ANNUAL DIVING REPORT

2006 EDITION

Formerly:
Report on Decompression Illness, Diving Fatalities and Project Dive Exploration
DAN's Annual Review of Recreational Scuba Diving Injuries and Fatalities Based on 2004 Data

DAN®
DIVERS ALERT NETWORK

Annual Diving Report – 2006 Edition

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Table of Contents

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Acknowledgments

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PROJECT DIVE EXPLORATION Dive Profile Collection (collectors and number of dives)

DATA COLLECTION CENTERS (2004)

Nekton Rorqual (Caribbean)	18,592
Nekton Pilot	25,778

DAN INTERNS (Summer 2004 interns)

Aaron Mishkin · Cozumel, Mexico	1130
Robert Conway · Ocean Frontiers, Grand Cayman	1222
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INDEPENDENT FRCs (2004)
Total dives submitted: **6,813 dives**

Top collectors (over 100 dives submitted):

Robert Forbes	Peter Berende
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Andrew Monjan	Brian Basura
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DAN uses a network of approximately 500 hyperbaric chamber facilities in the United States and around the world, of which approximately 218 provide annual reports on decompression illness (DCI) injuries. The DAN U.S. network is divided into eight regions, each overseen by a Regional Coordinator.

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1. INTRODUCTION

The 2006 Annual DAN Diving Report presents information on Project Dive Exploration (PDE), diving injuries, diving fatalities, and breath-hold diving incidents based on data collected during 2004. The Report has been simplified for 2006, but its fundamental content is unchanged.

As in previous reports, this introductory section presents a summary of data collection activity since the inception of DAN in 1981. New material has been added that describes several measures of diving safety.

1.1 Data Collection Activity since DAN's Inception

Figures 1.1-1 to 1.1-5 do not represent a complete picture of diving incidents or activity in the U.S., Canada, or world. They represent only data about which DAN became aware through calendar year 2004.

Figure 1.1-1 is the annual record of emergency calls, information calls, and e-mail requests for information to DAN Medical Services since the inception of DAN in 1981. Emergency calls and e-mail inquiries continue to rise gradually, but calls to the information line have decreased.

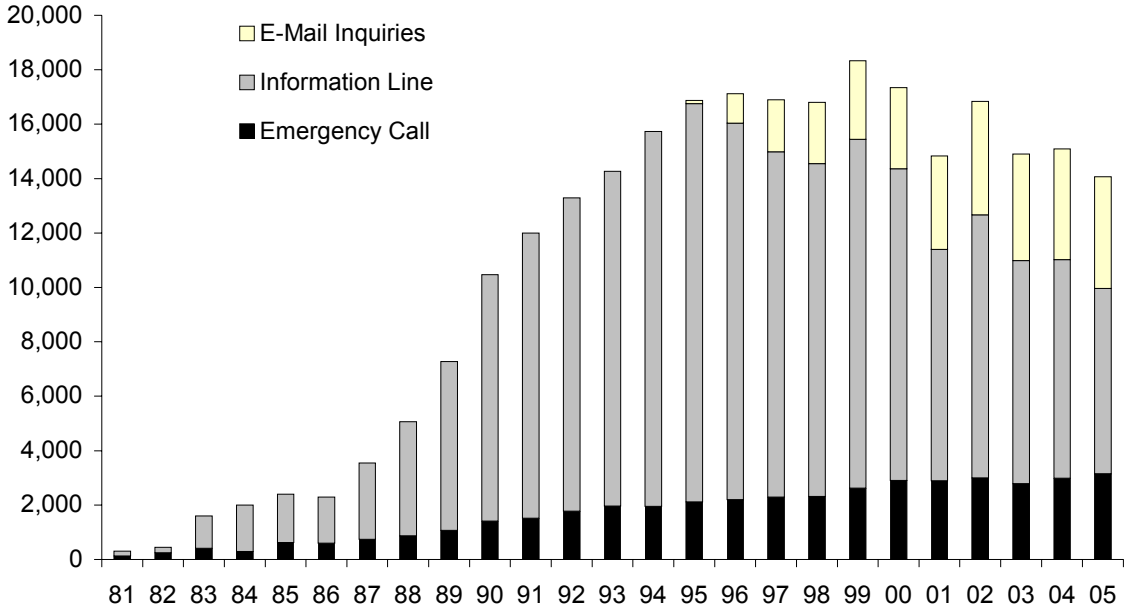

Figure 1.1-1 Emergency calls, information calls, and e-mail requests for information.

PDE is a prospective observational study of recreational diving dating from 1995, and Figure 1.1-2 is the cumulative history of PDE data collection. As of 2004, over 8,000 divers had contributed more than 100,000 dives with an overall DCS incidence of 3.6 cases per 10,000 dives.

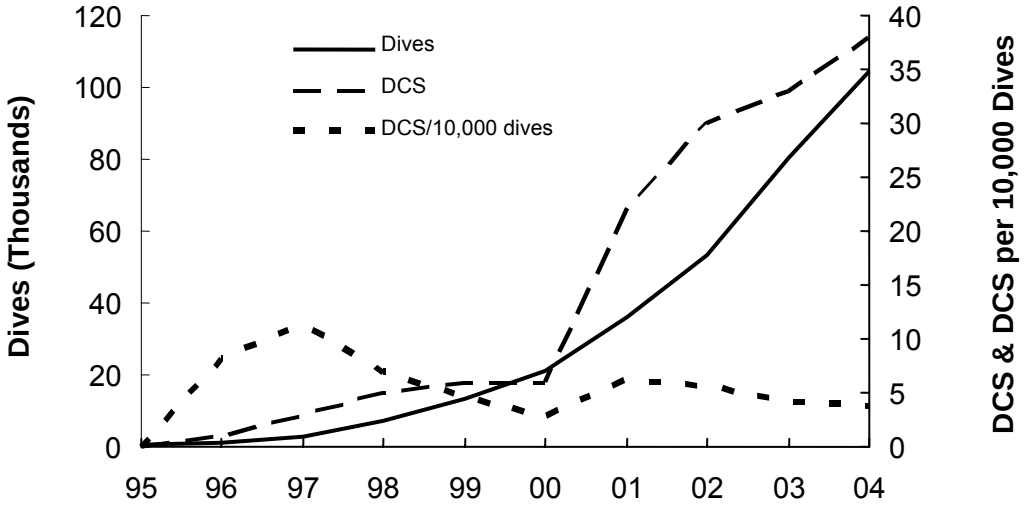

Figure 1.1-2 Cumulative Project Dive Exploration progress.

Figure 1.1-3 is the history of DAN's diving injury data collection for US and Canadian divers beginning in 1987. Decreased data collection in 2003 represented the effect of the Health Insurance Portability and Accountability Act (HIPAA). The rebound in 2004 reflects the beginning of a transition period in which the collection of injury data is expected to improve in quantity and quality as the new Medical Services Call Center (MSCC) reaches maturity over the next few years (see Section 3).

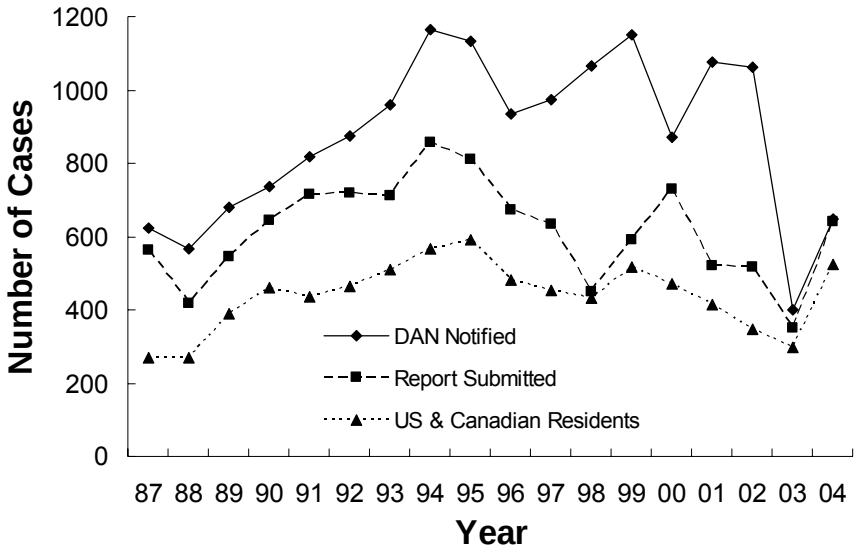

Figure 1.1-3 Annual record of dive injury cases collected.

Figure 1.1-4 is the annual record of US and Canadian diving fatalities that was started in 1970 by Mr John McAniff of the University of Rhode Island and transitioned to DAN in 1989. From 2002 to 2004, US and Canadian fatalities have been stable at 88-89 annually.

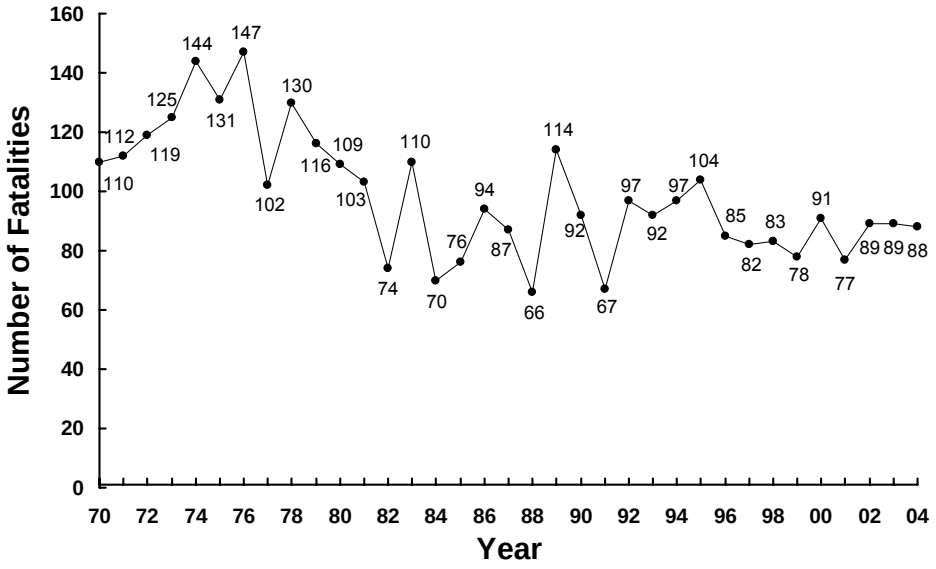

Figure 1.1-4 Annual record of U.S. and Canadian diving fatalities.

The 2005 Report introduced a section on fatal and non-fatal breath-hold diving incidents that occurred anywhere in the world. Figure 1.1-5 is new for the 2006 Diving Report and represents breath-hold cases voluntarily submitted to DAN since 1993. (Cases shown in Figure 1.1-5 are an unknown fraction of all cases that occurred.) A directed effort by DAN to collect breath-hold diving cases did not formally begin until 2005.

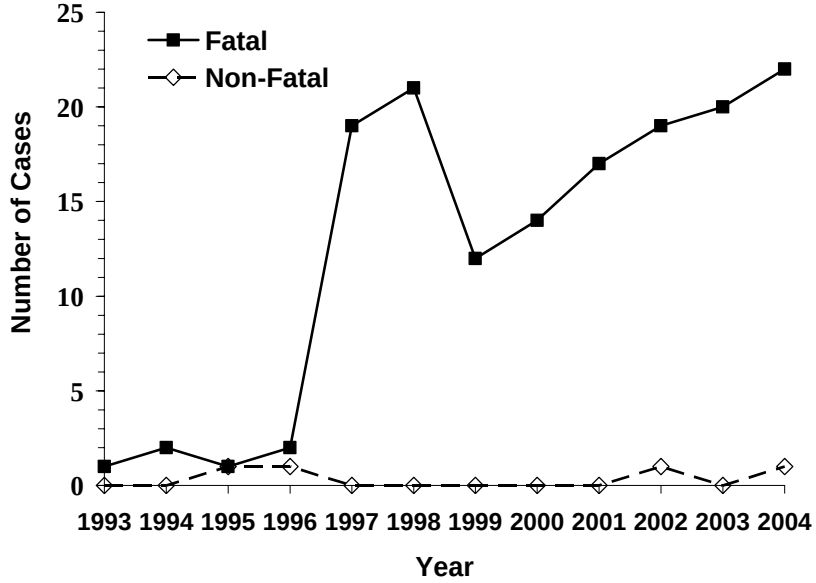

Figure 1.1-5 Annual record of U.S. and Canadian breath-hold diving injuries.

