after treatment for decompression sickness
29-year-old male, instructor level certification and experienced diver who had a medical history of asthma. Dive profile was a 3 hour dive to a maximum depth of 248 fsw (75 msw). The diver completed the dive without symptoms or issues but, once back on the boat, complained of nausea and tingling limbs. He told others on the boat he suspected DCS, as he had on several occasions previously. Soon after, he experienced a seizure that lasted approximately 30 seconds. He regained consciousness but complained of shortness of breath and dizziness. He was transported to the local emergency room and later transferred to a hyperbaric chamber for treatment. Post hyperbaric treatment, his condition deteriorated with increased respiratory distress and he was taken to the emergency room. He became apneic and was pronounced deceased despite resuscitative efforts.

11-22: Severe decompression sickness - omitted 40 minutes of decompression
64-year-old male, certified and experienced technical diver. The diver ascended from a deep dive of 214 fsw (65 msw) at a slow and controlled rate, but past his decompression ceiling and missed approximately 40 minutes of computer indicated decompression. Immediately upon surfacing he was in distress and lost consciousness as the boat crew assisted him out of the water. He did not regain consciousness. Autopsy findings cite evidence of DCS and AGE.

13-82: Air embolism and asphyxia - ran out of gas
60-year-old male, technical diving certified and experienced. Diver was found unconscious and without a pulse at the surface following a solo dive. His regulator was still in his mouth upon recovery, however both tanks were empty. According to the investigation reports, an autopsy revealed his death was due to an air embolism from a rapid ascent and missed decompression after a dive to a maximum depth of 174 fsw (53 msw). The victim's dive computer showed he had a rapid ascent from approximately 80 fsw (24 msw). A post-incident equipment inspection determined that the tanks on the rebreather were empty and the oxygen tank was shut off. The bailout tank was also empty and the regulator of that tank had not been deployed.

11-46: Loss of consciousness at depth due to myocarditis
58-year-old male, experienced diver, was reportedly diving within a group of nine to a maximum depth of 280-320 fsw (85-98 msw). They had been diving for a week and the deceased was on his eighth dive in the series. Fourteen minutes into the dive, he started to ascend. Others in the group saw him and followed to make sure he was okay. Upon reaching him they found him bailing out. One of his buddies purged the regulator for him and handed it to the decedent. He took a few breaths and the regulator dropped from his mouth. His buddies tried to get the decedent to keep the regulator in his mouth but it kept dropping out until at some point he became unresponsive. His buddies released him at about 175 fsw (53 msw) to surface while they completed their decompression. The decedent was recovered by boat crew on the surface. He was unconscious and not breathing. Approximately 45 minutes of CPR was administered before he was pronounced dead. A pathologist determined the cause of death as myocarditis. Equipment was inspected by an investigating agency and was found to be functioning properly.

11-16: Sudden death due to cardiomyopathy
65-year-old male, technical diving certified and experienced. Victim was on a solo wreck dive to a maximum depth of 130 fsw (40 msw). The victim signaled to another diver on the wreck that he was lost. The other diver assisted the victim to the ascent line and the victim signaled he was 'okay'. He then made a lap around the wreck and returned to the ascent line. Approximately ten minutes later, the other diver arrived at the ascent line and noticed the victim was upside down and motionless with his mask off his face. The victim's emergency tanks were lightly tangled in an old anchor line with fishing line and mussels. The responding diver attempted to place the victim's bailout tank regulator into his mouth and purged it in an attempt to get air into him. At this time victim showed no visible signs of life. The responding diver was unable to inflate the victim's BCD, so he inflated the victim's dry suit and sent the victim to the surface while he completed his decompression stop at 60 fsw (18 msw). A friend of the decedent noticed him floating at the surface on his back. The crew of the dive boat recovered the diver onto the dive boat and, after lifesaving efforts were unsuccessful, he was pronounced dead at a local hospital. A computer download showed the decedent stopped breathing from the rebreather approximately 32 minutes into the dive and very little movement was recorded after 35 minutes. The equipment and breathing gas was examined and analyzed and was found to be in excellent condition with no malfunctions or contamination. According to the pathology report, the cause of death was determined to be Cardiomyopathy with undetermined etiology and the manner of death natural.

11-89: Sudden distress underwater and death due to atherosclerotic cardiovascular disease
39-year-old male, unknown certification and/or experience level. Medical history included Type 1 diabetes and obesity. At an approximate depth of 230 fsw (70 msw), victim signaled to two diving buddies that he was in distress. His buddies started to assist him and at approximately 140 fsw (43 msw) the victim became unresponsive. The dive buddies placed an alternative air source in the victim's mouth and started in water compressions. At approximately 50 fsw (15 msw) the dive buddies were unable to sustain enough air to keep the victim at depth to complete their last decompression stops, so they inflated the victim's BCD and dry suit and sent him to the surface, missing 30 minutes of decompression. Victim was recovered at the surface and taken to a local hospital where he was pronounced dead.

12-35: Anoxic encephalopathy
49-year-old male, experienced open circuit diver, received rebreather training a year prior to fatal incident. He was diving in shallow water (15 fsw, 5 msw) at a lake with a dive buddy to practice using his rebreather equipment. Dive buddy noticed that he had stopped moving and found him unresponsive. Dive buddy surfaced and called for help and another diver assisted the victim to the surface and shore. CPR was started immediately and victim had a return of pulse before EMS arrived. He was airlifted to a nearby hospital where he was listed in critical condition, but later died. The equipment was inspected by the sheriff investigator. The diluent tank had 3100 psi, the oxygen tank showed zero psi. Victim's back-up tank pressure gauge also read zero psi. The position of the valve was in the off or closed position. According to the investigator examining the equipment, "I turned the valve and immediately heard the tank pressurize the line. The pressure gauge now showed 3300 psi".

12-20: Starting dive with an empty diluent tank resulted in death due to asphyxia
67-year-old male, certified technical and experienced diver. The victim's medical history included heart issues (specifics unknown) but was he cleared to dive. The planned maximum depth for the dive indicated in the dive trip briefing was 60 fsw (18 msw). He was attempting his sixth dive on day two of a dive trip. At approximately 15 fsw (5 msw) diver was noted missing during the initial post-entry headcount by the divemaster. It took the divemaster approximately 5 minutes

to locate the victim at 147 fsw (45 msw). The victim was brought to the surface and lifesaving efforts, including CPR and AED, were administered but the victim did not regain a pulse or consciousness. The equipment was examined by fellow divers and according to a witness statements, the unit was found to be in working order with oxygen supply almost full at 2600 psi. The diluent supply pressure was at zero psi and the mouthpiece position was in open circuit.

12-04: Sinking and drowning due to mismanaged buoyancy
69-year-old male, advanced certification and experienced diver, diving using a closed circuit rebreather with five other divers (three others on closed circuit and two on open circuit scuba), diving from a charter boat. After entering the water, the victim left the group as planned to dive solo to a depth of 100 fsw (30 msw). The victim was found deceased in 92 fsw (28 msw) over 6 hours after the initial descent. It is speculated that the victim suffered from equipment problems including dry suit squeeze which led to inhibited movement, and overweighting (victim was carrying 27 lbs (12 kg) of added weight in addition to the negative buoyancy created by his bailout system and underwater camera system) which would have added to the difficulty of maintaining neutral buoyancy on descent. Upon recovery, His mask was on his face and the breathing loop was no longer in his mouth. The victim did not have a low-pressure hose attached to his drysuit valve or a low-pressure hose attached to the breathable inflator attached to his BCD. His breathing loop was closed, bailout regulator was not attached to harness, and inline shut-off valve was in the closed position. The rebreather's diluent cylinder was also empty. Only nine lbs (four kg) of the 27 lbs (12 kg) the victim was using was considered releasable. There was no indication the victim attempted to dump his weight.

Conclusion
Rebreather diving and rebreather fatalities appear set to continue growing in frequency. In the above case summaries it is clear that improper equipment use significantly influenced a number of fatalities. Even simple mistakes such as forgetting to turn on a valve or connect an inflator hose can prove deadly. For this reason DAN co-hosted Rebreather Forum 3 in Orlando, Florida, on 18-20 May, 2012. Attended by the Who's Who of rebreather diving, the international cast of presenters covered topics ranging from rebreather user groups, through gas analysis, rebreather testing and ultimately moved to fatality prevention, including the promotion of adopting CCR check-lists.[4] In the above case summaries the human factor stands out as a major contributing factor in many cases. Check-lists will not remove the capacity of a diver to make serious mistakes but they do help divers identify many common errors before they enter the water. Errors such as failing to turn the oxygen on are easily made, appear regularly in rebreather fatality reports and yet are so easy to prevent.

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Section 2. Dive Injuries

2.1 DAN Medical Services Call Center (MSCC)

Daniel A. Nord, James Chimiak, Stefanie D. Martina, Brittany M. Trout, Matias Nochetto, and Petar J. Denoble

DAN was originally established to provide assistance for divers in need of recompression therapy. Medical Services was the primary operating department as it fulfilled the DAN mission by communicating with divers in need of assistance or information. However, that task has grown over the years to include a broader range of responsibilities. Medical Services now offers consultation to medical professionals providing care for injured divers, and helps with DAN efforts on injury prevention, education (i.e. through the medical information lines), as well as research data collection.

The MSCC database is a single web-based application on a secured server which allows medics (case managers) and physicians to document medical inquiries, emergency calls, physicians and chamber referrals. The application is vital to the DAN medical mission and has existed in various forms since DAN's inception. The web-based form was first introduced in 2005 and has improved over time with several iterations. The MSCC serves two fundamental purposes: documentation and data collection. First, documentation answers medical-legal needs and provides a record showing what's been done and what's been said. But most importantly, it is an electronic record which enables communication of information relevant for case management between everyone involved in patient care. This communication can include time critical coordination of healthcare facilities, healthcare providers, expert consultants, air ambulance, recompression facilities, embassy personnel and even search/rescue that can be on opposite sides of world. Documentation also supports Quality Assurance reviews, allowing us to continuously learn and improve our services.

Table 2.1-1 presents the volume of calls and services provided. In a four year period there were 51,745 calls or emails requesting some assistance, information or consultation. The medical staff answered more than 15,600 calls to the emergency line and more than 36,000 medical information calls and e-mails. Cases range from predictable dive issues anywhere in the world to the unique, including even non-diving scenarios. Figure 2.1-5 shows graphically the volume of calls. While email and information calls seem to have similar volumes in the reported four year period, emergency call volume appears to be increasing continuously and doubling in a four year period.

Table 2.1-1 Volume of calls in 2010-2013

Source	2010	2011	2012	2013	Total
Information Line	5727	6266	5923	5556	23,472
Emergency Line	2518	3493	4382	5047	15,627
E-mail	3470	3444	2758	3161	12,833
Totals:	**11,715**	**13,203**	**13,063**	**13,764**	**51,745**

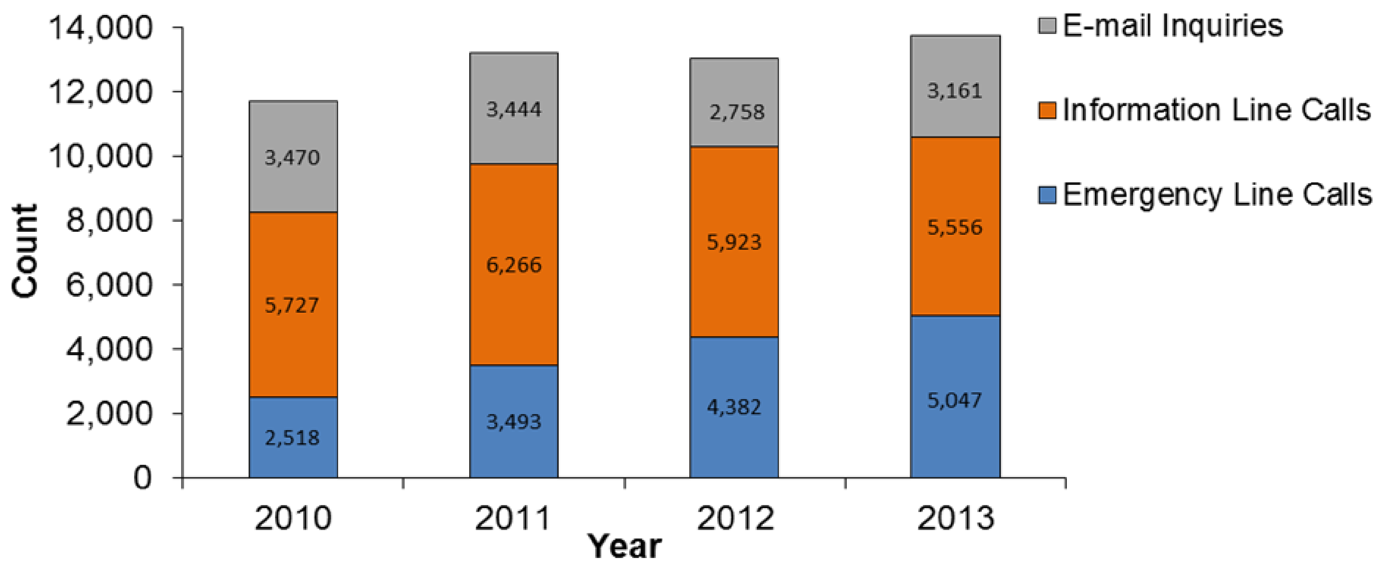


Figure 2.1-1 Emergency calls received in the MSCC

2.1.1 DAN Medical Information Services

The Medical Information Line includes access to Medical Services via e-mail. The phone and e-mail services are staffed Monday through Friday 8:30 am – 5:00 pm Eastern Standard Time in the U.S. and can be reached by calling +1-919-684-2948 or Ask a Medic on the DAN website at www.dan.org/medical. Common questions range from diving injuries to medical fitness to dive questions. Medical staff also provide consult with healthcare providers so they can better assist their patients.

Prevention and education are essential to keeping divers safe. Medical staff provide online and live education on topics ranging from dive planning to emergency care of diving injuries. These offerings are continually updated to keep pace with the most current standards of practice. Additionally, the department helps train and support hyperbaric medicine fellowships, as well as offering training in dive medicine to all levels of healthcare providers.

2.1.2 DAN Emergency Services

The best known service of the medical department is the operation of the 24-hour hotline, answered as "DAN Emergency Services". DAN Emergency Services provides around-the-clock access to on-call medical professionals with extensive training and years of experience in diving and travel medicine. They assist divers in need as well as healthcare providers who require timely consultation with a diving medicine expert. Calls that usually take the most time and assistance are those of suspected decompression illness that may require recompression treatment. DAN assists with providing help to injured or ill divers locate the appropriate facility where they can be evaluated by trained medical professionals and receive any treatment they need, while taking into account the constraints of given geographical locations. Neither diving medicine trained physicians nor hyperbaric treatment facilities are widely available which makes management of suspected DCI cases complicated. Sometimes complicated medical evacuations are indicated in the best interest of the injured diver. The allure of travelling to an uninhabited location that few divers have previously been is increasing. It may take days of travel by air and then boat to reach such a location. So when an emergency occurs, the medical capabilities aboard that vessel may be the only assistance available for a critical period of time. DAN's dedicated medical information specialists and physicians never give up and do their best to meet callers' needs.

These services are available to anyone and supported by membership with DAN. On-call medical staff also helps coordinate DAN Travel Assist services and benefits for members. DAN Emergency Services can be reached 24-hours a day by calling +1-919-684-9111.

2.1.3 Where are Divers being Treated?

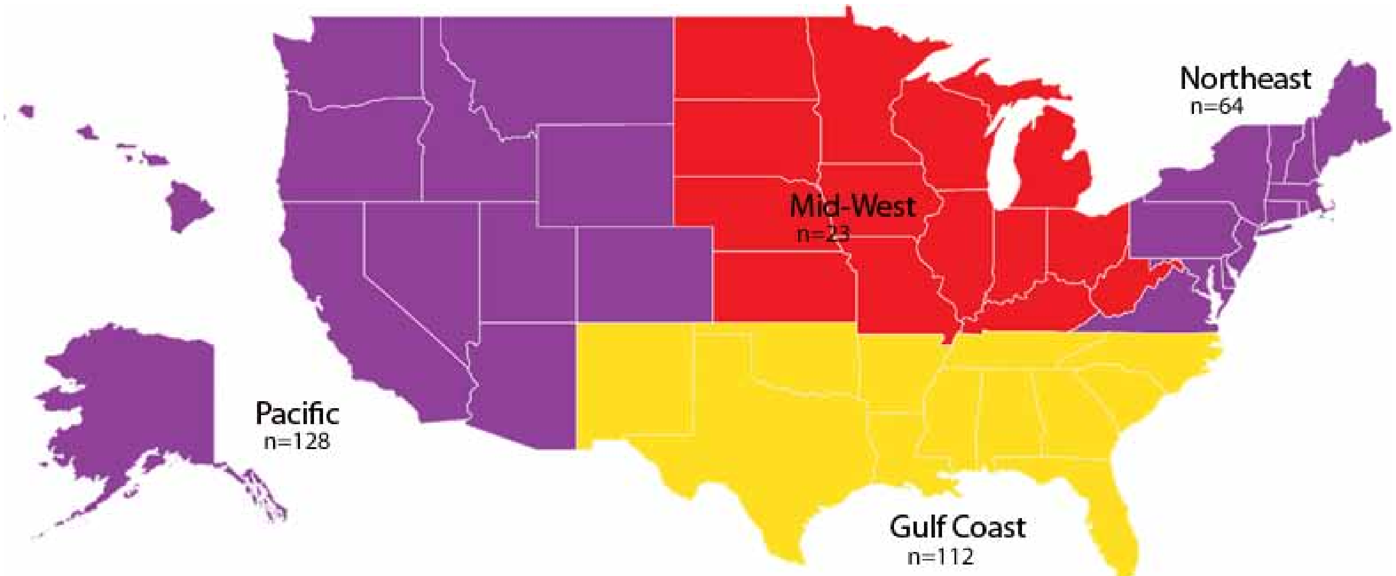
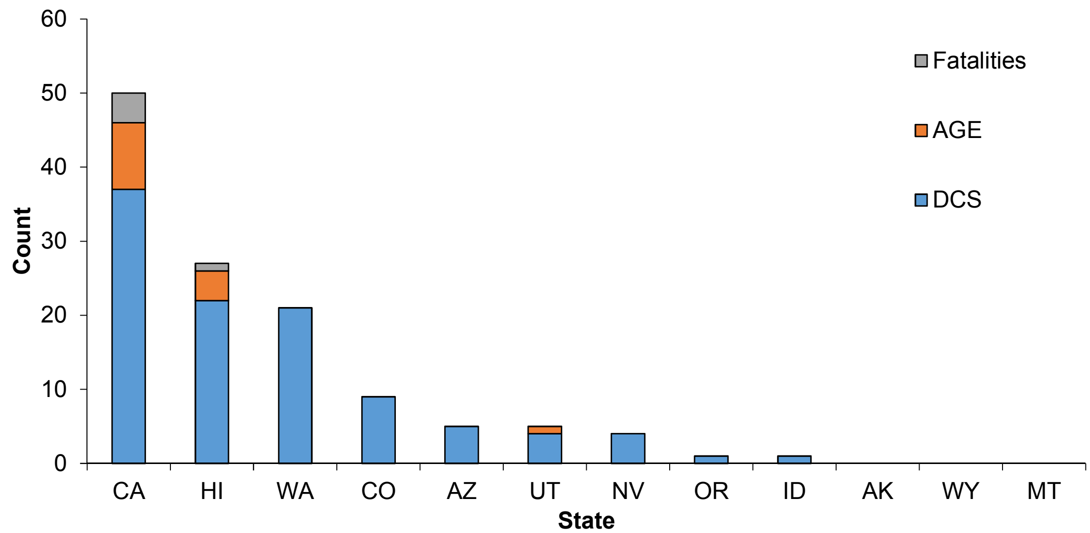


Figure 2.1.3-1 Where divers are treated by region (2013 Data)

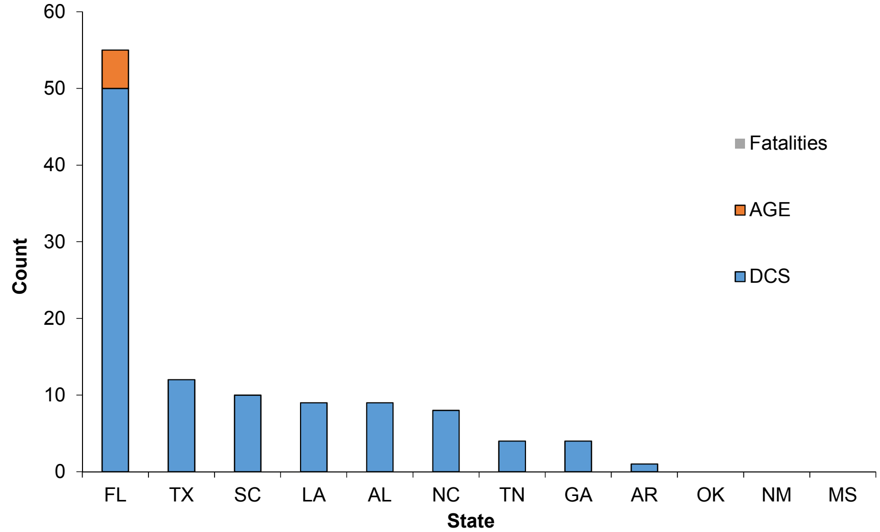
The 50 United States are divided into four primary regions; the Pacific Region, the Gulf Coast, the Northeast, and the Mid-West as illustrated in Figure 2.1.3-1. For 2013, DAN referral chambers within these regions reported a total number of 327 divers receiving treatment for decompression illness (DCI). It is important to note that this shows where the treatment was conducted, but not necessarily where the injury occurred.

The following charts illustrate the active states within these regions:

Pacific Region (n=128)

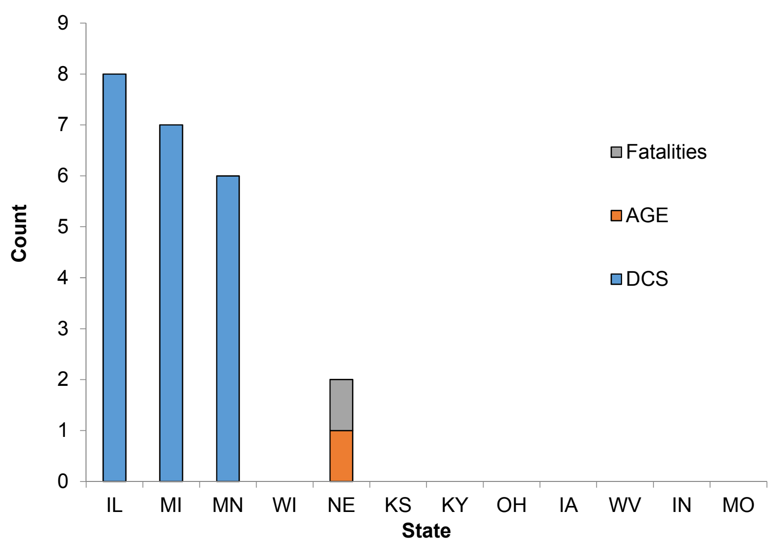


Gulf Coast Region (n=112)



Northeast Region (n=64)

Midwest Region (n=23)



2.1.4 DAN Travel Assist

DAN members enjoy a range of benefits which include medical, travel and personal assistance when traveling more than 50 miles from home. In addition to access to emergency and information line available to everybody, DAN members have access to DAN Travel Assist which works closely with DAN Medical Services to provide assistance with medically necessary evacuations and transfers, as well as medical monitoring, translations and insurance claims.

Table 2.1.4-1 and Figure 2.1.4-1 illustrate the increasing demand for medical assistance, consistent with the increasing volume of calls to DAN Emergency Services.

Table 2.1.4-1 Travel Assist services provided in 2010-2013

Source	2010	2011	2012	2013	Total
Medical Assistance	177	195	181	195	748
Personal Assistance	178	201	134	114	627
Travel Assistance	30	45	78	68	221
Total:	**385**	**431**	**393**	**377**	**1,596**

During the four year period shown below, DAN Travel Assist arranged a total of 232 medically necessary evacuations and transfers. Repatriation of Mortal Remains was provided in 72 cases over this same period of time.

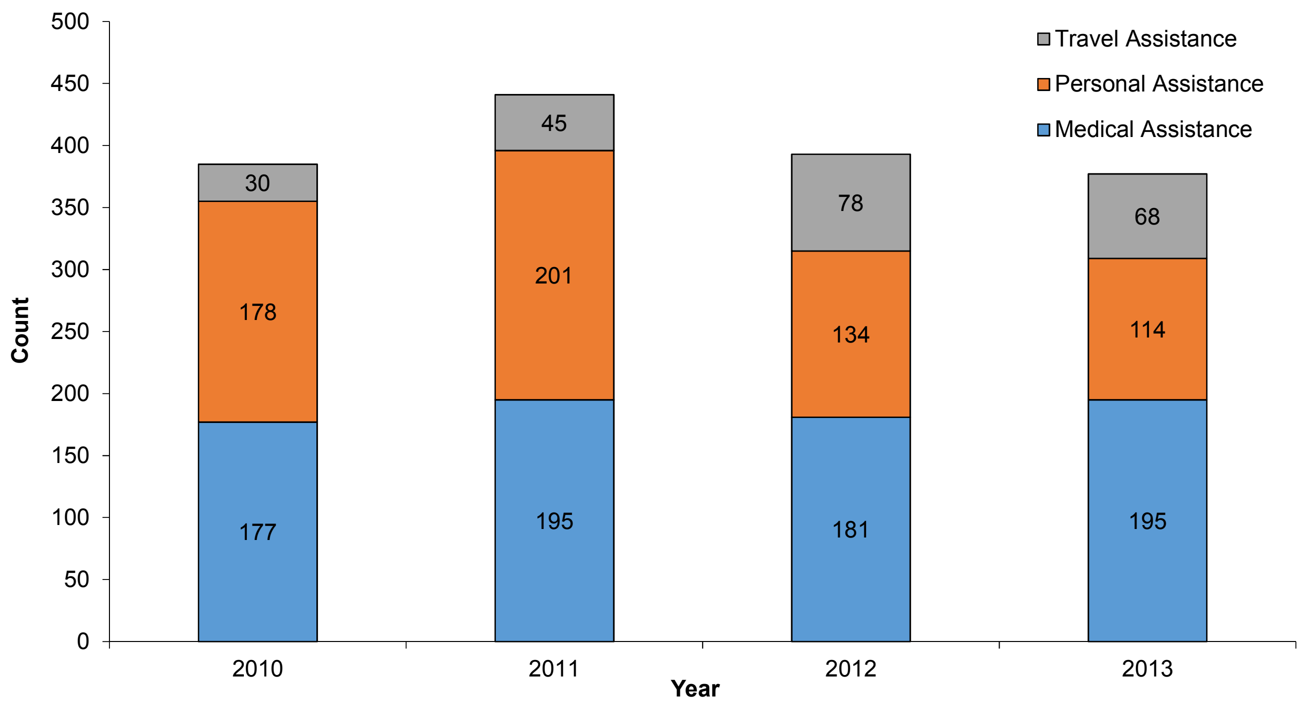


Figure 2.1.4-1 DAN Travel Assist services in 2010-2013

The origin of medical evacuations and their diagnoses are shown in Figure 2.1.4-2 and Figure 2.1.4-3. Most evacuations occurred within Southeast Asia and the Caribbean Basin, It is worth noting that the most common reason for evacuation was trauma (27 cases) while DCS and AGE ranked second with 12 evacuations.

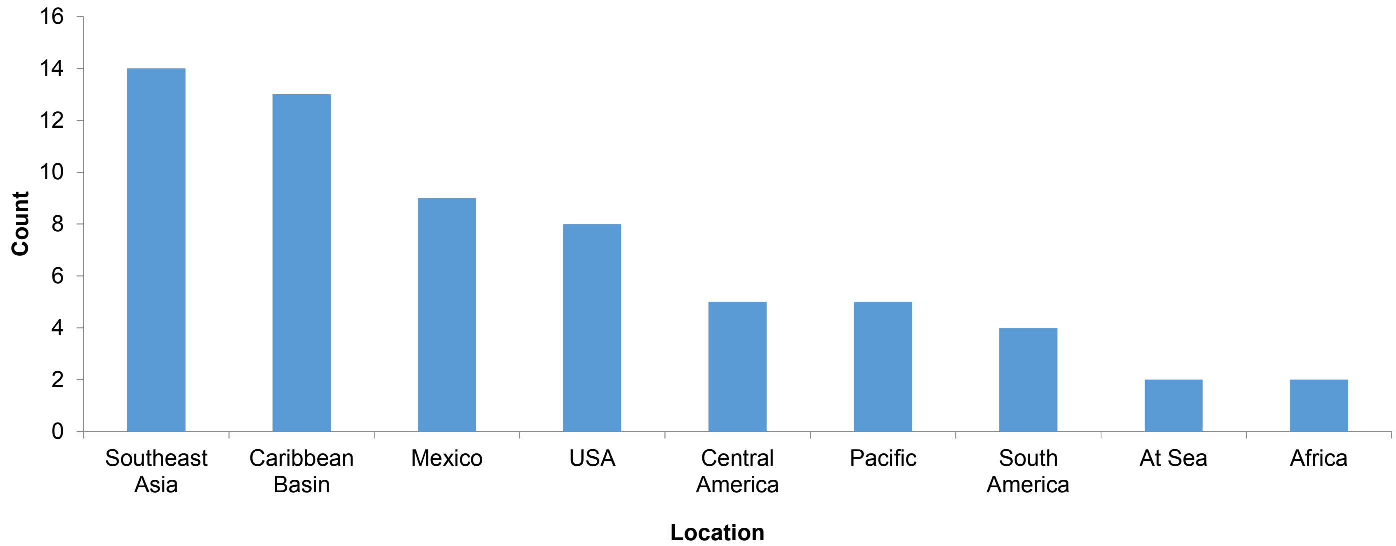


Figure 2.1.4-2 Origin of 62 cases of Travel Assist air evacuations in 2013

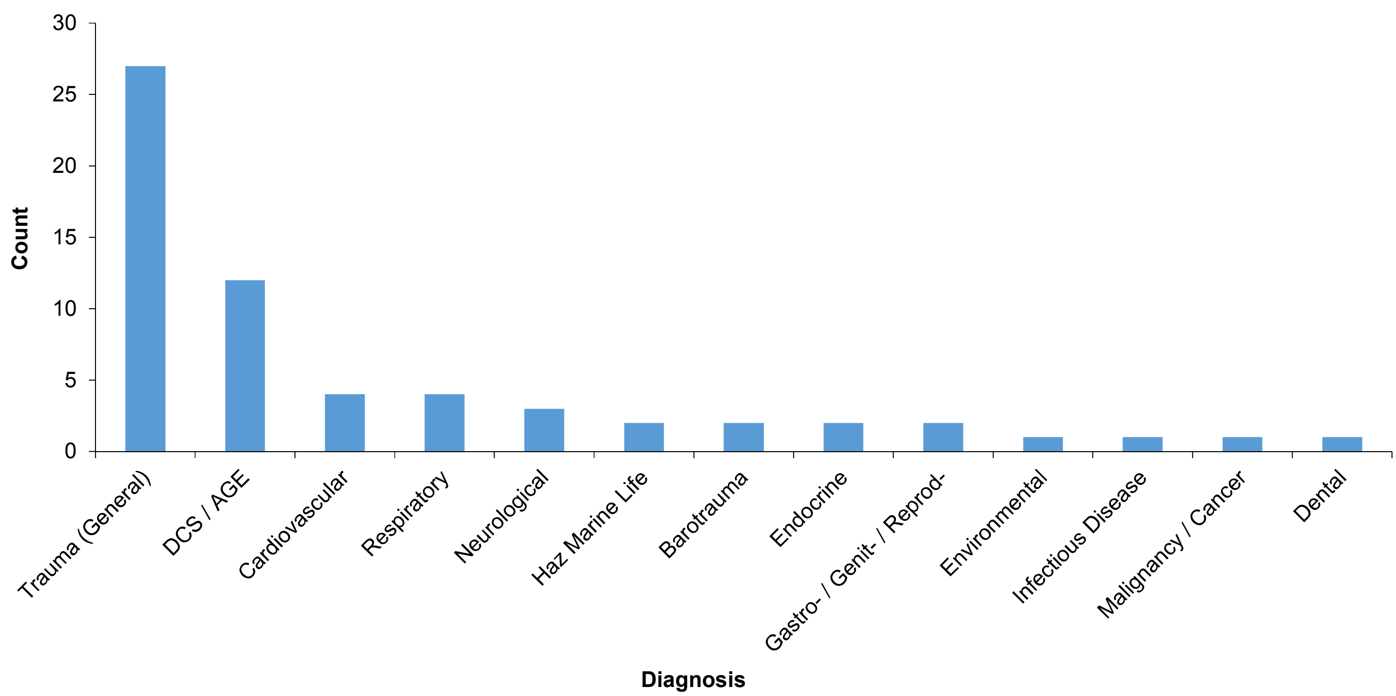


Figure 2.1.4-3 Diagnoses of cases Travel Assist evacuated in 2013

A typical evacuation case is described below.

Case 2-14: Evacuation from a general hospital to medical center with expert diving medicine staff
Caller is a 64-year-old male diver calling from Mexico and complaining of “rubbery legs”. He had completed a single 30 minute dive to 96 fsw (29 msw). About 40-60 minutes after surfacing, he noticed numbness on his upper thighs, an unsteady gait and tingling in both feet. He reported the dive as uneventful. He has completed this same dive several times with no incidents. He reports he is able to walk up and down the stairs but reports his legs “do not respond well”. Upon questioning, he further reported that this time he used a new wetsuit, and he had a “really hard time getting out of it”. Symptom onset apparently coincided with this effort.

At this time he was advised that his symptoms should be taken seriously and he should immediately seek medical evaluation at nearest medical facility. He was asked to call DAN back once he had been evaluated. The working diagnoses included stroke and neurological DCI.

Later that night DAN received a call from a local physician who evaluated this diver. He reported the patient exhibited an ataxic gait and decreased sensation over his thighs. The rest of the physical exam appeared normal. There were no signs of vestibular involvement. An EKG was performed with no abnormal findings. A consultation with a neurologist was scheduled and CT scan ordered to rule out a vascular injury within the brainstem.

A few hours later (early next morning), a follow up call with the patient was confusing in that he claimed to “feel fine”, yet he stated the numb area extended from his upper thighs to lower abdomen. He also states that he was able to walk when he drove in, but is not sure he could do it now. When asked about urination, he responded that he has not been urinating at all, and is not sure he can initiate urination on his own. No urinary catheter had been prescribed. The patient said he overheard the local Spanish-speaking doctors talking about neurocysticercosis. The case manager inquired about it with the local doctors who said they have identified lesions compatible with neurocysticercosis (a parasitosis with neurological compromise), and are also considering Guillain Barré syndrome (a neurodegenerative disease) as part of their working diagnoses. DAN recommended evacuating the patient to a higher level of care for further diagnostic procedures, to which they agreed. The patient’s DAN membership was expired, but he had the financial means to cover the expense for this evacuation.

The patient was medically evacuated to a university based hospital with a hyperbaric facility (Level 1+ recompression facility) within less than 24 hours from symptom onset. This hospital treats many injured divers and their physicians are expert in diving medicine. Upon admission, they diagnosed progressive neurological DCI with spinal cord involvement and neurogenic bladder. The patient received recompression therapy and ancillary care over the following three days showing significant steady improvement. Upon discharge, he returned to his home, where he continued with physical therapy. He made a full recovery about three months after the incident.

Early diagnosis in this case was confounded with an atypical presentation which could have been caused by other diseases considered in this case and with a diagnostic thought process (heuristics) of local physicians who had not seen a case of DCS before. Because of his previous and uneventful experience with this dive profile, the diver ignored the possibility of decompression sickness. For the objective observer, it would be wrong to judge the dive exposure just based on maximum depth and duration of the dive. If the diver had spent most of the 30-minute dive time at maximum depth (square dive) then the severity of decompression stress would be significant. However, if he had completed a multi-level dive profile, the stress would be theoretically less. The details of the dive profile were not known in this case, so the worst case scenario should have been assumed. The number one concern of his initial treating physicians was a stroke. They also had sufficient reasons to include neurocysticercosis and a Guillain Barré syndrome in the list of potential diagnoses. They had been working their usual way to make a final diagnosis for almost12 hours. However, the evolution of symptoms over the time that included bladder involvement, clearly indicated to DAN that DCS should be considered at the top of the differential list. Local physicians had no experience with DCS but they wisely accepted recommendations and evacuated the patient.

A local, hands on medical evaluation is indispensable. Just a phone call will never suffice to establish diagnosis with confidence and exclude other, possible life threatening conditions. Any qualified physician, regardless of specialty, has enough training and clinical skills to perform the requisite history and physical examination that can exclude other life threatening emergencies, and identify signs and symptoms consistent with the diagnosis of DCS. DAN cannot perform this vital on-scene function but can provide advice especially to those that do not regularly see diving related injuries or illness.

The fact that this diver reported his dive as “uneventful and conducted in the same fashion as many times before”, may prompt some investigation for other contributing factors like behavior before and after the dive. In this case, the diver had a difficult time getting out of his new wetsuit and had exhausted himself in the process. Symptom onset shortly after what he described as an extraordinary effort may be coincidental although strenuous post-dive physical activity is known to mobilize bubbles.

It is possible that the type of forceful effort involved in getting out of his wetsuit might have involved breath holding and increasing intrathoracic pressure in a similar fashion to what takes place while performing Valsalva-like maneuvers. Should a patent foramen ovale (PFO) be present, this could have shunted venous gas emboli to his left atrium and arterial circulation. During the patient’s hospitalization, the patient tested positive for a PFO. Although it is tempting to see this PFO as the smoking gun, we cannot say this with confidence as there may be intrapulmonary shunts that were not looked for or discovered. Furthermore, it’s well recognized that this etiology is still possible in the absence of any abnormal right-to-left shunts. Surfacing from a dive ends the exposure to compressed gas breathing, but the unloading of surplus gas lasts for hours and divers should avoid strenuous physical activity during that time. Following the “flying after diving guidelines” is a possible conservative guideline to help determine when it may be safe to return to strenuous physical activity.

Due to the geographic location where the injury took place and the availability of a 24 hour international airport in town, the logistics for a medical evacuation were remarkably seamless. A U.S.-based air ambulance was able to make a round trip from a major medical center in the U.S. within less than 6 hours. Many injuries take place where service providers are not readily available, or where air traffic depends on daylight and/or good weather. None of these were an issue here.

This was a serious DCS case that had a remarkably good outcome due to a number of factors:

1. Timely recognition of unusual symptoms following a dive
2. Timely call for assistance
3. Favorable geographic location with:
   - Available professional medical evaluation
   - Readily available assets and conditions for Med Evac
4. Aggressive case management with prompt call for Med Evac once local medical assistance reached its limits
5. Timely definitive treatment and aftercare
6. Patient’s financial resources to cover all expenses

2.1.5 Injuries reported through MSCC

The MSCC captures just a part of diving injuries and is most likely to capture cases suspected of specific diving injuries that require treatment in a hyperbaric chamber. It’s well recognized that the most common dive related injury is ear barotrauma, which is reflected in MSCC data although many more cases are probably treated in primary care settings or urgent care centers and remain unreported. In every diving report, one of our primary goals is to provide a slightly different angle to achieve the most impact at reducing injuries discovered upon review of the many recorded cases. By learning from both the good and bad experiences of others, we hope to continually improve the safety of diving. In this edition, we will provide a series of memorable cases for such purpose.

2.1.5.1 Decompression Illness (DCI)

Decompression Illness includes decompression sickness (DCS) and arterial gas embolism (AGE). DCS may be caused by free gas in tissues and circulation emerging from dissolved inert gas; AGE by gas in the arterial circulation originating from alveolar gas in over inflated or stretched tissue within the lungs.

Distinguishing between the two conditions is not always easy but it may be important in some cases. First aid is the same for both conditions and should not be delayed while attempting to figure out the right diagnosis. The primary concern of the DAN on-call case manager is to get the injured diver to a place where he or she can be evaluated by trained medical professionals and receive proper medical care depending on the nature and severity of their injury or illness. In a case of cerebral manifestations, a treating physician should attempt to distinguish DCS from AGE since the patients with AGE are occasionally treated with greater pressure (US Navy Treatment Table 6A (TT6A)) if admitted reasonably early post-injury. Thus, whenever possible, DAN case managers try to acquire details about dive profile, problems during the dive, ascent rate, symptom onset time, the evolution of symptoms, first aid administered and previous medical history. In some cases, AGE and DCS may be difficult to distinguish with certainty as symptoms of both can be present at the same time.

The difficulty is sometimes compounded by the patient‘s inability to effectively help with this inquiry and witnesses may not be reliable. The communication lines with patients and/or callers calling on their behalf may have technical issues or be interrupted before questions are asked. In many cases, calls come from physicians providing care for injured divers where they are requesting urgent consultation from DAN experts.

Spontaneous or unsolicited follow-up post-treatment reports from the treatment facility back to DAN are rare, and require DAN to locate divers, treating physicians, and follow up calls to treating facilities to get this valuable information and insure the patient receives the best treatment. DAN generally limit these attempts and to three times if accurate contact information was given by the callers. The rate of follow up completion in this reporting period was low and measures have since been taken to capture more detailed data. In 2014, DAN modified the MSCC, changed the communication center and quality assurance procedures, and added a position dedicated to follow up. These improvements in follow up completion and data quality will be reflected in the next annual report.

2.1.5.2 Decompression Sickness (DCS)

Decompression sickness manifests with symptoms and signs that often make it difficult to distinguish from many other conditions. The necessary condition for DCS is a dive exposure that causes a significant saturation with inert gas and the potential to create free gas in tissues and circulation if the ascent is too rapid. A properly controlled ascent is essential for keeping the gas dissolved while transported from the tissues to the lungs where it is off-loaded through respiration. A history of dive exposure and even “provocative dive exposure” is not sufficient for the diagnosis of DCS. There are two issues with using dive exposure as a diagnostic criterion. One is that there is no line that separates a harmful from innocuous dive exposure and the other is that self-reporting depth exposure and time is not always reliable despite divers carrying dive computers.

The so called No-Decompression Limit (NDL) is pragmatic and helps to separate lower risk dives from higher risk dives; but in fact, the risk is a continuum and increases with deeper and longer dives. The incidence of DCS in recreational diving is low because divers follow generally accepted guidelines to stay within No-Decompression limits. Additionally, multi-level dive profiles and limited gas supplies provide an extra margin of safety. Exertion, extreme water temperature, health afflictions and other factors add to the severity of exposure and may play a role in turning a previously safe dive into one that results in DCS. The association of these factors with DCS may be established statistically in large case series and prospective studies but hoping to identify causation in every single case is not a realistic goal. Usually, DAN case managers do not have sufficient data to rely on self-reported dive profiles and must be guided by the injured diver’s complaints until the results from a professional physical examination are available.

Definitive treatment of DCS (and AGE) requires a qualified hyperbaric facility. However, the path an injured diver should always follow begins with an emergency department or the nearest medical facility for proper evaluation and necessary stabilization. Even if the staff in such facilities are not familiar with diving injuries, with the assistance of DAN experts they can conduct hands-on evaluation and exclude other possible medical conditions.

However, the first step in diagnosis of diving injury is self-reporting. Divers should be familiar with the symptoms of diving injuries and learn how to report them. Denial and withholding information is quite common among injured divers who are in disbelief when considering the possibility of DCS. It is important to recognize that at least one in twenty divers will experience DCS in their diving career and at least one in three divers will likely experience ear barotrauma or some other minor dive injury.

Case managers are especially sensitized to symptoms that may be a part of DCS. Frequency of symptoms common to DCS reported by callers to the MSCC is shown in Table 2.1.5.2-1.

Table 2.1.5.2-1 Frequency of symptoms common to DCS reported by MSCC callers

Pain	496
Paresthesia	280
Skin	183
Nausea	136
Constitutional	108
Motor weakness	90
Respiratory	74
Vertigo	70
Hearing	50
Headache	50
Cortical	48
Cerebellar symptoms	47
Bowel	19
Nystagmus	18
Tinnitus	13

None of the listed symptoms is exclusively caused by DCS, but there are some patterns that increase the probability that they are manifestations of DCS.

Pain may have many causes, but pain in limbs and joints after a dive is highly suspect for DCS. Of course, other causes like injury and muscle strains are quite common. Divers should be prepared to endure specific questions about symptom details and previous medical history while the case manager attempts to evaluate the probability of DCS versus other possible causes that may be even more serious or even life-threatening. Just because one was diving does not eliminate the possibility that the new onset of pain may be something other than DCS.

Paresthesia is the second most commonly reported symptom associated with DCS. It is often colloquially referred to as “numbness and tingling or “pins and needles” To divers, the paresthesia may seem quite specific for DCS but there are many other possible causes which can confound the diagnosis.

Skin changes are reported more often in recent years since DAN and other educators have stepped up their effort to make divers aware of skin DCS symptoms. The diagnosis may be helped by providing a photograph of the affected area. MSCC received photos of a dozen such cases. Skin changes caused by DCS may appear as red dotted rash which can be confused with myriad of causes, and as a skin mottling (marblization) which post-dive can be caused by DCS. (see DAN skin DCS brochure and DCS booklet DCS)

Nausea and constitutional symptoms after diving may raise suspicion but they alone do not make the diagnosis of DCS. Motor weakness soon after a dive, is highly suspicious of DCS. It must be taken seriously and treated as DCS until disproved. When it affects limbs, it is most likely caused by decompression sickness of the spinal cord but other causes are possible. When associated with other manifestations of DCS such as skin, pain and constitutional symptoms, the diagnosis is more certain. Here are several cases involving motor weakness.

Case 2-01: Multi-organ manifestation of DCS
The call came from a member of the staff of a liveaboard who had an injured diver onboard. The diver had completed only one day of diving. The depths ranged from 45 - 90 fsw (14 - 29 msw). According to the dive computer, all dives were within the normal limits and did not require mandatory decompression stops. The last two dives showed a rapid ascent. Upon surfacing from the last dive, the patient developed acute confusion, dizziness, generalized weakness (staggering),

blotchy skin and itching throughout his abdomen. He also reported shortness of breath. He was placed in a sleeping bag and provided oxygen first aid. The liveaboard was 20 minutes away from the local port when the caller contacted DAN for consult and assistance in getting the member to medical care.

The symptoms presented in this case (cerebral, respiratory, motor and skin) along with their post-dive onset and evolution fit the diagnosis of DCS with a high index of suspicion. Although it would be difficult to find another condition with such a presentation, a professional evaluation is still necessary as some signs and symptoms could indicate the coexistence of another serious condition or even a completely different cause that may not be recognized by medically untrained staff. Once the boat reached the port, EMS took over and got the patient to a nearby hospital with an emergency department and hyperbaric facility where the patient was evaluated and properly treated for DCS.

Case 2-02: Know Thy Dive Computer!

The call for consult came from a physician in a hyperbaric department of a major medical center. He had a 42-year-old male who was diving in a spearfishing tournament. The patient reported making four dives but he knew only his depths. He didn't know his bottom times or surface interval times because the diver was unfamiliar with the computer he was using. His dives were to 33, 115, 100 and 108 fsw (10, 35, 30 and 33 msw respectively). The patient thought the computer may have advised no diving after the third dive, but he disregarded it and went on a fourth dive. That night, after the tournament, the patient developed left flank pain, motor weakness of both legs and disorientation. He went to a friend's house and attempted to self-treat with surface-level oxygen.

Two days later he went to the emergency department and was found to be ataxic with neurological deficits and left flank pain. He was treated on a USN TT6 with no extensions and experienced some degree of improvement. The following day he received another treatment on a USN TT5. His neurologic symptoms resolved but a slight left flank pain was still present.

This was an obvious example of severe DCS. It appears that the diver did not understand his dive computer which provides the primary safety measure – the control of dive exposure. He also did not present himself immediately to the hospital but instead attempted self-treatment. While surface oxygen may help to alleviate symptoms, it is not sufficient treatment for most cases and recompression should be administered. This diver was lucky that his injury seemed to be limited at the outset and did not progress.

Case 2-03: Surface oxygen did not suffice to prevent severe DCS after moderate exposure

The caller is a 55-year-old male who dove that morning to 100 fsw (31 msw) for 17 minutes breathing Nitrox 32%. All of his time was at 100 fsw. The dive was still within the no-decompression limits and the diver completed a safety stop. Upon climbing back on the boat, he started experiencing lower abdominal pain. He decided not to dive anymore and treated himself with oxygen for a period of two hours until it ran out. About an hour afterwards, the boat arrived back at the dock and the diver went home. He called the DAN emergency hotline because his symptoms returned and got worse. The skin on his legs, back, and stomach and just about everywhere from the waist down was numb and prickly. He was experiencing difficulty walking due to weakness in his left leg. He said it felt like his muscles did not want to work properly and he was having trouble standing. He denied any changes in skin color. He had been drinking water all day but was unable to urinate.

The case manager advised the caller that this is most likely a severe DCS and the caller agreed. Since he was only 10-15 miles from the medical center which has also a hyperbaric facility, he should have someone else drive him or call an ambulance. The caller said that since he drove himself home, he should be able to drive himself to the hospital. The case manager advised that this would be dangerous since he is already having trouble with his legs and his condition could worsen while driving. Patient was advised to call EMS and he did.

Immediately after this call ended, the case manager called the charge nurse in the emergency department and advised of patient coming and that he needs immediate attention. An hour later, the case manager verified that the patient had arrived and been transferred to hyperbarics. Several hours later, towards the end of expected hyperbaric treatment, the case manager called the hyperbaric chamber again. He learned that the patient did not improve much with standard USN TT6 and was at that time in his first extension at 60 fsw (18 msw).

After two treatment extensions the patient regained strength in his legs and his pain decreased to 1/10 but he was still unable to urinate and required a catheter. He also required several more hyperbaric oxygen treatments and eventually recovered to the point that he could be released home and continue physical therapy.

This case illustrated the need to admit for evaluation and treatment despite complete resolution of symptoms with surface oxygen first aid. The diver developed severe symptoms after a relatively moderate dive profile. Despite his use of enriched air nitrox (EAN) 32% as a breathing gas and staying within the no-decompression limit, he still suffered a severe spinal cord form of DCS.

Case 2-04: Headache, lightheadedness, dizziness, nausea and vomiting after spearfishing
This is a 62-year-old male, experienced diver, with an unknown prior medical history. He had a recent diagnosis of diabetes. The diver was spearfishing in the Gulf of Mexico about 30 miles offshore using a dive computer to monitor his dive profiles. He completed a series of four dives on air over two days on two different boats. No information is available for his dive profiles on that first day. The following day he did two dives; first to 120 fsw (37 msw) for 15 minutes and three hours later he completed a dive to 140 fsw (43 msw) for 25-28 minutes and problems ensued.

His dive buddy recounted that on the last dive, the diver spent the entire dive time on the bottom at 140 fsw (43 msw) with his spear gun. The dive buddy signaled several times to come up only to realize the diver was still on the bottom. The dive buddy put his hand in front of the diver's face but got no response. The diver was conscious but not responsive to his dive buddy. The dive buddy assumed the diver was suffering nitrogen narcosis; he physically grabbed the diver and the two began to surface. After completing a stop at 30 fsw (9 msw) for 5 minutes and another stop at 15 fsw (5 msw) for 5 minutes, they got separated. The dive buddy said his computer showed a decompression obligation and assumed the diver had a longer obligation due to his profile. Neither diver completed their decompression obligation because both ran out of air. The injured diver's computer was caught on video and can be heard alarming. Upon surfacing, the injured diver remembered everything about the dive and had no complaints.

Shortly after surfacing, the diver developed a headache with lightheadedness, dizziness, nausea and vomiting. Forty minutes after surfacing he was unable to stand or walk. The boat did not carry oxygen or first aid onboard. The ride back to the dock took about two and half hours. The diver was placed on surface level oxygen 30 minutes after returning to the dock. Transport to a local hospital by emergency medical services (EMS) was delayed one and a half hours after returning to the dock because the diver was in denial about the severity of his symptoms continued to direct his dive buddies to "give me another 10 minutes (oxygen)". A call to the local chamber found they were unavailable for treatment (an important reason to call DAN since the availability of any given recompression chamber often changes and is a challenge even for DAN to keep up with the most current status).

The diver's condition continued to decline after arrival at the hospital to the point that he had to be intubated and placed on a ventilator. Initial presentation at the hospital included hyperglycemia, tachycardia, and hypotension. The diver later developed left-sided pneumonia and kidney failure requiring dialysis. The diver was diagnosed with decompression sickness (DCS) and multiple unsuccessful attempts were made to find a facility that would accept him for hyperbaric treatment.

Two days after the dive, the diver was transferred to a facility with hyperbarics although he was still too unstable to treat with hyperbaric oxygen. Kidney function improved five days later and dialysis was discontinued. He was successfully removed from the ventilator 14 days after the accident. On day #15 he received his first hyperbaric treatment and day #16 he was discharged from the hospital and transferred to short-term rehabilitation. He continued with rehabilitation for an additional 77 days. He was advised to never dive again.

This is an example of risky behavior and ignorance of serious hazards in a geographic area with limited medical resources and no significant capability for treatment of diving injuries. Divers were warned by the boat captain who took them diving on the first day to account for this situation. However, the divers simply hired a second boat for the following day, and one that did not carry oxygen or first aid onboard. They discounted the risks associated with such isolation and continued with high risk diving. Once symptoms occurred, the divers were in denial. All this contributed directly to the occurrence of injury and to debilitating long term consequences.

Vertigo

Vertigo was reported in 70 cases. There are many possible causes of vertigo and the diagnosis is generally based on a set of specific tests, as well as evolution of symptoms over time. Sometimes vertigo resolved before the diagnoses was established. In divers, vertigo can occur during the depth change such as on descent and ascent or post-dive. It can be the result of barotrauma (during ascent or descent) or possible decompression sickness (the final stages of decompression or after surfacing). Subjective reports are difficult to evaluate because divers often confuse vertigo with dizziness. Here are two typical cases reported to MSCC.

Case 2-05: Acute dizziness beginning at depth

The caller identified himself as a dive instructor. He had a 30 year old female dive student who had difficulty on her first open water dive. The maximum depth reached was 30 fsw (9 msw) with a total bottom time of 20 minutes. Upon initial descent the student gestured that she felt dizzy. They proceeded to perform skills but after 20 minutes the dizziness became intolerable for the student. Instructor and student made a controlled safe ascent to the surface. Once back on the boat the student began vomiting. She denied any difficulty with equalization on this dive or at any time during her water training. The vomiting subsided on return to the resort. The diver slept for about 1 hour and felt no better. She was experiencing nausea with head movements.

The caller was concerned that her symptoms could indicate a decompression injury including a possible AGE. It was explained that since the symptoms started at depth any form of decompression illness was highly unlikely. There were many potential causes for her symptoms and a prompt evaluation by a physician was the best course of action. The physician's evaluation revealed no significant findings. The final diagnosis was acute motion sickness/anxiety.

Case 2-06: Acute vertigo after a long and shallow dive

A physician who is an emergency department attending contacted DAN regarding a 44 year old male commercial diver. He had made repeat dives within the hull of a docked ship to pump water out of the vessel. The maximum depth was 30 fsw (9 msw) for up to 4 hours. Similar dives had been made for the last 2 days without incident. Within 45 minutes of surfacing from today's dive he experienced sudden onset of acute vertigo, nausea and vomiting. He had difficulty walking and needed to reduce head movements as this increased the symptoms. EMS transported him to the local emergency department. On examination the diver also displayed nystagmus as well as all of the previously mentioned symptoms. He denied any difficulty with equalization especially any forceful maneuvers. Otoscopic examination of the tympanic membranes showed no evidence of any barotrauma. The caller was trying to determine if treatment in a chamber was indicated.

The shallow depth of the exposure would not typically suggest the possibility of inner ear decompression sickness (IEDCS). However, in the context of prolonged bottom times and physical exertion at depth, IEDCS could not be ruled out. DAN's dive physician consulted with the attending physician. The conclusion was again that despite the shallow dive, IEDCS could not be eliminated as a differential diagnosis and treatment in a chamber would be indicated. The patient was transferred to an appropriate facility some 45 minutes away from the initial hospital.

The first treatment was a USN TT6 which did not result in any significant improvement. The next morning he was treated with a second TT6 with measurable improvement. The patient still had some difficulty with walking but his vertigo was greatly reduced and the nausea, vomiting and nystagmus were resolved. A USN TT9 was provided the next day with marginal improvement. The patient was able to walk safely on his own and the opinion of the treating physician was that he would continue to improve with time. He was discharged that afternoon and was to consult with an ENT specialist. The diver did improve gradually over the next few weeks with ultimately complete resolution of all symptoms.

2.1.5.3 Arterial Gas Embolism (AGE)

AGE in diving occurs when, after gas is inhaled at depth, exhalation is slowed or obstructed during ascent. The gas expands, overinflates the lung and causes barotrauma if ascent continues. The AGE threatens anyone (not only divers) who breathe compressed gas. Indeed, AGE has been reported in breath-hold divers who took a breath from a compressed gas source at depth before returning to the surface. Expansion of gas within the lungs can over-distend tiny lung sacs (alveoli) and stretch segments of the lung, causing escape of gas into surrounding blood vessels. Lung rupture can occur from an ascent as shallow as 1 msw (3-4 fsw) if a diver takes a full breath of gas and ascends to the surface while holding it. Even a breath-hold ascent from 1.1 ATA may generate enough lung overpressurization to cause rupture.

Escaped gas can cause pneumothorax, pneumomediastinum, subcutaneous emphysema and/or arterial gas embolism. Entry of gas into circulation can block circulation in small end-arteries (arterial embolism) in various organs. The brain and the heart are most sensitive to this effect and are most likely to manifest symptoms. Cerebral arterial gas embolism (CAGE) is similar to a stroke, except that it is the result of gas emboli. Symptoms always develop suddenly. The quantity of gas and the areas of brain affected determine clinical manifestations. Smaller amounts of emboli may be well tolerated and manifest no symptoms The severity may vary from minor motor weakness, headache and confusion to disorientation, convulsions, loss of muscular power on one side of the body (hemiparesis), unconsciousness and coma. The underlying lung injury which opened the path for alveolar gas to enter circulation may be minimal and undetectable. Gas can enter small arteries directly adjacent to the bronchial tree or it can enter veins first and then pass through a PFO resulting in what is referred to as a paradoxical embolism. If the local manifestations of lung injury are absent, and the gas load during the preceding dive was substantial, the ability to distinguish an AGE from DCS may be difficult or even impossible.[1,2] On the other hand, even in obvious cases of AGE the untrained physician may miss the diagnosis or fail to treat it properly.

In this four year period there were more than one hundred calls to MSCC with concerns that the diver may have experienced an AGE. Diagnosis over the phone is never attempted; but when AGE is suspected, DAN directs divers to the nearest medical facility where they can be evaluated, stabilized and treated if necessary, or prepared for medical evacuation to a facility where definitive treatment will be provided. The final diagnosis is not known in many cases because often divers do not leave contact information or treating facilities do not provide reports. Here are several typical cases of AGE.

Case 2-07: Severe brain injury in a diver surfaced emergently from 120 feet

The caller was a hyperbaric physician who treated a 28-year-old male diver with diagnosed AGE. The diver run out of air at depth of 120 fsw (37 msw). He ascended to the surface with the aid of his buoyancy compensator device (BCD) and collapsed five minutes after surfacing. Hyperbaric treatment was initiated 4.5 hours later because of the travel time to the facility. The physician says they completed the USN TT6A with full extensions but there was no real improvement. They did not have the staff capabilities to provide another treatment that day. He stated the patient could move his extremities, respond to painful stimuli and was sometimes able to respond to verbal commands. He was not intubated. The patient did not have any significant medical history. MRI of the brain demonstrated multiple infarctions. The patient was admitted to the intensive care unit. The physician wanted to know if the patient should receive another USN TT6A.

This is a case where the diagnosis of AGE was very likely from the outset due to an obvious provocative factor (out of gas and emergency ascent), and abrupt, early post-dive onset of major neurological signs and symptoms. Experience from submarine escape training has shown that immediate recompression (within minutes of symptom onset) may save a life and revert brain dysfunction in most cases. However, recreational diving treatment facilities are almost always hours distant and with massive injury such as seen here, the success of recompression and hyperbaric oxygen treatment is uncertain. The MRI, which was done after the initial recompression treatment, has shown multiple infarcts; signs that this was a severe injury. MRI is not considered useful as a diagnostic tool for AGE before hyperbaric treatment, unless stroke is suspected. Regarding further treatment, DAN physicians advised to use a USN TT6 rather than USN TT6A. The difference between the two is that Table 6A begins with recompression to 6 bars (equivalent to depth of 50 m (165 feet)) for a short period of time with the aim to quickly crush bubbles and promptly re-instate circulation to blocked areas before the tissue dies (infarction) due to a lack of oxygen. After the first recompression treatment the bubbles in brain circulation are eliminated and there is no need for such pressure differential for the ongoing treatment regimen. The hyperbaric oxygen provided with a USN TT6 at 2.8 bar (18 meter; 60 feet) may help reduce damage to the brain and recover some lost functions. Follow up could not be obtained in this case and therefore the final outcome is not known.

Case 2-08: Marginal symptoms after a rapid ascent misdiagnosed
An emergency department physician called for consultation regarding a 42-year-old male patient who was a public safety diver. The day before, the patient surfaced rapidly from 40 fsw (13 msw). Immediately upon surfacing he felt altered mentation, “foggy feeling”, and sensation of being off-balance which did not improve overnight. The following morning he was taken to the emergency department for evaluation. His basic neurologic exam was unremarkable, the chest X-ray was normal, with no evidence of pulmonary abnormality, ear exam normal. The emergency department physician asked whether a HBO treatment was indicated, or would be of any benefit at this point since the insult had occurred 24 hours earlier.

Since that patient’s symptoms were reasonably consistent with a possible AGE, there was a provocative factor (a rapid ascent) and that the basic clinical exam did not find any other explanation for the patient’s symptoms, hyperbaric oxygen was recommended. The patient received a USN TT6 and reported that his symptoms resolved completely. Five days later the patient called again complaining of sensations of being “off” returning and becoming progressively worse over the last few days. At the time of call he felt mild dizziness, being “off”, and that his thought processes were slow. On re-admission to the hospital his MRI was clear. Other findings indicated possible inner ear issues, and he was prescribed meclizine which is commonly used to treat or prevent nausea, vomiting, and dizziness, as well as vertigo. After few days of meclizine treatment all his symptoms resolved with no recurrence.

Case 2-09: Fatal outcome of an unexplained DCI despite timely recompression treatment
This call came from a hyperbaric facility in the Caribbean. The caller was a physician at the chamber who had a 29-year-old male with DCS. The patient had completed a single dive to 35 fsw (11 msw) and during ascent was seen to have convulsions with loss of consciousness five feet below the surface. The diver was removed from the water and taken to a local hospital. Head CT was negative and chest x-ray was initially reported as normal. The only significant past medical history was a report of a”reduced lung capacity” about which the treating physician had no further information. This was the diver’s first scuba dive. It is not known if he had dive training. Dive details were not known. At the time of the call, the patient had left hemiparesis and sensory loss from the waist down. Telephone connections were poor which resulted in numerous interruptions for the DAN consult.

The condition relayed was classified as DCI regardless whether it was distinctly AGE or DCS. The patient was treated with a USN TT6 with full extensions. The physician called 30-minutes later and reported that the patient had another seizure just prior to treatment. The HBO was started but the patient was not improving. Soon, his condition worsened and he eventually became unresponsive. His breathing was rapid and shallow. Not much monitoring was available within the hyperbaric chamber. The chamber treatment could not be aborted due to the decompression obligation of the two inside attendants. By the time the decompression was completed, the patient had died.

The true diagnosis remains unknown. Findings of the post mortem investigation were not available. The early symptoms were consistent with a diagnosis of AGE. Convulsions while still underwater may not be the direct result of diving unless associated with breathing a hyperoxic gas mix, or experiencing severe hypoxia. Reports of witnesses are not always reliable, especially in a case that may involve some degree of liability. It was reported that this was a beginner diver who had been included on a dive tour although he was not qualified. Reports by the dive tour provider may have been defensively distorted. Regarding his progressive development of symptoms, hemiparesis with loss of sensitivity on both sides below the waist, this may have been an ascending spinal DCS, combination of AGE and DCS, or DCI precipitated by convulsions.

The local hyperbaric chamber in this case was situated within the hospital and attended by a physician. The chamber did not have advanced life support (ALS) equipment and as such would fit Level 2 chamber classification. For the most severe cases like this one, a Level 1 chamber with full ALS capability would be more appropriate. However, in the case of suspected AGE and obvious progression of symptoms, an immediate recompression may be life-saving and thus the right decision was made to use this chamber which was the only option within reasonable distance. The risk of complications in progressive cases like this is always present, but it should not prevent treatment which can be beneficial, if not life-saving in most cases.

Case 2-10. Seizures Should Not Prevent HBO Treatment of AGE.
This caller was a physician from a well-staffed and equipped hospital in Asia. He was seeking consult for 14-year-old boy who was injured while diving. While performing a safety stop at 5 msw (16 fsw), the boy panicked and surfaced in a rush. He seized on the surface multiple times. At admission, the patient was hypoxic, had cortical blindness, evidence of aspiration, and lesions on his chest and abdomen. His vitals were stable, but he continued to experience seizures. The local MD wanted to delay hyperbaric treatment due to the persistent seizure activity. The DAN consultant advised that HBO treatment should not be delayed. In the meantime, it was established that the patient had bullae in his lungs. The advice again was to recompress with a surgeon standing by to intervene with a chest tube if necessary. The risk of bulla perforating was small and HBO was likely lifesaving.

There were several cases of AGE with seizures. Less experienced physicians in substandard facilities fear convulsions in a patient while under pressure. However, when the patient is continuously attended by trained medical staff and under the supervision of a physician, seizures should not delay the treatment.

Case 2-11: AGE and Pre-Existent Seizures or Just Atypical Seizures?
The caller was a nurse practitioner at an emergency department. She had in her care a male diver in his thirties who had been participating in an advanced open-water dive class. During one exercise he became entangled in a rope and as a result made an uncontrolled ascent to the surface from a depth of 22 ffw (7 mfw). Upon surfacing he appeared disoriented then became unresponsive. Bystanders delivered rescue breaths. It was unclear if the diver was breathing spontaneously. After a few breaths the diver regained some degree of responsiveness but continued to be disoriented to place, time and others. He was provided high flow oxygen and transported by EMS to the Emergency Department. At admission he had difficulty following commands. Despite continued oxygen administration the patient was not improving. The caller suspected a possible arterial gas embolism (AGE) and was seeking the location of the nearest chamber that accepts emergent patients. DAN provided directions and the patient was transferred.

At the hyperbaric facility the patient was treated with a USN TT6. He had nearly complete resolution and returned to his baseline mentation. The plan was to treat again the next day with a USN TT5. Sometime prior to his scheduled treatment the patient exhibited another period of unresponsiveness in his hospital room. It was decided instead, to administer an additional USN TT6. The patient returned to his baseline mentation but within several hours after the USN TT6, he exhibited another period of unresponsiveness. Further diagnostic tests of the brain were ordered including CT, MRI and EEG. Both CT and MRI were negative but the EEG did detect a slight abnormality in signal transmission within the frontal lobe of the brain. The patient was treated with a USN TT5 the next day. Several times in the hospital he experienced short periods of unresponsiveness. No further treatments were planned pending further evaluations and diagnosis.

The patient's family volunteered information regarding his history. For an unknown period of time prior to the incident, the patient would randomly experience periods of "blank stares" with no awareness or memory of the events. After consulting with a neurologist it was opined that the patient has and was experiencing a form of seizure activity. He was placed on an anticonvulsant and continued the medication after discharge.

Blank stares are usually a manifestation of special form of epilepsy commonly referred to as "absence seizures" or "petit mal". They usually last a few seconds to 30 seconds during which time the subject is unresponsive. The consciousness returns to normal immediately. In this case, the confusion after absence was protracted and it is not clear if that was an atypical absence seizure or possibly an AGE combined with the pre-existing condition.

Case 2-12: Be aware of substandard medical care opportunities in developing countries
A 43-year-old male diver in excellent general health who lives temporarily in China was on holiday in Indonesia. He enrolled in an Open Water Diver certification course. The diver completed a series of five dives over three days. He was not using a computer to control his dives; he was guided by his instructor instead. No information is available about the first four dives. The fifth dive was 24 msw (79 fsw) for 45 min on air, one-on-one with the instructor.

After surfacing from the safety stop, the diver developed weakness, could not climb the ladder, suffered a syncopal episode while attempting to board the boat and required a rescue to bring aboard. He appeared to have suffered a right-sided paralysis (the duration not reported), tingling and numbness. He was able to see and hear but not move.

He had periods of visual disturbances and did not have sense of balance. He was placed on surface level oxygen and immediately rushed to the local hospital.

The diver was diagnosed with decompression sickness (DCS) by a local physician and treated with hyperbaric oxygen. After the treatment he reportedly had near complete resolution “except some weakness and mental cloudiness”, and he was released to his bungalow. Later that night he developed twitching and scattered, superficial numbness in legs, continued weakness, and difficulty walking but was able to sleep. The following morning he awoke to significant numbness and tingling in legs, waist, groin, lower back and fingertips. The diver was convinced by dive staff that leg numbness was normal due to excessive exercise so he wrongly dismissed his symptoms as overuse of muscles.

DAN was initially contacted by the diver’s father who was concerned after receiving an e-mail. Due to the diver’s remoteness, communication both by phone and e-mail was substantially limited. It took two days for the diver to receive the recommendation to return to the hospital for additional treatments. Signs and symptoms were more indicative of arterial gas embolism (AGE) rather than DCS. Limited training of the local hyperbaric staff resulted in an incomplete evaluation, incorrect initial treatment and an overly optimistic post dive evaluation and discharge despite the presence of significant neurological symptoms. When the diver returned to the hospital two days later, the staff consulted with local specialists and provided a four-hour hyperbaric treatment. Over the next several hours the diver recalls feeling 80-90% better, some lingering patches of numbness and tingling, but otherwise back to normal in every other way with no more weakness or mental cloudiness.

Four days after the initial injury the diver received one additional USN TT5 with a recommendation to travel to Singapore for further evaluation prior to returning to his home in China. After the first treatment in Singapore the diver had constant tingling in a few toes with patchy areas of transient numbness and tingling in right leg. The diver had one additional treatment in Singapore with marginal improvement. Physicians in Singapore concurred with diagnosis of AGE, more precisely CAGE (cerebral arterial gas embolism) and recommended no further diving.

Six weeks after the initial injury, and after what was thought to be almost complete resolution, the diver stated the right side of his body was weaker than the left, exercise is more difficult on the right side, muscles felt more flaccid on the right when resting, and continued superficial, transient tingling and numbness in patches on right leg.

2.1.5.4 Immersion pulmonary edema (IPE)

IPE, or swimming-induced pulmonary edema (SIPE), is fluid accumulation in the lungs that presents with shortness of breath (dyspnea) difficulty breathing, and coughing sometimes accompanied by frothy and bloody sputum (hemoptysis) during immersion. Symptoms typically resolve within 48 hours after exiting the water, but resulting complications and fatalities have been reported. Since first described as a rare condition in cold-water scuba divers, cases have been reported in various populations including triathletes, snorkelers, and combat swimmers in varying water temperatures. IPE can affect healthy populations as well as those with underlying cardiopulmonary conditions, especially hypertension.

From 2010 to 2013 there were 34 calls to the MSCC regarding patients with possible IPE. Six cases were classified as such by the treating physician and 28 cases were suspected cases of IPE based on reported symptoms. The diagnosis may be difficult to make, especially in cases that spontaneously recover before admission. At the time of the call results of clinical tests may not yet be available and follow-up information is limited in many cases. IPE could not be confirmed due to limited information available in three cases. Two cases reported difficulty breathing after surfacing from a dive with no additional details. One case reported shortness of breath but it was unclear if symptom onset occurred while immersed or afterwards. Additionally, this patient had a confounding medical history of a previous spontaneous pneumothorax.