1.2 Annual Diving Injury and Fatality Rates

To assess progress in diving safety, quantitative measures are essential. Based on data available to DAN, we have selected the following indicators for this purpose: (a) the annual incidence rate of DCS per 10,000 PDE dives (Figure 1.2-1); (b) the annual incidence rate of DCS per 10,000 PDE divers (Figure 1.2-2); (c) the annual incidence rate of injury claims per 10,000 insured DAN members (Figure 1.2-2); (d) the annual incidence rate of fatalities per 100,000 DAN members (Figure 1.2-3); and (e) the annual incidence rate of fatalities per 100,000 British Sub-Aqua Club (BSAC) members (Figure 1.2-3).

It should be noted that data presented in Figures 1.2-1 to 1.2-3 are from limited and restricted populations (specifically PDE volunteers, DAN members, and BSAC members), and generalizations to other populations may well be inappropriate. The value of such indicators, however, lies in contrasts and comparisons with similar information from other population samples as, for example, Scapa Flow and Warm Water diving (Figures 1.2-1 and 1.2-2) or DAN and BSAC fatalities (Figure 1.2-3).

Figure 1.2-1 shows the annual DCS incidence rates per 10,000 Scapa Flow dives and per 10,000 Warm Water dives for divers enrolled in PDE. The Scapa Flow dives took place in Scotland in the colder waters of the North Sea. About 85 percent of the Warm Water dives occurred in the Caribbean while most of the remainder were from the warm or temperate waters of the Atlantic or Pacific.

According to our data, the DCS incidence rate among PDE dives in Scapa Flow appears to have decreased nearly four-fold from 40 to 10 cases per 10,000 dives between 2001 and 2004. Confidence in the validity of this observation, of course, requires further analysis and independent confirmation. The incidence rate among the Warm Water dives fluctuated from 0 to 5 cases per 10,000 dives between 1998 and 2004.

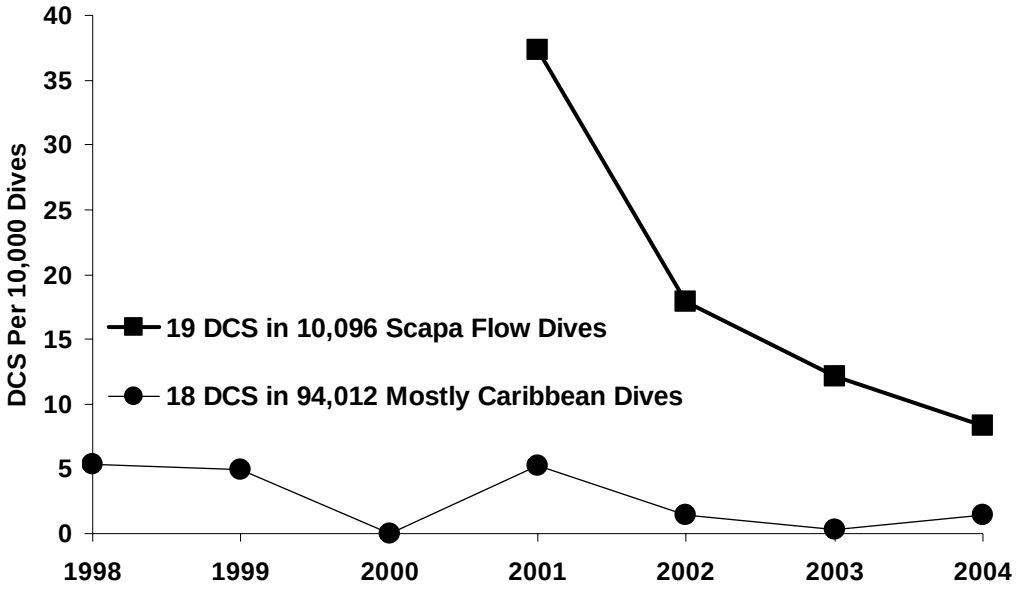

Figure 1.2-1 Annual DCS incidence rates per 10,000 dives at Scapa Flow and in the Caribbean among divers enrolled in PDE.

Figure 1.2-2 shows the annual DCS incidence rates per 10,000 Caribbean divers and per 10,000 Scapa Flow divers who were enrolled in PDE. The DCS incidence rate among Scapa Flow divers appears to have decreased four-fold from 400 to 100 cases per 10,000 dives between 2001 and 2004. The incidence rate among Warm Water divers fluctuated from 0 to 50 cases per 10,000 divers between 1998 and 2004.

Also shown in Figure 1.2-2 is the annual incidence rate of injuries for divers who submitted insurance claims per 10,000 insured DAN members. The annual claims rate for diving-related injuries was constant from 2003 to 2005 at about 55 claims per 10,000 insured members. Note that these claims included all diving injuries, not just DCS. Subsequent reports will expand the claims by ICD-9 Code to describe the nature of the injuries.

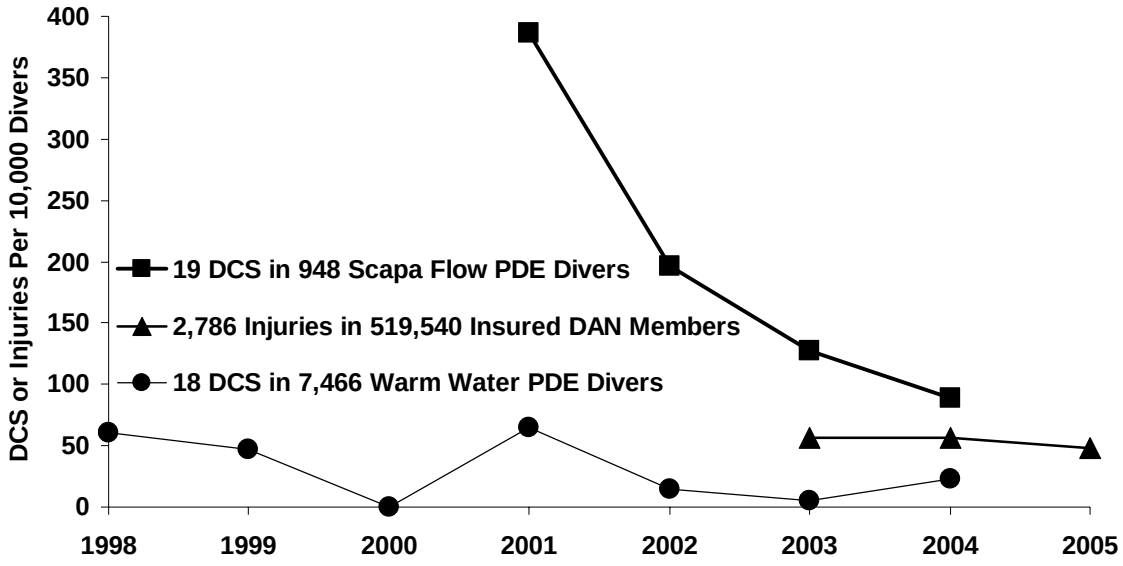

Figure 1.2-2 Annual DCS incidence rates per 10,000 divers at Scapa Flow and in the Caribbean among divers enrolled in Project Dive Exploration.

Figure 1.2-3 shows the annual incidence rates of fatalities among 100,000 DAN and BSAC members from 1997 to 2004. There was little difference in death rate for either insured DAN members or total DAN members. Both rates varied between 10 and 20 deaths per 100,000 members with an upward trend of about one death per 100,000 divers per year. Fatality rates for BSAC members were similar although with greater variability as the BSAC population sample was smaller.

For comparison with diving fatality rates, the US death rates in 2001 were 1.2 deaths per 100,000 people by drowning and 15.4 deaths per 100,000 people by motor vehicle accident (Injury Facts, 2004 ed., National Safety Council).

The significance of the upward trend in fatality rate over time (Figure 1.2-3) remains to be explored, particularly with regard to the aging of the diving population. For example, the 2004 edition of DAN Diving Report indicated that the mean age of diving fatalities increased from 39 to

48 years from 1989 to 2002 while the mean age of diving injuries increased from 33 to 39 years from 1987 to 2002. (The 2004 Diving Report is available at no cost to DAN members from the DAN Website.)

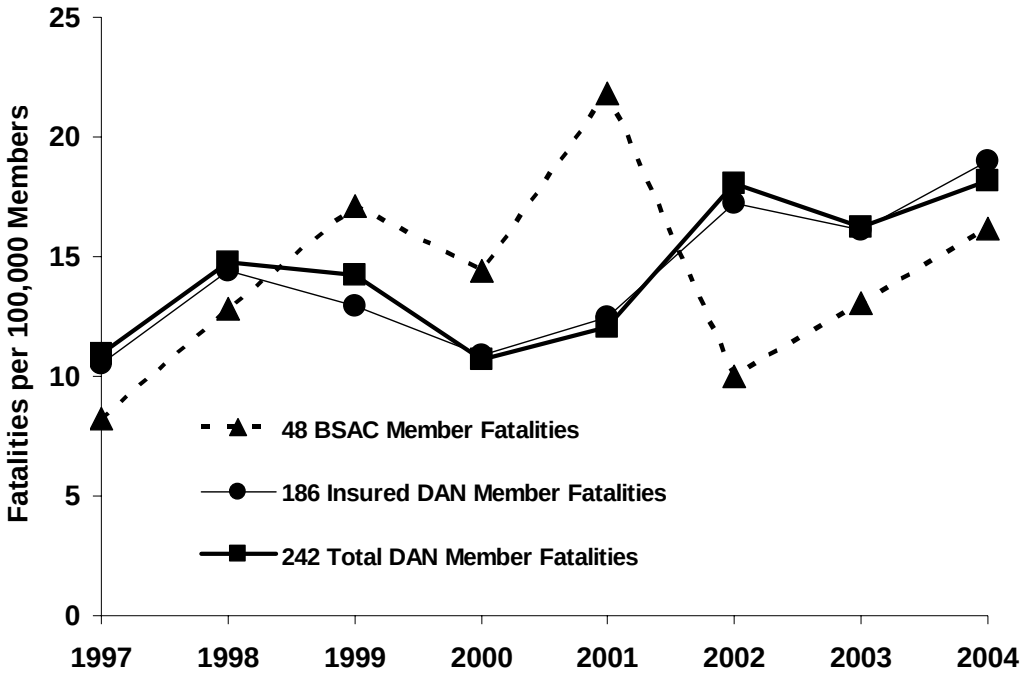

Figure 1.2-3 Annual diving death incidence rates per 100,000 divers for DAN and BSAC members.

2. PROJECT DIVE EXPLORATION

2.1 PDE in 2004

The reader is referred to the 2005 edition of the DAN Diving Report for PDE objectives and methodology. (The 2005 Diving Report is available at no cost to DAN members from the DAN Website.) The 2006 Report describes data from 1,521 divers, 3,265 dive series and 23,912 dives collected in 2004. The total number of dives logged by PDE through 2004 is 105,135. Figure 2.1-1 shows cumulative data collection from 1995-2004.

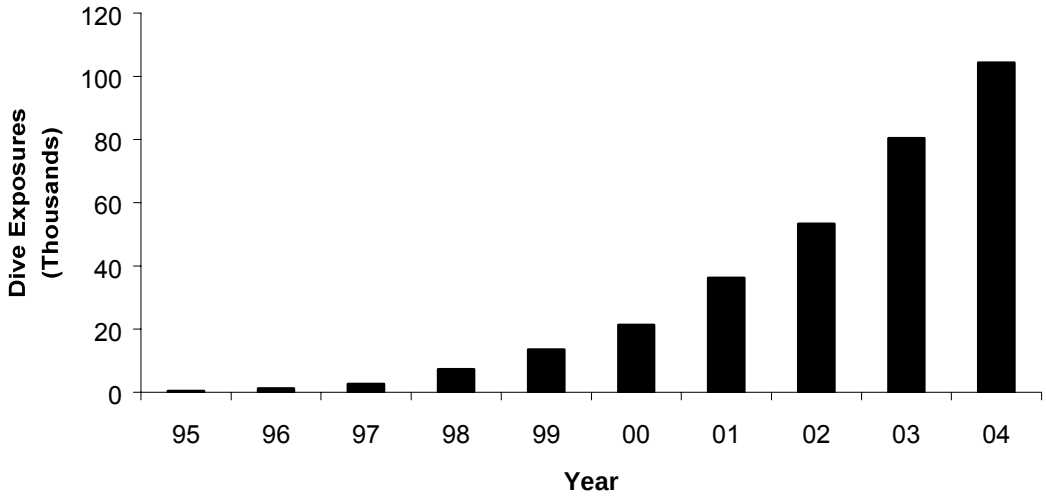

Figure 2.1-1 Cumulative number of PDE dives collected from 1995-2004 (n=105,135).