Of the suspected IPE patients, there were 20 males and 14 females. Eight calls were from the patient’s medical care team for consultation. Seventeen cases reported the patient having had either a past history of cardiovascular disease or evidence of cardiac dysfunction at the time of the IPE event (refer to Table 2.1.5.4).The other 17 cases had no known cardiovascular history or was not reported. Two callers reported having had similar symptoms on separate occasions while diving.

Table 2.1.5.4-1 Cardiovascular risk factors

Cardiopulmonary risk factors	Number of cases (N)
Hypertension or undefined heart disease	7
Elevated cardiac enzymes	4
Atrial fibrillation	3
Hypotension	2
Diabetes	2
Cardiomyopathy	1
Asthma	1

Note: Total does not equal 17 due to cases with multiple risk factors.

Of note, six patients reported having had a rapid ascent following symptom onset which can result in additional issues and further complicate the diagnosis.

One case was an experienced diver participating in her third day of diving. She conducted a dive to a maximum depth of 100 fsw (30 msw) and felt like she was inhaling water. She attempted to purge her regulator, then switched to her alternate regulator and finally to her buddy's with no improvement. She described feeling as if she was choking. She made an emergency ascent, and her computer indicated it was too rapid. At the surface she lost consciousness, was rescued to the dive boat, and then transported to the local emergency department. Chest x-ray revealed pulmonary edema. She was placed on continuous positive airway pressure (CPAP), treated with a diuretic, and monitored until symptoms resolved. Subsequent inspection of scuba gear by the police revealed no malfunctions.

One caller retrospectively reported a case of shortness of breath and coughing up blood during a cave dive a week prior. He had experienced similar symptoms on another dive approximately three and a half years ago. Both dives were conducted on a rebreather. He had a history of hypertension and reported fluid-loading prior to the first episode. He was advised that this condition may have been IPE and that it may return in a more severe form. He was advised to not dive before consulting with a diving medicine specialist.

Another case was a middle-aged woman participating in a dive rescue course. She made a cold-water dive to a maximum depth of 15 fsw (5 msw) for an unknown amount of time followed by a controlled ascent. During surface drills the diver experienced shortness of breath, chest discomfort, and coughed up blood. She was placed on oxygen and transported to the local emergency department. CT scan revealed fluid in the lungs. She was monitored until symptom resolution.

2.1.5.5 Boat Related Injuries

DAN Medical Services Call Center (MSCC) received a total of 8 calls with incidents related to boat propellers from 2010-2013. In 2013, The Florida Fish and Wildlife Conservation Commission (FWCC) reported out of 1,012 vessels involved in an accident, four vessels reported scuba diving as the activity engaged in at the time of incident. The highest reported activity was recreational cruising, with 550 vessels (Boating Accidents Statistical Report 2013, Florida Fish and Wildlife Conservation Commission). The US Coast Guard reported a US total of 58 injuries sustained from a person being struck by a propeller as the primary accident type; however, it is unknown how many of these occurred during scuba diving (2013 Recreational Boating Statistics, USCG).

Organizations outside of DAN focus their efforts to raise awareness of boat propeller injuries in swimmers and boaters, as boating injuries is a broader injury prevention issue not just affecting divers. Some propeller incidents may not be captured by DAN due to the traumatic nature of these injuries and the emphasis on immediate emergency medical care. Reporting a dive related incident to DAN using the online diving incident reporting system (https://www.diversalertnetwork.org/research/incidentReport/) is a means for divers to help educate others about near-misses, accidents, or injuries experienced or witnessed, including boating incidents while scuba diving.

To prevent injuries by death and propeller and vessel strikes, divers and boaters are encouraged to proactively be aware of one another. Boaters are encouraged to stay a safe distance away from diver down flags (300 feet / 90 meters in open water and at least 100 feet / 30 meters in inlets/navigation channels for Florida waterways) and be familiar with local boating regulations, as they vary by state and country. Divers should never assume boater visibility, therefore diver down flags and surface marker buoys (SMB) should be used to signal diving position. Divers are encouraged to stay within a safe range (300 feet / 90 meters in open water and 100 feet / 30 meters in confined water), and surface within 150 feet / 45 meters of a displayed dive flag/SMB.

Case 2-13: Boat propeller causes foot laceration
59-year-old male, unknown diving experience/certification, suffered a 4 in (10cm) foot laceration after being hit by a boat propeller while scuba diving abroad. The diver also suffered bone fracture and muscle tear as a result of the laceration. A physician at the scene was able to assist with initial medical support until the diver was transported to a local hospital. Surgical repair was done and physical therapy was required for full recovery.

Boat operators are encouraged to ensure the engine is off and the propeller is still before allowing boarding or disembarking, and to communicate with swimmers/divers to stay clear of the propeller at all times, even when it is not moving. Divers are advised to remain clear of the boat propeller at all times because even a disengaged propeller can cause injuries.

Case 2-14: Diver cuts foot by kicking propeller
38-year-old male, unknown diving experience/certification, was diving with a group. The diver suffered a foot injury after accidentally kicking a still propeller while the boat engine was off. The force from his foot hitting the still propeller during a kick resulted in tendons being cut and blood loss. He was transported to a local medical facility to receive care.

2.1.5.6 Rebreather Injuries

The number of injuries reported with rebreather diving is increasing with the rising proportion of divers using semi-closed and closed-circuit rigs. These are often used in technical diving but rebreathers are gaining in popularity for recreational use as well. The DAN MSCC received 67 calls concerning injuries in rebreather divers. This is summarized by suspected injury type in the table below.

Table 2.1.5.6-1 Injuries among rebreather divers

Injury Type	Number of Calls
Decompression Sickness	26
Non-Diving Related	17
Immersion Pulmonary Edema	7
“Caustic Cocktail”	7
Ear/Sinus Barotrauma	4
Loss of Consciousness	2
Suit Squeeze	2
Arterial Gas Embolism	1
Hyperoxic Myopia	1
Pulmonary Barotrauma	0

Decompression sickness was the most common injury in the cohort. This is not unexpected given the deeper depths and longer bottom times that can be completed with rebreather diving. One rebreather diver had completed two dives on air. The dives were to a maximum depth of 104 fsw (32 msw) and 128 fsw (39 msw) for a total run time of 63 mins and 64 mins, respectively. Approximately 40 mins post-dive, the diver experienced tingling and pain in his left shoulder. Localized redness of the skin was also present. The diver consulted with DAN and was recommended to seek attention at the nearest emergency department. He was treated for decompression sickness with one US Navy Treatment Table 6.

The second most reported injury was non-diving related. These are injuries that were confounded by diving but were due to unrelated illnesses or comorbidities.

Immersion pulmonary edema (IPE) and “caustic cocktail” were the third most reported injury types. IPE has been reported in higher prevalence in rebreather divers due to the possibility for increased lung loading.

2.1.6 References

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2.2 Dive Injuries - Emergency Department Admissions

Peter Buzzacott

The US Consumer Product Safety Commission (CPSC) maintains a National Electronic Injury Surveillance System (NEISS) that includes 100 Emergency Departments (ED) in the US and US Territories. Originally, only injuries associated with consumer products were entered into the database but since 2000, patient information has been collected for all emergency department presentations involving injuries. Each emergency department is awarded a statistical weighting and, from these weightings, an estimate of the total number of similar injuries nationwide can be made, with 95% confidence intervals. The data are publicly available here: http://www.cpsc.gov/en/Research--Statistics/NEISS-Injury-Data/

The NEISS data is used each-year by the National Safety Council to produce their annual statistical report on unintentional injuries, called Injury Facts. In this report, a comparison can be made between sports and recreational pursuits as shown in Table 2.2-1. Cells shaded in peach indicate the age-group with the highest percentage of emergency department admissions and cells shaded in yellow indicate the second highest percentage age-group of participants presenting at emergency departments. The number of participants in the US and territories is not known for each pursuit, nor is the number of times each participant engages in that pursuit per-year. Therefore, we cannot conclude from this table which sport has the highest or lowest risk of injury. What can be seen in this table, however, is firstly that scuba injuries account for far fewer hospitalizations each-year than any of the other sports or recreations in this table and secondly, that the sports with the highest percentage of participants under 25 years of age are team sports. This is, of course, heavily influenced by the fact they are sports played in schools. However, as the age distribution shifts towards older participants, and the proportion of participants under 25 years presenting at the emergency department falls, (as shown by the shift in colored cells to the right, and by the falling percentage in the last column), then scuba injuries share a similar age distribution as bowling, tennis and fishing. As stated above, that does not imply these recreations share the same levels of risk.

Table 2.2-1 Comparison between emergency department presentations for selected sports and recreations 2010-2013, overall count and percentage by age-groups

NEISS 2010-13	Total	%	%	%	%	%
Sport	**n**	**<15 yrs**	**15-24**	**25-64**	**65+**	**< 25 yrs**
Cheerleeding	149,860	52	47	1	0	99
Gymnastics	121,715	74	21	5	0	95
Football	1,844,480	51	40	9	0	91
Soccer	900,730	46	39	17	0	84
Basketball	1,758,153	33	48	19	0	81
Baseball	621,029	52	28	19	1	80
Ice hockey	75,149	33	48	19	0	80
Snowboarding	177,527	25	51	25	1	76
Volleyball	229,215	32	44	24	1	75
Mountain climbing	17,664	14	37	45	3	52
Horseback riding	259,929	18	23	54	5	41
Raquetball/squash	21,259	8	29	55	8	37
Archery	22,303	16	20	44	19	37
Bowling	79,211	22	14	52	11	36
Tennis	85,204	17	19	42	22	36
Fishing	680,864	22	13	54	11	35
Scuba	4,368	9	23	62	7	32
Golf	137,285	20	8	40	32	28

There were 136 cases involving scuba, equating to 4,368 estimated emergency department presentations (95% CI 1,334, 7,400), with an estimated 1114 in 2010, 518 in 2011, 1297 in 2012 and 1438 in 2013. Of those, 3,159 (72%) were male and 1,209 (28%) female. Care should be taken when extrapolating small raw numbers, in this case probably anything less than 2000 cases, because a few extra cases in the sample can grossly inflate the estimated number of cases. That said, the following tables and figures offer a guide only to the types of injuries that might be seen in any year in emergency departments that receive divers. The actual number might vary from almost zero cases to twice as many as estimated (that is, the confidence interval) as shown in Figure 2.2-2, the monthly estimated number of cases with confidence interval whiskers.

The estimated mean age of patients presenting at emergency departments with scuba related injuries is shown in Table 2.2-2. The wide confidence intervals indicate how imprecise these estimates are.

Table 2.2-2 Estimated mean age of patients presenting at emergency departments for scuba related injuries between 2010-13, by sex

Sex	n (%)	Mean Age (yrs)	95% CI
Female	1,209 (28)	36.1	10.9, 61.3
Male	3,159 (72)	38.7	11.9, 65.6
Total	**4,368 (100)**	**38.0**	**11.6, 64.4**

Figures 2.2-1 and 2.2-2 show the estimated monthly distribution of emergency department presentations.

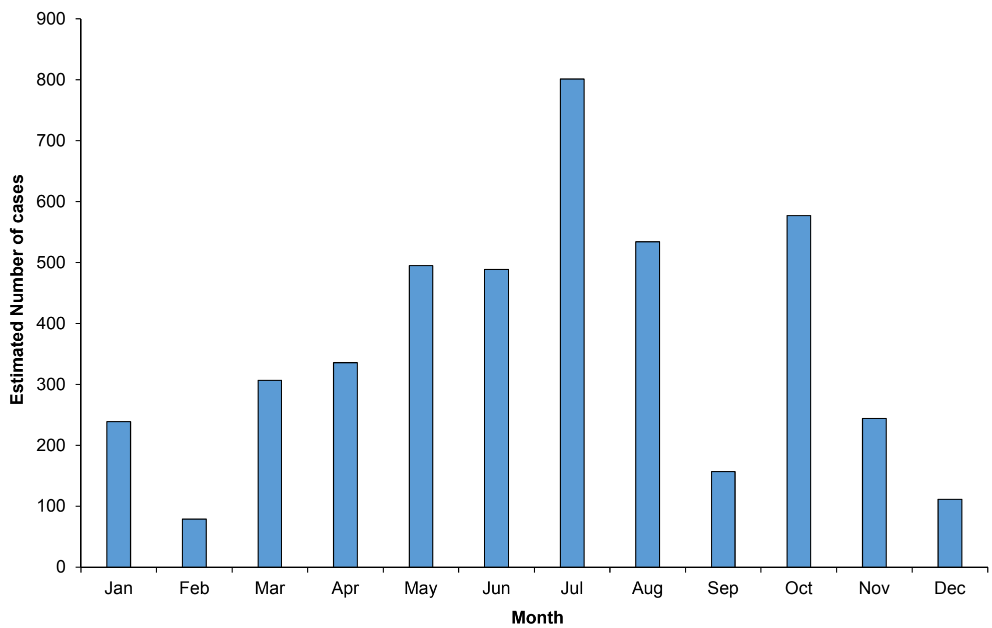

Figure 2.2-1 Monthly distribution of estimated US Emergency Department admissions for scuba injuries, 2010-13

As can be seen in both Figures 2.2-1 and 2.2-2, there is considerable variability month by month but overall injuries approximate the same monthly distribution as fatalities (see Section 1), peaking each-year around July and tapering off for winter.

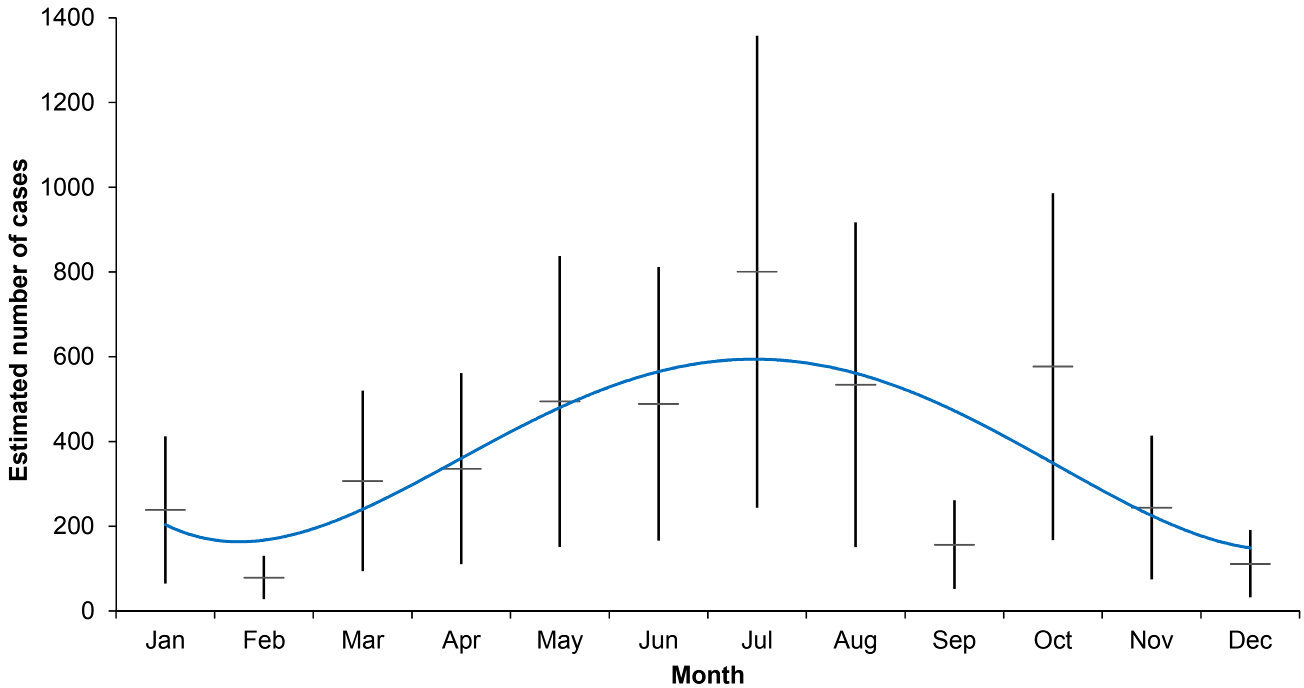

Figure 2.2-2 Monthly distribution of estimated emergency department admissions for scuba injuries, 2010-13, with 95% confidence intervals and trendline

Table 2.2-3 presents the areas of the body most affected when divers presented to the emergency department during 2010-13 and Table 2.2-4 expands the area of the body classification 'All parts of the body (more than 50% of body)' to show the types of injuries suffered.

Table 2.2-3 Body part affected by scuba-related injury 2010-13 (N.B. weighted estimate)

Body Part	NEISS Body Part Code	N (%)
Arm, lower (not including elbow or wrist)	33	133 (3)
Arm, upper	80	0 (0)
Ankle	37	31 (1)
Ear	94	1386 (32)
Elbow	32	68 (2)
Eyeball	77	272 (6)
Face (including eyelid, eye area and nose)	76	127 (3)
Finger	92	32 (1)
Foot	83	345 (8)
Hand	82	158 (4)
Head	75	126 (3)
Internal (use with aspiration and ingestion)	00	0 (0)
Knee	35	288 (6)
Leg, lower (not including knee or ankle)	36	174 (4)
Leg, upper	81	0 (0)
Mouth (including lips, tongue and teeth)	88	0 (0)

Table 2.2-3 (cont.) Body part affected by scuba-related injury 2010-13 (N.B. weighted estimate)

Body Part	NEISS Body Part Code	N (%)
Neck	89	0 (0)
Pubic region	38	0 (0)
Shoulder (including clavicle, collarbone)	30	111 (3)
Toe	93	0 (0)
Trunk, lower	79	63 (1)
Trunk, upper (not including shoulders)	31	405 (9)
Wrist	34	0 (0)
25-50% of body	84	0 (0)
All parts of body (more than 50% of body)	85	649 (15)
Not recorded	87	0 (0)
Total		**4368 (100)**

Of the 649 estimated cases with injuries affecting at least 50% of their body, Table 2.2-4 shows the type of injury suffered. Not unexpectedly, drowning or decompression sickness were the most common. The small numbers in the other categories represent a single actual emergency department admission in each category. All of the cell values in this table are so low that the actual prevalence of each injury cannot be estimated but, as mentioned before, they do suggest which types of injuries are suffered each year by divers.

Table 2.2-4 Code 85: All parts of the body (more than 50% of body) affected by scuba-related injury 2010-13

Diagnosis (Body Part 85)	NEISS Diagnosis Code	N (%)
Decompression sickness	71	276
Submersion (including drowning)	69	187 (4)
Diving Accident/Illness	71	48
Shortness of Breath	71	47
BPV	71	17
Hyperbaric	71	16
MI	71	15
Stroke / Air Embolism	71	15
Vertigo	71	14
Electric Shock	67	14
Total	**-**	**649**

Table 2.2-5 shows the diagnosis made for each case and the weighted estimate of possible cases in the US during 2010-2013. Classification code 71, “Other/Not stated” was by far the most common. Table 2.2-6 then further clarifies these code 71 cases.

Table 2.2-5 Diagnosis by NEISS classifications (Note: weighted estimate)

Diagnosis (All body parts)	NEISS Diagnosis Code	N (%)
Burns, thermal	51	16 (0)
Contusions, Abrasions	53	169 (4)
Dermatitis, Conjunctivitis	74	104 (2)
Dislocation	55	95 (2)
Foreign body	56	39 (1)
Fracture	57	133 (3)
Hemorrhage	66	16 (0)
Internal organ injury	62	444 (10)
Laceration	59	233 (5)
Puncture	63	80 (2)
Strain or sprain	64	173 (4)
Submersion (including drowning)	69	187 (4)
Other/Not stated	71	2663 (61)
Total		**4368 (100)**

Among the code 71 cases where body part was not code 85, Table 2.2-6, ear injuries were by far the most common. This is in keeping with the volume of calls received by the DAN Medical Services Call Center (MSCC) each-year regarding ear injuries. Once again the reader is reminded not to dwell on the numbers because they likely do not reflect the actual prevalence of injuries presenting at emergency departments, rather they simply confirm that these injuries do exist in the US. Additional research is required to quantify each injury.

Table 2.2-6 All parts of the body (more than 50% of body) affected by scuba-related injury 2010-13 (Body Part Code ≠ 85)

Other Diagnosis (Code 71)	NEISS Body Part Code (not 85)	N (%)
Ear pain/Otalgia/Otitis	94	832 (38)
Pain	35/36/37/79/92	302 (14)
Hemorrhage	77	240 (11)
Cellulitis	35/36/83	231 (10)
Chest pain	31	126 (6)
Dizziness/Headache/Syncope	75	110 (5)
Barotrauma	94	108 (5)
Octopus bite	33	70 (3)
Hand edema	82	39 (2)
Decompression sickness	31	31 (1)
Disruption	36	16 (1)
Paralysis	33	16 (1)
Tachypnea	79	16 (1)
Envenomation	92	16 (1)
Back disorder	31	16 (1)
Asthma	31	16 (1)
Leg numbness/cramp	36	16 (1)
Back Pain	31	15 (1)
Total		**2215 (100)**

Table 2.2-7 suggests the estimated greatest proportion of visits to the emergency department for scuba injuries resulted in divers being either treated and released or else being released without treatment. Though the actual number of fatalities is too small to give a trusted estimate, the indication is that the great majority of divers presenting to the emergency department with scuba injuries leave the hospital alive and well.

Table 2.2-7 Disposition of diving related Emergency Department admissions (weighted estimates)

Disposition	NEISS Disposition Code	N (%)
Treated and released, or examined and released without treatment	1	3672 (84)
Treated and admitted for hospitalization (within same facility)	4	219 (5)
Treated and transferred to another hospital	2	211 (5)
Left without being seen / Left against medical advice	6	110 (3)
Held for observation (includes admitted for observation)	5	79 (2)
Fatality, including DOA, died in the emergency department	8	77 (2)
Total		**4368 (100)**

Though detailed case notes were not available for the 136 actual cases listed by the NEISS, abbreviated case notes do offer an idea of the circumstances surrounding many of the injuries. An illustrative selection is reproduced here, with diagnostic abbreviations expanded for clarity:

2010 Emergency department admission notes

Case number	Case notes
100149233	43-year-old male went scuba diving today about 40 fsw (12 msw) developed severe pain in joints and chest. Decompression sickness.
100200501	48-year-old female was wearing a rented wet suit while diving and developed a rash all over chest. Contact dermatitis.
100809953	20-year-old male scuba diving and was bit by an octopus in the lower arm.
101019928	51-year-old male was scuba diving and was on a wreck hit side of wreck with ankle. Laceration foot.
100621584	48-year-old female was found unresponsive while scuba diving 15 fsw (5 msw) under water.
100544805	24-year-old male scuba diving in 10 fsw (3 msw) of water developed ear pain and otitis.
100921691	65-year-old male went scuba diving down 50 fsw (15 msw) for 30 minutes and developed severe chest pain upon ascent.
101035632	40-year-old male with syncope and dizziness. Recent scuba diving experience four days ago where he did two dives twice a day up to 80 fsw (24 msw). Diagnosis: syncope, headache.
100326602	Otitis media. 22-year-old male, pain since scuba diving on the weekend.
100936634	27-year-old male went scuba diving and upon ascent developed chest pain and nose bleed.
101122486	23-year-old male was scuba diving and ran out of air. Cardiac arrest.
100528769	14-year-old male went scuba diving to about 30 fsw (9 msw) and developed headache and facial pain; came up with bleeding in eyes. Conjunctival hemaorrhage.

100859397	29-year-old female went scuba diving down to over 30 fsw (9 msw) twice and came up; developed a severe headache. Diagnosis: headache, possible decompression.
100444519	50-year-old female was scuba diving when mask filled with water and she pulled out regulator. Diagnosis: near drowning, respiratory failure, barotrauma.
100325740	35-year-old male was scuba diving and cannot hear well. Diagnosis: left otitis media, eustacian tube dysfunction.
100800020	37-year-old scuba diving and developed severe pain in face at 30 fsw (9 msw) depth; then eyes started to bleed. Subconjunctival hemorrhage.
100448285	Diagnosis: perforated tympanic membrane. 23-year-old male scuba diving experienced sudden ear pain in left ear when descending.

2011 Emergency department admission notes

Case number	Case notes
110122085	Diagnosis: diving accident. 19-year-old female, rapid ascent from 85 fsw (26 msw). Blood in mouth when got to surface, shivering.
110362157	30-year-old male was scuba diving and exposed to coral reef after which developed itchy rash.
110641050	50-year-old male, was diving by himself and ran out of air at 200 fsw (61 msw) with rapid ascent. Diag- nosis: acute respiratory distress syndrome, decompression sickness.
110629066	64-year-old male, cardiac arrest-near, drowning. Co-divers rescued patient and started cardiopulmonary rescusitation at the water's edge.
110743227	47-year-old female, scuba diving, dove 35 fsw (11 msw), ear pain, continued with dive, ascent gradual and controlled, vomiting last 24 hours. Diagnosis: tympnaic membrane perforation due to barotrauma.
110432834	69-year-old male, fell and landed on his torso on his tank contusing chest.
110935413	Diagnosis: cellulitis. Leg/abrasion/right knee. 34-year-old female with abrasion to right knee injured while scuba diving; scraped on coral.
110707061	69-year-old female snorkeling and sustained a laceration to left knee on some coral.
111027280	68-year-old male, smoking cigarette wearing oxygen which caught fire burning face with 2% total body surface area, no fire department.
110122098	Diagnosis: perforated tympanic membrane left otitis externa left. 18-year-old male scuba diving at ~40 fsw (12 msw) heard pop to left ear. Had episode of vertigo, pain and fluid leaking from ear.
110649047	17-year-old male went scuba diving two days ago and developed severe pain in both ears. Diagnosis: barotrauma ears.
110832208	20-year-old male diving in harbor at 25 fsw (8 msw) and developed chest pain. Pneumomediastium.
110900138	30-year-old male scuba diving and had problems in 12 fsw (4 msw) of water, air issues and found at the bottom of the ocean. Diagnosis: near drowning scuba accident.

2012 Emergency department admission notes

Case number	Case notes
120620770	23-year-old female head injury. Hit head on someone's air tank while scuba diving.

Case number	Case notes
120733235	52-year-old male was scuba diving and struck right foot on coral, sustained an abrasion that got infected. Diagnosis: cellulitis foot.
130102099	Diagnosis: knee pain and swelling. 48-year-old male right knee pain after kneeling on sea urchin while scuba diving.
121037300	54-year-old male did three dives and developed chest pain and shoulder pain and transferred to hyperbaric chamber.
120910746	Diagnosis: chest pain. 44-year-old male complained of chest discomfort status post rapid ascent from 65 fsw (20 msw) while diving.
120213347	Right hand burn. 26-year-old female was scuba diving and went down to a sunken ship and pulling herself on a rope and sustained rope burn on hand.
120751590	67-year-old male scuba diving to 50 fsw (15 msw) and now has renal failure.
120643976	50-year-old male went down about 90 fsw (27 msw) while scuba diving and passed out. Brought to the surface. No heart beat. Cardiopulmonary resuscitation near drowning.
120855178	45-year-old male was scuba diving at 29 fsw (9 msw) and was later found at surface with loss of consciousness. Diagnosis: hypothermia, drowning.
121104418	77-year-old male -foot laceration. Had three pounds (one kilogram) scuba diving weight fall on foot.
120930901	Diagnosis temporomandibular joint disorder: 41-year-old female while diving to 40 fsw (12 msw), pulled the regulator out of mouth & put it back had a lot of pain to lower jaw.
120910768	Diagnosis: chest pain. 15-year-old male, status post while diving with dad, reports “rapid ascent” from ~65fsw (20 msw). Reports “chest feel funny”.
120341160	18-year-old male scuba diving at aquarium and developed nose bleed and toothache.
121252424	Diagnosis: skin erosion of left leg. 22-year-old male possible inflammation on left leg from scuba diving in Red Sea; possibly cut on coral.
120760653	53-year-old male developed chest pain and shoulder pain, headache after ascending from a scuba dive of 75 fsw (23 msw). Decompression sickness.
120445970	Diagnosis: thumb pain; status post envenomation lionfish. 50-year-old male stung by a lion fish. Right thumb. While scuba diving, impaled by lion fish spines.
120716031	Diagnosis: otalgia ear pain. 37-year-old female complaining of bilateral ear pain while scuba diving max depth 41 fsw (12 msw), felt pain in ears at 10 fsw (3 msw).
121100101	42-year-old male scuba diving went down 40 fsw (12 msw) and ears popped. Diagnosis: perforated ear drum.
120666999	23-year-old female, patient complaining of right shoulder pain status post diving in ocean. Diagnosis; right dislocated shoulder.

2013 Emergency department admission notes

Case number	Case notes
130234418	Diagnosis: nausea without vomiting suspected Type II decompression sickness. Dizziness, jaw pain, subacute. 35-year-old male scuba dive to 74 fsw (23 msw), feel nauseated near syncope.
130840638	41-year-old male, diving at 70 fsw (22 msw) and felt weak and confused; had stroke from air emboli and transferred to hyperbaric chamber.
130457916	60-year-old male working under his boat with scuba apparatus and touched the metal piling and felt a shock all over body. Severe pain electric shock injury.

Case number	Case notes
131049122	49-year-old male was scuba diving and when he surfaced he couldn't move his arm. Diagnosis: arm paralysis.
130933751	33-year-old male reports air embolism, shortness of breath from scuba diving
130802344	43-year-old male scuba diving at 100 fsw (30 msw) and developed numbness, tingling extremities with decompression sickness.
130755037	26-year-old female scuba diving and was down to 60 fsw (18 msw); came up too quickly and developed pain in joints and hand tingling. Decompression sickness.
130450676	54-year-old male went scuba diving down about 75 fsw (23 msw) severe eye pain with subconjunctival hemorrhage.
131234551	40-year-old male diving 75 fsw (23 msw) and developed dizziness head and nausea when ascending too rapidly. With decompression sickness now.
130903301	46-year-old female entered water for scuba dive and became short of breath. Worsening as dive went on to 74 fsw (23 msw). Diagnosis : Immersion Pulmonary Edema.
130523137	42-year-old male was scuba diving and hit face on coral. Laceration face.
130660797	42-year-old female, scuba diving and slipped on a rock and fractured tibia and fibula.
130324221	30-year-old female was in diving class diving to 15 fsw (5 msw) nose started bleeding with ear pain. Diagnosis: barotrauma.
130546606	55-year-old male twisted ankle walking in sand with dive fins on. Diagnosis: achilles tendon injury, anklesprain, calcaneus fracture.
131151045	62-year-old male scuba diving and felt funny afterward and had a myocardial infarction.
130912415	59-year-old male chest wall pain while scuba diving.
130710689	44-year-old male was scuba diving and impaled self on fish hook. Diagnosis: foreign body right hand.

In conclusion, we do not yet know exactly how many emergency department admissions occur each-year as a result of scuba diving, but in the US it is likely somewhere between one and two thousand cases. This chapter shows the range of injuries from scuba diving that an emergency department might encounter, ranging from an octopus bite, electrocution, crush trauma, broken bones and, of course, barotrauma, especially barotrauma to the ears. Future work aims to further elucidate the burden of scuba injury, including hospital admissions in the US.

SECTION 3. DIVING INCIDENT REPORTING SYSTEM (DIRS)

Peter Buzzacott

The Diving Incident Reporting System (DIRS) collects volunteered diving incident reports through the DAN website. Divers are encouraged to report any unintended outcome an unwanted adverse event that occurred during diving. Reports of fatalities are re-directed to the diving fatality investigation team. The DIRS project commenced in late 2012. There were eight incidents reported in 2012 followed by 66 in 2013. The majority of the reports (n=57, 77%) were made in English, the rest (n=17, 23%) in Portuguese. The victim of the incident being reported made the report first hand in 41 cases (55%) and reports involving third parties accounted for the remaining 33 cases (45%). The monthly distribution of reports for 2013 is shown in Figure 3-1.

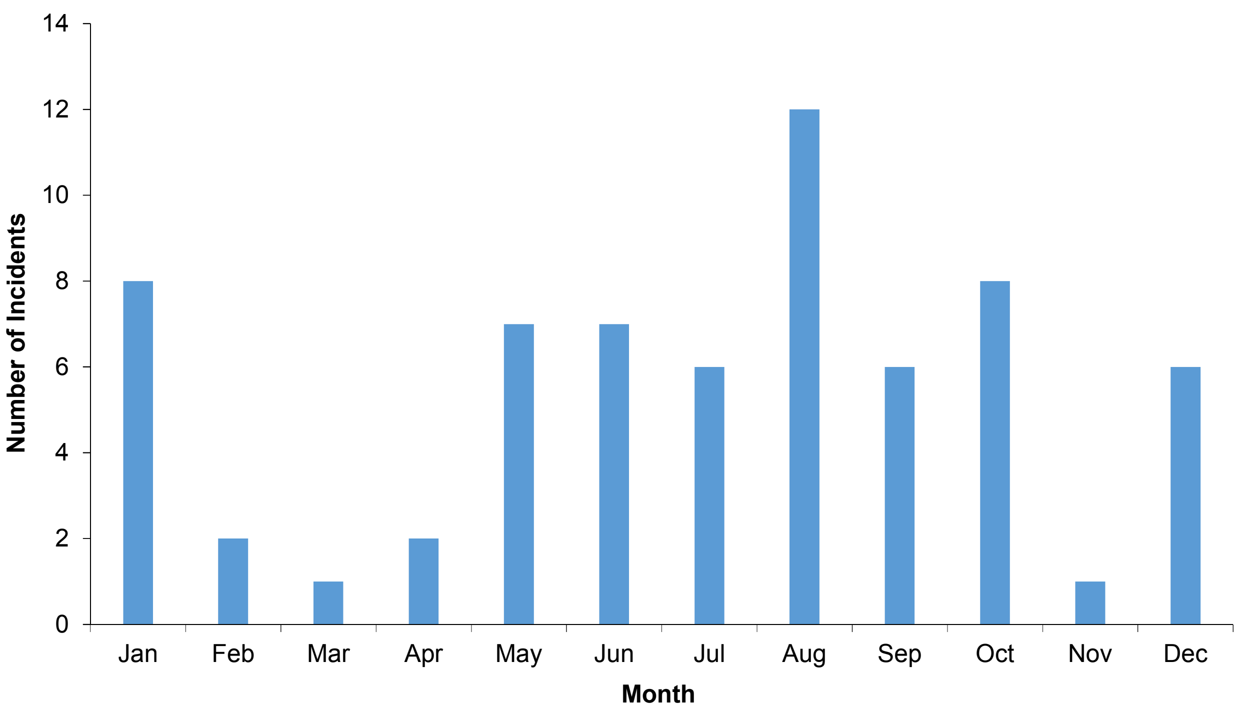

Figure 3-1 Month distribution of diving incident reports in 2013

Fifty-four incidents (73%) were reported during the same year in which they had occurred and another 13 (18%) incidents had occurred during the previous calendar year. The remainder (n=7, 9%) occurred more than one year before they were reported to DAN. The majority of incidents happened on the first day in a diving series, as shown in Figure 3.2.

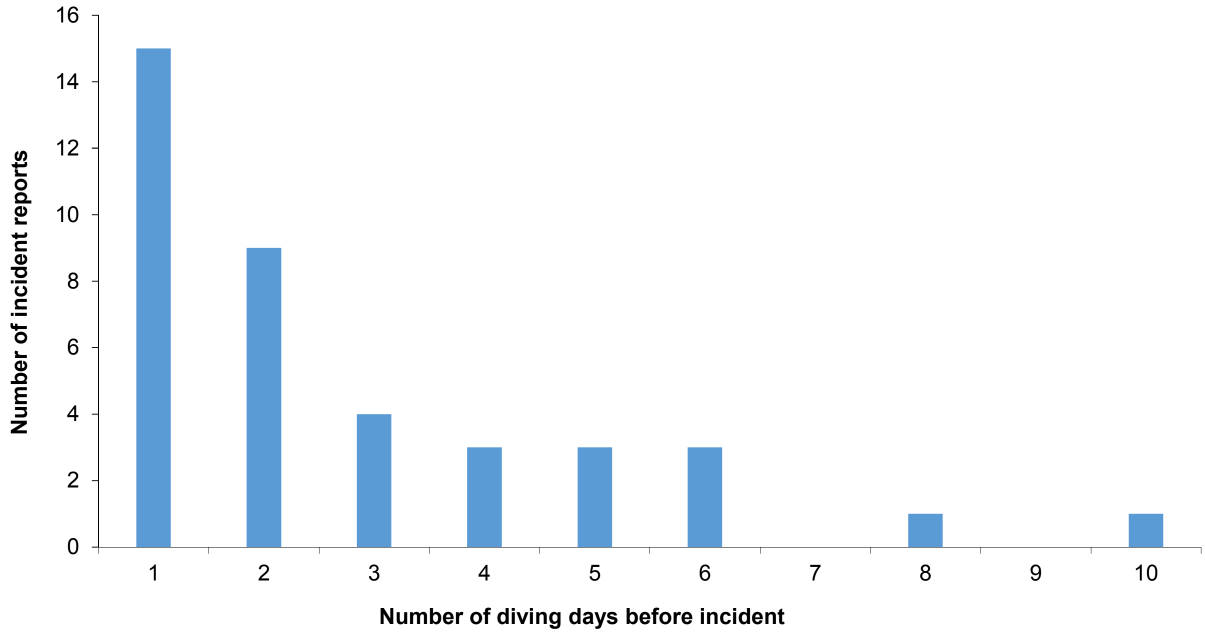

Figure 3-2 Number of days in the diving series when the incident occurred

Familiarity with the incident dive site was reported in 66 cases. In 34 of those cases (52%), the diver was diving at the site for the first time while 32 incidents (48%) occurred during return visits. The majority of incidents (59%) took place during the first dive of the day, 27% during the second dive and 14% the third dive. Inexperience featured prominently in reported incidents, with 68% of reports involving divers with less than two years since first certified to dive. Indeed, of the 70 divers who reported their training status, 12 divers (17%) reported having no formal training. Four divers reported having made 2000 dives or more, (two of those 5000 lifetime dives each). The mean number of dives made by the fifty other divers who reported their experience was 137 dives (range 0-900). The mean number of dives made within the previous year, for all divers, was 31 dives (range 1-107) and within the previous month 7 dives (range 1-12).

Characteristics of the divers involved in reported incidents are given in Table 3-1.

Table 3-1 Characteristics of divers involved in reported incidents

	Male (n=55)	Female (n=15)	Overall (n=70, range)
Age	46 (range 17-71)	42 (range 14-64)	45 (range 14-71)
Body Mass Index	22 (n=41, range 13-38)	22 (n=12, range 16-49)	22 (n=53, range 13-49)

Nine of the reports (12%) involved the use of rebreathers while 65 (88%) involved open circuit diving. Four incidents (5%) occurred at the surface, depth was not reported in 27 cases (36%) and among the remaining 43 reports (60%) mean depth was 21 msw (69 fsw). Where reported depth was greater than 0 msw (0 fsw), the mean maximum depth of the dive site was 27 msw (89 fsw). The mean maximum depth ever reached by the diver affected by the incident (n=52 reported, 70%) was 41 msw (135 fsw).

The type of support each incident involved is presented in Table 3-2.

Table 3-2 Type of support through incident dives

Surface support type	N (%)
Group	23 (31)
Dive partner – direct supervision throughout dive	17 (23)
Dive partner – limited supervision	16 (22)
Not reported	10 (14)
Other	3 (4)
None/solo	2 (3)
Underwater	2 (3)
Surface supplied scuba	1 (1)

Overhead diving was reported in 10 dives, including three in kelp and seven in caves. Time of day when the incident occurred was noted in 68 cases and were at dawn (n=1, 1%), in the day (n=57, 84%), at dusk (n=5, 7%) or at night (n=5, 7%). Fifty-five dives (74%) were made in the ocean/sea, 12 (16%) in freshwater and seven (10%) were not described. Water temperature showed a preference for warmer water, as shown in Table 3-3.

Table 3-3 Water temperature for reported incidents 2012/2013

Temp	<4°C	4-9°C	10-15°C	16-20°C	21-26°C	27-32°C	>32°C	Unknown
N (%)	1	4	8	9	17	22	4	9

Visibility during incident dives ranged from poor (<3m, n=11, 17%), moderate (3-15m, n=29, 44%) to excellent (>15m, n=26, 39%).

The altitude of incident dive sites was reported in 68 cases and ranged from 0-305m (n=65, 97%), 305-100m (n=1, 1%) to >1000m (n=2, 3%).

The dive platform from which incident dives occurred are presented in Table 3-4.

Table 3-4 Dive platform for incident dives 2012/2013 (n=74)

Platform	N (%)
Day boat	41 (55)
Beach/shore	13 (18)
Liveaboard	7 (9)
Not declared	6 (8)
Pier	5 (7)
Other	2 (3)

The severity of the outcome was reported in 71 cases, as either death (n=12, 16%), injury (n=36, 49%) or no injury reported (n=32, 43%). Case summaries describe incidents happening while diving wrecks (n=8, 11%), during training dives (n=4, 5%), dives involving decompression (n=6, 8%), rapid ascents (n=9, 12%) and/or loss of buoyancy control (n=7, 9%). Three incidents (8%) were caused by gas contamination and 16 (22%) were due to equipment malfunction, as shown in Table 3-5.

Table 3-5 Types of equipment malfunction reported to DAN through DIRS in 2012/2013 (n=16 cases)

Equipment failure	Frequency	Percent
Regulator free flow	5	31
Malfunctioning BCD uncontrollable inflation	2	12
Air turned off by dive supervisor at entry	1	6
Current limited cells in rebreather	1	6
Full face mask leaking gas through unclosed vent	1	6
Second-stage swivel o-ring failure	1	6
Started the dive with an empty tank	1	6
High pressure SPG hose exploded	1	6
Low pressure hose spontaneous rupture	1	6
Loose screw on backplate allowed tanks and wing to pivot	1	6
Second stage leaking water	1	6

Of the 16 incidents involving equipment failure, 13 (81%) involved an air supply problem and the other three (19%) a buoyancy control problem.

In 12 (16%) of the 74 reported incidents, the outcome was fatal; in 36 (49%) of cases, a non-fatal injury resulted as shown in Table 3-6.

Table 3-6 Non-fatal injuries reported to DAN through DIRS in 2012/2013 (n=36 cases)

INJURY	Frequency	Percent
Decompression Illness	14	39
Ear injury	6	17
Gas poisoning	3	8
Near drowning	2	6
Immersion pulmonary edema	1	3
Stomach pain	1	3
Allergic reaction	1	3
Attacked by fish, head trauma	1	3
Barodontalgia –lost five fillings (two exploded)	1	3
Crushed fingers from boat at pier	1	3
Hit on head by boat, drowning, renal failure and atrial fibrilation	1	3
Hole in hand	1	3
Knee ligament	1	3
Myopia (short sightedness)	1	3
Numb fingers	1	3
Sealion bite to stomach	1	3
Thrown down on rocks, loss of consciousness	1	3

While statistics can help identify certain possible targets for preventive interventions, case vignettes are richer in detail and often highlight learning points. A selection of edited case reports now follows. These are actual reports from divers received by DAN through the DAN Diving Incident Reporting System (DIRS). Units of measurement have been converted into both imperial and metric, abbreviations and slang have been clarified and the names of people, dive boats, dive businesses and specific locations have been removed. Other than those few changes, the original tone of each report has been retained in the hope readers might get a more authentic feel for the experiences being reported. DAN thanks everyone who supplied incident reports in 2012 and 2013.

Rebreathers

12-001: Immersion Pulmonary Edema

Wreck diving with a rebreather. Surface conditions: sunny, approximately 92ºF (33ºC), no current at surface, mild chop. Reported bottom conditions prior to dive: 86°F (30°C) to thermocline at 200 fsw (61 msw), 52ºF (11ºC) at deck at 300 fsw (91 msw). With the reported cold conditions at the bottom, I borrowed a 5mm hood from one person and a 5mm wetsuit from another person, as all I had was a 3mm wetsuit & hood. My buddy dove his dry suit.

The descent was uneventful. I noted the thermocline at 186 fsw (57 msw). It continued to get colder as we descended, and was 52ºF (11ºC) at the deck of the wreck. Our plan was to swim along the deck until we got too cold and then ascend. After a few minutes at depth, I had a tickle in my throat and coughed a few times. Visibility was easily 100 ft (30 m), and current was very mild. We swam slowly along the deck. I was quite cold. I continued to cough a bit every 30 seconds or so. After about 10 minutes at depth we were swimming over a hold between the smokestacks on the wreck, and I felt like I was working hard and breathing hard while diving. I was getting really cold and decided I didn't want to work hard at depth while cold so I signaled my buddy to ascend. We began our ascent and decompression. I continued to cough occasionally.

During the ascent, somewhere around 200 fsw (60 msw) I noticed a "gurgle" in my breathing. It felt like I was gargling water right behind the top of my breastbone, below my Adams' apple. I continued coughing and gurgling, which was not normal. I had 52 minutes of decompression remaining on my dive computer at that point. I decided that I would simply focus on staying on the loop, exercising as little as possible, to get as far through decompression as I could.

As we got to the first decompression stop in the 90 fsw (27 msw) range, we were back in the warm 86ºF (30°C) water. My buddy pulled back the hood from his dry suit to cool off. Since I was still coughing he pointed at my throat and I nodded, 'yes', still coughing. Around 70 fsw (21 msw), I was having a hard time breathing over the gurgling and was very hot, so I wanted to take off the borrowed hood. Ordinarily I would just get off the loop, remove my mask and pull off the hood but it would have been very difficult to maintain proper decompression stop depth while performing this operation. I decided that I already had enough stressors and so instead handed my scissors to my buddy and asked him to cut the hood off me. I asked him to cut the hood back from my forehead. He cut a bit (which helped with breathing), but then stopped when he cut off a hunk of my hair. We continued decompression for a few more minutes. Breathing continued to get harder. I grabbed my scissors again and this time pointed my buddy at cutting off the hood by cutting it downward under my chin. I was a bit cooler without the hood and definitely better able to breathe over the gurgling as we continued to decompress.

The boat rapidly came to us as is our emergency protocol and the safety diver entered the water with an open-circuit tank of oxygen. She offered it to me and was going to clip it to me, but I waved her off and wrote on the slate – "no exercise, can't breathe". I was quite worried that the oxygen bottle would compromise my buoyancy and I would need to swim. The safety diver clipped the oxygen bottle to my buddy and swam back to the boat to report in.

We completed deco with me coughing and gurgling as I breathed. On the boat pickup, the captain placed the boat where I didn't have to swim at all and the safety diver removed my bail out bottles and fins in the water. As soon as I was on deck, many hands removed my rebreather and wet suit, and I got started breathing 100% oxygen. The ambulance was at dock when we got there. I refused the offered helicopter ride to the chamber and asked them to take me instead to the local hospital to be treated for pulmonary edema, which they did. X-rays at the hospital confirmed pulmonary edema and they kept me overnight for observation, took another x-ray in the morning that showed significant improvement, and then released me. Today, the outcome is good, health is good and I have no lingering issues.

12-002: Current limited cells cause excess solenoid firing
I noticed that the solenoid was firing too often for a constant depth dive. I bailed out and ended the dive with my buddy. On the surface, I changed an oxygen cell and flushed with oxygen. The display was higher than 1.0 which implied that the old cell had been current limited even at 1.0, let alone a set-point of 1.3. After changing all three cells, it was clear that the old cells were the problem.

At the time, I owned five rebreathers; and thinking back, I realized that I hadn't used this one in over a year. I didn't do a cell check at 20 fsw (6 msw) to confirm that they could read over 1.3. Now I do a cell check on every dive.

Equipment Failures

13-010: Unintended rapid ascent due to uncontrolled inflation
Diving from a liveaboard near a remote island in South America, I was hanging out on a coral ledge at 93 fsw (28 msw) watching Hammerhead and Galapagos sharks at a cleaning station. As I started to swim to a different position I hit the inflator button on my new BCD. The button jammed and shot me straight up to the surface in an estimated 15 seconds, despite me frantically pulling on the shoulder mounted dump valve. There was so much noise and so many bubbles surrounding me and obscuring my vision that I probably could not have disconnected the inflator hose even if I had thought to do so. I broke the surface not far from the dive skiff and was picked-up where upon the skiff driver immediately started me on a DAN bottle of oxygen which I continued to breathe from after returning to the boat. Also at the dive master's direction, I took a cool shower, drank lots of water, stayed quiet and mostly out of the sun for remainder of the day. This was the 18th dive on the last diving day of a seven day diving trip. We had been diving nitrox at approximately a 32% mix all week. Dives were generally in the 100 fsw (30 msw) range for 50-60 minutes. This particular dive was the first dive of the last day and only lasted 20 minutes which may explain why I have had virtually no after effects from this incident.

13-011: High pressure hose rupture blasts gas under the skin
The accident happened to the boat driver, who decided to help one of the divers. The victim held the first stage regulator with his left hand and opened the tank valve with his right hand. While doing this the high pressure hose exploded and made a hole in the boat driver's left hand which started to bleed and the most weird thing was seeing his left arm full of air. We stopped the bleeding by applying pressure and we stop the air at his arm pit area with bandage pressure. Then we massaged his arm to push the trapped air to his hand and it helped a bit, we saw some bubbles came out from his hand. We administered oxygen during the time it took us to reach the harbor again, approximately 20 minutes. We called ahead for an ambulance and when we arrived the ambulance was there. I recommended his boss take him to the recompression chamber but he told me the doctors will take care of him. Later, I just asked for his state of health, his boss told me he is OK and ready to get back to the job.

13-023: Freezing free-flow leads to emergency ascent
Dove to a depth of 60 ffw (18 mfw) in 39°F (4°C) fresh water and my regulator began to free flow. I could not stop it so I retrieved my secondary mouthpiece and had trouble getting it in my mouth. Ascended to surface quickly and thawed primary regulator. Descended again to 25 ffw (8 mfw) and made a 3 minute safety stop. After the dive, I discussed this incident with a divemaster and realized that I should have left the primary in my mouth and ascended slowly.

13-039: Swivel O-ring failure causes loss of gas
We were diving and I was filming around 14 msw (45 fsw) when the dive guide spotted a stingray. After a total dive of 18 minutes I suddenly heard a loud bang and screaming. I looked around for the origin of the screaming when a stream of bubbles came up from my regulator. I took my regulator out to check out the problem and saw that all the air came out of my swivel. At the same moment I was finning towards our dive guide.

The dive guide saw me swimming towards him with my regulator in my hand. He finned fast towards me and gave right away his own regulator. At that moment, my cylinder was getting buoyant and we went towards the surface while we were buddy breathing. The dive guide spread his fins to slow down our ascent. This whole incident took less than two minutes. I was calm and just before it happened had taken a deep breath of air. I was concerned about the buoyancy of my aluminum cylinder. I could not close my valve otherwise that would have been my first action.

The zodiac of the live-aboard was waiting for us at the surface. It took me back to the boat and the guide went back down to the other divers. I rested by lying aboard for the first half hour and drank small sips of water. After that I looked at my diving gear. The O-ring was sticking out of the Swivel. I took out the Swivel and I am not going to use it again.

Remote Location Injuries

12-005: Unrecognized decompression sickness
A 58-year-old female on a recreational dive trip in the tropics with her husband, reports repetitive dives on six consecutive days with an appearance of torso “rash” after the fourth day of diving. The patient was unsure of the cause and reports taking Aleve for “inflammation” with no improvement noted. She continued to dive and noticed the “rash” improved while underwater. The torso discoloration then resolved after her last dive (on day six) and prior to her flight home. She reported no issues on the flight home.

After returning home the diver made an internet search for “blotchy skin rash after diving” and learned about skin bends. At that point, she contacted DAN and was directed to a DAN-trained referral physician. On subsequent examination the diver was found “completely asymptomatic and intact neurologically with no pertinent findings to report.”

Editor: If any diver notices an unusual rash after diving then call the DAN Emergency Hotline on +1-919-684-9111

12-006: A warm post-dive shower is followed by a skin rash
After the third dive of the third day of our Caribbean dive trip, I was alarmed when I noticed my dive computer nitrogen level indicator was near the red. I checked other dive computers on my buddies and saw the same so I was not too concerned as it was still in the yellow zone. After getting back to my room, I decided to wash my suit and just jumped in the shower to wash it. I used warm water to rinse the soap out while I showered, in hindsight I realized that was a mistake as it probably caused the rash I later had on my chest. While waiting for supper, I was very thirsty and drank several glasses of icy water. I was having trouble taking a deep breath without coughing and I felt very tired. Just before supper I felt sick and went to my room. Thanks to my dive partners’ alertness they came in to check on me. I remember them asking me if I was ok and then I passed out. They opened my shirt and noticed a rash on my chest. They demanded that I go to hospital immediately and began to administer oxygen from the resort. My dive partner was on the phone with DAN emergency most of the one hour trip to the hospital. It was frustrating for us as they put him on hold for a very long time.

After a complete check over at the medical center, it was determined that I was not having heart issues so they took me to the decompression chamber which was another 20 minutes away. The doctors there made another exam and determined that I probably had some decompression sickness but that it wasn’t severe enough to need any time in the chamber. The hospital then called and informed us that I was very dehydrated based on the blood test they had done. We decided to go back to the hospital for more observation and to administer a saline IV. They talked me into staying overnight. I had another incident later in the night when I passed out once more. The remainder of the stay was fine and I was discharged the next morning. I did not dive the remainder of the trip.

Editor: The DAN Emergency Hotline works 24-hours a day, every day, to arrange evacuations and treatment all over the world, often through the night when island staff need to be found and woken. This can be frustrating for divers when they do not know what is happening behind the scenes.

13-029: Yachtsman suffers stroke, evacuated by DAN
After traveling by sailboat to many remote islands around the Caribbean for five years, my wife and I were on our way from the coast of Guatemala to the Rio Dulce River in our 44’ Island Packet sailboat. As we were approaching the sand bar at the entrance to the river, my face became flushed and I had an enormous headache. While trying to navigate the entrance to the river I found that I could not focus on the compass to stay on course. I felt like my eyes were crossing so I couldn’t steer properly. The next thing I knew, I was on a panga (a small dugout style motorboat used throughout Central & South America) headed for the local hospital (clinic) in Livingston.

When I passed out, my wife had taken the wheel and headed back out to sea so we wouldn’t run aground. She found three young men in the panga and yelled for them to help. They lifted me out of the sailboat into the panga. One of them stayed on the sailboat to take it into Livingston. The other two stayed with me in the panga. When we arrived at the hospital, the nurses and doctors immediately began examining me. I was conscious but very groggy (out of it). After a period of time, the doctors thought I had either had a heart attack or a stroke. This hospital was really nothing more than a clinic to treat locals for colds and minor illnesses. The doctors told my wife they needed to give me some aspirin in case I might have had a heart attack. They sent her down the street to the pharmacy to purchase the aspirin as they did not have any in the clinic.

After consultations with others in the clinic, the doctor decided that I needed to be transported to Guatemala City, a 5 hour overland trip. They began calling around town to see if someone had a car to transport me in. At that time, my wife decided to call DAN to see if I should be med-evaced back to the US. After consultation with DAN doctors and local doctors, DAN decided that I should be med-evaced back to the US since the local doctors were not sure what was causing the seizure. Since my condition had stabilized, DAN advised us that a plane would be sent by 12:30 pm the next day to pick me up. Around 12:15 pm, I was worried that we had not heard from DAN and asked my wife if we should call them again. Then before she could make a call, a doctor and a medic from DAN walked into the clinic and announced, “We’re here to take you home”.

Livingston does not have an airport and the nearest location was five hours away in Guatemala City. So DAN had arranged with the Guatemalan army to land on an Army Base 30 minutes away by boat. They had arranged to have a boat ready to take us to the army base where a Lear Jet awaited. The plane had to make a stop in Tikal to clear customs and then headed directly for Florida, our home. When we arrived at the airport, DAN had arranged for customs to be there to clear us in and had an ambulance waiting to take us to the hospital.

When we arrived at the hospital, the local emergency room staff was waiting for us and immediately took us to a room they had prepared for us in the Intensive Care Unit (ICU). The DAN doctor and medic did not leave until the ICU staff had me hooked up to all the machines and the hospital nurses and doctors were responsible for my care.

It was amazing to see the efficiency and effort that DAN had employed to get me safely back home to a “real” hospital.

Editor: DAN Membership is not the same as DAN Insurance. If divers intend visiting a remote destination then good quality insurance coverage can prove to be a life saver.

Out of Gas Reports

13-001: Omitted pre-dive check and a forgotten skill at the surface
My wife and I were on a twilight/night dive. I geared up quickly, checked my regulator and BCD inflator but failed to check my SPG. I entered the water and the group (led by a divemaster) quickly descended.

I noticed my regulator breathing much harder. Soon after I only received half a breath and realized my tank was empty. I rapidly decided between swimming to my wife and swimming to the surface, and headed for her. She was swimming away from me but I caught up to her. I was already feeling air hunger when I reached her. I grabbed her octopus but put it into my mouth upside-down and was initially unable to obtain air from it. After several more tries I got a breath of half water, half air. I signaled to my wife to surface. We made an emergency swimming ascent. On surfacing, I dropped my weights and she inflated her BCD (I was unable to inflate via the power inflator - the tank was empty). We shouted for help, and eventually a snorkeling instructor came to our aid, guiding us to another boat, where we left the water. Neither of us was injured, although I did aspirate some seawater.

We determined that the dive crew had given me a nearly empty tank, and I did not detect it since I had not checked my SPG.

Editor: No-one expects to run out of gas while diving. Rather than panic and head for the surface, this diver kept a cool head and ascended on his wife’s alternate air source. At the surface though, he did not inflate his BCD because he was out of gas. Remember, orally inflating a BCD is a basic skill taught in open water diver courses and it is worth occasionally practicing this skill at the end of a dive.

13-018: Starting dive in overhead cavern with half empty tanks
A 25-year-old female diver performing a second dive on a 63 cubic foot (~9 Litres*) tank without refilling it. The diver ran out of air at about 50 fsw (15 msw) in an overhead environment. While exiting the cavern while breathing from another diver's alternate second stage, the divers became entangled in a line. While attempting to free themselves, that diver also ran out of air. The divers conducted an emergency swimming ascent out of the cavern and then made a rapid ascent the last 20 feet (6 m) to the surface. Both divers inhaled water during the ascent. Upon reaching the surface, the divers were given emergency oxygen and EMS responded to the scene. The husband refused treatment, the wife was transported to the hospital where she remained overnight for observation and was then discharged.

*In the US, tank volumes are specified as though the tank is filled with air to its working pressure and then the gas contained within the tank were to be released into normal atmospheric pressure. In this case the diver's tank would hold the equivalent of 63 cubic feet of gas at atmospheric pressure, compressed into the tank. Outside the US, tank volumes are simply the volume of water each tank holds. Depending upon the working pressure, it is common in the US for a 9 Litre tank to hold 63 cubic feet of compressed air, so that is the equivalent volume suggested here in brackets.

13-032: Unknown air pressure leads a public safety diver to make an emergency ascent
This was a night dive training for a volunteer water rescue group. It was a shore based dive, tendered, wearing a full-face mask with voice communications. Our full face mask has a "gill" that allows the diver to breathe outside air on the surface so the mask can be in place and yet not breathe tank air. Prior to submerging, the "gill" is closed so tank air is then used but air is not let out of the mask. I believed I had closed mine, however it was not closed completely. There is a little flap that is supposed to prevent air from escaping out of the gill, however, apparently mine was not seated correctly so once I submerged, my regulator was flowing some amount of air out the gill continuously. Being at night and in murky water, the shore support didn't notice it and, since it wasn't a leak between my face and the mask, I didn't notice it either.

I commenced my search pattern and at five minutes the shore tender asked me for an air pressure reading. Even with a light, with the murky water and fogged face mask, I couldn't read my pressure gauge. I asked the tender if I should surface to read it, but because it was only five minutes into my dive, and I was the 5th diver and we still hadn't found the dummy and it was getting late, they said "no, you are good. Keep searching". Because the full face mask had a good positive pressure, air was escaping out the gill but no water was coming in. This increased my air consumption to 3-times or more of my regular air consumption. At 10 minutes they were going to call for another air check but the tender was distracted by the on scene commander trying to give updated search instructions. At a little after 11 minutes I started getting water in my mask. The air pressure in the tank was no longer enough to keep water from coming in the gill and water would leak down to the regulator, then when I inhaled it would splash up in my face from the area of the regulator, not from the gill. Because I was still getting some air, but the purge button wasn't doing anything, I assumed my regu- lator had failed. I was at approximately 20 fsw (6 msw) depth and did a slow emergency ascent, exhaling all the way to the surface. Fortunately, I had no issues or follow-on complications, although I did breathe 100% pure oxygen for several minutes after the dive. For me it was a great reminder to make better pre-dive gear checks, not let the tender be responsible for my safety, and not get complacent or let standards relax towards the end of a dive.

Editor. This case serves as a good reminder that, ultimately, every diver is responsible for his/her own safety.

Encounters with Marine Life

13-024: Head wound inflicted by trigger fish
I was attacked by a large king triggerfish while diving one of the reef sanctuaries just out from the beach. The fish hit me hard in the head from behind. My buddy saw that I had a large bite wound in my scalp and we quickly aborted the dive. The divemaster and I skipped the safety stop and had the boat take us back to the beach where an emergency responder was waiting.

I didn't see the fish before it charged at me. It charged once, turned, and once more charged right at me before I could turn and fin away. I fended off the animal with my dive camera initially before it struck me in the head. The divemaster and several others in my group witnessed the attack. The divemaster applied pressure on the ascent, then I applied pressure with a towel while on the boat ride back to the beach. I was helped to a lounge chair on the beach where the resort emergency responder provided first aid and cleaned and dressed the wound. I was then taken to the hospital for stitches.

13-030: Diver bitten on stomach by seal
I was called to respond by a liveaboard's land-based representative who stated that one of their ship´s passengers had been a victim of a sea lion attack, consisting of a bite to the stomach. Upon arrival at the beach, the patient had already been bandaged by the crew prior to my arrival. We transported him to a private clinic. Once under the doctor´s care, I assisted with removing the bandages and was able to evaluate the wounds, consisting of mainly two parallel lacerations of 2" x ½" x ½" deep (5 cm x 1 cm x 1 cm deep) approximately and some minor "satellite" puncture wounds. The doctor and his staff then proceeded to clean the wound, apply local anesthesia and suture. Two internal stiches were required for each laceration as well as a drain device/"shunt". Surface coil stiches for both lacerations and one of the puncture wounds also were necessary. As a precaution, a tetanus shot was also given to the patient by a nurse with the doctor´s prescription.

That evening the patient was released by the physician and escorted by us to his hotel. DAN World / Traveler EMS was contacted immediately after via e-mail and later by phone. The patient, who was lucid and conscious during the whole process, stated that at the time when the sea lion attack took place, he was SCUBA diving at less than 20 fsw (6 msw), with a group of about 24 other divers, at the sea lion colony under the supervision of at least one divemaster/guide. After the attack took place, he was assisted by fellow divers and crew aboard the ship, and his 3.2 mm wet suit removed before first aid was provided on board.

Buoyancy Problems

13-003: Rough seas demand greater fitness
With 5-6 feet (1-2 m) seas and a current described as a half knot, this dive involved poor decision making all around. Many divers were seasick, myself included. I was diving in a drysuit and double 108s (15-Ls) with a wing. I elected to go in the water last and was advised to "get below the current immediately" so I had no air in either the drysuit or wing. I was determined to dive because I had already spent the money and wasn't going to waste it.

The current was strong enough that divers went in holding a rope and the first mate pulled them to the hang bar. I believe the current was closer to 3 or 4 knots. After a giant stride entry, I was pulled to the hang bar but could not swim into the current and immediately realized I was in trouble. My inflator had gone over my back and I could not reach it, and I did not think to use the drysuit inflator. Kicked myself to the surface telling mate I needed help. He wanted to pull me back to the hang bar. Finally, the dive operator heard me and entered the water to check on me and assist me to the ladder. I could not make him understand that I needed my inflator. The seas seemed huge. I was seeing the starboard side prop from the port side of the boat. I have no recollection of the journey to the ladder but I must have missed it because I was on the current rope, on my back and "zooming" to the end of it. Something was tugging my regulator and I was inhaling a mist of water and air. After a tremendous effort by the operator and my dive buddy, I had the ladder but the boat took a large wave, turned me sideways and the ladder hit me on the temple. I saw my vision narrow to a yellow tinged tunnel and remember only my loss of the current line, sinking, a mighty push on my feet and reacquisition of the line. I remember hearing shouts to get ropes on me. I continued struggling and finally I was on the rear platform, unable to move. I was simply exhausted and could not move to help myself onto the boat.

I was somehow gotten onto the boat, stripped of my drysuit, given oxygen immediately and for the whole ride in. A Coast Guard craft intercepted us on the way, put medics on board and we continued in to the USCG Station to a waiting ambulance. At the hospital I was diagnosed as a salt water "partial" drowning and given continuous oxygen therapy. I was later transferred to hospital where treatment continued and it was noted that I had a kidney issue. My existing medications were adjusted (I am diabetic and was being treated with Naproxin for some joint pain). I was released the next day, went home to my own doctor and was immediately admitted to the local hospital where they continued treatment for drowning, then renal failure and finally atrial fibrillation. I was in the hospital for about 10 days and continued to convalesce for nearly a month.

This incident was my fault entirely, making poor decisions at each point. I was seasick, dehydrated, overheated, diving with the wrong gear, determined to go simply to avoid wasting the money, ignoring the experience of other divers who chose not to dive, accepting the notion that I'd feel better in the water and finally diving with no buoyancy. I have recovered completely, have had some dives since then and plan to continue diving but with this experience as a guide for future decisions.

13-020: Diver drops weight to establish positive buoyancy
Dropped weight, unable to stay buoyant at the surface.

Editor: Correct weighting, confirmed by a buoyancy check at the start of every dive, not only reduces drag in the water and thus reduces air consumption, it ensures a diver can achieve positive buoyancy at the surface after the dive.

13-031: Experienced diver helps prevent an uncontrolled ascent
I regularly dive with a small group of experienced divers. On this occasion, an Advanced Open Water Diver with about 30 dives experience came with us to do an after work dive on a wreck with a maximum depth of 110 fsw (34 msw).

A few minutes into my dive I heard a rapid tank tapping and another diver pointed him out to me as he ascended from the wreck far from the anchor line. He was buoyant and gaining speed. I was diving with a Diver Propulsion Vehicle (DPV) and was able to quickly ascend from 90 fsw (27 msw) to 65 fsw (20 msw) and bring him back to the anchor line at 90 fsw (27 msw). If I had not grabbed him he would have made an uncontrolled accent and surfaced in current, unable to get back to the boat on his own. On the anchor line other divers came over, we communicated that I'd take him up and that the other divers would finish their dives.

We worked our way up the anchor line taking it extra slow and did an extra-long safety stop. By the time we were ready to surface from the safety stop he looked much better although he had thrown up through the regulator during the safety stop. We made it back on the boat. I made sure there were no medical issues other than seasickness and we made an assessment of the incident.

Polluted Gas

13-022: Contaminated gas affects several divers on the same boat
I noticed a weird taste when checking my regulator during pre-dive check . Not knowing what it was I entered the water. Shortly after, I started having vision and breathing issues. I signaled my dive partner and we surfaced; both of us could barely make it to the boat. My friend on board said that my eyes were rolling upwards in my head when I exited the water with the help of a deck hand. After some time, I threw up and had a hard time breathing. The episode lasted about an hour. My dive partner was also taken with the same symptoms along with one other diver who almost drowned at the rear of the boat. After contacting the dive shop to inform them to check the equipment they use to fill their tanks, they denied any issues and informed us they would send copies of their most recent inspection, but this never happened.

Editor: If any diver suspects a polluted tank fill and they have legal control over that tank then contact DAN for a gas analysis kit and have your gas tested.

Ear Injuries

13-005: Trouble equalizing leads to barotrauma
I was participating in the first dive of a series of seven dives planned over four days. During the descent, at around 20-30 fsw (6-9 msw), I had difficulty equalizing the left ear and felt pain for a few seconds to a minute. I stopped the descent, signalled my divemaster, ascended a bit and equalized until the discomfort passed. That worked and I continued my descent. The same thing happened again at around 50 fsw (15 msw) but this time suddenly I heard a loud explosion sound in my left ear and immediately felt a strong pain. It disappeared almost as fast at it had appeared and I continued my dive. I also felt very dizzy and nauseous for about a minute but that soon also disappeared. I had no other problems for the rest of the dive and we ascended.

I continued diving as scheduled without any other problems. However, the mild pain in my left ear remained until the end of the trip. I consulted a doctor to be sure I could fly back home. He found middle-ear barotrauma and a bacterial infection of my left ear. When I was back home, I saw a doctor skilled in dive medicine. Sixteen days after that explosion event. She said the otitis had healed. Six weeks later, I saw the doctor again and she declared that my ear was completely healed. She checked my ears, did a couple of tests and told me that I could dive again.

13-021: An assistant instructor suffers a reverse block
I was an assistant instructor with a group of three students, one instructor and a divemaster for the deep dive. At the end of the dive we ascended and I experienced a reverse block in my right ear. I descended again until it was relieved and then very slowly started ascending again. I was not able to clear it for about 10 minutes. Several times I had to descend and then try to ascend again. Even when I managed to clear it such that I could surface without severe pain, my right ear was still very sore. The next day, I got an appointment with my primary care physician in the afternoon. He sent me to an ENT. The ENT said that the eardrum and Eustachian tube were fine. They performed a pressure test on both ears, as well as a hearing test. Everything appeared to be fine and my hearing was very good in both ears.

Miscellaneous Reports

13-025: Stomach pain after a training dive
My daughter, 14 years of age, was taking practical exercises as part of the Open Water Diver certification. The day after her first open water immersion, my daughter complained of abdominal pain during the whole surface interval between dives. Her instructor diminished the pain by indicating we did not have to worry, as it was probably accumulated gas, which happens very often while diving. After her second immersion, her pain increased up to a point where it was uncomfortable for her, but later receded. The pain eased and mildly increased during the following day, yet on the next day it peaked and we had to take her to the hospital where she received a physical exam and several clinical tests.

After the tests, my daughter was diagnosed with decompression illness Type 1 caused by a diving accident. The doctor considered it necessary and urgent for her to be immediately hospitalized and was treated in the hyperbaric chamber for more than 4 hours. My daughter stayed at the hospital for two more days, with a second treatment at the chamber for 90 mins before she was allowed to leave the hospital.

13-027: Buoyancy wing comes loose during dive
A very experienced technical diver got distracted and mounted the wing (BC) on his double cylinders incorrectly (forward backward). Already wearing a dry suit at a temperature of 30°C (86°F), he realized his mistake and quickly remounted his equipment. The group was then divided into two teams. The three CCR divers descended 10 minutes before two OC divers. The ship wreck lies 55 msw (180 fsw) deep in a place of strong current. The diver in question was the second OC diver in the line of descent (last of the five divers). When he reached the bottom we noticed a large volume on the right side of the double tanks. To our surprise the volume was the lower part of his wing (BC).

The back plate and wing are connected by two screws and the bottom screw had come loose, allowing the output of the wing and movement side-to-side of his double cylinders. Immediately, we cancelled the dive and began to surface. Through DSV speech we warned the diver of the situation and told him to keep his head up during the ascent to prevent the double cylinders deviating laterally. At the surface, the diver had trouble keeping afloat because of the wing; the wing being in that position was not helping. Aided by the group at the surface, the diver left the water unharmed.

13-034: Post dive shower leads to case of skin bends
We made two boat dives and then one shore dive an hour after lunch. I felt fine when I went back to the place I was staying at with friends. I took a shower and then started to itch. The itching got worse and then I started to feel pain in my lower back, just by my hips, and in one breast. I also had a little blurred vision and some dizziness but that subsided as soon as I ate dinner. So I pulled up my shirt and showed my friends and they were like, “OMG!” My skin was blotched in red. I called DAN and they referred me to a doctor, who happened to be right next door. I had a case of “skin bends” He did a series of tests. Very informative doctor said that the nitrogen liked to attach itself to the fatty parts of the body so that explained why I was having the pain in the areas that I did. He told me to return the next day for a visit and said that most of this should subside on its own. And thankfully it did. The next day the pain and the blotches were gone and he gave me strict orders, no more diving this trip. I’m really glad I had DAN insurance I can’t even imagine what it would have been like without it. Thank you all for your help and concern. You did everything to get me the help that I needed. Appreciate you all very much. I’m back home and all is good.