Table 2.2-1 shows dives in the groups who contributed PDE data from 2002-2004. The Nekton Cruise boats were the largest contributing group in all three years. DAN Interns were the second largest group.

Table 2.1-1 Sources of PDE data.

Source	2002	2003	2004
Liveaboard Collection Centers	6,593	13,046	12,040
DAN Interns	4,878	6,449	3,939
Scapa Flow Collection Center	2,795	2,476	2,412
Recreational Dive Professionals (RDP)	1,283	2,396	2,173
Independent divers	1,511	2,400	3,348
Total	**17,060**	**26,767**	**23,912**

The Scapa Flow Group from Scotland (CWWD) represents cold water wreck divers. The Recreational Dive Professionals (RDP) Group represents dives collected by dive instructors and dive guides mainly in the Caribbean. Independent divers submitted dive logs directly to DAN via the internet from the dive log software (DL7 Level 3-compatible) available with Cochran and DiveRite computers and, recently, Uwatec computers.

2.2 Divers

This section presents information about PDE divers including age, gender, certification, years since certification, and chronic and acute medical conditions. While PDE divers were volunteers from the general recreational diving population, they were not necessarily representative of this population. Most were 30 to 50 years of age and 30 percent were female (Figure 2.2-1). Twenty-two percent were over age 50, and four percent were under age 20 (Figure 2.2-2). Sixty-six percent of female divers held Open Water, Advanced Open Water, or Specialty certification while this fraction was only 46 percent for males (Figure 2.2-3). Forty-nine percent of males held Cave, Technical, Instructor, Rescue Diver, or Dive Master certification while only 30 percent of females did so. Only one percent were student divers. Thirty-eight percent were within five years of certification. This group has declined in size from about 42 percent since 1998 (Table 2.2-1). Divers with more than ten years since certification had increased from about 26 percent in earlier years to 38 percent in 2004 reflecting aging of the general diving population seen elsewhere. Allergy, high blood pressure, and ear or sinus problems (8 to 20 percent) were the most common chronic health conditions (Figure 2.2-4). Less common conditions (2-3 percent) included asthma, heart disease, previous DCI, and diabetes. Reported acute health conditions (Figure 2.2-5) included orthopedic problems and seasickness (16 percent) and flu or upper respiratory infections (five percent).

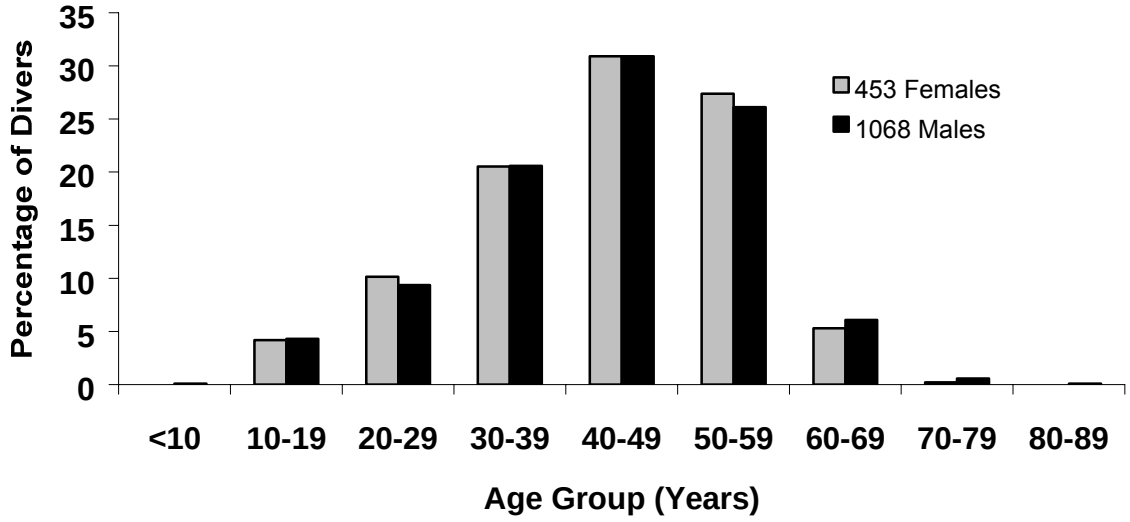

Figure 2.2-1 Age and gender of divers (n=1,521).

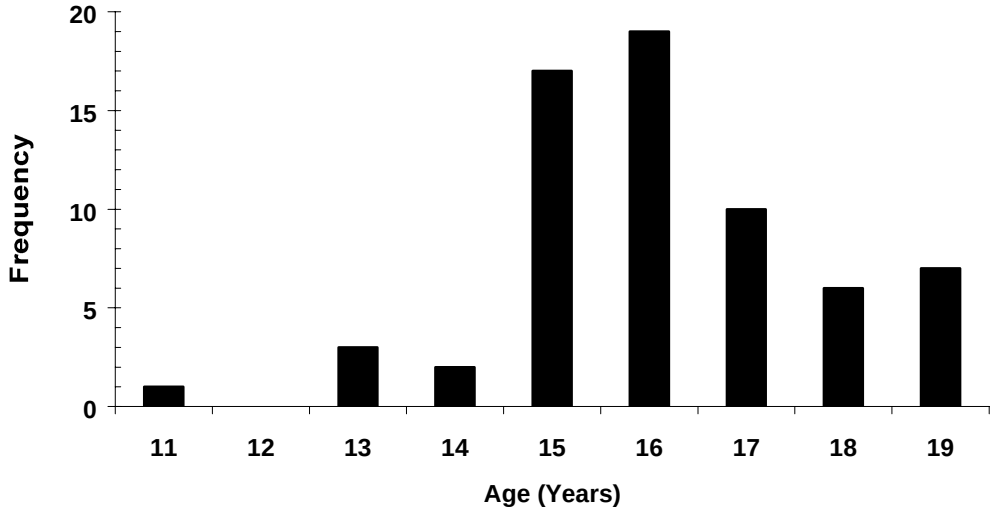

Figure 2.2-2 Age distribution of pre-teen and teenage divers (n=65)

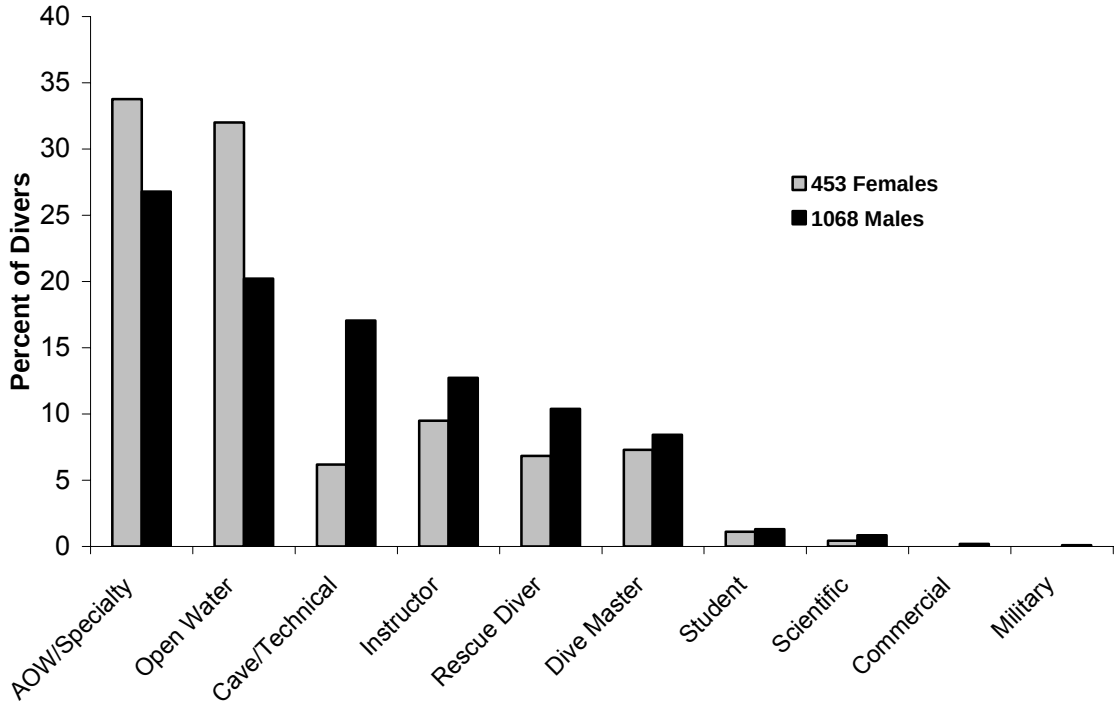

Figure 2.2-3 Percentage of 2004 PDE volunteers by certification of divers and gender (n=1,521).

Table 2.2-1 Percentage of PDE volunteers by number of years since certification.

Years of Diving	1998	1999	2000	2001	2002	2003	2004
1	19.3	16.4	17.9	15.5	15.6	10.7	11.9
2	4.8	7.1	9.8	6.4	6.4	8.6	6.2
3	7.8	7.9	7.1	10.9	7.1	5.9	8.4
4	6.0	7.9	6.3	6.0	6.6	4.4	7.1
5	4.4	3.5	5.4	3.8	5.1	6.7	5.4
6 - 10	25.3	23.7	21	19.4	18.4	20.5	23.4
> 10	26.7	26.2	29.3	26.3	30.1	35.6	37.6

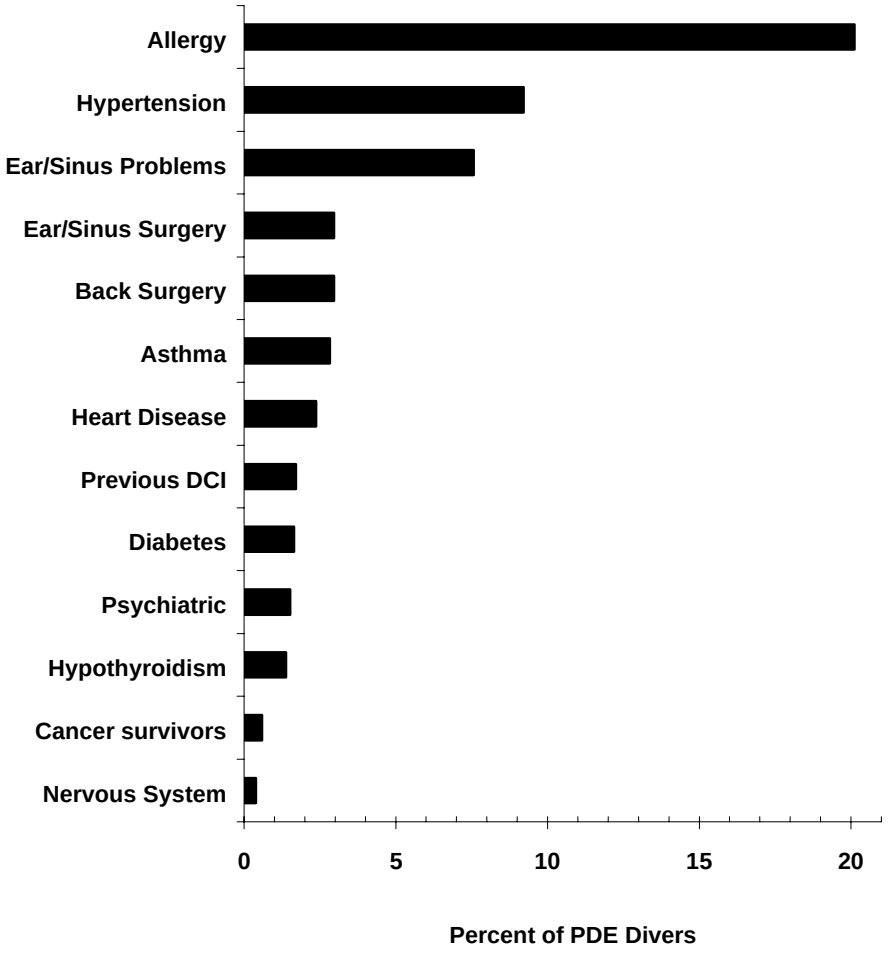

Figure 2.2-4 Chronic health conditions reported by PDE volunteers (n=1,521).