13-038: Diver enters the water with tank valve turned off
I went out with a reputable dive outfit to the nature preserve near a Pacific Island. The group went out with four divers and two divemasters. The drop in was a negative buoyancy back roll into the deep side of a vertical wall (800 msw, 2600 fsw deep). The divemasters stated that this was due to the currents. I was uncomfortable with this entry style with the experience of the divers in the group but said nothing. Also, the other divers were all in rental gear of generally poor quality. A loss of buoyancy on entry would mean we would never find the body much less be able to affect a rescue.
As I was the only experienced diver in the group of clients, I dropped in first. Prior to entry, I checked all my gear and tested my regulator and inflator. I then dumped the air from my BCD and moved into position. The deck hand checked all my equipment and made sure my tank valve was opened. I rolled in and dropped down 6-10 feet (~3 m) and took my first breath. Nothing. Now I was underwater, slightly negatively buoyant, with no air for breathing or inflation. I kicked for all I had and was able to reach the boat and grab a hold of the swim deck. The deck hand was then able to reach over and turn my air back on.

Analysis: The deck hand turned my air off instead of on and did so without my knowledge. Had I not had high quality equipment, well-tuned buoyancy and good fitness I'm not sure I would have survived this simple mishap.

Editor: Always turn the valve all the way on, or all the way off, and take a breath while looking at the gauge before entering the water. If the pressure gauge indicates you have gas, and it does not move when you breathe from the regulator, then you will not find yourself in the same situation as this diver.

Section 4. Breath-hold dive incidents

Neal W. Pollock

4.1 Introduction

Breath-hold diving is defined as in-water activity involving some diving equipment, but no self-contained or surface-supplied breathing gas. Breath-hold divers operate in a wide range of environments, pursue an assortment of goals, and wear various combinations and designs of suit, external weight, mask, snorkel and/or fin(s).

Common breath-hold activities include snorkeling, spearfishing, collecting and freediving. Snorkelers may remain completely on the surface with no purposeful breath-hold, or they may use breath-hold in typically limited surface diving efforts. Breath-hold spearfishing incorporates the act of underwater hunting for food into the breath-hold exercise. Collecting generally refers to underwater hunting without spear devices. Maximizing breath-hold time and/or depth is generally not the primary motivator for either spearfishing or collecting. The challenges of the hunt, however, can encourage divers to push their limits. Freedivers are explicitly employing breath-hold techniques, with or without descent from the surface. Increasing breath-hold time and/or dive depth are common goals. The nature of the dives will vary dramatically with the individual skill and training level of participants.

Competitive freediving has grown in popularity in the past two decades. Discovering a talent for breath-hold performance can rapidly catapult a competitor from novice to elite status. The field has developed rapidly as an extreme sport. The International Association for the Development of Apnea (AIDA; http://www.aida-international.org) recognizes numerous competitive disciplines. The organization tracks record performance and ensures compliance with accepted safety standards. The disciplines and current record performances are summarized in Table 4.1-1. These records are not shown to promote competition, only to demonstrate that breath-hold diving can be quite different from the classic view of skin diving activity.

Table 4.1-1 AIDA-Recognized Competitive Freediving Disciplines and Record Performance (current August 2015)

Discipline	Description	Record Performance	
		Male	Female
Static Apnea (min:s)	resting, immersed breath-hold in controlled water (usually a shallow swimming pool)	11:35	9:02
Dynamic Apnea - with fins (ft [m])	horizontal swim in controlled water	922 (281)	778 (237)
Dynamic Apnea - no fins (ft [m])	horizontal swim in controlled water	741 (226)	597 (182)
No-Limits (ft [m])	vertical descent to a maximum depth on a weighted sled; ascent with a lift bag deployed by the diver	702 (214)	525 (160)
Variable Weight/Ballast (ft [m])	vertical descent to a maximum depth on weighted sled; ascent by pulling up a line and/or kicking	476 (145)	417 (127)
Constant Weight - with fins (ft [m])	vertical self-propelled swimming to a maximum depth and back to surface; no line assistance allowed	420 (128)	331 (101)
Constant Weight - no fins (ft [m])	vertical self-propelled swimming to a maximum depth and back to surface; no line assistance allowed	331 (101)	233 (71)
Free Immersion (ft [m])	vertical excursion propelled by pulling on the rope during descent and ascent; no fins	397 (121)	299 (91)

Extensive safety and disqualification protocols have kept the incident rate in competitive freediving extremely low.[1] The same level of safety does not always exist outside of organized events. The risk of injury or death is higher for breath-hold divers who do not have proper training or who fail to ensure the presence of adequate safety backups when pushing their limits. Educational efforts are critical since it requires little equipment to practice breath-hold. The lack of equipment definitely should not be equated to inherent safety. Breath-hold divers are susceptible to the physiological stress of immersion, hypoxia, hypercapnia, and, if diving vertically, to potentially immense squeeze forces. Loss of consciousness is the most obvious concern with breath-hold diving. Additional risks include entanglement, entrapment and problematic boat or animal interactions.

DAN began active collection of breath-hold incident case data in 2005. The initial effort included a retrospective review of cases from 2004, (those reported to DAN or found through active Internet searches). Automated keyword searches were then established to capture new reports as soon as they appeared online. A database was developed to target information of primary interest. Details on the structure of the database can be found in the proceedings of the 2006 breath-hold workshop.[2] Unlike the data analyzed by DAN for compressed-gas diving injuries, the breath-hold incidents include cases without geographical restriction. Reviews of breath-hold incidents have been included in DAN annual diving reports since 2005. Electronic copies of these reports are available for download at no cost (http://www.diversalert-network.org/medical/report). The annual number of cases captured from 2004 through 2013 (mean±standard deviation) was 65±18 (range 30-82; Figure 4.1-1).

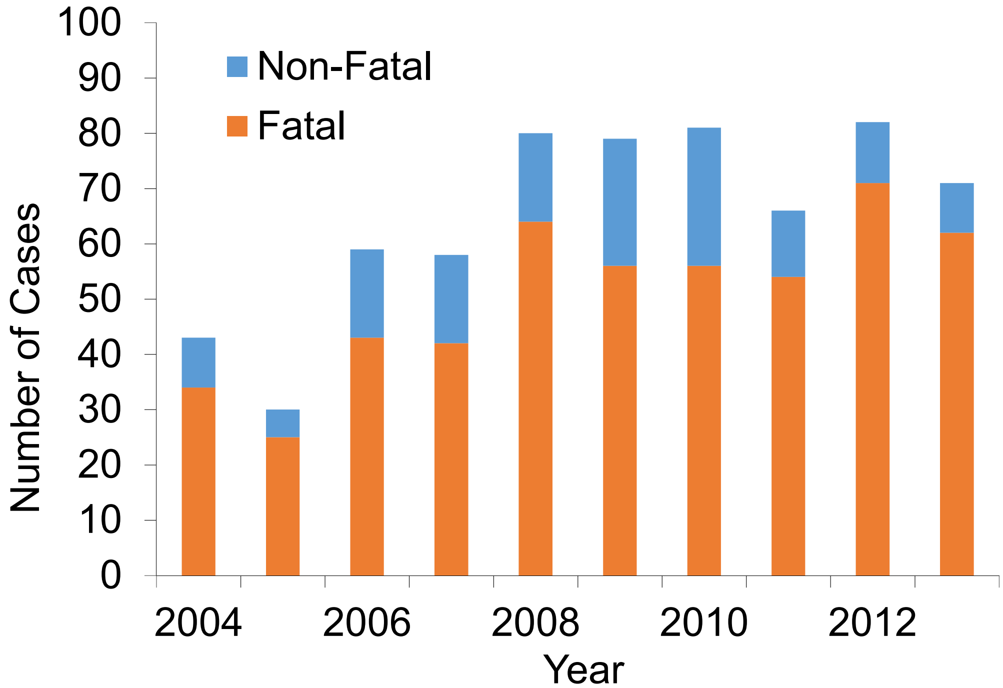

Figure 4.1-1: Breath-hold incident case capture, 2004-2013, fatal and non-fatal (n=649)

The purpose of incident data collection and analysis is not to assign blame but to learn from past events. Some incidents occur even when sound experience, planning, equipment and support are in place. Such events serve as reminders of the fundamental risks and encourage us to evaluate our behaviors accordingly. Other incidents arise from flaws in equipment maintenance, equipment use, training, or procedures. Incident analysis and program review can reduce the future risk for all participants.

A fundamental challenge in the study of injuries is incomplete information. The investigative effort can require a substantial amount of deductive reasoning and often some guesswork to interpret events. In this report, we summarize the available data and speculate when reasonable.

4.2 Cases in 2010-2013

Most cases were initially identified through automated internet searches, typically as online newspaper articles. Some cases were reported to DAN directly by individuals involved in or aware of particular incidents. Complete details were rarely available.

A total of 300 breath-hold cases were captured in 2010-2013; 243 fatal (81%) and 57 non-fatal (19%). The annual tallies are found in Table 4.2-1.

Table 4-2.1 Breath-hold cases 2010-2013

Year	Fatal	Non-Fatal	Total
2010	56 (69%)	25	81
2011	54 (82%)	12	66
2012	71 (87%)	11	82
2013	62 (87%)	9	71
All	**243 (81%)**	**57**	**300**

Incidents were reported from 42 different countries. Forty percent (n=119) occurred in the US, distributed between 10 states or territories. More than three events occurred in three states: Hawaii (40 cases; 34%), Florida (33 cases; 28%) and California (24 cases; 20%). This concentration is similar to that seen in previous years and almost certainly reflects the popularity of water-related activities and possibly some reporting bias. It is highly unlikely that our fatal case capture reflects true total numbers. It is certain that some fatal events that could have involved breath-holding are not reported in such a way as to enter our database. This situation is even more marked for non-fatal cases. The non-fatal cases represent an anecdotal sample, useful for insight and illustration, but in no way representative of the frequency of related events.

The majority of incidents in which the environment is known occurred in the ocean (n=271; 91% of the 298 with known environment). Fourteen cases occurred in lakes or quarries, nine in swimming pools, two in rivers or springs, and two in caves.

The primary activity described for the incident dive was most frequently snorkeling (n=164; 56% of the 293 with activity reported), then spearfishing (n=53; 18%), freediving (n=46; 16%), and collecting (n=30; 10%). The utility of this categorization is probably limited for fatal cases. The presence of specific equipment, for example, a speargun, or a history or communicated plan for an outing provides weight for categorical assignment, but specific actions or events contributing to an incident can easily confound categorical distinctions, as can reporter bias.

Figure 4.2-1 presents the sex and age breakdown for the 2010-2013 cases. The majority of victims were male (n=247; 83% of the 299 with sex identified). The mean age (±standard deviation) was 42±18 years, ranging from 7 to 93 years.

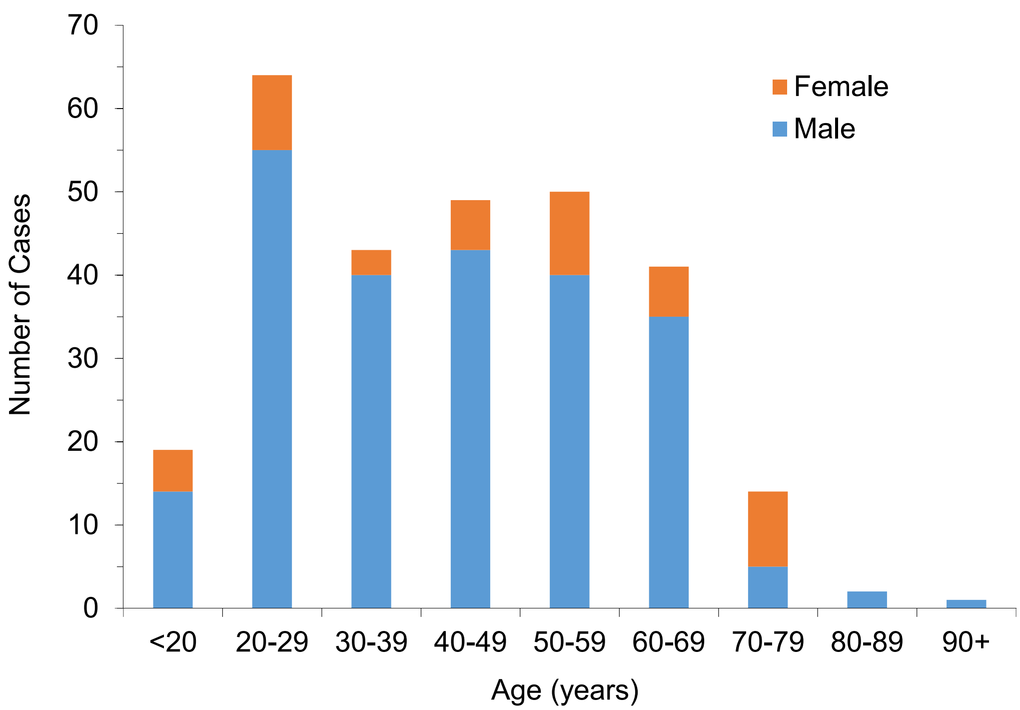

Figure 4.2-1: Age and sex distribution of breath-hold incident victims in 2010-2013 (for 283 of 300 total)

Information regarding the support available to divers was captured in 74% (n=223) of the cases. The most common patterns were diving with a partner (n=70; 31% of known), diving with a group (n=67; 30% of known), and then solo or unsupported (n=52; 23%). A large number of additional cases (n=34; 15%), was best described as activity with oversight somewhat removed and likely not immediately available for support. This was most commonly seen with families or groups remaining on shore while the in-water activity was taking place. The effectiveness of oversight is difficult to evaluate in most cases, but the delay to recognize a developing problem is a factor common to many injuries. There is no chance of someone else being able to recognize problems and render aid when diving alone. Protection may be only somewhat improved by others remaining on shore. Close supervision and the capability to take immediate and appropriate action can resolve many potential problems before they become serious. This is best achieved by a partner or group standing by in the water to provide support.

Evaluating the effectiveness of the assistance provided to stricken victims can be difficult. Immediately bringing an otherwise healthy but unconscious breath-hold diver to the surface and then protecting the airway from further water entry can be highly effective in preserving life. A slower recovery would likely be less effective, but the determination of the impact of a delay is challenging if for no other reason than it is not known exactly when a problem arose. It should also be appreciated that even a quick response might not make a difference for a medically-compromised individual.

Close and informed support is likely to improve outcomes, certainly over completely unsupervised activity and likely over poorly supervised activity. The informed partner or monitor can ask questions to more fully appreciate and be prepared for risk. The lack of informed supervision may grow if efforts to ban breath-hold activity in swimming pools continues to take root. It is easy for swimmers to hide such activities from lifeguards or other swimmers, leaving potential rescuers much less prepared if problems do occur. Rather than banning breath-hold, a more prudent course may be to ensure that all swimmers, breath-hold divers, instructors, lifeguards, and parents appreciate the risks and the reasonable limits of safe practice. Understanding factors playing a role in incidents is one of the best ways to advance understanding.

4.3 Cause of Death or Injury and Contributing Factors

Cause of death is typically determined by medical examiners assigned to fatality cases. The usefulness of the finding can be limited, particularly if the cause of death is determined to be drowning. More important are the efforts to identify root causes, triggers that can initiate a cascade of events, factors contributing to the unchecked cascade, and/or specific disabling agents or injuries leading directly or indirectly to the outcome. The search for contributing factors is challenging, particularly in the case of unwitnessed events, because physical evidence is often not present or possibly confounding.

The factors that lead to the inevitability of an incident are difficult to identify, but certainly of great value in preventing future occurrences. The available data for all 300 cases were reviewed to identify the primary disabling agents (Table 4.3-1). Such could not be confidently established in over one-third of the cases, which were most often unwitnessed events, some for which the body was not recovered, or those for which only minimal information was available.

Table 4.3-1 Primary disabling agent ascribed to 2010-2013 breath-hold incidents

Disabling Agent	Count	Percentage
Hypoxic blackout	40	25
Animal-involved injury	38	23
Medical health	29	18
Environmental conditions	24	15
Boat strike	21	13
Entanglement	5	3
Poor physical fitness	5	3
Total	**162**	**100**

Hypoxic Blackout

The most commonly identified disabling agent was hypoxic blackout (n=40; 25%). It is likely that many of the problems in this group were consequences of intentional action. Outside of casual snorkeling, many breath-hold divers employ strategies to extend breath-hold time, most notably hyperventilation. It certainly increases breath-hold time, but by delaying or obliterating the normal warning system that keeps the breath-hold safe. The absence of physical evidence associated with fatal events involving apparently young and physically fit individuals has led some to speculate on the possibility of exotic conditions like long Q-T syndrome being contributing factors. While this is certainly possible, the much simpler and more likely explanation in most cases is that excessive hyperventilation was the trigger.

There is no simple formula to differentiate between safe and unsafe (excessive) hyperventilation. Breath-hold divers must be sufficiently informed to appreciate the risk and then encouraged to err on the side of safety since loss of consciousness typically develops without warning. Knowledge and thoughtful action are critical. Ignorance, or knowing but thinking that the physiological hazards can be avoided, can create a very high mortal risk that is evident in our fatality case reports every year.

Each normal respiratory cycle is followed by a brief interruption of breathing (apnea) prior to the next inspiration-expiration cycle. The duration of the apnea is primarily controlled by the partial pressure of carbon dioxide in the arterial blood. The range is fairly narrow during relaxed, involuntary respiration, from a high of 45-46 mm Hg at the start of the respiratory cycle to a low of approximately 40 mm Hg at the end of the cycle. Voluntary breath-hold can allow the carbon dioxide partial pressure to climb well into the 50 mm Hg range or beyond depending in large part on motivation. Eventually, however, a breakpoint is reached when the urge to breathe is overwhelming. Many breath-hold divers know that ventilating the lungs in excess of metabolic need, that is, hyperventilation, will flush carbon dioxide from the body and delay the point at which carbon dioxide accumulation reaches breakpoint during a subsequent breath-hold. The accumulation of oxygen stores associated with hyperventilation is trivial in comparison with the clearance of carbon dioxide since the normal concentration of carbon dioxide in the blood is 140-160 times the concentration found in the atmosphere. Without hyperventilation, there is a buffer in oxygen stores. The urge to breathe rises while consciousness is still stable. Any hyperventilation reduces carbon dioxide levels enough to erode the buffer. Very limited hyperventilation will not erode the buffer enough to create a high risk of loss of consciousness, but it is a soft line to where excessive hyperventilation can delay the urge to breathe long enough for the oxygen partial pressure to fall below the level necessary to maintain consciousness, before any urge to breathe is felt. It is critical to understand that the loss of consciousness associated with hyperventilation-augmented breath-hold can occur with absolutely no warning.

Breath-hold physiology is more complicated when divers travel vertically through the water column. The increasing ambient pressure during descent increases the partial pressure of gases in the lungs and bloodstream. This effectively makes more oxygen available to the cells. While the partial pressure of carbon dioxide concentration is also increased by the ambient pressure increase, it will likely remain well below breakpoint in the first phase of the dive, particularly if hyperventilation was employed to lower it pre-dive.

The most critical phase of the breath-hold occurs during surfacing, when the partial pressure of oxygen falls at a dramatic rate due to the combined effect of metabolic consumption and the decrease in ambient pressure. A state of acute hypoxia can develop rapidly, particularly in the shallowest water where the relative rate of pressure reduction is the greatest. The carbon dioxide partial pressure will not help in this phase since it is also reduced by the reduction in ambient pressure, potentially moderating or reducing the urge to breathe. Ultimately, the risk of hypoxia-induced loss of consciousness without warning is elevated. The classic presentation of this condition – hypoxia of ascent – is seen in a diver who loses consciousness just before or shortly after surfacing. Losing consciousness after surfacing and taking a breath is possible because it takes time for the newly inspired oxygen to reach the brain. Many will be familiar with the term 'shallow water blackout,' but this label is frequently misapplied to cases where the change in ambient pressure is not a factor, in addition to the fact that the term was originally coined to describe a very different condition of high carbon dioxide levels associated with scrubber failure in closed-circuit rebreather divers. For these reasons 'hypoxia of ascent' is preferred.

The categorization of cases of blackout as hypoxic loss of consciousness (HLOC) or, more specifically, as hypoxia of ascent is generally dependent on witness observations. Confirming where the loss of consciousness developed is generally not possible in unwitnessed events. A victim found on the bottom could have lost consciousness there, but it is more likely that consciousness was lost near the surface and was followed by a loss of airway gas (and the positive buoyancy it provides) that ultimately caused the victim to sink to the bottom.

Hyperventilation-induced blackout is probably the greatest single life threat in breath-hold diving. The cases identified almost certainly represent a marked underestimate of the problem even within our sample. At least some of the unwitnessed fatal cases likely involved hyperventilation-induced loss of consciousness, but this cannot be confirmed even with autopsy because there is no specific physical evidence left to be discovered. Most cases that are resolved without serious outcome are unlikely to be reported.

It is very common for a diver rescued from blackout to wake within seconds and have no memory of the event. Some may initially argue that they did not blackout until they realize that they came to their senses in surroundings different from last recall. Those who experience these events firsthand (as victim or rescuer) realize how close anyone can be to loss of consciousness in a very unforgiving environment. Regardless of what some want to believe, there is no reliable warning prior to blackout. The effect of hyperventilation to increase breath-hold diving risk was described in the medical literature more than 50 years ago[2] and we are still losing divers to aggressive practice. It is likely that limiting hyperventilation to no more than the equivalent of two full ventilatory exchanges will increase breath-hold time but not will not remove enough carbon dioxide to inhibit the uncontrollable urge to breathe long enough for consciousness to be threatened. Hyperventilation in excess of this limit will produce an escalating risk of abolishing the vital drive to breathe.

Animal-Involved Injury

The second most commonly identified disabling agent was animal-involved injury (n=38; 23%). Twenty-nine of the cases involved sharks, three involved jellyfish, two involved a crocodile, one a barracuda, and one an alligator. The animal-involved category is a class of incident most likely to be overrepresented in our database, given the physical evidence of the altercation and the substantial media attention. At the same time, it is certain that many minor animal-involved injuries will likely not be captured in our database.

Medical Health

The third most commonly identified disabling agent was health issues (n=29; 18%). Many of these presented with reasonable to strong evidence of cardiac involvement; some were more ambiguous and could have involved cardiac issues or physical fitness issues. Not having complete autopsy results for some of these cases makes confirmation difficult. The associations between age, health and fatal diving injuries have been described for divers.[3]

While water activities can be healthful, they do create a physiological strain that can be problematic for individuals with compromised health. Immersion in water, regardless of depth, prompts an increase in blood returning to the heart that causes it to contract harder. Breathing resistance and physiological deadspace are increased by breathing through a snorkel. Wearing bulky equipment, and particularly a weight belt, can increase the strain of swimming, as can entry and exit requirements in rising sea state conditions. The initial exposure to immersion and any in-water activity is best done under benign conditions with easy ingress and egress and no pressure to continue should discomfort arise. It is not uncommon for vacationers to want to participate in ‘once in a lifetime activities’ that may expose them to more physiological stress than advertised or expected. Those who are medically or physically compromised can be at undue risk, a situation that may not be appreciated by them or by event organizers.

Environmental Conditions

Environmental conditions were identified as the primary disabling agent in 24 cases (15%); typically involving rough water conditions. It is possible that a lack of physical capacity was critical to the outcome of these cases. Physical fitness is rarely well documented, but can play a huge role in helping individuals handle a range of conditions. High levels of physical fitness creates a reserve capacity that can be called upon whenever needed. Addressing emergent needs quickly and without pushing physical limits can stop the cascade of events that often lead to poor outcomes.

Boat Strikes

There were 21 cases (13%) involving boat strikes. The physical trauma, typically involving propellers, can be devastating. It is possible that boat strikes are overrepresented in the database due to the greatest physical evidence and media attention. It is also possible that low visibility equipment in common use by breath-hold divers may work against surface safety.

Entanglement

There were five cases in which entanglement was identified as the disabling agent. It is possible that poor physical fitness and compromised medical health played a role in these cases.

Poor Physical Fitness

There were five cases in which poor physical fitness was specifically identified as the disabling agent. It is extremely likely that poor physical fitness played a role in many other cases.

A cross-section of illustrative case studies is found in Appendix A.

4.4 Reducing Breath-Hold Risks

Breath-hold diving includes a wide range of activities. Some are appropriately described as extreme; others as relatively benign. The margin of safety can be quite narrow for extreme diving. In such activity, appropriate safety precautions and backups are essential. The safety procedures employed in competitive freediving are usually extremely effective. Shifting away from the tight controls of the competitive field or from the typical medically healthy, physically fit, and well-trained participant can increase the risk.

The medical and physical fitness of individuals must be considered prior to participation in any diving activity. Those with significant medical issues should be evaluated in advance, and may well be discouraged from participation. Those close to the low physical fitness end of qualification should participate only under the most benign conditions. An orientation in a shallow pool or confined water is much more appropriate than being dropped off the back of a boat in deep water with the possibility of current or wave challenges. Implementing an orientation step for persons of possible concern might encourage some to appropriately reconsider participation and others to participate with more comfort and confidence.

The blackout hazard associated with pre-breath-hold hyperventilation stands out as the greatest risk to generally healthy individuals participating in breath-hold activity. Efforts to discourage hyperventilation face quiet but powerful resistance because it is so effective at increasing breath-hold time. The risk of loss of consciousness without warning may be difficult for the enthusiast to appreciate. Competitive freedivers increasingly acknowledge the inevitability of blackout in association with hyperventilation-augmented dives. They protect themselves, however, by ensuring close support throughout and following every dive.

The greatest risk is to divers without extensive backup support, whether these are unmonitored novices who have discovered hyperventilation or experienced spearfishermen determined to not let the fish get away. Safety-oriented education and rational guidelines are required for both groups to keep them safe. Buddy-diving in a one-up, one-down manner in good visibility water shallow enough for all divers to get to the bottom easily can take the novice safely through the relatively high-risk phase of learning. A group of three (one-down, two-up) may be preferable as dive depths begin to increase. It is a typical rule of thumb to allow a recovery period of at least twice the dive duration for modest dives, progressively longer for deeper dives. A group of three or four, diving in series, facilitates this schedule and ensures that one or more of the divers available at the surface for backup is at least partially rested. This is important since it is highly unlikely that optimal performance will be achieved during the stress of a rescue. Establishing safe habits in the beginning will hopefully keep safe habits in place. Safety protocols become more complicated as dive depths are increased, potentially involving counterbalance systems or mixed-gas diver support, but a commitment to safety can keep personal and group practices evolving appropriately.

Freedivers should be defensively weighted, neutrally buoyant with empty lungs at 30 ft (9 m) or deeper, to ensure that if they have problems at or near the surface they are more likely to remain at the surface where they can be found and assisted more quickly and easily. Overweighting can cause a diver to sink; especially if gas is expelled from the airway during ascent. Momentum established during ascent can carry the diver to the surface even if consciousness is lost. Adequate support requires an appropriate network. Close support protocols that have divers shadowed during the final portion of their ascent and the first 30 seconds of the post-dive period can address the majority of issues. The risk of loss of consciousness continues post-breath-hold until the oxygen in an inspired breath reaches the brain to counter hypoxia. The critical first aid when a victim is reached immediately after losing consciousness is to hold the airway clear of the water. Consciousness is often quickly restored with no sequelae.

Another technique that creates some risk for breath-hold divers is lung packing. It is used to increase the volume of gas in the lungs above normal total lung capacity immediately prior to commencing breath-hold. While it can assist the diver, it also increases the likelihood of pulmonary barotrauma.[4] The hazards of all techniques must be appreciated as well as the benefits. Each should be used thoughtfully and with caution foremost.

The solo freediver takes on much greater risk in all respects. The major price of independence is the loss of support in the moments upon which a life can turn. The sense of self-confidence, if not invincibility, often stands in the way of smart decision-making. The idea that blackout can occur without warning - while true - is a direct challenge to this self-perception.

There are a couple of ways to strike a compromise. The simplest is to carefully restrict pre-dive hyperventilation. Two or three deep inspiratory-expiratory exchanges prior to breath-hold will still reduce the carbon dioxide levels in the blood and increase breath-hold time, but without creating the high risk of hypoxia-induced blackout associated with more hyperventilation. The alternative is to hyperventilate freely, but then limit dive time. Butler (2006)[2] reviewed published data and concluded that limiting breath-hold time to 60 seconds could accommodate varying patterns of hyperventilation and physical activity with minimal risk of loss of consciousness.[2] While the time limitation might be too restrictive for some, it would be a good alternative for those making safety the top priority.

A freediver recovery vest is now available for breath-hold diving that will automatically inflate after a user preset time at depth or maximum depth or if another descent immediately follows surfacing. While such a device would not eliminate the risk of blackout or guarantee survival, it would improve the odds of survival by making sure that the diver was returned to the surface.

Breath-hold divers spend a lot of time on the surface. To reduce the risk of undesirable boat interactions, they should avoid boat traffic areas whenever possible and clearly mark their dive site with high visibility floats, flags and other locally-recognized markers. In addition, they should wear high visibility colors to mark themselves. The predominance of equipment in dark colors or, more recently, camouflage patterns, runs contrary to visual safety practices. The safest choice is high visibility throughout - suit, hood, snorkel, gloves, fins, and whatever else might break the surface. Underwater hunters may argue for the benefits of reducing their visibility underwater. Camouflaged divers have to rely more on the surface floats, support boats and tenders to warn surface traffic of their presence.

All divers need to be aware of the hazards they face and strategies to reduce their risk. Receiving initial training by qualified persons makes the transition into any activity smoother and safer. Ongoing education, which includes learning from the mistakes of others, is important to ensure that the risk of participation remains low. Further background can be found in a separate review.[5] As a final note, it must be remembered that problems not unrelated to diving can develop during periods of diving activity. Appropriate and timely medical evaluation is at least prudent, but may also be critical for a good outcome.

4.5 Ongoing Research

The greatest challenge in studying fatal events is that complete details are rarely available. DAN has established an online reporting system to expand the collection of cases, particularly non-fatal events for which more complete details may be available. It is expected that the additional insights will be extremely helpful in identifying additional factors contributing to incidents. Visit the site at: http://DAN.org/IncidentReport. Continued effort is required to promote awareness among breath-hold enthusiasts and community leaders.

4.6 Conclusion

A total of 300 breath-hold diving incidents occurring between 2010 and 2013 were collected by DAN; 243 fatal (81%) and 57 non-fatal (19%). The victims were most often male (83%). The most commonly identified disabling agents were hypoxic blackout (likely facilitated by excessive hyperventilation), animal-involved interactions (primarily between shark and spearfishermen), health issues (primarily cardiac), environmental conditions, and boat strikes, respectively. Improving the appreciation of hazards may offer the greatest defense against future adverse events. Sharing incident information is an important part of that process. Our efforts will continue to expand case collection, both fatal and non-fatal, and to provide insights for the community.

4.7 References

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Appendix A. Breath-Hold Incident Case Reports

Neal W. Pollock

Hypoxic Blackout

F - 10391
This 30-year-old male was freediving with friends in 10 m (30 ft). The group separated and he was diving alone for some period of time. His friends subsequently found him floating motionless on the surface close to the boat. He was pulled onto the boat and resuscitation initiated, albeit unsuccessfully. Autopsy records were not made available.

The details are limited in this unwitnessed event, but the diver's decision to freedive without close supervision was a critical problem. Apparently in good health, the most likely explanation was loss of consciousness resulting from hypoxia of ascent. The victim's weighting was appropriate for him to remain on the surface after ascent, but with no partner or team providing close supervision and able to protect his airway, he succumbed.

F - 10401
This experienced and apparently healthy 31-year-old male was spearfishing with a group in approximately 100 fsw (30 msw) near a shipwreck. He descended to recover some equipment. Visual contact was not maintained by the group on the surface. An unsuccessful search was initiated when the group recognized that he had been down too long. The victim was subsequently recovered by police divers.

The unwitnessed events make interpretation speculative. Hypoxic blackout does seem to be the most likely issue. It is possible that exertion at the bottom could have prompted loss of consciousness at that point, but it would be more likely that blackout occurred during ascent, when oxygen levels fall rapidly through the combined effects of metabolic use and decreasing ambient pressure. If the diver was not positively buoyant when consciousness was lost then he would sink to the bottom. Maintaining visual contact could possibly have helped if loss of consciousness occurred later in the ascent, when skilled divers might have been able to catch the victim and bring him to the surface more quickly.

NF - 10439
This 18-year-old male was spearfishing with a partner at a depth of approximately 65 fsw (20 msw). They began a relaxed ascent and his buddy noticed the victim slow and then begin to sink. He was able to catch him and bring him to the surface and to their boat where they were assisted by two other freedivers. The victim regained consciousness, was transferred to EMS, and made a full recovery.

This case demonstrates how a life-threatening event can be quickly managed by effective close supervision. The aware and capable partner was able to quickly effect a rescue, undoubtedly the lifesaving action. It was fortunate that the partner had sufficient reserve to rescue the victim without getting into trouble himself. In this case, having both divers underwater simultaneously was fortuitous. This is a good example of where a freediver recovery vest could have increased the margin of safety. Even if the victim's vest did not inflate immediately upon his loss of consciousness, his partner could have established a secure hold on the victim and activated one of their vests to speed the ascent, reducing the risk of a second blackout. It cannot be confirmed, but given the relaxed state of the victim immediately prior to the event, it is likely that the victim employed excessive hyperventilation, delaying the urge to breathe long enough for hypoxic loss of consciousness to develop with no warning. Limited hyperventilation is often used to reduce the carbon dioxide content of the blood to delay the urge to breathe. The cost of this is a reduction in the time buffer between the urge to breathe and a state of hypoxia that drives blackout. The erosion of the buffer time will not be noticed when all goes well. The problem is that there is no indicator to say how much of the buffer (if any) remains and what the true demands of the dive will be. Not having a problem with a given level of hyperventilation on one dive provides no assurance that the same outcome will follow another dive. It is critical that divers who choose to employ hyperventilation realize that it creates a substantial risk. Hyperventilation should be used with great restraint and only when reliable close supervision by competent partners is available. Limiting hyperventilation to the equivalent of no more than two full vital capacity exchanges appears to be relative safe, that is, it does not erode the safety buffer so much that loss of consciousness is expected. There is no line for absolute safety, though, so all breath-hold divers should appreciate the risk and keep it as low as feasible.

F - 12599
This 20-year-old male was freediving with a partner. He suffered from hypoxia of ascent, losing consciousness while surfacing, and sinking back to the bottom. A scuba diver went in to recover him, but the subsequent attempts at resuscitation were unsuccessful.

Defensive weighting calls for freedivers to be neutrally buoyant with empty lungs at a depth underwater, no less than 15 ft (5 m) for shallow diving, and in excess of 30 ft (9 m) for deeper diving. Since hypoxia of ascent most frequently develops as breath-hold divers are approaching the surface, this makes it easier for divers on the surface to effect a rescue, bringing the unconscious victim to the surface quickly. Victims often recover quickly when their airways are protected from further water entry. The time required to deploy a surface diver and bring a victim up from the bottom can be too long for successful resuscitation.

Animal-Involved Injury

F - 10412
This 24-year-old male was spearfishing from a small boat with a partner. They speared a large grouper that subsequently retreated under some rocks at about 35 fsw (11 msw). The pair took turns trying to wrestle the fish out. The third person remaining on the boat observed that both men made five to 10 dives attempting the recovery. The victim failed to surface from his last descent. His partner subsequently found him unresponsive on the bottom and brought him to the surface. The victim was then pulled into the boat and resuscitation efforts initiated while transporting him to onshore EMS. The victim did not regain consciousness.

The competitive drive of spearfishing can distract participants to push themselves beyond safe limits. Excessive hyperventilation (ventilatory exchange in excess of the equivalent of two full vital capacity exchanges) might be used to quickly prepare for the next breath-hold, and the normal termination of a dive could be delayed if a goal is felt to be in sight. Such conditions are probably the most likely to lead to hypoxic blackout on the bottom. If not there, a delayed ascent increases the likelihood of hypoxia of ascent.