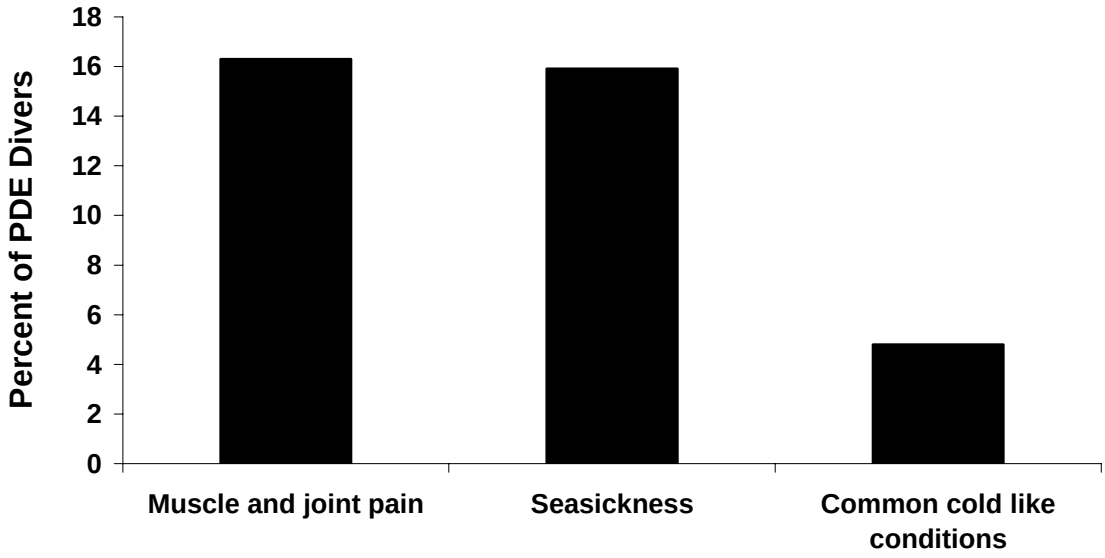

Figure 2.2-5 Acute health problems before diving reported by PDE divers (n=1,521).

2.3 Dive Conditions

This section reviews the diving environment, dive platform, breathing apparatus, reasons for diving, thermal protection, subjective thermal comfort, and subjective work rate.

Ninety-seven percent of PDE dives were collected in saltwater while a little over one percent came from freshwater and about one percent of dives were done in caves or caverns. Two-thirds of the dives were from liveaboards and 26 percent from charter boats (Figure 2.3-1). Ninety-nine percent of the dives used open-circuit breathing apparatus. Rebreathers were used in less than one percent and surface-supplied in 0.02 percent. Ninety-nine percent reported sightseeing as the purpose of diving with teaching/learning, photography, proficiency, spear-fishing, or non-professional work declared in less than one percent.

Thermal protection depended on the geographic area. Eighty-seven percent of divers on liveaboards operating in the Caribbean wore wetsuits or less thermal protection whereas 99 percent of divers in Scapa Flow wore drysuits. Of the beach and dayboat dives, nine percent were done in drysuits. Most divers indicated they were comfortably warm (Figure 2.3-2). Scapa Flow divers with drysuits reported being cold on 15 percent of dives and hot on 20 percent whereas the other dive groups were generally more comfortable (Table 2.3-1). Divers who were cold often reported leaking drysuits. Nearly 80 percent of PDE divers reported doing light work and nearly 20 percent reported moderate or heavy work (Figure 2.3-3). Thirty-six percent of Scapa Flow divers reported moderate or heavy work while liveaboard and beach and dayboat divers reported moderate of heavy work on only 15-20 percent of their dives (Table 2.3-2).

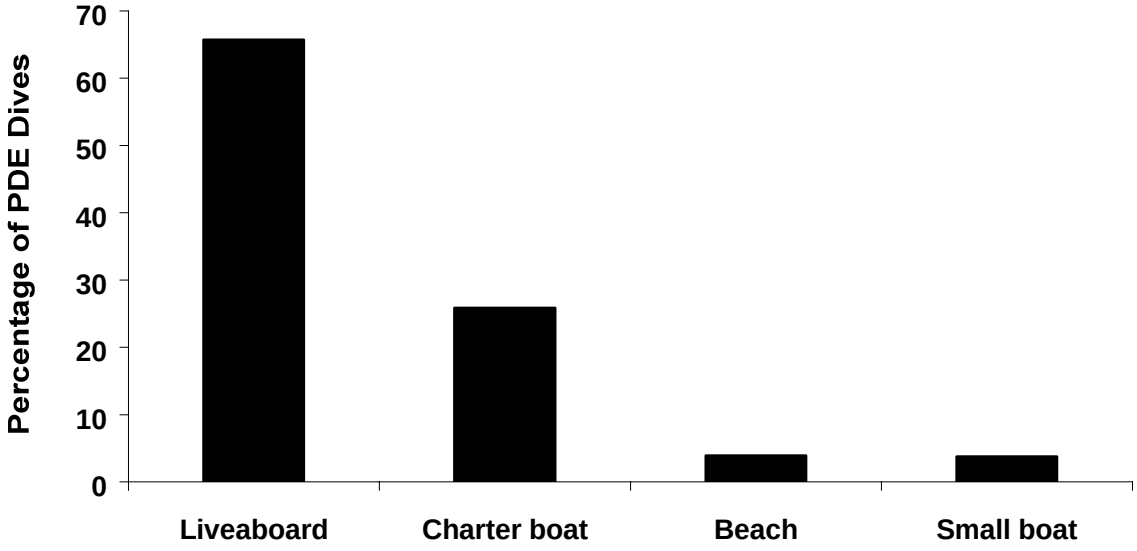

Figure 2.3-1 Percentage of the PDE sample by dive platform (n=23,947).

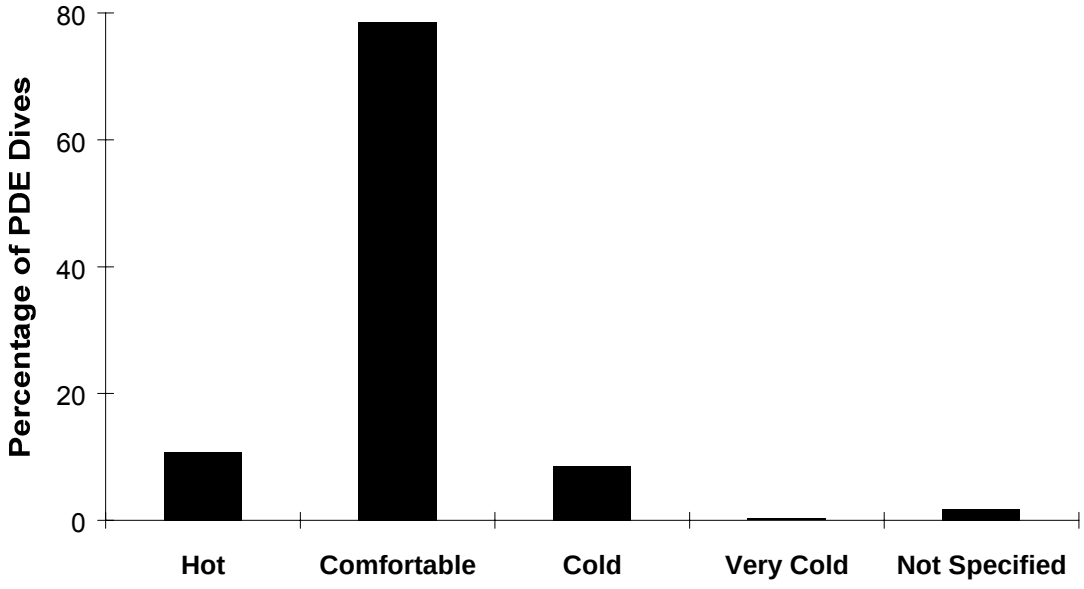

Figure 2.3-2 Subjective thermal comfort of PDE divers (n=23,947).

Table 2.3-1 Reported thermal comfort in PDE dive groups (n = 23,912).

Thermal Comfort	Dive Group (%)			
	Liveaboard	Beach and Dayboat	Scapa Flow	Recreational Dive Professionals
Hot	6	20	20	9
Comfortable	85	67	65	85
Cold	8	8	14	6
Very cold	0	1	0	0
Not reported	1	4	1	0

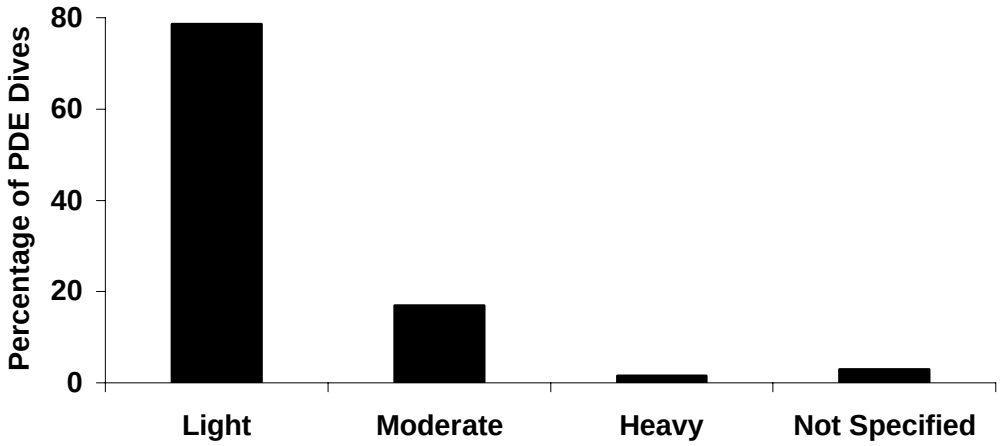

Figure 2.3-3 Percentage of the PDE sample reporting the indicated subjective workload (n =23,912).

Table 2.3-2 Reported work rate in PDE subgroups (n =23,912).

Work Rate	Dive Group (%)			
	Liveaboard	Beach and Dayboat	Scapa Flow	Recreational Dive Professionals
Light	84	74	62	73
Moderate	13	20	34	7
Heavy	2	1	2	0
Not reported	1	5	1	20

2.4 Dive Profiles

Section 2.4 describes the breathing gases, repetitive dive status, number of days in the dive series, number of dives in the series, maximum dive depths, deepest and last dives in the series, maximum depth for each day of multi-day series, dive planning methods, decompression stops, and altitude exposure.

The breathing gas was reported as air in 69 percent of PDE dives, nitrox (a nitrogen-oxygen mix with greater than 21 percent oxygen) in 30 percent, and a mix containing helium in one percent. Fifty-eight percent of the dive series were multi-day, 25 percent were single-day repetitive, and 17 percent were single dives (Figure 2.4-1). Dive profiles from liveaboards were predominately repetitive and multi-day. About 40 percent of all dive series occurred in one day. Dive series with 2-4 dives made up over one-quarter of all dives and were collected mainly from beach and dayboat divers (Figure 2.4-2). Forty-seven percent made 5-29 dives in a series (Figure 2.4-3). The typical diving pattern for from liveaboards was 10-19 dives over six days. Series with more than 30 dives over seven or more days diving were contributed, for the most part, by recreational dive professionals.

Twenty percent of the dives were deeper than 90 fsw/27 msw (Figure 2.4-4), and the last dives of the series were to lesser depths than the deepest dives (Figure 2.4-5). During multi-day diving, the mean average depth decreased progressively from 73 fsw (22 msw) on the first day to 19 fsw (6 msw) by the tenth day (Figure 2.4-6). Thirty-five percent of Scapa Flow dives and 25 percent of beach and dayboat dives were deeper than 90 fsw (27 msw) whereas only 10-13 percent of liveaboard and RDP were this deep (Figure 2.4-7).

Dive computers were used for 81 percent of the PDE dives while in 17 percent, another diver was followed (Figure 2.4-8). Only about one percent of PDE divers used tables. Ninety-eight percent of Scapa Flow divers used dive computers (Table 2.4-1) and did the most dives with required decompression stops (some using oxygen-rich gas mixes) while liveaboard divers did the most safety stops (Table 2.4-2). At least 30 percent of PDE divers reported flying after diving (Figure 2.4-9).

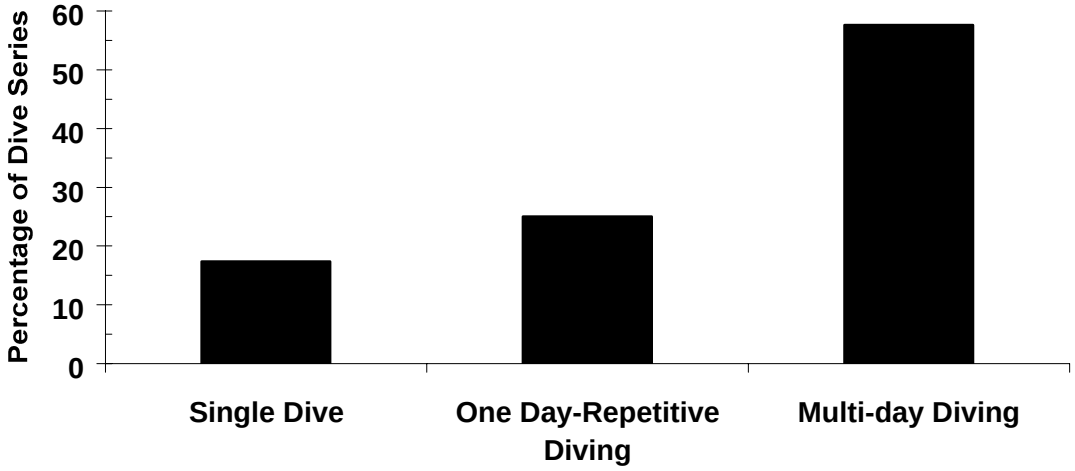

Figure 2.4-1 Single, repetitive, and multi-day dive series (n = 3,265).

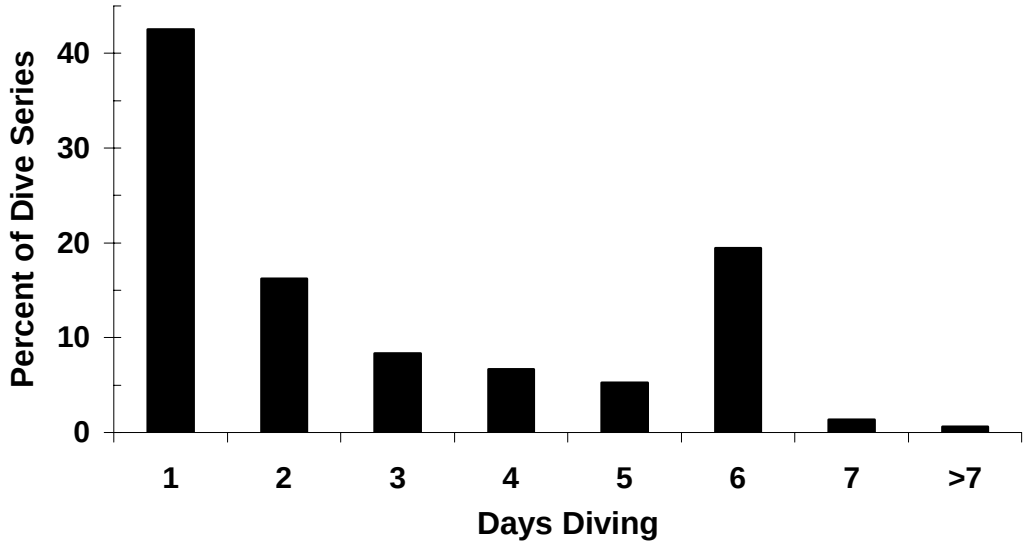

Figure 2.4-2 Number of days in dive series (n=3,265).

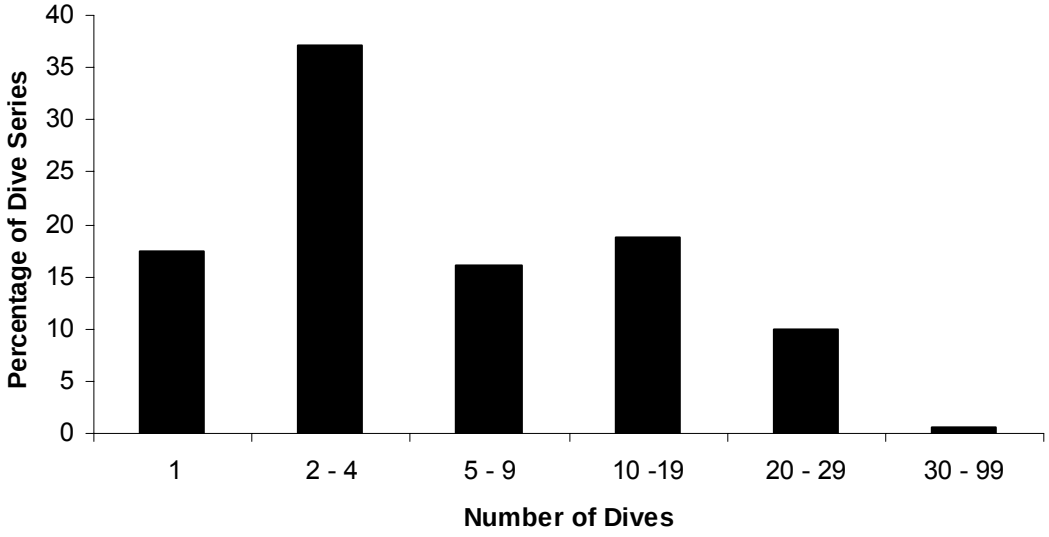

Figure 2.4-3 Number of dives in Dive Series (n=3,265).

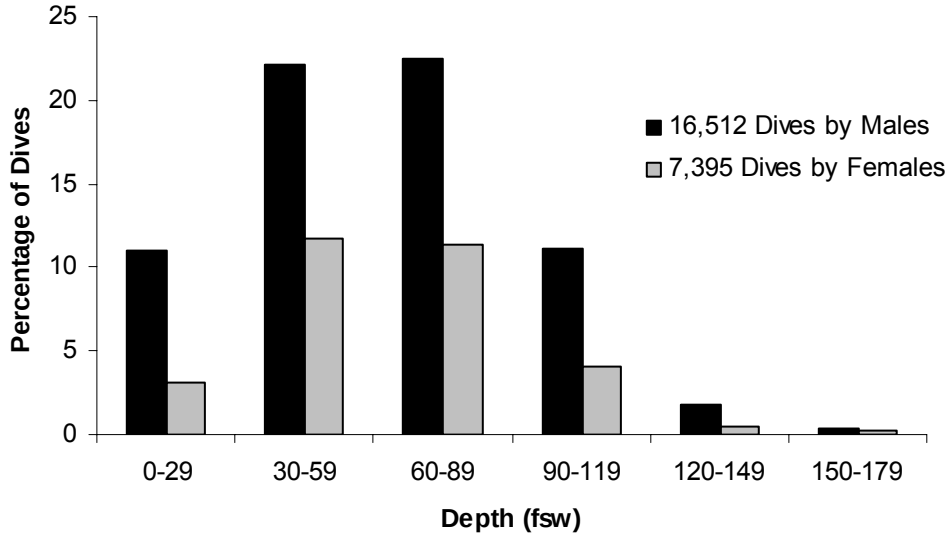

Figure 2.4-4 Maximum depths of PDE dives (n = 23,907).

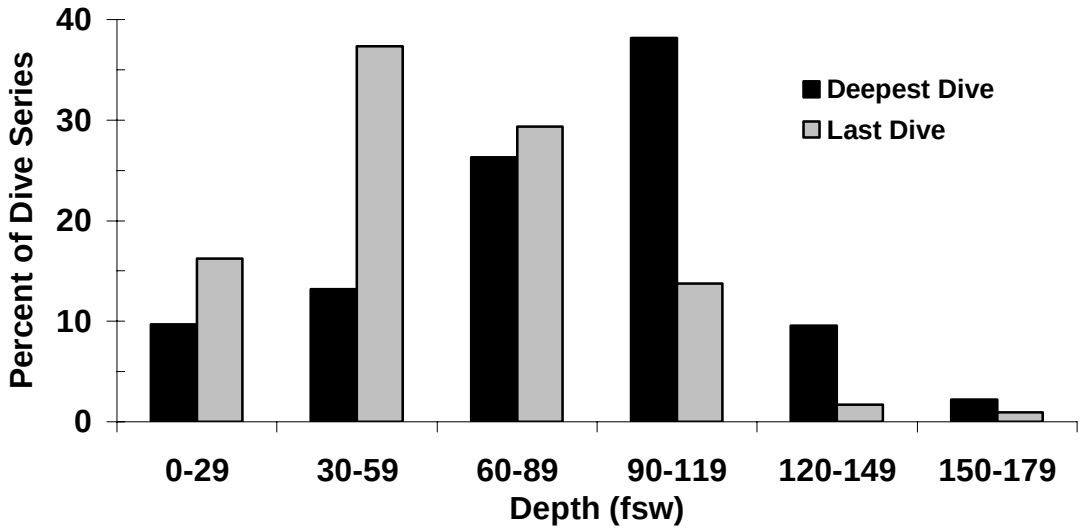

Figure 2.4-5 Depth of deepest and last dive in PDE dive series (n=3,265).

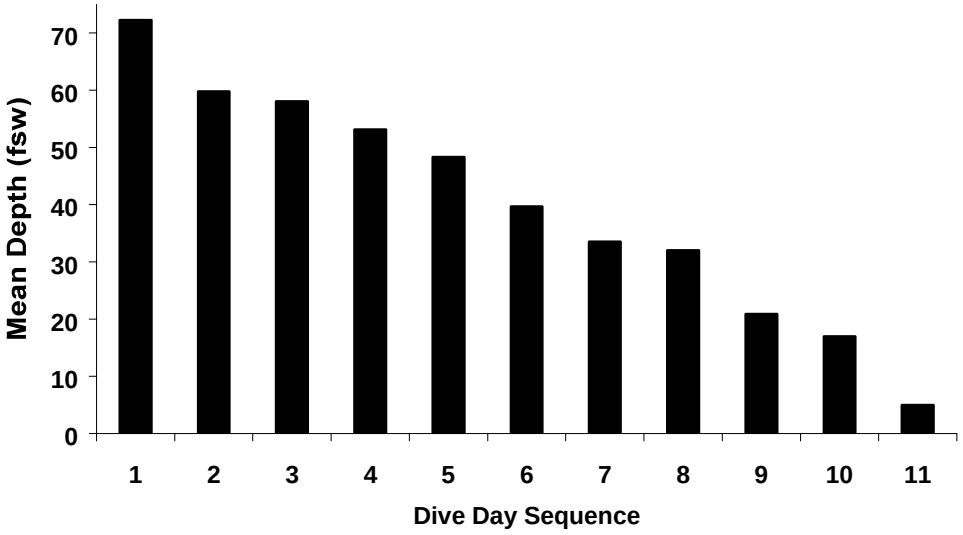

Figure 2.4-6 Dive depth by day sequence in dive series (n = 23,907).