F - 13637
This 68-year-old male was spearfishing with a group when he was attacked by a shark estimated to be 16 ft (5 m) in length, possibly a tiger. He was separated from the group when the shark struck. It was unclear if he was carrying any catch with him at the time.

The risk of shark-human conflict can increase when catch is carried by or near a diver, especially in low visibility conditions.

Medical Health

F - 10419
This 68-year-old female was snorkeling with a partner in calm waters accessed from shore. She complained feeling ill and wanted to return to shore. She then appeared to be disoriented and slipped underwater. Her partner was able to bring her into shore and start resuscitation efforts until EMS arrived. She was pronounced dead of heart failure at the local hospital.

The benign conditions and surface-based activity make it likely that medical health played a pivotal role. Many vacationers with no diving experience consider snorkeling as an alternative to experience the water. It is generally not well appreciated or communicated that even benign conditions impart a significant physiological load. Immersion in water causes a shift in the blood volume from the periphery to the central circulation, putting an additional burden on the heart that has to pump harder to manage the increased load. Breathing through a snorkel adds ventilatory deadspace and breathing resistance. Ballast weight given to the snorkeler increases the work that must be done to move with the load, more so if the extra ballast creates poor trim and increases frontal surface area during swimming. Inefficient kicking technique can demand more effort than would otherwise be required. The stress of the experience, particularly if all factors are not optimal, can add an additional physiological burden. Ultimately, while snorkeling can be a desirable activity, it is not without risk and may not be appropriate for health-compromised individuals. Close supervision and fast response to problems help manage the risk.

F - 12577
This 50-year-old male tourist was snorkeling alone. He was found floating and unresponsive and removed from the water. Efforts to resuscitate were unsuccessful. An autopsy concluded death from cardiac arrest, not drowning.

See comments in case above.

F - 12617
This 60-year-old male with a medical history of heart problems was snorkeling while on vacation. He lost consciousness while in the water. He was then taken onto a boat where efforts at resuscitation were unsuccessful. The death was ruled as natural causes, cardiac-related.

See comments in case two above.

Environmental Conditions

F - 10399
This 33-year-old male abalone diver was struck by large wave and began to struggle. He was quickly lost from the sight of his companions. He had no known medical conditions and was reportedly a good swimmer. His body was found face down and recovered 200-300 yd (60-90 m) offshore approximately 80 min later by a rescue helicopter. The Coast Guard described conditions as clear skies, minimal winds and swells of 2-4 ft (0.6-1.3 m).

Incidents involving seafood harvesters are common, particularly during short open seasons. The risk is increased if participants do not maintain their skills and physical fitness outside of the season. The time pressure can increase the risk to participants, encouraging them to exceed their capabilities. Efforts should be made to ensure physical readiness in advance of the opening.

F - 12603
This 29-year-old male was snorkeling with friends when a strong wind and high wave advisory was in effect. He was swimming near a reef 660-1000 ft (200-300 m) from shore when strong winds and waves associated with a tropical storm swept him out to sea. His body was recovered on the surface the next day by a Coast Guard patrol vessel.

Active weather systems create hazards, making it unsafe to be in the water. If caught unaware during building conditions, a rapid exit is generally best, avoiding rough terrain, if possible.

Boat Strikes

NF - 10415
This 32-year-old male snorkeler run over by speed boat. He suffered serious but non-life-threatening lacerations to his legs and feet. He did not have a diver-down flag near him, as was legally required in that state.

Breath-hold divers often spend more time on the surface than compressed gas divers. Safety from boat traffic must be considered in activity planning. Flying appropriate and recognized dive flags, staying close to marked and staffed safety platforms, avoiding all but low traffic areas, wearing high visibility equipment, watchfulness, and public education are all important elements to promote safety.

F - 11473
This 50-year-old female was on a commercial snorkeling tour boat. The water conditions were described as rougher than normal. She was one of the first in the water once it arrived on site. She was apparently swept under the boat and was fatally injured by the turning propeller.

Safety procedures on on motorized boats should ensure that snorkelers cannot be brought into the proximity of turning propellers. Engines should be secured and boats stopped before divers enter the water. Watchfulness is critical to avoid being too close to spinning propellers.

NF - 10443
This male snorkeler was at a depth of approximately three feet (one meter), above a coral reef and near a commercial dive boat. A speedboat passed over the diver at high speed, towing the victim for approximately 1000 ft (300 m) before stopping. The diver had propeller marks on his weights and was bruised, but had no major injuries. The boat operator was in violation of local law concerning maximum speed (5 knots) and proximity to the reef (1000 ft [300 m]) and to boats flying a dive flag (165 ft [50 m]). The boat operator was angry, however, and claimed that the diver should pay for the damage to the boat.

Boat operators are generally responsible and do not set out to injure others, but the onus remains on the surface swimmer to protect his or her own safety.

Poor Practice

F - 10393
This 21-year-old male was with two friends at night near a shallow freshwater cave. He chose to swim through the cave alone, and did not surface. His friends did not have lights to search for him. His body was later recovered from a depth of eight feet (3 m) of water.

Breath-hold diving through a cave, even a shallow one, carries significant risk. Doing so at night, and when partners did not have lights to make rendering assistance feasible, increased the risk substantially. It is unclear whether the victim became disoriented or experienced physical trauma, but in any case, even with the small distances involved, the situation had no margin of error.

F - 11503
This 24-year-old male was snorkeling with a group in approximately 12 ft (4 m) of water depth about 100 yd (30 m) from shore in a lake. He developed cramps and was unable to support himself. He was wearing a weight belt and sank to the bottom. He was recovered by a lifeguard, but attempts at resuscitation were unsuccessful.

Weight belts are worn in a manner to be quickly ditched in case of emergency. Dropping the ballast weight makes it easier to ascend and/or stay at the surface. The fact that many fatal victims are found on the bottom with weight belts still in place indicates that thoughts of ditching may be forgotten during periods of stress, even if the ditching could immediately resolve the situation. The importance of proper ditchable ballast - that which can be dropped with minimal, and generally one-handed effort - should be reinforced during training and ongoing activity.

F - 12595
This 40-year-old male was collecting sea cucumbers. A rope tied to his waist was entangled on a reef that he swam through. He was unsuccessful in freeing himself and drowned.

Loose equipment can pose a hazard. Care must be taken to reduce the risk of entanglement. A second level of protection may be provided by tools carried to help with extrication.

Appendix B. Diving Related Fatalities In Australian Waters 2010

John Lippmann, Christopher Lawrence, Andrew Fock, Thomas Wodak, Scott Jamieson, Richard Harris, Douglas Walker.

Introduction

DAN Asia-Pacific collects information on diving and snorkelling fatalities throughout the Asia-Pacific region. However, the effectiveness of this data collection varies greatly between countries.

In Australia, dive fatalities are comparatively well investigated and most are logged on a National Coronial Database to which DAN AP has access. It often takes several years before the coronial investigations are completed and for detailed information to become available.

Dive fatality reporting plays an enormously important role in accident prevention, and DAN AP is committed to providing substantial resources in pursuing this task.

The reports shown here are only brief summaries of the cases for 2010. Detailed reports of these deaths have been published in the joint journal of the South Pacific Underwater Medical Society (SPUMS) & European Baromedical Society (EUBS). We are very grateful to the various Australian State Coroners and the NCIS for their assistance with this project, and to the members of the public who have provided information. We need divers to contact us when they hear of diving-related fatalities so that we can collect as much information as possible.*

*Lippmann J, Lawrence C, Wodak T, Fock A, Jamieson S, Harris R, Walker D. Provisional report on diving-related fatalities in Australian waters 2010. Diving & Hyperb Med. 2015; 45(3):154-175.

Each year in Australia there are deaths associated with snorkeling and diving using compressed gas (i.e., SCUBA or surface-supplied breathing apparatus). Although some accidents are unavoidable, many might have been prevented through better education about the proposed activity and/or associated risks; proper medical screening; greater experience; commonsense; improved supervision; or better equipment maintenance and design. The aim of the DAN Dive Fatality Monitoring is to educate divers and the diving industry and to inform diving doctors on the causes of fatal dive accidents in the hope of reducing the incidence of similar accidents in the future and of detecting, in advance, those who may be at risk. This report includes the diving-related fatalities between 1 January and 31 December 2010 that are recorded on the DAN Asia-Pacific (AP) database.

Breath-hold and snorkeling fatalities

BH 10/01
This 39-year-old male, other than being obese, appeared to have been relatively healthy. He was an experienced snorkeler and scuba diver who was certified seven years earlier but had been diving unqualified for many years prior to that. He regularly dived alone catching crabs. On a warm, still night, he went snorkeling alone at a familiar site with a large wreck in 4-6 msw (13 -20 fsw). When he failed to return home, a large air, sea and underwater search was conducted the next day, without success. Police divers searched inside the wreck but found no trace of the victim. However, three months later, the victim's badly decomposed body was found within a compartment inside the wreck. His body was soon recovered by police divers. His weight belt was still in place but his mask, snorkel and one fin had been displaced. The cause of death was unknown.

BH 10/02
This 77-year-old male overseas tourist was obese, with a history of coronary bypass surgery, hypertension and high cholesterol. His swimming and snorkeling ability and experience were unreported.

He and a friend were on a day trip to the Great Barrier Reef (GBR) on a large tourist vessel. The group was taken to an anchored pontoon, from which organized snorkeling is conducted. In addition to public announcements of the risks posed by various health conditions when snorkeling, there was a pre-snorkel briefing and guests were asked to declare relevant medical details. The victim didn't make any declaration.

He was provided with a mask, snorkel, fins, stinger suit and a life vest. There was a surface chop, waves up to one meter (three feet) high and a strong current. Soon after entering the water, the victim was swamped by some swells, banged his head on a buoy, began to panic and signalled for help. The lookout sent a nearby boat to assist but the victim soon became unconscious. The boat driver and two assistants could not lift the victim into the boat due to his size, so they towed him to the pontoon. CPR was commenced and oxygen gear and an AED were brought. The battery of the AED was flat and needed to be replaced, which delayed its use by several minutes. CPR was continued for a total of about 50 minutes before the victim was pronounced dead. The cause of death was cardiac-related.

BH 10/03
This fit, active 27-year-old man had no known existing medical conditions. He was a qualified scuba diver and keen spearfisher. Dressed in board shorts and wearing a mask, snorkel and fins, he was thought to have been practicing extending his breath-hold time in the swimming pool of the residential complex where he lived.

Another tenant entered the pool area and noticed the victim lying motionless on the bottom of the pool, apparently unconscious. He called for help and for an ambulance, while a bystander entered the water and, with difficulty, lifted the victim to the surface and out of the pool. He was unconscious, not breathing and his face was blue. When another person arrived, CPR was commenced and continued until paramedics arrived. There were stomach contents and frothy sputum in the victim's mouth. Advanced life support (ALS) was implemented and he was transported to hospital where he died the next day. The cause of death was drowning, likely as a result of 'breathholding blackout'.

BH 10/04
This 24-year-old, male, overseas tourist was in Australia on a working holiday. His medical history is unknown although his friend believed him to be healthy, but "not a strong swimmer". The victim and his friend were on a guided tour of a semi-tropical island with an inland freshwater lake. Wearing shorts, swim goggles and a snorkel, the victim snorkeled for a short time before returning to shore. He then re-entered the water and the friend noticed him snorkeling about five metres from the shore. The friend looked away for possibly 30 seconds, and when he turned back his friend was nowhere in sight. Despite a short search by the group and others, the victim was not found. Police divers found the victim's body the next day, after a presumed submersion time of 16 hours. The cause of death was given as drowning.

BH 10/05
This 55-year-old man was severely obese. He had a history of coronary artery bypass , diabetes, hypertension and high cholesterol. His swimming ability and snorkeling experience were unknown

The victim went on a snorkel safari on the GBR. At the dive shop, he and others were briefed on medical issues and snorkeling and were asked to write any personal medical conditions on the relevant form. The victim declared hypertension but no other medical conditions. Because of his size, the tour operator assessed him as a potential risk and allocated him to a small group with a snorkel guide. At the dive site, the victim wore a mask, snorkel, fins and a two-piece wetsuit without a weight belt. He also took a 'noodle' buoyancy aid. The water was described as calm and visibility was 3–6 meters (10-20 feet). There was no current.

Shortly after entering the water, the victim rolled onto his back, holding onto the 'noodle' and complained that his wetsuit was too tight. The guide handed him a life ring to help support him while she removed his wetsuit top. He became distressed, and asked to return to the boat. The guide signalled to the boat driver and they began to swim towards the boat. When the boat arrived, the victim could not lift himself into it and became less responsive. The boat driver was unable to drag him aboard owing to his size and the guide used the 'noodle' to support the victim as they were towed to the boat. Two staff dragged the now unconscious victim onto the boat and rolled him into the recovery position to help clear frothy sputum from his mouth. BLS began promptly and supplemental oxygen was added using a resuscitation mask with oxygen inlet. Contrary to local regulations, there was no defibrillator available on the boat. The victim was taken to a nearby island, arriving about 55 minutes later. Resuscitation was soon abandoned. The cause of death was cardiac-related.

BH 10/06

This 27-year-old, male tourist was on a working holiday. There was no information about his medical history. He was described by his friends as a weak swimmer. He and four friends went swimming from a surf prone beach with a coral reef nearby. At the time, waves were reported to be less than one meter. The visibility was not reported, but a local diver later stated that it typically became poor in the afternoons, owing to a freshening wind and choppy surface conditions. The victim was wearing a mask, snorkel and board shorts.

After snorkeling for a while, the friends headed further from shore while the victim remained closer to the beach. When the friends returned around 20 minutes later, there was no sign of him. They notified locals who contacted the police. There was little information provided due to language difficulties and the absence of a proper interpreter. Eventually, the victim's body was found the next morning lying on the seabed about 10 meters (33 feet) from shore, at a depth of about 6 meters (20 feet). He was still wearing his mask and snorkel. The cause of death was given as drowning.

BH 10/07

This 73-year-old man had a history of heart arrhythmia (atrial fibrillation) and bilateral hip replacements. His swimming experience was not reported. He had snorkeled before, although it seems he was relatively inexperienced as two days earlier he was reported to have "swallowed a lot of water".

He was on a vessel with six friends when they decided to snorkel. He was wearing a mask, snorkel and 'rashie' but no fins. The water was warm and there was not much current. After about 20 minutes, the victim signalled to the boat driver that he wanted to be picked up. He said that he was OK but did not want to snorkel any longer. While trying to board the boat, made more difficult due to his large size, he became exhausted, short of breath and began coughing. He was unable to climb the ladder despite assistance from others. With his leg straddled over the boat, he was slowly towed to the main vessel.

After being helped aboard, he was sitting in a deck chair near the stern, looking very ill, and wheezing, exhausted and short of breath. He fell out of the chair and was unable to get back into it. He became unconscious and was rolled onto his side so that "muck" could be cleared from his mouth. BLS was commenced and continued during the boat ride to a nearby island, where two nurses applied ALS, unsuccessfully.
The cause of death was given as drowning due to cardiac arrhythmia.

BH 10/08

This 60-year-old man was reported as "fit for his age", a highly experienced freediver and spearfisher, as well as an active and experienced recreational and commercial scuba diver. He was being treated for well-controlled bipolar affective disorder, depression, hypothyroidism and insomnia.

The victim went spearfishing with a friend, also an experienced spearfisherman, at a familiar site. Wearing a wetsuit, weight belt and carrying mask, snorkel, fins and a line with float, the pair walked about 350 meters (1,148 feet) from the car park down a rocky hill to reach the shoreline. However, the victim had to return to the car to retrieve a forgotten item. They entered the water from the rocky shore. The weather was warm, there was a light wind and the swell was around 1.5 meters (5 feet) high. The buddy described the conditions as "challenging, but not beyond their capabilities". After swimming through a channel in the rocks they began spearfishing in 10–15 meters (32-49 feet). After several dives, the victim reported that he was "having trouble catching my breath and am going in". The buddy said that he would follow soon and, after several more dives, he also swam, against a current, towards the agreed exit point. When nearby, the buddy noticed the victim's fins on a rock and saw the victim floating face-up at the surface near the rocky shoreline, still wearing his weightbelt. When the buddy reached him, the victim was unconscious, blue and not breathing.

He began CPR, assisted by bystanders. After every few cycles the airway needed to be cleared of water and stomach contents. The victim died despite continued resuscitation by the buddy and ambulance crew.

The friend later reported that on their last dive outing approximately five weeks earlier, which involved strenuous breath-hold dives over an extended period, the victim "ran out of steam" while swimming back to shore. The buddy noted that his friend looked unwell and, on feeling his pulse believed it to be very fast. He advised the victim to see a doctor but this advice went unheeded. Apparently he had been scuba diving in the interim. The cause of death was cardiac-related.

BH 10/09
This 30-year-old man was an experienced and apparently competent breath-hold diver and a member of a spearfishing club. He appeared to be healthy and was receiving no medical treatment. He went spearfishing from a small boat with two others.

The weather was warm, the water temperature 22°C (72°F), the current light and visibility was at least 15 meters (49 feet). They initially anchored the boat in a depth of about 15 meters (49 feet) and dived there for about an hour. When they reboarded the boat, the victim seemed to be fine but mentioned that it had been a bit deep for him. They moved and anchored in shallower water, about 10 meters (33 feet) deep and dived again. After a while the victim swam off by himself and snorkelled nearer to the boat.

When his companions returned to the boat about 35 minutes later, the victim was found nearby, floating vertically just below the surface, unconscious, with his weight belt on. He was dragged onto the boat and one buddy commenced CPR while the other called for help. It was necessary to roll the victim onto his side periodically to drain large amounts of water and blood-stained froth. CPR was continued until paramedics were available but the victim was declared dead shortly afterwards. The cause of death was given as drowning secondary to heart disease.

BH 10/10
This 64-year-old woman was an overseas tourist who was reported to be a competent swimmer but with no prior snorkeling experience. The victim and her daughter were among other tourists on a commercial snorkel tour on a charter boat. Prior to departure, she signed a liability waiver that confirmed that she could swim and was aware of the risks on the planned activity. Although she spoke no English, her daughter, a fluent English-speaker, translated it for her. She was issued with a mask, snorkel, fins and wetsuit which were dry-tested for correct fit.

Once at the site, the victim entered the water with nine other snorkelers and a guide to snorkel with some manta rays. The depth and visibility were about 15 to 20 meters (49-66 feet), and the water was described as calm and warm with no current or surge. As the rest of her group were re-boarding, the victim was seen snorkeling without obvious distress, with her arms by her side and finning some 10 meters (33 feet) from the boat. A crew member entered the water to help her but before he reached her she went limp. He rolled her over and noticed that she was unconscious with froth flowing from her mouth.

She was brought aboard and placed in the recovery position as she was vomiting. Her airway was cleared and she was found not to be breathing. CPR was begun and oxygen equipment was provided but proved useless as the only delivery device was a non-rebreather mask which is unsuitable for use with a non-breathing victim. Resuscitation efforts were abandoned about one hour later.

At the request of the family, only an external autopsy was conducted and, as a result, the cause of death was recorded as “unascertainable”.

BH 10/11
This fit 31-year-old man was an experienced breath-hold diver and spearfisherman. He had recently attended an extended apnoea training program. He and six friends, also experienced, set out for a day’s spearfishing from two boats. After some ‘warm-up’ diving at depths of 12 meters (39 feet), they moved to a new site, anchoring the boats on a wreck. The depth ranged from 23 meters (75 feet) at the top of the wreck to up to 30 meters (98 feet) to the sand.

The victim and five of his friends entered the water while one of the group remained on a boat as a lookout. The victim was wearing a mask, snorkel, fins; 1.5 mm thick wetsuit with hood; weight belt with 4.5 kg (2.2 lb) and was carrying a speargun. When they entered the water there was no current. They dived for a while using a ‘one-down-one-up’ protocol for greater safety. After a while, one of the group’s spear became stuck in the wreck. The victim offered to get it and was reported to be seen “breathing-up” on the surface before descending, carrying a friend’s speargun. After about 30 seconds, the owner of the stuck spear felt the tension on its attached cord release, indicating that the victim had freed it but became concerned when the victim failed to surface. The buddies then performed many dives in an unsuccessful attempt to find their friend.

Almost four hours later, about five minutes into their search, police divers located his body near the wreck at a depth of 30 meters (98 feet). He was brought to the surface and declared dead by a doctor who had arrived with one of the search teams. The cause of death was given as drowning (possibly subsequent to ‘breathholding blackout’.)

BH 10/12
This 28-year-old male overseas tourist was an experienced spearfisherman who had qualified as an Open Water Diver in his home country four months earlier. He was working on a large live-aboard vessel on the GBR in exchange for a discount on accommodation and diving. He did not declare any medical conditions on a pre-dive/snorkel medical questionnaire. He could hold his breath underwater for up to 90 seconds and tended to snorkel alone.

After a briefing, the victim entered the water with around 30 others. He was wearing a mask, snorkel and fins, a stinger vest and bathers. The weather and sea conditions were described as good with a slight breeze and current, and visibility of 10 meters (33 feet). The skipper of the vessel was reported to have been acting as the sole look-out.

When a pre-departure head-count was taken about two hours later, the victim was missing. After an on-board search, some boats and snorkelers entered the water and, after about 20 minutes, found the victim’s body close to where he had last been seen by a witness, and reportedly by the skipper, outside the delegated snorkeling area. He was lying on the seabed. He was brought on board and CPR was begun but was unsuccessful. One rescuer reported that the boat’s bag-valve-mask O_2 unit was not functional due to a missing part.

Scuba diving fatalities

SC 10/01
Although still obese, this 46-year-old woman had lost 40 kg since having gastric banding surgery five years earlier. Since losing the weight, she was described as being in good health, despite controlled hypertension. She led a reasonably active lifestyle. She had begun diver training 17 months earlier but withdrew shortly into it. One year later, she recommenced training and successfully completed this several months before this incident. She had also completed several post-certification dives.

The victim and her buddy, a much more experienced diver, set out on a shore dive in a small harbour. The weather was described as cool but sunny, there was a slight chop on the surface of the sheltered waters although it was rougher beyond the shelter of the rocks, where there was also some surge. The victim and her buddy, both wearing standard scuba gear, entered the water from the boat ramp and swam underwater towards a rock wall. Visibility was good initially but deteriorated nearer to the wall. The victim indicated that her dive computer was not working although at this time she seemed to be fine. About 40 minutes into the dive, the victim grabbed her buddy’s arm and showed her gauge, which now read 30 bar. After checking her own gauge (which read 120 bar), the buddy handed her ‘octopus’ to the victim and they swam along together for about five minutes at a depth of approximately 7 meters (23 feet) before the victim grabbed the buddy and indicated, insistently, that she wanted to surface.

On reaching the surface, after what was described as a slow, controlled ascent, the victim was very anxious, gasping for air and unable to speak, only communicating by nodding or shaking her head. They were now about 100 meters (328 feet) from shore and, as they were being swamped by waves, the buddy suggested they re-descend. When the victim continued to shake her head and struggle, the buddy told her to roll onto her back and began to tow her towards a moored boat. After about five minutes she noticed that the victim was unconscious and then called for help.

Rescuers arrived within about two minutes and, after some in-water rescue breathing, the victim was dragged into a boat where BLS was begun by bystanders who were relieved by paramedics on reaching shore. The victim failed to respond. The cause of death was given as drowning.

SC 10/02
This 46-year-old woman was healthy and led an active lifestyle. She was a strong swimmer who certified as a diver 27 years earlier and had done more than 86 dives, although had none for the past 11 years. She had two sets of her own regulators – one was old and familiar, the other newer and yet unused. A friend had lent the victim and her husband a full cylinder which her husband had tried out some three months earlier, leaving it with a residual pressure thought to be about 150 bar.

The dive site was off a sandy beach in a protected bay with surrounding reef. On arrival, she had dressed into a 3mm wetsuit, weight belt with 5.5 kg (12 lbs) of weights, mask, snorkel, fins, BCD and was using her old scuba regulator and a 10 L steel tank. She was seen entering the water alone. Conditions at the time were reported to have been a light wind, quite choppy, a swell of less than one metre inside the reef, a depth of 1–5 m, a slight current, a water temperature of 18°C and visibility likely to be less than 2 meters (7 feet). She was reported missing approximately 5 hours later.

Police divers located her body two days later, submerged at a depth of less than 1 meter (3 feet), 20 meters (66 feet) from shore and about 150 meters (492 feet) from where she had entered. Most of her equipment was still in place, including her weight belt, although her regulator was out of her mouth and her mask was slightly displaced (although marks on her forehead indicated that this was recent) and it contained some "pink fluid". The cylinder was empty.

When later tested by police, the equipment was found to be in poor condition. The cylinder contained some seawater which was tested and believed likely to have been introduced post mortem. The low pressure hose had some obvious weaknesses and was easily bent and, when this occurred, the air supply to the demand valve was completely cut off. The demand valve, which although reported to have a slight 'free-flow', was found to be difficult to breathe from and allowed water ingress in inverted positions. The BCD inflator/deflator mechanism was also faulty, leaking air into the BCD indicating that the wearer would need to dump air regularly to maintain their position in the water. The cause of death was given as drowning.

SC 10/03
The victim was a 51-year-old experienced male cave diver who had no known medical problems and appeared healthy. He had performed many freshwater cave dives with a regular cave diving buddy over the past nine years. This buddy described him as a calm and safe diver. The victim normally dived with twin back-mounted cylinders of air, but on this particular weekend he was trying a sidemount diving system for the first time. He was also using new regulators and a new drysuit, although he was an experienced drysuit diver. He and his regular cave diving buddy completed two cave dives the previous day without incident, aside from the victim falling and injuring his toe.

The next day the pair prepared to dive in a deeper, less restrictive cave. The visibility was clear. His buddy stated that the victim was not himself. In fact, he had been somewhat withdrawn and unhappy all weekend. He was distracted, disorganised and required several reminders about usually routine aspects of dive preparation. The divers both used twin cylinders of air (the victim in his new side-mount configuration) and each diver also carried an additional 'travel' gas cylinder containing nitrox.

After about 7 minutes, the pair dropped their travel gas cylinders at 35 meters (115 feet), the victim needing some help with this task. From this point, the victim was not responding swiftly to signals and was already possibly suffering the effects of narcosis. A degree of buddy separation then followed with the buddy dropping down to 45 meters (148 feet) before being joined by the victim. The buddy then headed down further to 52 meters (171 feet) for three minutes before seeing the victim above him, inverted in his drysuit. The buddy assisted with righting the victim, at which time the latter indicated he wanted to ascend. The buddy led the pair back to the travel cylinders but again the victim fell behind. He had stopped and was motionless and facing back into the cave. A light signal attracted his attention, and then the victim swam out past the buddy but failed to stop and collect his travel cylinder. He then became inverted again but, on this occasion, when the buddy tried to assist, the victim appeared to panic and pull the buddy's mask off. The buddy performed a barely controlled ascent along the steep roof of the cave, closely avoiding drowning himself. After recomposing himself on the surface, he re-descended to do his decompression. He looked down to see the victim swimming along the cave floor at around 35 meters (115 feet) before he became inverted for the last time and stopped breathing.

When police divers recovered the victim's body the next day, they found him to be entangled in the guideline and his side-mount cylinders were completely empty. When tested, all other equipment was found to be in good working order. The cause of death was given as drowning.

SC 10/04
This 48-year-old man was described as overweight with a history of diabetes and cardiac disease. He was a keen and regular diver although he had not dived since some cardiac surgery 11 months earlier. He was also not taking required post-surgical medication. He had spent a few days fishing with friends and had complained of chest pain and shortness of breath several days before going diving.

The victim and his regular buddy went scuba diving from a small boat. One friend remained on board and other friends were on another boat nearby. Earlier that day, the victim had complained of breathing difficulty and chest pain and he appeared to be stressed while gearing up. The plan was to catch some crayfish and abalone.

The victim and his buddy entered the water and descended to the seabed at a depth of 6 meters (20 feet). After about 10 minutes, he indicated that he was having difficulty breathing, signalled to his buddy and ascended. On the surface, he was distressed and told his buddy that his chest hurt and he could not breathe. When the boats came alongside, he was dragged onto one of the boats, "in and out of consciousness" and with froth coming from his mouth. One of his companions began CPR for a short time before paramedics arrived and implemented ALS for about 25 minutes before pronouncing him dead. The cause of death was cardiac-related.

SC 10/05
This 31-year-old woman had no known medical history and appeared to be healthy. She had suffered a non-fatal drowning incident as a child. She and her partner had learned to dive two years earlier in an attempt to help her overcome her fear of the water. They were both certified as Open Water Divers in Thailand two years earlier but were inexperienced, having done only seven dives, all under supervision, the last being nine months prior, and all in Thailand's tropical waters.

She and her partner/buddy entered the water from the shore for their first unsupervised dive. There was a light wind and surface conditions were likely to have been calm, with visibility of around 8 m and the water temperature was about 14°C (57°F).

After about 20 minutes at a depth of around 4 meters (13 feet), the buddy could not see the victim and surfaced to look for her or her bubbles. Unable to see either, he re-descended and looked underwater for another five minutes before surfacing and returning to shore. He then phoned a local dive shop to ask for advice. The owner immediately contacted other divers who he knew were nearby and asked them to help with a search. The victim was soon found lying face-up on the bottom at a depth of 4 meters (13 feet) with her regulator out of her mouth. She was brought to the surface and dragged onto the boat where CPR was begun. Resuscitation was continued by paramedics when they arrived, but was unsuccessful. The cause of death was given as undetermined was likely to have been drowning.

SC 10/06
This 49-year-old woman was severely obese, with a history of mild hypertension, high cholesterol, anxiety and depression. Over the previous year she had been hospitalized several times for acute chest pain which settled after heart medication was given. Standard cardiac investigations at that time showed no evidence of a heart attack. On-going symptoms resulted in further cardiac tests which were not definitive. She also suffered episodes of acute shortness of breath requiring hospital admission. Further tests revealed little and she was prescribed Salbutamol (a common asthma medication) although there was no definite diagnosis of asthma.

In an effort to improve her fitness, she enrolled in an Open Water Course. She underwent a diving medical with a doctor with training in the assessment of fitness to dive but it appears that she didn't reveal her previous cardiac and respiratory problems. The doctor noted her obesity and hypertension but issued a fitness to dive certificate.

On the day of the first open water dive, the victim and four other students were under the supervision of two instructors and a trainee divemaster. The dive was from the shore and along a jetty, a relatively shallow site with sand banks before deeper water. The conditions were windy with a slight surface current. The group geared-up on the beach. The victim was wearing a 6.5-mm wetsuit and hood, BCD, 14 kg (30 lbs) of weights distributed between a weight belt, integrated pockets and ankle weights and a scuba unit. She was buddied with the trainee divemaster. The divers waded about 50 meters (164 feet) into the water parallel to the pier until they reached chest-deep water. They then put on their fins and snorkeled for a few minutes to the dive buoy to descend. The depth here was 2.5 msw (8.2 fsw). However, the victim was too buoyant, so her buddy put an additional 3 kg (7 lbs) of weights into her BCD pockets before she was able to descend.

Almost immediately, after possibly a meter of descent, the victim signalled that she wanted to ascend. When she and her buddy reached the surface, the buddy inflated the victim's BCD. The victim complained of breathlessness and nausea and was noted to be breathing rapidly and deeply, with a faint wheeze. Her buddy began to tow her to shallower water but the victim began to panic when a wave washed over. The buddy continued to alternately tow the victim and support her as they walked slowly towards shore. After another small wave splashed over the victim's face, she began to cough and became flushed. She asked a bystander to fetch her Salbutamol from her bag. Once in shallower water the victim was helped to remove her hood and scuba unit and to unzip her wetsuit. She self-administered a total of four puffs of Salbutamol and an ambulance was called. However, she soon deteriorated and became unresponsive and looked blue with yellow, frothy sputum coming from her mouth. She was dragged to shore and placed in the recovery position as the rescuers believed that she was still breathing. Paramedics arrived soon afterwards and found her to be unconscious, not breathing and pulseless. ALS was begun, with suction required frequently, but the victim failed to respond. The cause of death was unascertained, however, cardiac-related pulmonary edema was likely.

Rebreather fatality

RB 10/01
This 49-year-old man was obese and had a history of depression and migraine. He also had a history of chest pain which had been investigated but no cause found.

He was a qualified divemaster and had been an active and experienced open-circuit diver. He had recently purchased a 10-year-old Dräger Dolphin rebreather which had been converted from a semi-closed to a fully-closed unit by the friend who had sold it to him. That friend also certified him to use a Dolphin rebreather two months earlier. There is some debate about the configuration of the unit during this training. The diver's logs indicated that he had possibly done about 10 dives using this unit; all relatively shallow.

On the day of the incident, the victim's buddy, with whom he had dived about ten times before, stated that the victim appeared to be quieter than usual and complained of having a headache. He said that he would take some medication for his headache and the buddy offered him a seasickness medication, which he took. The pair then set out with other divers on a charter boat which took them to a wreck sitting at a maximum depth of about 39 m.

The victim was wearing a drysuit with undergarments, hood, leg gaiters, boots and fins, mask, BCD, his rebreather (with one cylinder of air and one of oxygen), a bail-out cylinder (containing nitrox 29.6) which was connected to his drysuit inflator. He carried 11 kg (24 lbs) of weight, distributed around the shoulders of his rebreather and in two ditchable mesh bags. The buddy was diving on open-circuit breathing nitrox 30.

After their initial descent was aborted by the victim, they re-descended and reached the wreck at a depth of 36 meters (118 feet). The pair swam around the wreck for a while until, wishing to stay with his no-decompression limits, the buddy indicated that he wanted to surface. The victim signalled agreement and they began to ascend. However, the victim appeared to have trouble leaving the bottom. Not knowing what the problem was, the buddy offered assistance but was waved away by the now wide-eyed and anxious-looking victim. Finally, the buddy grabbed the victim and inflated his own BCD, but this was insufficient to lift them as the victim was so heavy. When the buddy let go of the victim, his own positive buoyancy caused him to rise rapidly until he could dump some gas. Unable to see the victim, he then decided to do a controlled ascent to get help, believing that the victim was conscious and breathing when he last saw him.

Shortly afterwards, a trio of divers found the victim lying on the deck of the wreck. He was unresponsive, his eyes were closed and his regulator was hanging loosely in one corner of his mouth. Two of them held the victim, one inflated her BCD and they brought him to the surface.

He was unconscious and frothy sputum was oozing from his mouth and nose. He was soon dragged aboard the dive boat and CPR was commenced and continued as the boat sped back to the jetty, where paramedics implemented ALS, without success.

The ditched rebreather unit was received by police four days later. When examined it had been modified to work as a mechanically operated closed circuit unit. Both the oxygen and diluent tanks were empty and the diluent tank contained seawater. The mouthpiece was partially bitten through. The bailout cylinder was turned off and contained 190 bar pressure.

The cause of death was given as unascertained. While a convulsion was not observed, the indication that the mouth-piece was bitten through is highly suggestive of convulsion from oxygen toxicity.

Surface supplied breathing apparatus diving fatality

SS 10/01

This 48-year-old man had a history of cardiac abnormality and suffered from angina, and a variety of cardiac arrhythmias. He had previously been on a several medications, there was no record of any currently prescribed medications. Although he was severely obese (BMI 36.9 $kg{\cdot}m^{-2}$), he was described as reasonably fit and played underwater hockey. There is no record of him having any training, certification or medical examination for scuba diving.

The victim, who was said to have been a keen and scallop diver of many years, went diving for scallops with two friends from a boat. The weather was reported to have been sunny and calm with a light wind. After an uneventful dive to 6 msw (20 fsw), the group moved to a new site, anchoring their boat in about 8 msw (26 fsw) depth. The victim was wearing a wetsuit with an additional vest with attached hood but was not wearing a BCD.

After a surface interval of 30 minutes, he and one of the friends dived together, using a home-made 'Hookah' while their friend remained on the boat to watch the compressor. The victim's 'hookah' hose was threaded under his weight belt from behind, between his legs and under his weight belt at the front, around his left shoulder and, finally, around his neck to the demand valve. He did not carry a bail-out bottle. The pair soon became separated as visibility deteriorated. After surfacing, the buddy looked back and saw the victim on the surface about 40 meters (131 feet) away, struggling, with his head and shoulders just above the water. He was wearing his mask and his regulator was out his mouth. He sank briefly before surfacing again and calling for help. The friend in the boat began to haul in the line and the victim was brought to the surface unconscious, and not breathing. CPR was attempted but was not successful.