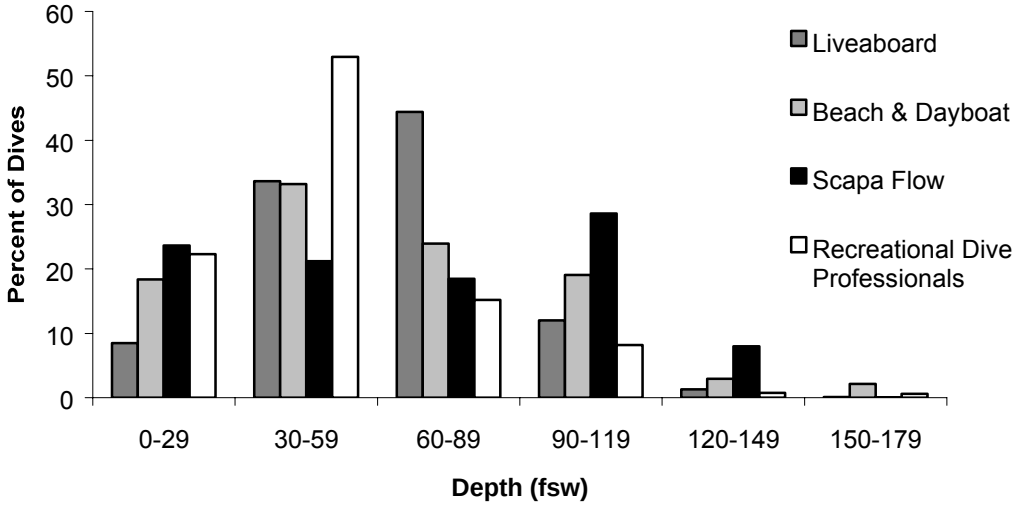

Figure 2.4-7 Distribution of dive depths among PDE subgroups (n=23,907).

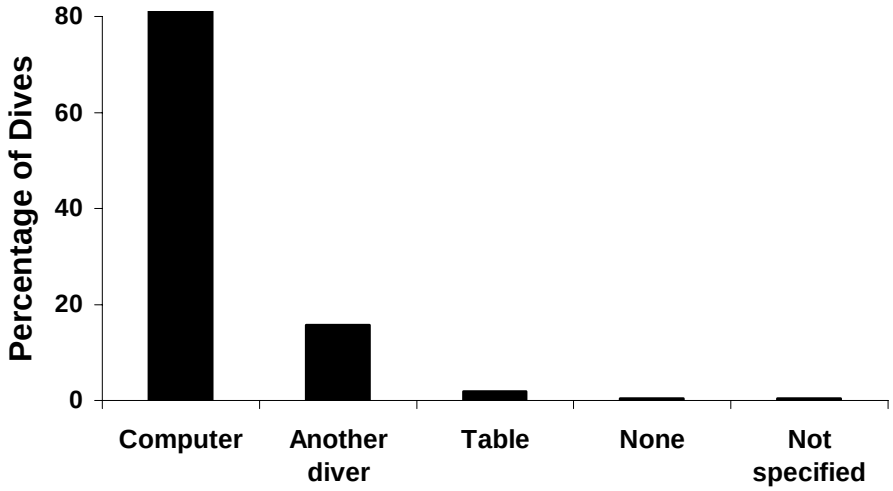

Figure 2.4-8 Number of dives by dive planning method (n = 23,907).

Table 2.4-1 Dive planning method among PDE subgroups.

Dive Plan	Percentage by Subgroup			
	Liveaboard	Beach and Dayboat	Cold Water and Wreck Diving	Recreational Dive Professionals
Dive computer	81.5	82.4	97.9	88.1
Table	0.3	4.4	2.1	9.5
Another diver	0.2	1.8	0.0	0.0
Not reported	18.0	11.5	0.0	2.4

Table 2.4-2 Dives with decompression or safety stop in PDE subgroups.

Decompression Procedure	Percentage by Subgroup			
	Liveaboard	Beach and Dayboat	Cold Water and Wreck Diving	Recreational Dive Professionals
Safety Stop	96	63	55	35
Decompression Stop	1	8	35	0
None	2	20	8	5
Not reported	1	9	2	60

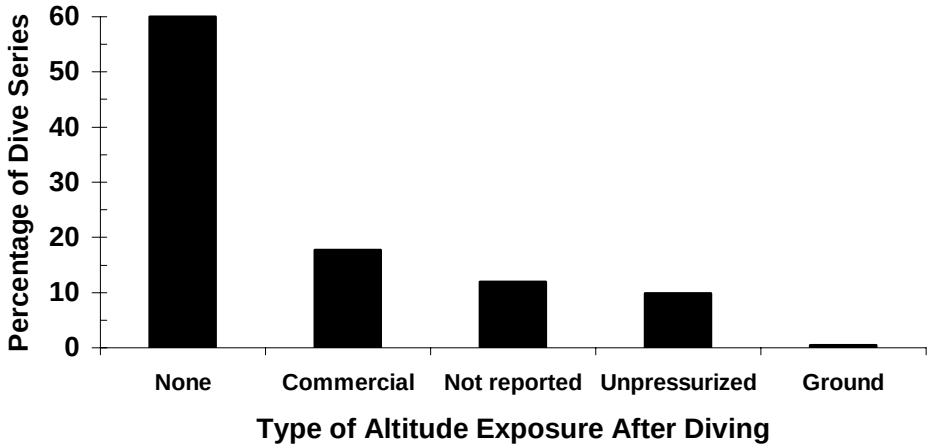

Figure 2.4-9 Percentage of PDE divers reporting altitude exposure after diving (n = 3,265).

2.5 Dive Outcomes

Because there are no certain methods of diagnosing decompression illness (DCI includes AGE or DCS), we offer operational definitions for six possible outcomes of the PDE dives. The outcomes were based on reports by PDE volunteers of events, symptoms, and signs in daily logs or in the 48-Hour Report. Reports that were potentially decompression related were followed up with the diver or recompression facility. As a measure of decompression stress, the DCS probability (P_{DCS}) was estimated from the dive profile based on the method described by Gerth and Vann (Gerth WA, Vann RD. Probabilistic gas and bubble dynamics models of decompression sickness occurrence in air and N_2-O_2 diving. Undersea Hyperb Med 1997; 24:275-292).

Definitions of the six possible outcome categories were:

Uneventful.

- Events, signs, or symptoms were denied.

Incident.

- Incidents include procedural problems or equipment problems that did not result in major harm. Equalization problems are included here, such as temporary ear pain or discomfort. These were not reported as injuries.
- Potentially hazardous procedural or equipment events were reported but signs or symptoms were not reported.

Non-DCI Injury or Symptoms.

- Injuries, signs, or symptoms unlikely to be DCI upon review of medical history.
- Pulmonary barotrauma (pneumothorax, mediastinal emphysema, subcutaneous emphysema) in the absence of neurological or cardiopulmonary signs or symptoms.
- Headache in the absence of other signs or symptoms described by the Perceived Severity Index (PSI, see page 48 in the 2005 edition of the DAN Diving Report).
- Injuries, signs, or symptoms not attributable to AGE after a single dive to less than 30 fsw (10 msw).
- Sign or symptom onset times longer than 24-hrs after the last dive or altitude exposure.

Ambiguous.

If any of the following criteria are present:

- Insufficient exposure (single dive to less than 30 fsw/10 msw).
- Signs or symptoms that could be ascribed to a non-DCI cause.
- Confounding medical conditions that could explain the symptoms.
- Spontaneous symptom resolution after less than 20 minutes with surface oxygen or less than 60 minutes without oxygen.
- Inadequate information.

Arterial Gas Embolism (AGE).

If all three criteria are present:

- Symptom onset time of less than 15 minutes post-dive.
- Presence of cerebral neurological signs, symptoms, or findings.
- Symptom duration greater than 15 minutes.

Rapid ascent, out-of-gas, cardiopulmonary symptoms, pneumothorax, or mediastinal or subcutaneous emphysema increase the confidence of AGE diagnosis.

Decompression Sickness (DCS).

- Onset of signs or symptoms within 24 hrs of diving or altitude exposure after diving.
- Signs or symptoms in accordance with PSI categories.
- Type I DCS (DCS I) included PSIs of Pain, Skin/Lymphatic, Constitutional/Non-Specific.
- Type II DCS (DCS II) included PSIs of Serious Neurological, Cardiopulmonary, Mild Neurological. Other PSIs could also be present.

Table 2.5-1. Summary of outcomes

Outcome		n Dives
Uneventful Dive		22,621
Incident		1,291
Non-DCI Injury		12
Ambiguous		2
DCI	DCS I	2
	DCS II	3
	AGE	0

2.5.1 Incidents

PDE divers reported 95% of their dives to be uneventful. Incidents (procedural and equipment) were reported in 5 percent (Figure 2.5.1-1 and Table 2.5-1). The most common procedural problem was equalization, reported after 2.7 percent of PDE dives followed by buoyancy trouble at 0.9 percent. The face mask was the most commonly reported equipment problem (0.69 percent) followed by the dive computer (0.4 percent). No incident was associated with injury.

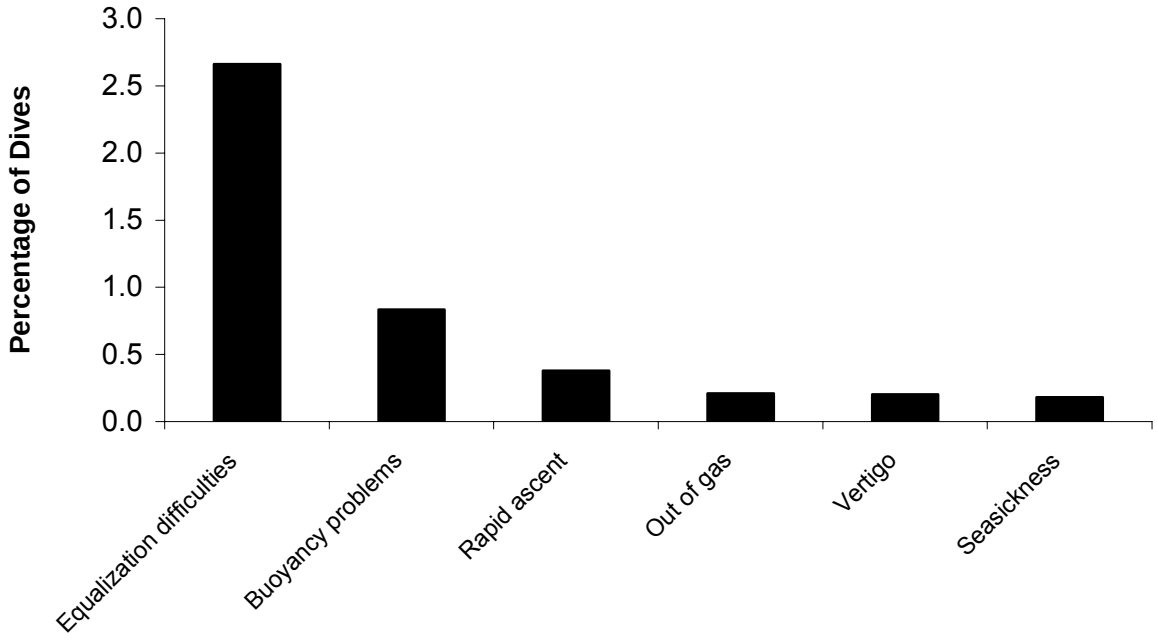

Figure 2.5.1-1 PDE dives with reported procedural problems (n=23,947).

Table 2.5.1-1 PDE dives with reported equipment problems (n=439).

Equipment Problems	Frequency	Percent
Face mask	115	0.69
Computer	66	0.40
BC	54	0.33
Fins	48	0.29
Breathing apparatus	46	0.28
Weight belt	45	0.27
Other	21	0.13
Depth gauge	21	0.13
Thermal protection	15	0.09
Regulator	3	0.02
Pressure gauge	3	0.02
Mouthpiece	2	0.01

2.5.2 Non-DCI Injury or Symptoms

Twelve divers reported headaches. Ten were from Scapa Flow. Three divers reported fatigue on their 48-hour report forms.

Out of 591 reported instances of equalization problems during the dive, six divers reported symptoms after the dive that were severe enough to concern them or made them skip the dive. One diver reported short-lasting vertigo. One diver had severe symptoms that were treated as AGE and recompressed (see Case 1).

Case 1. Sinus barotrauma.