When later tested, the Hookah unit was found to be in poor condition with multiple faults, some which likely contributed to the incident by interrupting the air supply. The cause of death was given as cerebral arterial gas embolism (CAGE).

Appendix C. Asia-Pacific Diving Deaths 2010 (Excluding Australia)

Scott Jamieson & John Lippmann

Following are summaries of the 41 diving (snorkeling and compressed gas) deaths within the Asia-Pacific region (excluding Australia) recorded by DAN Asia-Pacific for the 2010 calendar year. We believe that this account likely far from exhaustive and that many incidents escape scrutiny through lack of reporting or visibility.

Relatively little information is often available at all, or readily assessable by DAN Asia-Pacific, for fatalities in most countries in the Asia-Pacific. Australia is the greatest exception and so these are reported separately. With many of the following cases, the information received was scant, often consisting of a single paragraph in a news report with very little detail.

In addition, in some of the developing countries, autopsies are often not conducted, or are done by examiners without diving medical knowledge. For this reason, the possible disabling injuries or causes of death are not suggested here.

FIJI

FJ-SC 10/01
This 19-year-old male was part of a group collecting sea cucumbers (beche-de-mer). He surfaced screaming and then disappeared. His diving equipment and catch were recovered but the victim was not seen again. Of note: At this same location two years prior, another diver was taken by a shark.

FJ-SC 10/02
This 64-year-old American tourist was diving with a group. On surfacing, he experienced stroke-like symptoms, aspirated water and lost consciousness as a result of complications from a pre-existing medical condition (cancer). Resuscitation attempts were unsuccessful.

FJ-SC 10/03
This 28-year-old Australian female was an inexperienced diver who had completed one dive on this trip and seemed to be quite unfamiliar with parts of her equipment. The dive site for the second dive was approximately 24 meters (78 feet) deep, the water was choppy and a very strong current was running. The victim was diving, without an allocated buddy, in a group consisting of two divemasters (DMs) and five other divers – another two divers were diving without guides.

Many of the divers became separated immediately on descent due to the current. The victim was last seen swimming alone at a depth of about 6 meters (20 feet). Most of the other divers were surfacing at this stage due to low air from working hard in the current. The two DMs were noted to have surfaced, switched tanks and quickly reentered the water. One brought the victim to the surface about 17 minutes from when she was last seen alive. She was given on-going CPR by some of the customers during the boat trip to shore and in a taxi to hospital. After 45 minutes she was declared dead. The victim's tank was completely empty. The oxygen equipment on the boat was almost completely out of gas, corroded, missing parts and in very poor condition. The boat crew seemed to be untrained in CPR.

INDIA

IND-BH 10/01

This 25-year-old woman was a tourist visiting a tropical island resort which has a strong focus on watersports including snorkeling and diving. This island is also located only 70 km (43 miles) from a saltwater crocodile sanctuary. The victim had gone snorkeling from the beach with her boyfriend who witnessed a large saltwater crocodile surface, grab the victim in its jaws and drag her underwater. Her body was recovered two days later. The attack is described as unusual as it occurred in open water over a coral reef and not close to mangroves. It was also an unusual time of day for the predator to be hunting.

INDONESIA

IN-BH 10/01

This 71-year-old woman was a tourist visiting a popular beach to go snorkeling. She was a doctor in her home country. On this day, there were 100 tourists on the cruise. Shortly after arriving at the island, the victim left the group to go snorkeling by herself at a local reef. A search was initiated when she failed to rejoin the group and her body was found a short time later.

IN-BH 10/02

This 28-year-old ex-pat Australian male victim, was manager of a local dive shop and a very experienced breath-hold diver. He had been snorkeling on a deep drop off and failed to surface. His body was found in 12 meters (39 feet) of water. Others were freediving in the area but there was no close buddy system in place. Breathholding blackout was believed to have been a likely cause of his demise.

IN-BH 10/03

This 33-year-old male tourist was freediving with friends when he failed to surface from a dive. His body washed ashore three days later. At this time he was still wearing all his gear. The police reported that he was trying to extend his times underwater and may have drowned. Breathholding blackout was a likely precipitant.

IN-SC 10/01

The victim was a 37-year-old woman who was undergoing scuba training at the time of her death. She had already completed one dive and was undertaking the controlled emergency swimming ascent (CESA) skill on the second when she experienced an out-of-air emergency due to a closed cylinder valve. By the time the victim was recovered to the boat she was unconscious and vomiting. CPR was not commenced until the boat reached shore 20 minutes later. Her cylinder was found to be turned off but with approximately 140 bar of gas remaining.

IN-SC 10/02

This 41-year-old male tourist was on a recreational dive under the supervision of an instructor when he went missing. Despite an extensive search the man was not found until four days later when his body, still wearing all the diving equipment, was washed ashore.

IN-SC 10/03

This 71-year-old American tourist was diving at a site with strong currents. He had done previous dives with this operator but it is not known if he had dived this location previously. He always dived under the supervision of a dive guide. On this dive, he struggled with the current and surfaced with breathing difficulties. He became unconscious and was taken ashore where CPR was commenced, albeit unsuccessfully.

IN-SC 10/04

This 62-year-old man was a very experienced diver with over 3000 lifetime dives although he had not dived for almost a year. He had just arrived from the USA and this was his first dive for the trip. Conditions were described as good, calm with no currents and he was buddied with an instructor. After about 20 minutes into this 20 meter (66 feet) dive, the victim indicated that he wanted to ascend and made a direct, controlled ascent to the surface. On surfacing, he began to vomit. He was assisted into the boat, laid down on a bench and several minutes later became unconscious with noisy, labored breathing. Oxygen was supplied via a demand valve and mask during the trip back to shore. Soon after, he stopped breathing, CPR was commenced and he was transported to a nearby hospital where he was pronounced dead.

KOREA

KOR-SC 10/01
This 53-year-old man was a volunteer diving as part of recovery efforts searching for survivors from a vessel that had sank. He was a trainer for the naval diving school. The dive was made in poor conditions with low visibility (<1m or 3 feet), strong currents (>5 knots) and depths of 40 meters (131 feet). It was reported that the victim exceeded his time/depth limits and lost consciousness at around 24 meters (79 feet). He was brought to the surface but could not be revived.

KOR-SC 10/02
Very little information is available on this incident. It seems that the 45-year-old diver may have been undertaking training and drowned.

MALAYSIA

MY-BH 10/01
This victim was a 41-year-old expatriate American living in Malaysia was demonstrating breath-hold diving to his two sons. He had been hyperventilating to try and swim two lengths of a pool underwater. After he had spent 5 minutes motionless on the bottom, his sons realized something was wrong and dragged him out of the pool. CPR was performed unsuccessfully.

MY-BH 10/02 & 10/03
This double fatality involved a mother and daughter, both Chinese nationals, aged 58 and 31 respectively. They were snorkeling from a tourist boat were soon seen having difficulties and trying to get attention of the boatman. The boatman was notified and went to the rescue. First aid was provided however the pair continued to have “breathing difficulties” and died en-route to medical aid.

MY-BH 10/04
This man was snorkeling with a group off the beach. Sometime later, one of his friends saw his body floating about 100 meters (328 feet) from the shore. The friend alerted lifeguards who recovered the victim and CPR was attempted, without success.

MY-SC 10/01
This 14-year-old Australian boy was on a brief diving vacation with his father at a resort in Sabah. He had no significant medical history, and prior to SCUBA training, he underwent a diving medical assessment by a physician trained in diving medicine in accordance with Australian Standard AS 4005.1. This found no obvious contra indications to diving. His diving history included a total of six dives, including training dives.

After a first, apparently uneventful multi-level dive of 18 msw (59 fsw) for 45 minutes, he mentioned that he had been sneezing underwater and that he had an “itchy feeling” in his chest after surfacing but this did not appear to bother him. They dived again after a surface interval of one hour and 15 minutes. This dive was also to a maximum depth of 18 msw (59 fsw), again reportedly following the reef into shallower water throughout the dive. The dive appeared to be problem-free until they ascended to the safety stop. The ascent was normal but, at the stop, he swam to the other divers and began to squeeze his right arm with his left hand as though it was numb. Soon after this he appeared to float towards the surface, unconscious.

He was quickly brought aboard the boat which immediately departed for the resort, some 10-15 minutes away. There was no oxygen equipment on board. He was initially unconscious and convulsing and froth was coming from his mouth, although he was breathing spontaneously. The convulsions continued throughout the boat trip to shore although he was intermittently responsive between seizures. On arrival at the resort, he was provided some low concentration oxygen first aid and eventually transferred to hospital by ambulance. There was no doctor with knowledge of diving medicine and, despite the clinical history and some test results that would indicate the likelihood of a CAGE, he was treated for stroke. He only received low concentration oxygen and progressively deteriorated. When a navy doctor arrived six hours after the accident and diagnosed likely DCI, the urgency of the situation was not appreciated and immediate management was not changed. By the time he was evacuated to a suitable recompression center (32 hours post-incident) his condition was unsalvageable and he died several days later.

MY-SC 10/02
This 34-year-old male victim was diving a remote deep wreck from a liveaboard vessel. He was a qualified tech diver who was also an experienced wreck diver. The group became concerned when he had not surfaced after his planned dive time. He was found out of air at a depth of 48 meters (157 feet) inside the wreck, slightly entangled in the permanent guideline and out of air.

MY-SC 10/03
This French tourist entered the water with two buddies early afternoon. Sometime later the buddies returned to shore and discovered that the victim was not with them. A report was made to police, around two hours after the victim had entered the water, and a search commenced. His body was found floating the following morning, near where he went missing.

MY-RB 10/01
In a tragic case of history repeating this victim had been the instructor on a technical dive 12 months prior where one of his students had died. He was a veteran 68-year-old dive instructor with thousands of dives. Seven years prior he had cardiac bypass surgery but had been declared fit to dive (most recently in the week leading to this trip). It is believed that he had a heart attack during the ascent and lost consciousness. His buddy bought him to the surface where boat crew performed CPR but he was later pronounced dead in hospital.

NEW ZEALAND

NZ-BH 10/01
This 56-year-old, apparently fit and healthy woman, was part of a group snorkeling with dolphins. She was on her second swim of the day when she signalled distress. The boat maneuvered to her and she signaled “OK” before rolling on her back with snorkel still in place. She began to cough and was returned to the boat where she complained of severe shortness of breath. There was no oxygen available on the boat. She deteriorated progressively and became unconscious. When the ambulance met the boat on arrival at the jetty, the victim was in cardiac arrest and her airway was obstructed by vomit and frothy sputum. She died in hospital; the cause of death being immersion pulmonary edema.

NZ-BH 10/02
The 49-year-old man was enjoying an end of year party on a launch when he decided he would try and get some mussels. He stripped off and entered the water. He dived below the surface and was seen shortly after floating and with his waist length hair tangled in the kelp. CPR was unsuccessful.

NZ- BH 10/03
The 57-year-old man was snorkeling with his girlfriend and teenage daughter when he got into difficulty. After an undetermined period he was found floating face-down by his partner who towed him to shore. Resuscitation with O_2 was carried out for 30 minutes until the rescue helicopter arrived. He died at the scene

NZ-BH 10/04
The 52-year-old male was snorkeling with friends to collect seafood. He failed to surface from a dive. His friends and man in a kayak searched for him for over 90 minutes until a scuba diver found him trapped under a ledge.

NZ-SC 10/01
This man was scuba diving from a boat. He surfaced and called for help after running out of air. His BCD was not inflated and he was struggling to stay afloat. The skipper of the dive boat attempted to rescue him but got into trouble himself. People on a nearby boat heard cries for help and rescued the skipper and attempted CPR on the victim. Paramedics from a rescue boat also attempted CPR but were unsuccessful.

NZ-SC 10/02
The victim in this case, a 36-year-old male, was an experienced diver who, at the time, was diving for crayfish from a boat in water approximately 40 meters (131 feet) deep. He was seen to surface and call for help, before sinking. He re-surfaced briefly, with mask off, BCD deflated and weight belt on. Although those on the boat cut the anchor rope, the propeller fouled and they could not make headway so were unable to reach him before he sank. His body was found a month later.

NZ-SC 10/03
This 40 year-old male was diving for paua. He had planned to dive for 30 minutes. After 30 minutes his friend saw him on the surface and went to check on him. He was face down with his mask on his forehead and regulator out. He showed no signs of life. CPR was performed without success. He was under weighted and the gauge he was using read higher than actual - both possibly contributing to his out of air situation.

PHILIPPINES

PH-SC 10/01
This man was participating in a technical dive to recover bodies from a sunken ferry at 67 meters (220 feet). At about 52 meters (171 feet) during the ascent, he indicated to his buddy that he was feeling unwell. He then ascended quickly to 43 meters (141 feet) where he became unconscious. He was taken to a recompression chamber where he initially appeared to be responding to treatment (i.e., regained consciousness and responded to commands), but died two hours later, reportedly from a cardiac episode. On initial inspections, nothing was found to be wrong with his equipment.

PH-SC 10/02
This male diving instructor was diving as part of an ocean cleanup event. During the dive he felt ill and surfaced. He boarded the boat but died on the way to shore; apparently from a cardiac event.

PH-SC 10/03
This 20-year-old man was a Korean tourist who was undertaking an Advanced Open Water course with three friends. At a depth of 19 meters (62 feet), he was seen to panic. He was found unconscious at the surface and rushed to hospital but failed to recover.

PH-RB 10/01
This man, a highly experienced technical diver and instructor was ascending from a 147 meters (482 feet) dive made using a 'Megalodon' rebreather. At 87 meters (285 feet), his buddy noticed that he had let go of the line and was descending. The buddy started to descend but was unable to go further without personal risk and he had noted that the victim's breathing loop was no longer in the victim's mouth as he was sinking deeper. The body was never recovered.

THAILAND

TH-BH 10/01
This 63-year-old Swedish male was travelling as part of a tourist group. They were snorkeling over a coral reef when it is believed that the victim suffered a heart attack and died.

TH-SC 10/01
This 47-year-old British man was an experienced cave and technical diving instructor. He had already completed a deep air dive on this day and this second dive was planned to be to 30 meters (98 feet) in order to show another group to an alternate guideline within a cave that drops to 97 meters (318 feet). He was wearing twin cylinders. At a depth of around 20 meters (66 feet) he dropped off the guideline and was not seen again. The other divers surfaced to raise the alarm but the victim was not found.

TH-SC 10/02
This 32-year-old male had received some training in trimix diving from a friend who was trimix certified but not an instructor. He was attempting to dive on a wreck at 67 meters (219 feet) as part of an archeology group conducting surveys. He was using independent twin cylinders. One cylinder had a trimix and the other a 50% nitrox. For an unknown reason he swapped to the nitrox mix at 67 meters (219 feet) convulsed and died.

TH-SS 10/01
This man, a 63-year-old tourist from India, was undertaking a surface supplied Reef Walk experience dive. After around 10-15 minutes, he was seen to clutch at his chest and ascend. He collapsed as he was boarding the boat and was not able to be revived.

The tour guide told police that the victim had experienced breathing difficulties which the guide had attributed to the higher air pressures which was required to keep water out of the helmets.

VANUATU

VAN-BH 10/01
This 37-year-old New Zealand man was an experienced breathhold diver who had a history of previous blackouts on ascent. On the morning of the fatal dive, he completed a single scuba dive to the around 18 meters (59 feet). He was due to fly and therefore restricted himself to snorkeling in the afternoon. The others in his group were on scuba and reported him diving down to them at 18 meters (59 feet) before indicating he was going to a different part of the reef. Around 10-15 minutes later he was found on the bottom with blood around his nose and mask. He was brought to the surface unconscious and CPR was commenced but he was unable to be revived.

VAN-BH 10/02
Very scant information known about this death. The victim was snorkeling off a well-known resort and was caught in a current and dragged out to sea where, presumably, he died.

VIETNAM

VN-BH 10/01
This 27-year-old male was a Russian tourist who had been scuba diving with a group from a tourist boat. It appears that he later re-entered the water to snorkel. Reports vary as to the circumstances of this fatality with some suggesting that the boat left without him and others stating that it was noticed that he was missing after 10 minutes and passengers were sent back on another boat so that the dive boat could search for him. His body was found five days later by a fisherman, some 800 meters (2,625 feet) from where he went missing.

VN-BH 10/02 and 10/03
Dynamite fishing is still a relatively common, although illegal, practice in parts if Vietnam. In this incident, a group of three men, two Russians and a Frenchman, were snorkeling and it is reported that nearby fishermen were dynamiting for fish. The survivor (one of the Russians) recalls a blast before losing consciousness. He was pulled from the water unconscious and when he regained consciousness advised rescuers that his two companions were still missing. A search located their bodies.

Appendix D. Japanese Divers

Yasushi Kojima (edited by Peter Buzzacott)

Between 2003 and 2014 there were 589,684 entry-level diver certifications issued in Japan, 51% of them issued to female divers. Over the same period there were 1,178,487 diver certifications of all levels issued in Japan and 48% of those were to female divers. This is higher than found in other countries. Table D-1 shows the proportion of female divers in various diver surveys.

Table D-1 Proportion of recreational divers that are women

Survey Year	Survey	n	% women divers
1999	West Australian PADI recreational divers	477	28
2000	US and Australian dive club members	709	30.5
2001	DAN member recreational divers	1653	24.6
1983-2010	Divers treated for DCS in Hawaii	400	28.8
2004	West Australian recreational divers	500	25
1995-2004	PDE Recreational divers	4,711	30
<2004	British asthmatic recreational divers	100	32
2000-2007	USA insured DAN members	1,304,358*	36
2008	West Australian recreational divers	163	28

*Member years

From the above we might speculate that, in many parts of the world, the proportion of recreational divers that are women is probably between a quarter and a third. Why this is higher among Japanese diver certifications is unclear.

Among insured members of DAN Japan at the time of writing (September 2015) 6,162 of 15,059 (41%) were female yet between 2004-2012 there were 11 diving fatalities involving DAN members, only one of which (9%) was female. Similarly, of the 110 diving fatalities reported in Japan by the Coast Guard, where the sex of the victim was noted, only 28 (25%) were female, a much lower proportion than found in either diver certifications or DAN members.

Could it be that female divers are at lower risk of a diving fatality? In the US, a review of DAN members insured between 2000 and 2006 found women overall to be 2.8 times less likely to die while scuba diving than men.[1] However, given that it is possible women may, on average, dive for fewer years and/or make fewer divers per year during those years, the lower proportion of Japanese women divers in diving fatalities compared with certifications and DAN memberships makes it difficult to interpret the raw likelihood of dying while diving in Japan. Continued research by DAN Japan into this issue aims to better understand the risks of dying among divers of either sex.

Certifications

Table D-2 shows the entry-level diver certifications issued between 2003 and 2014, by sex and overall. It appears that the overall proportion of new divers that were female reflects the distribution of the sexes in Japanese society, last measured in 2013 at 51.4% by the World Bank, up slightly from 51.1% in 2000.[2]

Table D-2 Entry-level certifications in Japan by year and sex, and overall, 2003-2014

Year	Male	%Male	Female	%Female	Total
2003	21,684	44.2%	27,389	55.8%	49,073
2004	21,425	45.8%	25,362	54.2%	46,787
2005	22,050	48.1%	23,766	51.9%	45,816
2006	25,129	47.4%	27,897	52.6%	53,026
2007	25,831	48.5%	27,389	51.5%	53,220
2008	26,677	48.9%	27,867	51.1%	54,544
2009	23,608	49.2%	24,404	50.8%	48,012
2010	25,002	50.4%	24,600	49.6%	49,602
2011	26,950	52.8%	24,117	47.2%	51,067
2012	26,620	51.6%	24,941	48.4%	51,561
2013	20,804	46.1%	24,288	53.9%	45,092
2014	21,936	52.4%	19,948	47.6%	41,884
Total	**287,716**	**48.8%**	**301,968**	**51.2%**	**589,684**

This balance almost continues through to all certification levels, as shown in Table D-3.

Table D-3 All level certifications in Japan by year and sex, and overall, 2003-2014

Year	Male	%Male	Female	%Female	Total
2003	43,687	47.2%	48,953	52.8%	92,640
2004	46,528	48.1%	50,182	51.9%	96,710
2005	47,782	49.9%	48,058	50.1%	95,840
2006	58,707	51.6%	55,047	48.4%	113,754
2007	59,369	52.4%	53,910	47.6%	113,279
2008	57,865	52.3%	52,752	47.7%	110,617
2009	53,958	52.8%	48,195	47.2%	102,153
2010	53,050	53.1%	46,784	46.9%	99,834
2011	51,348	55.9%	40,479	44.1%	91,827
2012	52,136	54.4%	43,705	45.6%	95,841
2013	39,529	47.2%	44,281	52.8%	83,810
2014	43,925	53.4%	38,257	46.6%	82,182
Total	**607,884**	**51.6%**	**570,603**	**48.4%**	**1,178,487**

However, as reported in worldwide statistics by PADI in 2002[3], the proportion of females at instructor level dive courses in Japan is substantially lower than at entry-level, as shown in Table D-4.

Table D-4: Instructor-level certifications in Japan by year and sex, and overall, 2003-2014

Year	Male	%Male	Female	%Female	Total
2003	6,430	72.2%	2,470	27.8%	8,900
2004	6,803	71.9%	2,662	28.1%	9,465
2005	6,820	71.7%	2,693	28.3%	9,513
2006	7,389	71.7%	2,921	28.3%	10,310
2007	7,449	71.9%	2,911	28.1%	10,360
2008	7,642	72.5%	2,892	27.5%	10,534
2009	7,355	72.5%	2,795	27.5%	10,150
2010	7,524	72.4%	2,870	27.6%	10,394
2011	8,597	73.8%	3,049	26.2%	11,646
2012	9,557	75.6%	3,082	24.4%	12,639
2013	8,593	75.8%	2,748	24.2%	11,341
2014	7,938	76.7%	2,410	23.3%	10,348
Total	**92,097**	**73.3%**	**33,503**	**26.7%**	**125,600**

Fatalities

Data concerning diving fatalities and missing divers was supplied by the Japan Coast Guard for years 2005-2014, as shown in Table D-5.

Table D-5: Diving fatalities and missing divers reported by Japan Coast Guard

Year	Cases
2005	14
2006	11
2007	17
2008	18
2009	14
2010	25
2011	9
2012	22
2013	17
2014	11
Total	**158**

In 2012, the average age of male fatalities was 51.6 years, females were 50.9 years and the overall average was 51.4 years. There were 11 deaths between 2004 and 2012 among insured DAN Japan members, 10 male (91%) and one female (9%). The female was 24 years old, the average age of the ten males was similar to that of the Japan Coast Guard cases, at 49.2 years, which is also similar to the average age of male DAN Japan members in 2015, at 47.9 years. Table D-6 presents the number of fatalities, and DAN Japan insured members, per year for 2004-2012. Overall, there were 159,543 insured member-years and 11 deaths among those members during that period, giving an overall average of 1 death per 14,504 member-years, or 0.69 deaths per 10,000 member-years. This rate compares very favorably with that found among DAN USA members at 1.64 deaths per 10,000 member-years between 2000-2006, and among members of the British Sub-Aqua Club over the same period at 1.44 per 10,000 member-years.[4,5]

Table D-6: Diving fatalities and annual membership of DAN Japan, 2004-2012

Year	Member Fatalities	Number of members at 31 December each year
2004	0	17,507
2005	3	18,269
2006	1	18,730
2007	1	18,596
2008	1	18,505
2009	2	17,979
2010	1	17,322
2011	2	16,633
2012	0	16,002
Total	**11**	**159,543**

Conclusion

Though the proportion of females at entry-level diver certification appears to reflect the nationwide proportion outside of diving, that proportion falls with increasing certification and it is not yet known for how many years women and men dive in Japan, nor how many dives they make. Therefore, we cannot yet accurately estimate the exposure to diving each year.

Women suffer fewer diving fatalities but as stated above, we do not know if that might be due to less exposure over time and further research is warranted into this. Overall though, the fatality rate among DAN Japan insured members compares well with that found in the US and in the UK.

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Appendix E. DAN Classification of Hyperbaric Medical Facilities

Matias Nochetto, Petar Denoble

For optimal case management of diving injuries, it is of utmost importance to have up-to-date and easily accessible information about available treatment opportunities in the patient's vicinity. DAN maintains a database of hyperbaric facilities willing to receive injured divers with a detailed interface with Medical Services Call Center (MSCC). Hyperbaric facilities are classified according to their medical and technical capabilities as well as availability during the day. This classification is for the purpose of diving injury case management and referral only. If there is a local Diving Hyperbaric Medicine (DHM) physician in charge of case management, the treatment and disposition of the injured diver are at his discretion; however, DAN is always readily available for consultation when needed.

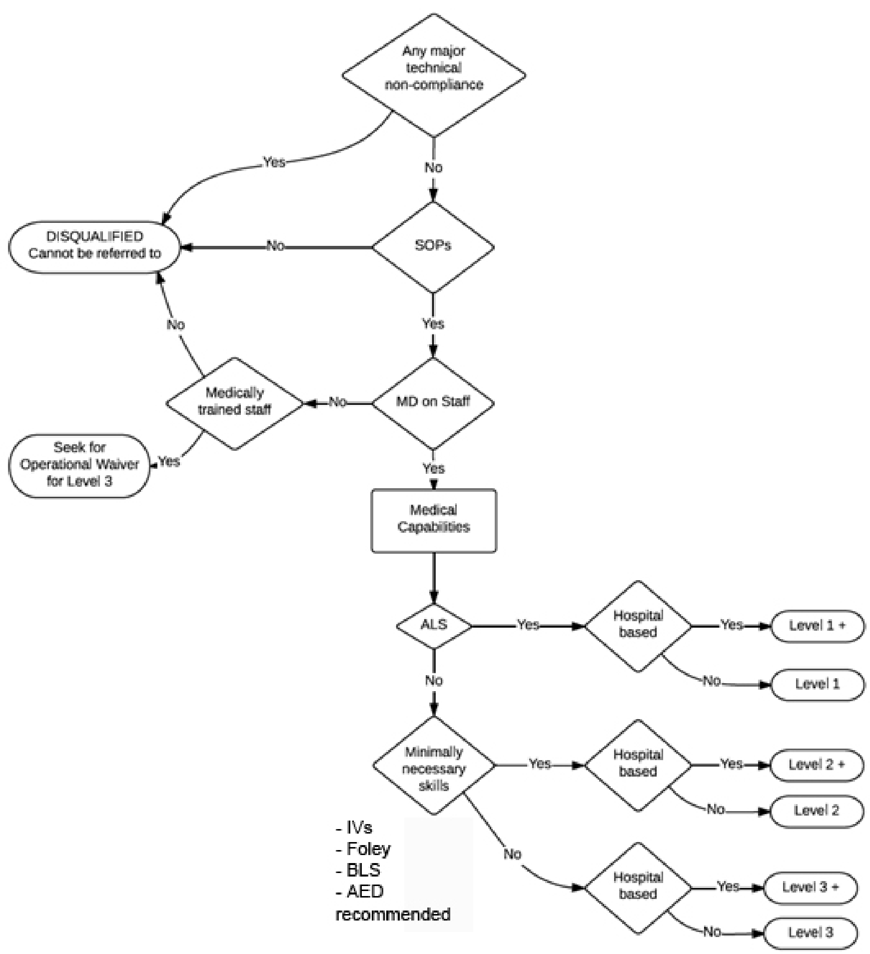

Figure E-1 Hyperbaric facility assessment classification flowchart

Technical and operational safety

Technical and operational safety of the hyperbaric facility is a prerequisite for the referral of patients by DAN. Guidelines for assessment are provided in the book Risk Assessment by Francois Burman and re-printed by DAN. Basic requirements include:

- Technical compliance with internationally accepted standards
- Sound standard operating procedures in place
- Staffed with trained staff

The status is compliant, deficient or unknown.

1. Hyperbaric treatment capabilities
   This criterion aims to describe what level of hyperbaric treatment could be provided. Top capabilities are listed first.
   - Multi-place chamber, 6+ bar treatment regimens, mixed gas available
   - Multi- or mono-place, USN TT6
   - Multi- or mono-place, HBOT less than USN TT6
2. Medical capabilities
   - In-chamber ACLS/ICU capabilities
   - Basic medical procedures: vital functions assessment, iv., urethral catheterization, basic neuro exam
   - No medical procedures
3. Medical oversight
   - Diving and Hyperbaric Medicine (DHM) trained and practicing physician
   - DMT + physician
   - DMT only

Table E-1 DAN classification of hyperbaric facilities by level of care

Level of care	Hyperbaric treatment capabilities	Medical capabilities	Medical supervision
Level 1	6+ bar, mixed gas) or 2 - (TT6)	(In-chamber ACLS/ICU capabilities)	(DMO/DHM Specialist)
Level 2	(TT6)	(Basic medical procedures: vital functions assessment, iv., urethral catheterization, basic neuro exam)	(DMT + physician)
Level 3	(less than TT6)	(No medical procedures)	(DMT only)

Overall classification level regresses to the lowest level in any category.

Availability of hyperbaric facilities

The urgency of hyperbaric treatment in case of diving injuries is considered important. However, the number of 24/7 available facilities are few and decreasing. The chambers are then color-coded based on availability:

- Green – available 24/7
- Yellow – normal business hours; must call to check availability
- Red – temporarily out of service
- Blue – clinical HBO only (not receiving divers)

Additional information provided in the flashcard

- Multi- or mono-place; maximum treatment pressure; treatment gases
- Contact information: facility, medical director, hospital (if applicable)
- Notes

Table E-2 Matching patient with facility

Hyperbaric Facility Capabilities	Patient classification		
	A – Severe: Progressive DCI, Concomitant serious medical conditions	B – Stable neurological DCI, patient conscious and breathing spontaneously	C – Mild DCI Pain only, skin rash only, minor static numbness and tingling
Level 1	+	+	+
Level 2		+	+
Level 3			+

Why DAN does not publish a list and contact information of hyperbaric facilities

DAN invests a lot in maintaining the most complete and up-to-date database of hyperbaric facilities available to provide recompression and hyperbaric oxygen treatment to injured divers. However, due to daily changes in the status of hyperbaric facilities and their readiness and availability, there is no publishable up-to-date list that could serve the public. Every time a referral is needed, a DAN case manager verifies before referral that the chamber is available.

The case below is one of many that illustrates what it takes, in some cases, to get an injured diver to a proper facility.

The caller was male, in his fifties, calling on our emergency services line with a complaint of possible DCS. The caller was diving the day before from a friend's boat and was spearfishing. He made three dives each to about 120 fsw (37 msw) for an estimated bottom time of 20-30 minutes. He believed the surface intervals were 90-120 minutes but was unsure. He was unsure of the breathing gas but suspected it was just air. They were not using computers or tables for dive planning. No safety stops were completed on any dive. On the last dive, he was at 100 ft (30 m) and saw he was down to 600 psi and was going to make an ascent but he saw a fish and his gun was still loaded. He pursued the fish to at least 110 fsw (34 msw). On his way back up he was inflating his BC for buoyancy assistance and had great difficulty at 30-40 fsw (9-12 msw) drawing breath from his regulator. He then made an out of air ascent.

Within 10 minutes he started to feel some pain in the elbows followed by paresthesia and weakness of the legs. There was no oxygen onboard. The boat captain took the patient back in the water to a depth of 35 feet (11 meters) for about 30 minutes in an attempt to decompress. The patient then drove back home few hours away.

The day after, he called because he continued to have paresthesia and strange feeling in his both legs. He said he could walk normally and most of the feeling had returned. He also complained of muffled hearing in his ears. Below is a time sequence of the DAN case manager's actions.

DAN case manager called hyperbaric treatment facility one (HTF #1) to advise of this patient. They said they had only one nurse practitioner present that day and would not be able to treat the patient as needed. They suggested contacting the hospital.

18:51 GMT	Attempted to call hospital. Spoke with technician in Hyperbaric Medicine Department (HTF #2). They usually do not treat emergency cases but advised to call back in a little while as she tries to get administrative approval.
18:52 GMT	Attempted call to hospital. Unable to reach anyone in HBO.
19:00 GMT	Call back to patient to advise we were having trouble finding an available facility. Diver was advised to admit to nearest emergency department for work up and may need to be transferred. Patient is not happy since he knows he needs to be treated as soon as possible.
19:10 GMT	Call to a military facility (HTF #3). They are not able to treat. Suggests calling HTF #4.
19:12 GMT	Call to HTF #4 and spoke to staff in HBO department. He will find out if they can see the patient and he will call back.

19:55 GMT	Attempted to call again HTF #2 for administrative approval to treat patient. Left message.
19:55 GMT	Return call from staff at HTF #4. They can see patient. Have him come to HBO directly instead of ED.
19:56 GMT	Called the patient and let him know.
20:10 GMT	Received voicemails from HTF #2 again now advising they cannot see emergent cases. Second voicemail from HTF #5. They would love to see the patient but are full right now and could not do a USN TT6.
Day 2 17:14 GMT	Received a voicemail from patient thanking us for assistance and to provide an update on his treatment. Returned call and left a voicemail.
Day 3 17:26 GMT	Patient called back. He received USN TT6 first day and improved significantly. He received two more USN TT9 next day and last night. He is very happy with the care received.

Appendix F. Glossary

Neal W. Pollock

Absorbent (rebreather)
Chemical compound used to remove carbon dioxide from breathing gas. See “Scrubber.”

Acetaminophen
Tylenol, paracetamol, N-acetyl-p-aminophenol, APAP. A non-prescription drug that is used as an alternative to aspirin to relieve mild pain and to reduce fever.

Adult Respiratory Distress Syndrome (ARDS)
Severe inflammation of the alveoli (air sacs) of the lungs, inhibiting gas exchange, and carrying a high threat to life.

Advair
Prescription drug that prevents the release of substances in the body that cause inflammation. It is common used to prevent asthma attacks and flare-ups or worsening of chronic obstructive pulmonary disease (COPD) associated with chronic bronchitis and/or emphysema. Advair contains the steroid fluticasone and the bronchodilator salmeterol. Salmeterol works by relaxing muscles in the airways to improve breathing.

Aerobic Capacity (VO_2 max)
The maximal amount of oxygen that can be consumed per unit of time. Determined through a short, graduated test to exhaustion while expired gases are captured and analyzed. Often reported in weight-indexed units of milliliters of oxygen consumed per kilogram body weight per unit time ($mL \cdot kg^{-1} \cdot min^{-1}$).

Agonal Breathing
An abnormal pattern of breathing characterized by sporadic gasps with audible effort. Possible causes include cerebral ischemia and severe hypoxia. Agonal breathing often pro- gresses to complete apnea and death.

Albuterol
A prescription drug (also known as salbutamol) used to prevent and treat wheezing and shortness of breath caused by breathing problems (e.g., asthma, chronic obstructive pulmonary disease). It is also used to prevent asthma brought on by exercise. Albuterol belongs to a class of drugs known as bronchodilators. It works in the airways by opening breathing passages and relaxing muscles. Nervousness, shaking (tremor), mouth/throat dryness or irritation, cough, dizziness, headache, trouble sleeping, or nausea may occur. Serious side effects include fast/pounding heartbeat, muscle cramps/weakness. Rare but very serious side effects include chest pain and irregular heartbeat. Rarely, this medication has caused severe, sudden worsening of breathing problems/asthma (paradoxical bronchospasm).

Alternobaric Vertigo
Dizziness and disorientation resulting from unequal pressures in the two middle ears. Usually transient.

Ambiguous DCS
A case where the diagnosis of DCS is not certain; for example, a case with sufficient decompression exposure but minimal, atypical symptoms or symptoms of short duration that spontaneously resolve.

Antiemetic
A drug that prevents or treats nausea and vomiting, typically used to treat motion sickness.

Antihistamine
Drug that may be part of some over-the-counter (OTC) med- icines for allergies and colds. Some antihistamines cause drowsiness. See “Over-the-Counter.”

Annual Fatality Rate (AFR)
The annual fatality rate is a count of deaths occurring within one year in a specified population (incidence) divided by the number of persons in the specified population (the denominator). AFR is usually expressed as the number of deaths per 10,000 persons or per 100,000 dives.