A case initially diagnosed as AGE by the treating chamber was reclassified as sinus barotrauma. The diver was a 31 year-old male, 6 ft tall and 180 lb (BMI=24.4 kg/m^2), with five years of experience and over 300 dives in the last twelve months and 1,500 dives in the last five years. He made three dives over a two-day period. Upon arrival at the surface after a problem-free dive to 80 fsw/24 msw (Figure 2.5.2-1; P_{DCS}=0.37%), he felt a strong pain behind his left eye and reported seeing a bubble in his eye when looking into a mirror although his vision was normal. He was given first aid oxygen within seven minutes after surfacing and taken to a hospital. The oxygen did not relieve the pain. When seen by an ENT specialist after two hours, there was no bubble in his eye, some bloody liquid poured from his nose, and the pain decreased substantially. He was diagnosed with AGE at the chamber and treated by recompression on Table 6. By the end of the treatment his symptoms were completely relieved. He was back to diving a week later. DAN physicians reclassified this case as sinus barotrauma.

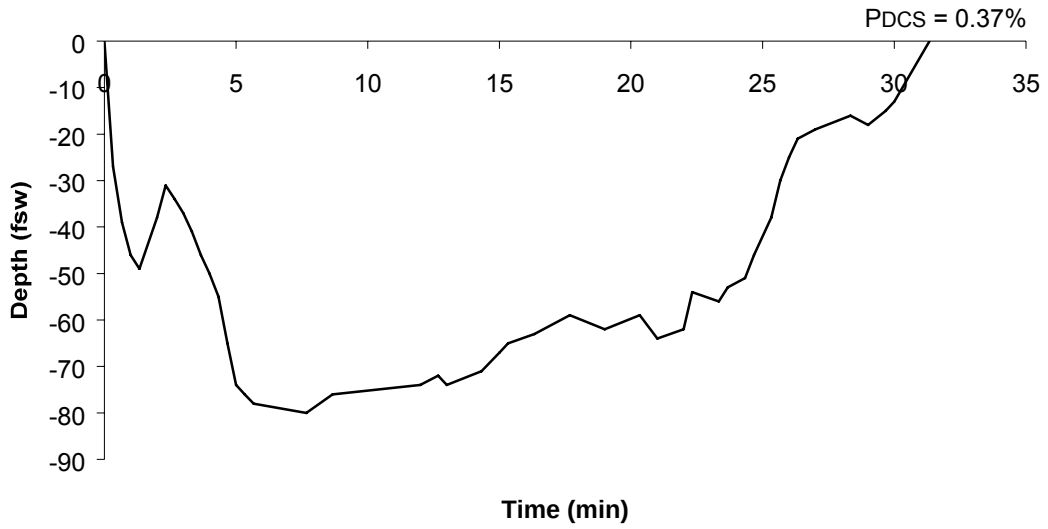

Figure 2.5.2-1 Sinus barotrauma initially classified as AGE.

2.5.3 Ambiguous

One diver called the DAN Hotline for advice because he said his head was “in a fog” after flying home. His symptoms cleared completely the next day without treatment. One diver, who flew home 36 hours post-dive, reported a mild discomfort in his left elbow during the flight. He self-

administered oxygen but the symptoms did not change. After a good night's sleep he was symptom free. Two divers had more specific symptoms in the cases described below.

Case 1

A 41-year-old female, 69 inches tall and weighing 143 lbs (BMI=21.2 kg/m^2), with a history of allergy, back pain, and ear/sinus surgery made six dives in three days from a Caribbean charter boat. Her first dive on the third day was to 100 fsw (30 msw) with a second dive to 45 fsw/13 msw (Figure 2.5.3-1). She had problems on the safety stop due to surge. After the dive, she had slight tingling and numbness in her arms and toes. The symptoms were not severe enough to prompt her to seek medical advice. Symptoms resolved completely within 24 hours without treatment.

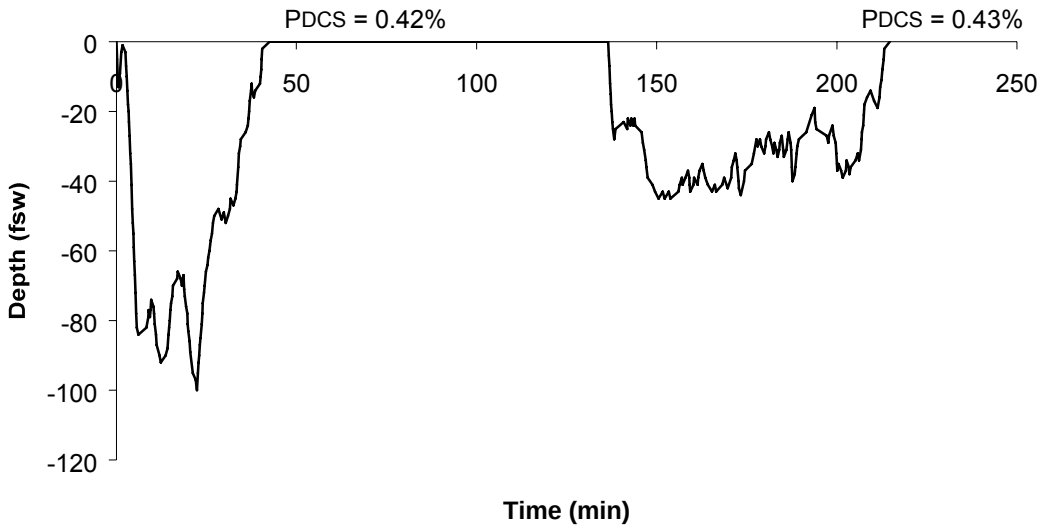

Figure 2.5.3-1 Mild tingling and numbness in arms and toes resolved spontaneously without treatment. Classified as ambiguous.

Case 2

A forty-year-old female, 63 inches tall and 139 lbs (BMI=24.6 kg/m^2), with advanced open water certification and 104 lifetime dives had been treated for DCI 14 years earlier after she experienced seizures upon surfacing. She underwent an extensive medical work up after that incident. Computerized x-ray image of her brain and test for patent foramen ovale (PFO) were negative. This time, she dived from a liveaboard in Caribbean, making 15 dives in five days to maximum depths of 57-153 fsw (18-47 msw). Dives from her last day are shown in Figure 2.5.3-2. The estimated P_{DCS} after the last four dives were 1.8, 3.2, 4.5, and 2.9%, respectively. Five hours after the last dive, she felt exhausted, lightheaded, dizzy, and her lips were numb. She was given two 20 minute surface oxygen cycles with a 20 minute air break. All symptoms disappeared except fatigue. She did not seek any medical evaluation for this episode. All symptoms except numbness of the lips were constitutional. As numbness of the lips is not common in DCS and could be due to hyperventilation, we classified this case as ambiguous.

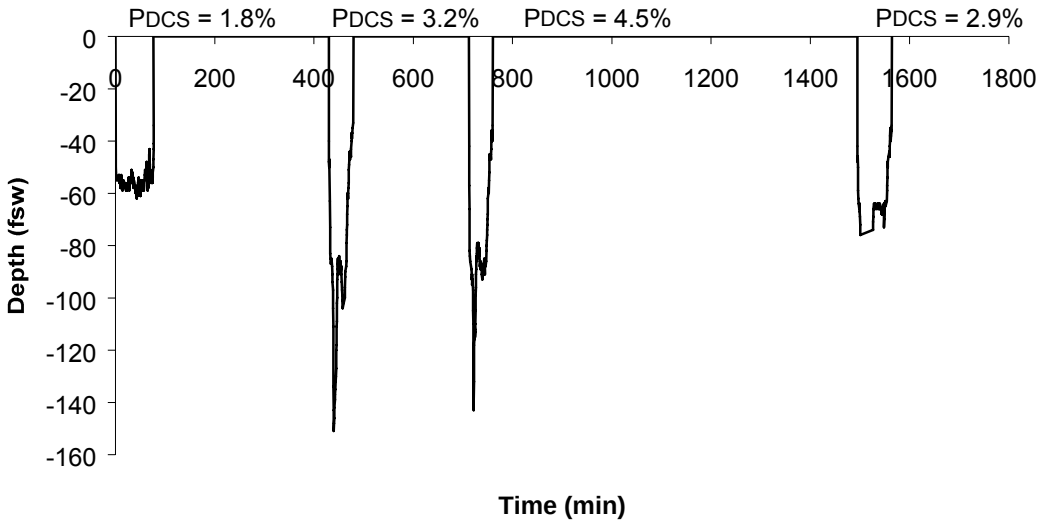

Figure 2.5.3-2 Exhaustion, lightheadedness, and dizziness resolved (except for fatigue) with first aid oxygen. Classified as ambiguous.

2.5.4 DCS

There were five DCS cases for an annual incidence of 2 cases per 10,000 dives. Two cases classified as DCS I and three cases as DCS II (one cardio-pulmonary) were reported. First aid oxygen relieved symptoms in two cases. One case received treatment Table 6 in addition and the other was not recompressed. All cases resolved completely.

Case 1. Pain in right arm (DCS I).

This was an experienced, 34-year-old male diver, 6 feet tall and 185 pounds (BMI=25.1 kg/m^2), with a history of back surgery and ear barotrauma. He dived from the beach, instructing students, for two consecutive days and made two dives on the first day and three dives on the second day. He breathed compressed air and wore a drysuit. One student made many short dives, and the instructor ascended several times to help. About four hours after the dive, he became aware of a pain in his right arm. The pain was about three inches above the wrist in the radius with a severity of 5 on a 0-10 scale. It persisted for a full day spreading into the thumb and elbow of the same arm. After consulting DAN, the diver was admitted to a hyperbaric chamber two days after symptom onset. He received one recompression treatment following the Kindwall protocol with complete symptom relief.

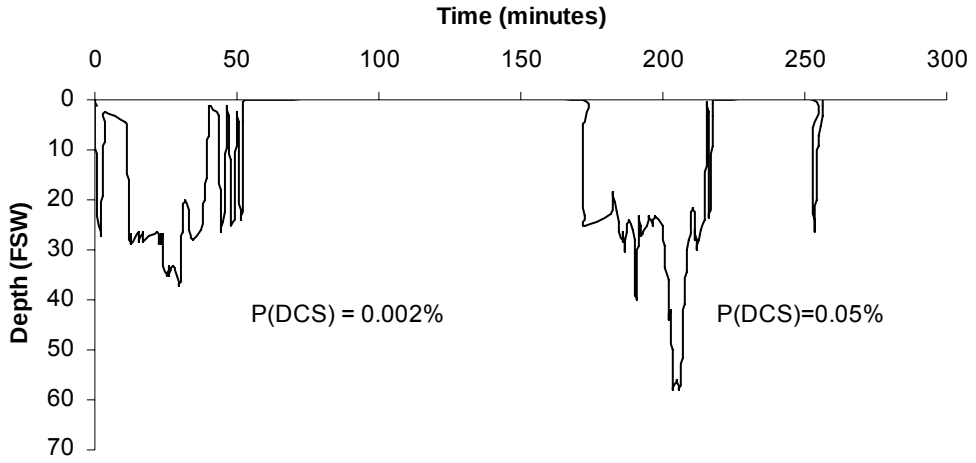

Figure 2.5.4-1 Pain in right arm relieved by recompression. Classified as DCS I.

Case #2. Skin bends (DCS I).

A 52-year-old female diver, certified 15 years earlier, was an occasional diver with about 80 lifetime dives. She was 63 inches tall and weighed 200 pounds (BMI=35.4 kg/m^2). She made a series of 7 dives in 7 days from a pier. Her seventh dive was to a depth of 146 fsw (45 msw) with 25 minutes on the bottom and a total underwater time of 59 minutes (Figure 2.5.4-2). The estimated P_{DCS} was 2.4%. She developed a skin rash around her midsection and shoulders with discomfort and pain in the skin of the affected areas. After a radio consultation with a diving physician, she was administered oxygen at 10 Lpm for 24 hours. The pain and discomfort resolved. Upon return to the US by air, she underwent a 5-hr hyperbaric treatment although she didn't have any symptoms. She returned to diving after a year (2005) and experienced a similar episode of skin bends after two dives to 50 and 40 fsw (15 and 12 msw). Her symptoms resolved again on oxygen, and she was not recompressed.