Arterial Gas Embolism (AGE)
Gas in the arterial circulation. In divers this may be caused by a sudden reduction in ambient pressure, such as a rapid ascent without exhalation that causes over-pressurization of the lung and pulmonary barotrauma. The most common target organ is the brain, and the usual signs and symptoms include the rapid (<15 min) onset of stroke-like symptoms after reaching the surface.

Arterionephrosclerosis
Patchy, wasting scarring of the kidney due to narrowing of the lumen (cavity) of the large branches of the renal artery.

Aspiration
The drawing of a foreign substance, such as water or gastric (stomach) contents, into the respiratory tract during inhalation.

Ataxia
A gross lack of coordination of muscle movements. Examples include: unsteady gait (walk), tendency to stumble, slurred speech, difficulty with fine-motor tasks (e.g., buttoning a shirt), slow eye movements, and difficulty swallowing.

Atherosclerosis
Thickening and hardening of the arteries caused by the accumulation of plaque.

Atmosphere (atm)
Measure of atmospheric pressure indexed to the normal conditions at sea level. Normal sea level pressure is 1.0 atm, 1.013 bar, 14.695 pounds per square inch, 101.3 kilopascals or 760 mm Hg.

Atmosphere Absolute (ATA)
Ambient pressure, including the barometric pressure of the air above the water.

Auscultation
The act of listening for sounds made by internal organs, for example, the heart and lungs, to aid in diagnosis.

Automated External Defibrillator (AED)
A portable electronic device that automatically assesses patients for life-threatening cardiac arrhythmias (dysrhythmias) of ventricular fibrillation and ventricular tachycardia. If identified, the device can be activated to provide a shock to interrupt the dysrhythmia and allow the heart to reestablish an effective rhythm. The device will not recommend a shock in the absence of a target dysrhythmia.

Barotrauma (BT)
A condition caused by a change in ambient pressure in a gas-filled space due to the effects of Boyle's law. When gas is trapped in a closed space within the body, the gas will be compressed if the depth increases and will expand if the depth decreases. Barotrauma injuries of descent include ear squeeze, tympanic membrane rupture or sinus squeeze. Injuries of ascent include pulmonary barotrauma, which can result in air embolism, pneumothorax or pneumomediastinum. See "Boyle's Law."

Benzodiazepine
A class of drugs that act on the central nervous system as tranquilizers, such as Librium and Valium.

Body Mass Index (BMI)
BMI is measure of body weight:height proportionality used to predict body composition. It is computed by dividing body weight in kilograms by the squared height in meters. BMI is often used as a convenient surrogate for actual body composition measures. Categorization by BMI (in kg·m-2): <18.5 = underweight; 18.5 to <25.0 = normal; 25.0 to <30.0 = overweight; 30.0 to <35.0 = grade 1 obesity; 35.0 to <40.0 = grade 2 obesity; and ≥40.0 = morbid obesity.

Bounce Dive
Any dive where the diver returns to the surface with little or no decompression. This is opposed to a saturation dive, where decompression can require many days, depending on the depth.

Boyle's Law
Under conditions of constant temperature and quantity, there is an inverse relationship between the volume and pressure for an ideal gas. Volume increases as pressure de- creases and vice versa.

Bradycardia
Unusually slow heart rate.

Breathing Bag
See "Counterlung."

British Sub-Aqua Club (BSAC)
The club-based organization that serves as the governing body of sport diving in the United Kingdom.

Buoyancy Compensator (BC)
Device used to regulate buoyancy during diving activity. Necessary given the buoyant changes associated with gas compression and expansion.

Carbon Monoxide (CO) Poisoning
Carbon monoxide binds to hemoglobin 200-250 times more effectively than oxygen, effectively reducing the oxygen carrying capacity of the blood.

Cardiomegaly
Enlargement of the heart, either due to thickened heart muscle or an enlarged chamber.

Cardiopulmonary Resuscitation (CPR)
Treatment protocols employed when a person's heart and/or breathing stops.

Catalina Oxygen Treatment Table
An 11:52 h:min therapeutic recompression protocol that employs oxygen breathing with air breaks to treat severe decompression sickness. The protocol employs a maximum pressure equivalent to a depth of 60 fsw (18 msw), with a second step at 30 fsw (9 msw). Conceptually, it is a super-extended US Navy Treatment Table 6.

Cause of Death (COD)
The medically determined reason for death. This is often distinct from the factors leading to the situation in which death occurred.

Cerebrovascular
Pertaining to the blood vessels of the brain.

Channeling (rebreather)
Improper operation of a scrubber bed that allows passage of gas without effective removal of carbon dioxide. May be caused by scrubber material compression or inadequate packing.

Chi Square (statistics)
A non-parametric statistical test that compares outcome patterns expected by chance with outcome patterns that are observed.

Chokes
Pulmonary decompression sickness. Respiratory distress after a dive characterized by sore throat, shortness of breath, and/or the production of pink, frothy sputum. The cause of chokes is poorly understood but may result from low-pressure pulmonary edema resulting from large quantities of bubbles in the venous circulation that damage the cells of the blood vessel wall leading to pulmonary capillary leakage, circulatory blockage and respiratory dysfunction due to impaired gas exchange.

Cholelithiasis
Formation of gallstones.

Cholesterolosis
An intracellular accumulation of lipids (cholesterol). Sometimes associated with inflammation of the gallbladder (cholecystitis) and gallstones (cholelithiasis). At gross examination, 1-2 mm yellow micropolyps contrast the red aspect of the surrounding mucosa, explaining the term "strawberry gallbladder."

Ciguatera
Poisoning caused by the ingestion of marine fish with flesh contaminated by dinoflagellate neurotoxins.

Clonus
An abnormal form of movement marked by rapid succession of contractions and relaxations of a muscle.

Closed-Circuit Rebreather (CCR)
A breathing set that delivers oxygen and recycled gas from which carbon dioxide has been chemically removed from the expired breath.

Computed Tomography (CT)
Medical imaging technique that uses a large series of two-dimensional X-ray scans to generate detailed three-dimensional images.

Coronary Artery Disease (CAD)
A disease with many causes resulting in the thickening, hardening and narrowing of the medium to large-sized arteries of the heart.

Counterlung (rebreather)
The flexible compartment of a rebreather that serves as a volume reservoir for the breathing diver.

Cyanosis
Appearance of a blue or purple coloration of the skin or mucous membranes due to the tissues near the skin surface having low oxygen saturation.

Decompression Dive
A dive that requires decompression stops during ascent; limits vary with the dive tables or computer model used.

Decompression Illness (DCI)
The broad term that encompasses both decompression sickness (DCS) and arterial gas embolism (AGE). DCI is commonly used to describe any disease caused by a reduction in ambient pressure. It is used because the signs and symptoms of DCS and AGE can be similar and because recompression is the treatment for both.

Decompression Sickness (DCS)
A disease caused when the total dissolved gas tension in a diver's tissue exceeds ambient hydrostatic pressure and gas bubble formation occurs and promotes biochemical effects/reactions. Symptoms may include itching, rash, joint pain, muscle aches or sensory changes such as numbness and tingling. More serious symptoms include muscle weak-

ness, paralysis or disorders of higher cerebral function, including memory and personality changes. Death can occur from DCS, although very rarely in modern times. See “Type I DCS,” “Type II DCS” and “Type III DCS.”

Decompression Stop
An obligatory stop in the ascent from a dive required by a decompression model. The duration and depth can vary by model. Stops are mathematically determined and may not reflect the actual decompression stress experienced by the diver. See “Safety Stop.”

Depth-Time Profile
See “Dive Profile.”

Diabetes
A disease characterized by improper production or improp- er use of insulin in the body. Most common form is Type II (non-insulin-dependent diabetes mellitus; NRDM), largely controllable by diet and exercise. Less common is Type I (insulin-requiring diabetes mellitus; IRDM), which demands insulin therapy.

Diaphoresis
The state of sweating profusely.

Diluent
Gas used in a rebreather to reduce (dilute) the fraction of oxygen in the breathing gas. See “Mixed Gas.”

Diphenhydramine
An antihistamine compound used for the symptomatic relief of allergies.

Disabling Injury
In diving, an injury that renders a diver unable to survive in a subaquatic environment or that directly causes death.

Diuretic
Agent that stimulates urine production and subsequent reduction in the body fluid volume.

Dive Computer
Personal electronic device that continually measures time and pressure during a dive, calculates remaining no-decom- pression dive time according to the embedded mathematical algorithm and provides instructions for decompression as applicable. Dive computers may employ one or more of a number of mathematical models to compute decompression status. Some dive computers integrate breathing cylinder pressure to estimate time remaining for the gas supply.

Dive Log
The dive log is a document maintained by divers in which relevant information about dives is recorded. The amount of information depends on personal interest of divers. See “Dive Log-7” for the computerized dive log information collected by DAN for studies of decompression safety.

Dive Log-7 (DL-7)
A standard computer format for recording dive profile information that can be uploaded directly to DAN.

Dive Profile
A set of depth-time-gas points describing the dive. The number of points depends on the minimal recording interval of the dive recorder and can vary from one second to one minute. A recording interval of five seconds or less provides sufficient detail for DAN studies of decompression safety.

Dive Recorder
An electronic device that records depth and time during the dive. The recorder does not calculate saturation of the body with inert gas and does not provide any instruction for decompression. Some recorders are designed as “black box- es,” with no visible display, while others have a display to indicate current depth and time of dive.

Dive Safety Lab (DSL)
A project to collect computerized dive profiles and dive outcome information, developed and conducted by DAN Europe, designed to share goals and methodology with DAN’s Project Dive Exploration. See “Project Dive Exploration.”

Dive Series
Dives conducted in rapid enough succession that they are not independent. Project Dive Exploration (PDE) defines a series as all dives not followed by 48 hours without diving or flying exposure.

Diving Accident Report Form (DARF)
A form used by DAN from 1987 through 1997 to collect information about injured divers treated in recompression chambers.

Diving Injury Report Form (DIRF)
A form used by DAN from 1998 through 2004 to collect information about injured divers treated in recompression chambers.

Dwell Time (rebreather)
The length of time expired gas in a rebreather remains in the carbon dioxide scrubber.

Dysarthria
A motor speech disorder resulting from neurological injury of the motor component of the motor-speech system. It is a condition in which the muscles that help produce speech are effectively impaired, making it very difficult to pronounce words.

Dyspnea
Difficulty breathing, often described as unpleasant or uncomfortable; often referred to as air hunger.

Emergency Medical Services (EMS)
System responsible for providing pre-hospital or out-of-hospital care by paramedics, emergency personnel, emergency medical technicians, and medical first aid responders.

Enriched-Air Nitrox (EAN; Nitrox; Oxygen-Enriched Air)
A nitrogen/oxygen breathing gas mixture containing more than 21% oxygen, usually made by mixing air and oxygen. The most commonly used mixture contains 32% oxygen.

Epistaxis
Nosebleed.

Equivalent Air Depth (EAD)
The underwater depth at which air would provide a similar absolute content of nitrogen to that found in a given enriched-air nitrox breathing mixture.

Facial Baroparesis (Alternobaric Facial Nerve Palsy)
A reversible paralysis of the facial (seventh cranial) nerve resulting from pressure introduced through the middle ear.

Feet of Freshwater (ffw)
A unit of pressure synonymous with depth in freshwater. Thirty-four feet of freshwater is equal to approximately 1.0 atmosphere, 1.0 bar, 14.685 pounds per square inch, or 0.01 kilopascals of pressure. The differences in density of seawater and freshwater result in small pressure differences at the same absolute depth.

Feet of Seawater (fsw)
A unit of pressure synonymous with depth in seawater. Thirty-three feet of seawater is equal to approximately one atmosphere, 1.0 bar, 14.685 pounds per square inch, or 0.01 kilopascals of pressure. The differences in density of sea- water and freshwater result in small pressure differences at the same depth. The fsw term is commonly used by the dive industry. For metric users, the reference is meters of sea- water (msw); 1.0 fsw = 0.3048 msw (arithmetic conversion).

Field Research Coordinator (FRC)
A trained volunteer who helps DAN collect data for Project Dive Exploration (PDE).

First Aid Oxygen (FAO)
See "Surface Oxygen Treatment"

Fisher Exact Test (statistics)
A non-parametric statistical test similar to Chi Square except that it calculates an exact p value; useful if the marginal is very uneven or if the value in a single cell is a very small value. Exact p values tend to be more conservative than most approximate estimates such as Chi Square or t-test.

Flying After Diving (FAD)
Flying after diving involves exposure of divers to a secondary decompression stress. Pressurized commercial airliners are required by law to be able to maintain the cabin altitude at 8,000 ft (2,438 m). The actual cabin pressure is typically greater than this. In one study the average was around 6,000 ft (1,800 m), approximately 80% of the atmospheric pressure at sea level. Unpressurized aircraft may reach altitudes in excess of 8,000 ft. Following diving, there can be enough residual nitrogen dissolved in the body for the secondary decompression stress of flying to cause decompression sickness. For this report, all flights within 48 hours after diving are considered "flying after diving." Practically, divers can also be exposed to secondary decompression stress post-dive by driving to altitude.

Freediving
Breath-hold diving conducted while wearing a mask and some form of fin or fins. Freedivers generally dive to depth and train to increase their range. Freediving is typically con- ducted in open water settings. See also "Breath-Hold Diving" and "Snorkeling."

Gradient Factors
Used to mathematically adjust decompression limits to a chosen degree of conservatism. They are typically applied to the Buhlmann algorithm. Gradient factors limit the fraction of M-value achieved during ascent. M-values represent the theoretical maximum allowable gas pressure computed for tissues intended to avoid bubble formation, although it is now known that bubbles commonly form below M-value. Gradient factors are assigned in two parts. For example, a 30/70 setting would require a first stop at 0.3 (or 30%) of the M-value, and then control the ascent to bring the diver to the surface at 0.7 (or 70%) of the M-value.

Hart-Kindwall Oxygen Recompression Treatment Table
A 2:30 h:min recompression protocol used to treat decompression sickness. Oxygen is breathed throughout,

typically in a monoplace chamber. The protocol employs a maximum pressure equivalent to a depth of 60 fsw (18 msw). Decompression travel is at 1 ft·min-1 (2 ft·min-1 if all symptoms were mild and cleared within the first 10 min of reaching 60 fsw).

Hazard
A condition, event or circumstance that could lead to or contribute to an unplanned or undesirable event and cause injury or material damage.

Health Insurance Portability and Accountability Act (HIPAA)
US Federal legislation designed to protect the privacy and interests of individuals and their families. DAN collects dive injury and fatality information in compliance with HIPAA.

Heliox
See “Mixed-Gas.”

Hematocrit
A measure of red blood cell volume in a sample volume of blood. Normal ranges are 40-53% for males and 35-46% for females.

Hemoptysis
The coughing up of blood or bloody sputum from the lungs or airway.

Hyperbaric Oxygen (HBO)
The therapeutic administration of oxygen under conditions of substantially increased atmospheric pressure. See also “Hart-Kindwall Oxygen Recompression Treatment Table” and “US Navy Treatment Table.”

Hypercapnia
Condition in which the level of carbon dioxide in the blood is higher than normal.

Hyperglycemia
Condition in which blood glucose (sugar) is higher than normal.

Hyperoxia
Condition of higher-than-normal partial pressure of oxygen. In medicine, it refers to excess oxygen in the lungs or other body tissues, which can be caused by breathing air or oxygen at pressures greater than normal atmospheric pressure.

Hyperreflexia
A condition in which the deep tendon reflexes are exaggerated.

Hypertension
High blood pressure. A medical condition associated with the development of heart disease and stroke.

Hyperventilation
Voluntary ventilation of the lungs in excess of metabolic need (achieved by increasing depth of breaths and/or rate of breathing). Often used to lower carbon dioxide content of the bloodstream and increase breath-hold time. Excessive hyperventilation will increase the risk of loss of consciousness due to hypoxia. See “Hypoxia of Ascent.”

Hypocapnia
Condition in which the level of carbon dioxide of the blood is lower than normal. This state is typically produced by hyperventilation.

Hypoglycemia
Condition in which blood glucose (sugar) is lower than normal.

Hypoventilation
Ventilation of the lungs at an abnormally slow rate, not meeting metabolic needs, resulting in a net accumulation of carbon dioxide in the blood, which will drive the urge to breathe in a healthy person.

Hypoxemia
Condition of lower-than-normal partial pressure of oxygen in the blood. See “Hypoxia of Ascent.”

Hypoxia
Condition of lower-than-normal partial pressure of oxygen. May be experienced by breathing a gas mixture at the surface that was intended for a deep bottom. See “Hypoxemia” and “Hypoxia of Ascent.”

Hypoxia of Ascent
Unconsciousness resulting from hypoxia compounded by surfacing at the end of a breath-hold dive. The reduction in pressure associated with returning to the surface causes the oxygen partial pressure to fall faster than through metabolism of the gas alone. This condition is commonly called shallow water blackout in North America, but this term was previously used in the UK to describe a different problem. See also “Hyperventilation,” “Hypoxia,” and “Hypoxic Loss of Consciousness.”

Hypoxic Loss of Consciousness (HLOC)
Loss of consciousness resulting from an acute state of hypoxia.

Immersion Pulmonary Edema (IPE)
A shift of fluid into the alveolar space of the lung, secondary to water immersion. The cause is multifactorial; factors that may play a role in addition to immersion include fluid loading, cold stress, suit and breathing system resistance, exercise and high gas density. The net effect is an increase in pulmonary pressure and membrane permeability, which drives fluid out of the bloodstream.

Incidence Rate
The number of new cases in a defined population in a given time period.

Incident
An event or occurrence.

Inner Ear Barotrauma (IEBT)
Trauma to inner ear frequently caused by a rapid rise of middle ear pressure causing an inward bulge of the round window and an outward bulge of the stapes foot plate. Implosion of the round window is possible. IEBT is usually as- sociated with significant middle ear barotrauma.

International Association for the Development of Apnea (AIDA)
The Worldwide Federation for breath-hold diving, established in 1992. AIDA manages and oversees the recognition of records, organizes competitions, and promotes stan- dards for freediving education.

In-Water Recompression
Practice of returning a diver back underwater as an emergency treatment of decompression sickness. Logistical and safety issues make therapeutic treatment in a recompression chamber the standard of care for decompression sickness symptoms.

Infiltrates
Abnormal regions of opacity (non-transparency) with poorly defined margins visible in the lung (typically seen in X-rays).

Intracardiac
Within the heart.

Ischemia
Inadequate delivery of blood to a local area due to a blockage of blood vessels in the area.

Kruskal-Wallis (statistics)
A nonparametric statistic used to compare three or more samples. The null hypothesis is that the groups have comparable distributions; the alternative hypothesis is that at least two of the samples differ (with respect to median). It is analogous to the F-test used in analysis of variance (parametric). While analysis of variance tests depend on the assumption of normal distribution, the Kruskal-Wallis test is not so restricted.

Lasix
A prescription medication, furosemide (trade name Lasix) is a commonly used as a diuretic to treat hypertension and edema.

Lung Barotrauma
See "Pulmonary Barotrauma."

Mean (statistics)
The arithmetic average calculated by taking the sum of a group of measurements and dividing by the number of measurements. See "Median."

Median (statistics)
The middle value in a range of numbers. Half the numbers are higher than the middle value and half are lower. The mean and median will be extremely similar if the group of numbers is normally distributed. See "Mean."

Mediastinal Emphysema (Pneumomediastinum)
Air that surrounds the heart (not within the heart or blood vessels). This is usually the result of pulmonary barotrauma.

Medical Services Call Center (MSCC)
The computerized logging system, introduced in 2006, that captures all calls, emergency and information, and emails received by the DAN Medical Services Department.

Meniere's Disease
A disorder of the inner ear that can affect hearing and balance. It is characterized by spontaneous episodes of vertigo, tinnitus (perception of roaring, buzzing or ringing in the ears) and hearing loss.

Metabolic Demand
The energetic requirement of the body; typically measured indirectly by the amount of oxygen consumed in respiration.

Meters of Seawater (msw)
Metric unit of length or depth; 1.0 msw = 3.28084 fsw (arithmetic conversion). See "Feet of Seawater."

Middle Ear Barotrauma (MEBT)
Caused by an inability to equalize middle ear pressure with that of the ambient (surrounding) pressure. The insult may occur on compression ('squeeze') or ambient pressure reduction ('reverse block'). See "Otitis Media."

Mixed-Gas
Any breathing gas made by mixing oxygen with other gases. Mixed-gas usually consists of oxygen plus nitrogen and/or helium. Heliox refers to helium and oxygen mixtures, nitrox to nitrogen and oxygen mixtures. Trimix refers to mixtures containing helium, nitrogen, and oxygen.

Multi-Day Diving
Dives spread out over a period longer than 24 hours but where the surface interval between successive dives is less than 24 hours.

Multi-Level Dive
A dive where the diver spends time at several different depths before beginning his or her final ascent to the surface. Usually associated with dive computers that allow a diver to ascend gradually from maximum depth while tracking the decompression status.

Myocardial Infarction
Heart attack. Death of some of the cells of the heart from lack of adequate blood supply resulting from constriction or obstruction of the coronary arteries.

Myxoid Tumor
A connective tissue tumor with a 'myxoid' background, composed of clear, mucoid substance.

Nitrogen Narcosis
Euphoric and anesthetic effect of breathing nitrogen at greater than sea level pressure. All gases except helium have an anesthetic effect when their partial pressure is increased. Because nitrogen is the principal component of air, its anesthetic effect is the most pronounced in divers at depth and may cause serious impairment of mental abilities. Nitrogen narcosis is often first noticed when breathing air at depths beyond 60-100 fsw (18-30 msw).

Nitrox
See "Enriched-Air Nitrox" and "Mixed-Gas."

No-Decompression Dive or No-Stop Dive
A dive where direct ascent to the surface is allowed at any time during the dive without an obligatory decompression stop.

Non-Steroidal Anti-Inflammatory Drug (NSAID)
Medications used primarily to treat inflammation, mild to moderate pain, and fever.

Normal Distribution (statistics)
A group of numbers is normally distributed when the majority is clustered in the middle of the range with progressively fewer moving out to both extremes. The frequency plot of a normal distribution appears as the classic bell-shaped curve.

Nystagmus
A rapid, involuntary, and oscillatory movement of the eyeball, usually from side to side.

Obesity
See "Body Mass Index."

Otitis Externa
Inflammation of the outer ear and ear canal. May be caused by active bacterial or fungal infection or secondary to der- matitis only with no infection. Also known as swimmer's ear.

Otitis Media
Inflammation of the middle ear, in diving frequently caused by difficulties in equalizing middle ear pressure. See "Middle Ear Barotrauma."

Over-the-Counter (OTC)
Medications/Drugs purchased legally without a prescription.

Oxygen-Enriched Air
See "Enriched-Air Nitrox."

Oxygen Sensor (rebreather)
A sensor used to measure the partial pressure of oxygen in the closed-circuit.

Oxygen Toxicity
Syndrome caused by breathing oxygen at greater than sea level pressure. Primarily affects the central nervous system (CNS) and lungs. CNS oxygen toxicity may come on im- mediately and be manifested by seizures, twitching, nausea and visual or auditory disturbances. It may occur in a highly unpredictable manner at partial pressures greater than 1.4 to 1.6 atm in an exercising diver. Pulmonary oxygen toxicity can take much longer to develop (hours) but may occur at lower partial pressures of oxygen (>0.50 atm). Pulmonary oxygen toxicity is caused by inflammation of the lung tissue, resulting in shortness of breath, cough and a reduced exercise capacity.

p Value (statistics)
Level of significance established to denote a significant difference in statistical tests; also known as alpha. Often set at $p<0.05$.

Paraparesis
Partial paralysis of the lower limbs.

Paresthesia
Numbness or tingling of the skin; a common symptom of DCS in recreational divers.

Partial Pressure
The pressure exerted by a single component gas, typically in a mixture of gases.

Patent Foramen Ovale (PFO)
An opening between the right and left atria of the heart. Normally closed and sealed by tissue growth after birth, almost 30% of the adult population retain some degree of patency (openness). 'Probe patency' describes the ability to work a blunt probe through the opening during autopsy. Such openings may be small and functionally irrelevant.

'Physiologic patency' describes an opening large enough to allow meaningful flow of blood directly between the two chambers. A small portion of those with a PFO will have the highest degree of patency. Blood passing from right to left through a PFO bypasses lung filtration. Any bubbles present in such blood would be distributed throughout the body, potentially increasing the risk of serious decompression sickness if the bubbles impinged upon sensitive tissues. Some divers investigate the option of medical closure of PFOs. The risk of PFO in divers can also be mitigated by conservative dive profiles that do not produce bubbles.

Paua
A large, edible abalone found in New Zealand.

Perceived Severity Index (PSI)
A measure of the severity of decompression injury.

Pleural Space
The small potential space between the parietal and visceral layers of the pleura that lines the thoracic cavity. It is a potential space since there is no actual space, instead it is filled with a lubricating fluid that reduces the friction between the pleural layers as the lungs expand and contract.

Pneumomediastinum
See "Mediastinal Emphysema."

Pneumothorax
A collection of gas in the pleural space (the fluid-filled potential space surrounding the lungs), which results in the collapse of the lung on the affected side.

Project Dive Exploration (PDE)
A long-term study developed by DAN to collect computerized profiles of diving exposures and information on the health outcome (symptomatic or asymptomatic). The accumulated data can be useful to model decompression risk.

Protected Health Information (PHI)
Information that could disclose the identity of a research subject, patient or decedent according to the Health Insurance Portability and Accountability Act (HIPAA). PHI includes names, address, birthdate, social security numbers, etc. DAN does not disclose PHI to any party other than employees, representatives and agents of DAN who have a need to know.

Pulmonary Barotrauma (PBT)
Damage to lungs from expanding gas. See "Barotrauma."

Pulmonary Emphysema
A medical condition commonly caused by smoking that leads to abnormal distension of the lungs resulting from the destruction of its supporting and elastic internal structure.

Pulmonary Overinflation Syndrome (POIS)
A group of barotrauma-related diseases caused by the expansion of gas trapped in the lung, or over-pressurization of the lung with subsequent over-expansion and rupture of the alveolar air sacs. It includes arterial gas embolism, tension pneumothorax, mediastinal emphysema, subcutaneous emphysema and rarely pneumopericardium.

Pulmonary Overexpansion
Abnormal distension of the lungs. In divers, pulmonary over- expansion usually results from the effects of Boyle's law. It can cause rupture of alveoli and penetration of gas into various surrounding spaces, causing mediastinal emphysema, pneumothorax or arterial gas embolism. See "Pulmonary barotrauma."

Rales
Wet, clicking, rattling or crackly lung noises heard on auscultation of (listening to) the lung during inspiration. The sounds are caused by the opening of small airways and alveoli collapsed by fluid in the air spaces.

Rapid Ascent
An ascent rate fast enough to put a diver at increased risk of decompression illness (DCI), usually at rates in excess of 60 fsw (18 msw) per minute.

Rebreather
Self-contained breathing device that recirculates some or all of the expired gas to increase efficiency. Systems may be semiclosed or fully-closed-circuit.

Recompression Treatment
Treatment involving a return to pressure. Typically completed in a recompression chamber but, in some cases, may involve an in-water return to pressure. Well-established, standard treatment tables exist for recompression chamber therapy. See “United States Navy Treatment Tables 5 and 6 (USN TT5 and TT6)” and “Hart-Kindwall.”

Repetitive Dive
A dive in which residual nitrogen remaining from a previous dive affects the decompression requirements of the subsequent dive. Some decompression computers carry over information from previous dives for 24 hours or longer, depending on the decompression model used. For the purposes of DAN’s injury reporting, a repetitive dive is any dive occurring within 24 hours of a previous dive. See “Residual Nitrogen.”

Representative Sample (statistics)
A group selected from a population for testing that reasonably represents the characteristics of the population.

Residual Nitrogen
Nitrogen content in excess of the ambient levels as a result of recent diving exposure. See “Repetitive Dive.”

Residual Symptoms
Symptoms remaining at the conclusion of treatment. May respond to additional treatments, be refractory to further treatment but eventually resolve spontaneously, or remain permanently.

Resolution of Symptoms
Symptoms resolving (disappearing) at some point after appearance. Resolution may be spontaneous or in response to treatment and partial or complete.

Reverse Block
Overpressure developing in a blocked middle ear space during ascent as ambient pressure falls and internal pressure cannot be equalized. Symptoms include pain and dizziness; tympanic membrane rupture may result if equalization of space is not possible.

Rhomberg (Sharpened)
The Sharpened Rhomberg test is intended to detect ataxia, commonly used for diver assessment. The subject stands erect on a firm, level surface with feet aligned in a tandem (heel-to-toe) position. The arms are then folded across the chest. Once stable, the subject is instructed to close his or her eyes and to maintain the position for 60 seconds. The measured score is the time in seconds the position is held. The end is marked by opening of the eyes or movement of the hands or feet to maintain balance.

Risk
The chance or probability that a person will be harmed or experience an adverse health effect if exposed to a hazard. It may also apply to situations with property or equipment loss.

Safety Stop
A recommended halt in the planned ascent to the surface (usually for 3-5 min at 10-20 ft [3-6 m]) intended to reduce the risk of decompression injury. A safety stop is not an obligatory decompression stop required by tables or a dive computer. See “Decompression Stop.”

Sarcoidosis
A chronic disease of unknown cause characterized by the enlargement of lymph nodes in many parts of the body and the widespread appearance of granulation tissue (granulomas, typically produced in response to infection) derived from the reticuloendothelial (macrophage) portion of the immune system.

Scrubber (rebreather)
Refers to the chemical compound (absorbent) used to remove carbon dioxide from breathing gas.

Scuba
Self-contained underwater breathing apparatus.

Scuba Epidemiological Reporting Form (SERF)
An injury recording system for DAN that replaced the DIRF. It emphasizes collection of recorded dive profiles.

Semiclosed-Circuit Rebreather (SCR)
A type of rebreather that injects a mixture of nitrox or mixed gas into a breathing loop to replace that which is used by the diver for metabolic needs; excess gas is periodically vented into the surrounding water in the form of bubbles.

Sequelae
A pathological condition that is a consequence of a previous disease or injury.

Setpoint (rebreather)
The oxygen partial pressure to be maintained by the device. Oxygen is added to the circuit when the oxygen partial pressure falls below the setpoint. Often user-adjustable within a limited range. See “Solenoid.”

Shallow-Water Blackout
The term was initially coined to describe impaired con- sciousness associated with the use of closed-circuit oxy- gen rebreathers, likely due to inadequate carbon dioxide scrubbing. It was subsequently usurped to describe hypoxia of ascent in breath-hold divers. The ambiguity of usage makes it an out-of-favor name, particularly for the breath-hold application, where hypoxia of ascent is recommended. See "Hypoxia of Ascent."

Snorkeling
Swimming with mask, snorkel and fins. Snorkelers may remain at the surface or conduct breath-hold dives. See also "Breath-Hold Diving" and "Freediving."

Solenoid (rebreather)
Electromagnetic valve that opens to inject oxygen into mixed-gas closed-circuit rebreathers. Activated automatically or manually to maintain the setpoint.

Spearman Rank Coefficient (statistics)
Statistical test that measures the relationship between two variables when data are in the form of ranked orders.

Square Dive
A dive in which the descent is made to a given depth and where the diver remains for the entire dive before ascending to the surface or stop depth.

Standard Deviation (SD) (statistics)
A measure of the variability within a group of numbers reported with discussion of means, appropriate for a close to normally distributed sample. Approximately 68% of the values will be within one SD of the mean (half above the mean and half below), approximately 95% within two SD, and approximately 99% within three SD. Outlier values, deviants from the norm, are conservatively identified as those more than two SD from the mean.

Steatosis
A process resulting in the abnormal retention of lipids within cells. Also known as fatty or adipose degeneration.

Subcutaneous Air (Subcutaneous Emphysema)
Air under the skin after pulmonary barotrauma. The most frequent location is around the neck and above the collarbones where the gas may migrate after pulmonary overexpansion.

Sudden Hearing Loss (SHL)
Sudden hearing loss (SHL) is defined as a hearing loss of at least 30 dB over three or more contiguous frequencies, occurring over a period of 72 hours or less. The cause is variable and often cannot be confirmed. It is frequently accompanied by tinnitus and may or may not resolve spontaneously.

Surface Interval Time (SIT)
Time spent on surface between sequential dives.

Surface Oxygen Treatment (SOT)
Oxygen delivered at the surface with a therapeutic intent. Gas may flow from the supply system in a continuous mode or through a demand valve upon inspiration of the conscious, spontaneously breathing injured person. The breathing circuit may be open (releasing exhaled gas to the environment) or closed (reusing exhaled gas after carbon dioxide is removed). The delivery interface may be some form of simple non-rebreathing facemask, a partial rebreathing facemask or a nasal cannula. The fraction of oxygen delivered to the injured person and the oxygen flow rate required will vary dramatically depending on system configuration and use.

Tachycardia
Abnormally rapid heart rate.

t-test (statistics)
A statistical test used to determine if there is a significant difference between the means of two different groups.

Thrombocythemia
A blood disorder of excess cell proliferation. It is characterized by the production of too many platelets in the bone marrow.

Tinnitus
The perception of sound within the ear in the absence of corresponding external sound. Frequently described as a ringing noise, but a variety of presentations are reported. May be unilateral or bilateral and intermittent or continuous.

Travel Assist
Travel assistance plan available from DAN that covers necessary medical evacuation.

Triggering Event
A tangible or intangible barrier or occurrence that, once breached or met, causes another event to occur. In other words, the pivotal event leading to the ultimate outcome.

Trimix
See "Mixed-Gas."

Type I DCS (DCS I, Musculoskeletal DCS)
Decompression sickness where the symptoms are felt to be non-neurological in origin such as itching, rash, joint or muscle pain.

Type II DCS (DCS II, Neurological or Cardiopulmonary (DCS)
Decompression sickness where there is any symptom referable to the nervous or cardiovascular system.

Type III DCS (DCS III)
A serious form of DCS sometimes seen after long deep dives with a rapid ascent. Type III DCS is thought to be caused by arterial gas embolization after a dive where a large quantity of inert gas has been absorbed by the tissues. Presumably the arterial bubbles continue to take up inert gas and grow, causing a rapidly deteriorating clinical picture.

United States Navy Treatment Table 5 (USN TT5)
A 2:15 h:min therapeutic recompression protocol that employs oxygen breathing with air breaks to treat decompression sickness. The protocol employs a maximum pressure equivalent to a depth of 60 fsw (18 msw). Extensions can increase the duration at 30 fsw (9 msw).

United States Navy Treatment Table 6 (USN TT6)
A 4:45 h:min therapeutic recompression protocol that employs oxygen breathing with air breaks to treat decompression sickness. Commonly used. The protocol employs a maximum pressure equivalent to a depth of 60 fsw (18 msw), with a second step at 30 fsw (9 msw). Extensions can increase the duration at either 60 fsw or 30 fsw (9 msw). Extremely similar to Royal Navy Treatment Table 62.

United States Navy Treatment Table 9 (USN TT9)
A 1:02 h:min therapeutic recompression protocol that employs oxygen breathing with air breaks. The protocol employs a maximum pressure equivalent to a depth of 45 fsw (14 msw).

Upper Respiratory Infection (URI; ‘cold’)
The most frequently reported acute health problem from the DAN sample of injured divers.

Vasovagal Syncope
Transient loss of consciousness (fainting) resulting from a sudden drop in heart rate and blood pressure and subsequent reduction in brain blood flow. It may be triggered by a variety of stressful conditions.

Venous Gas Emboli (VGE)
Gas phase, also known as bubbles, located in the veins returning blood to the right side of the heart or in the pulmonary artery, delivering blood from the right heart to the lungs where bubbles are filtered out of circulation. See “Patent Foramen Ovale.”

Vertigo
Sensation of irregular or whirling motion, either of oneself (subjective) or of external objectives (objective).

Waist-to-Hip Ratio (WHR)
Used to assess for disproportionate accumulation of tissue in the abdominal region, such accumulation being associated with increased health risk. WHR is computed by dividing the circumferences of the waist at the narrowest point by the circumference of the hips at the widest point. Optimal scores are ≤0.8 for men and ≤0.7 for women.

Divers Alert Network
6 West Colony Place
Durham, NC 27705
DAN.org