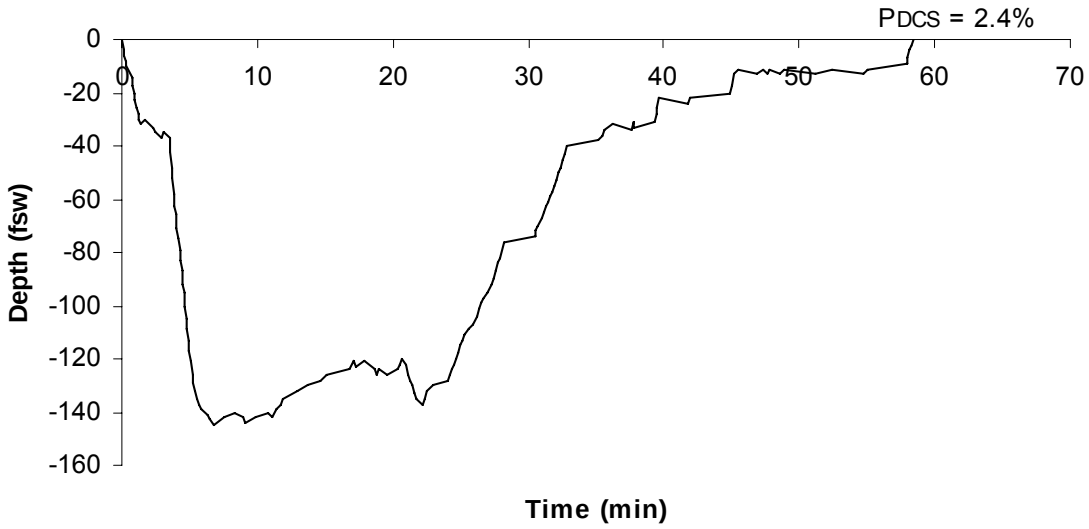

Figure 2.5.4-2 Rash and discomfort on trunk resolved with first aid oxygen. Classified as skin bends.

Case #3. Mild neurological DCS (DCS II).

This 45-year-old male, experienced diver, dived in Scapa Flow and made three wreck dives in two days. His third dive was the first dive of the second day. He went to 116 fsw (35 msw), using open-circuit scuba with nitrox (24% O_2) and a drysuit. He omitted 18 minutes of his planned decompression because he couldn't dump air from his suit to control buoyancy at the decompression stop. The estimated DCS risk after his third dive was 1.98%. Ten minutes after surfacing he developed itching and pins and needles in his left hand. He was administered surface oxygen and his symptoms resolved. The doctor at local hyperbaric chamber where the diver was admitted soon after his symptom onset, considered this DCS and treated him on Table 6. No symptoms or findings were reported before the treatment and he stayed asymptomatic throughout and after the treatment.

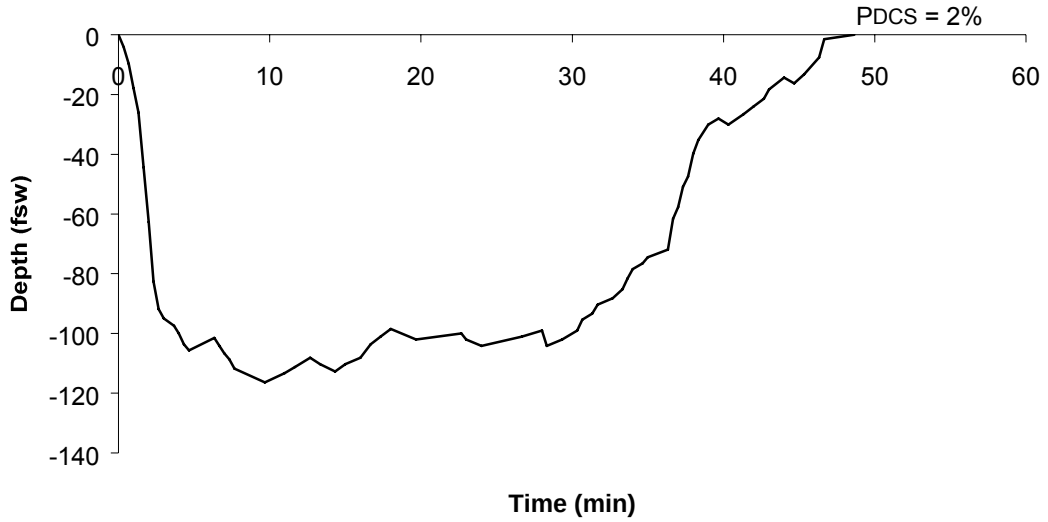

Figure 2.5.4-3 Itching and pins and needles in left hand resolved with First aid oxygen. Classified as mild neurological DCS.

Case #4. Serious Neurological DCS (DCS II).

A female diver on a liveaboard in the Caribbean reported in her 48-hour report that she felt faint and weak, had numbness in her right arm, and could not grasp with her right hand. She was sent to a local hyperbaric chamber and received two treatments on Table 6 and two on Table 5. She was symptom free after treatment and flew home four days later. Her dive profile was lost due to a technical error.

Case #5. Cardio-pulmonary DCS (DCS II).

This was an experienced 25-year-old female technical diver with a history of previous DCI. She dived in Scapa Flow and made six wreck dives over three days. On the last day, her first dive was to 110 fsw (34 msw). After a three hour surface interval, she made another dive to 62 fsw/19 msw (Figure 2.5.4-4). The estimated DCS risks for these dives were 1.8% and 2.3%. Upon surfacing, she experienced tightness in her chest and a general feeling of being unwell. She fainted during examination at a local hospital, but her chest x-ray revealed no abnormalities. She was transferred to a hyperbaric chamber and treated on Table 6. Her symptoms resolved during treatment. Subsequent echocardiography revealed she had a PFO.

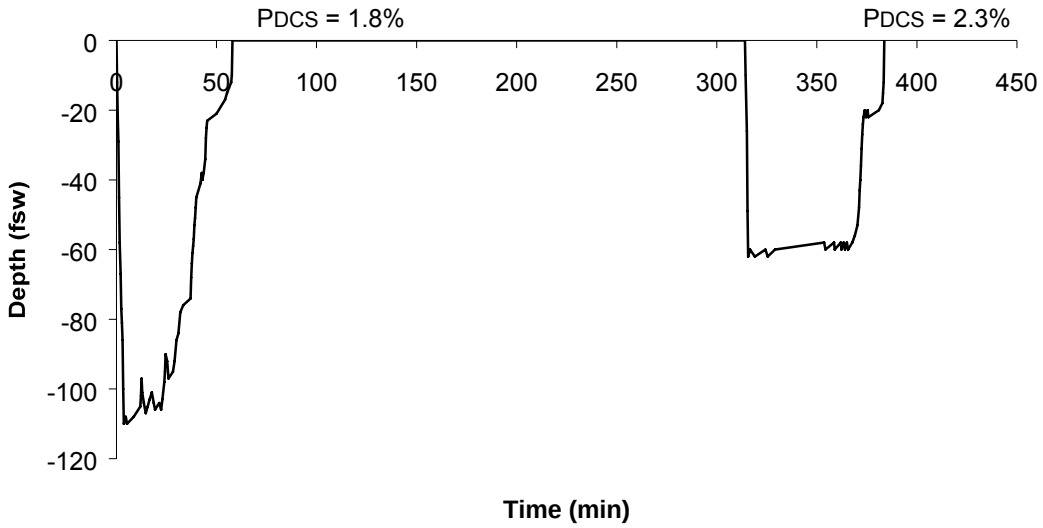

Figure 2.5.4-4 Tightness in chest, a feeling of being unwell, and fainting were relieved by recompression. Classified as cardio-pulmonary DCS (DCS II).

3. DIVE INJURIES

The investigation of recreational diving injuries is an important part of DAN's mission to improve diving safety. DAN has collected information on recreational scuba diving injuries since 1987. The Health Insurance Portability and Accountability Act of 1996 (HIPAA, Title II), however, significantly affected how DAN could collect clinical data and led to a decrease in injury reports submitted over the past two years (Figure 1.1-3).

HIPAA has changed not only the way in which DAN collects data but also how DAN manages calls to the Emergency Medical Hotline. To make this process both HIPAA compliant and more efficient, a new online system has been developed designated the Medical Services Call Center (MSCC). With appropriate security authorizations, the MSCC allows medics, physicians, chambers, and evacuation services in different geographic locations to communicate quickly over the Web and so improve the speed and safety with which injured divers are triaged and delivered to care. A prototype version of the MSCC was implemented in the spring of 2006 and has already reduced the data entry workload and improved reliability. The MSCC includes an electronic version of the Scuba Epidemiology Report Form (SERF), the replacement for the Diving Injury Report Form (DIRF), and allows chambers to enter and retrieve their own case data online.

The primary purpose of the MSCC is clinical management, but by design, it captures all the information needed to address key questions for diving injury research. Advantages of the MSCC over DAN's previous systems (DIRF and DARF – Diving Accident Report Form) include: (a) data entry in real time while the information is fresh; (b) availability of anonymized data to the international diving medicine community through the Web; (c) case follow-up from onset through resolution of residual symptoms after treatment is finished; (d) avoidance of time-consuming and error-prone duplicate data entry; and (e) improved Quality Assurance review capability.

The Injury Section of the 2006 Diving Report falls within the HIPAA-mandated transition to the MSCC from the previous injury collection systems. When the transition is complete, clinical data from the MSCC will be stripped of patient-identifying information to make it compliant with HIPAA regulations. This research data will be available as de-identified cases with information about dive profiles, symptom onset and severity, therapies, and resolution of residual symptoms. Longitudinal analysis of these data will someday allow assessment of: (a) the probability and severity of decompression injury for a given dive profile; (b) the natural history of injury resolution; (c) the effects of therapeutic interventions; and (d) the probability of injury resolution.

The transition data discussed below are less extensive and less accurate than in the past because of changes required by HIPAA. Beginning with the 2008 Diving Report when transition to the MSCC is complete, more cases of greater accuracy will be available for analysis.

3.1 Data Sources, Case Classification, Onset Time and Diagnostic Confidence

Hyperbaric chambers throughout the world, particularly in the US, Caribbean, and Latin America, voluntarily send information to DAN on cases they treated. In 2004, 218 chambers sent 640 usable injury reports, but fewer reports were received from areas where injuries are usually

common such as Mexico and the Cayman Islands, possibly the result of reduced diving activity due to severe weather. Of 640 reports, 176 were in the older DIRF format while 464 were collected with the SERF or MSCC. Figure 3.1-1 shows the international sources of injury reports.

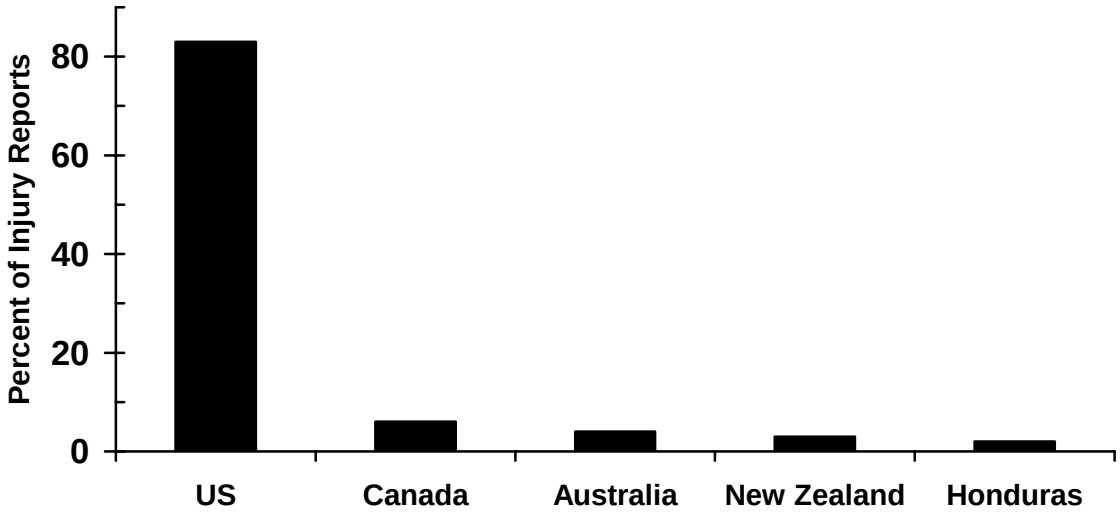

Figure 3.1-1 International source of injury reports for 2004 (n=640).

Diving injury cases were classified by the reporting chambers as DCS, AGE, DCI (AGE or DCS) or NDR (Not Dive Related). The frequency distribution of these categories is shown in Figure 3.1-2.

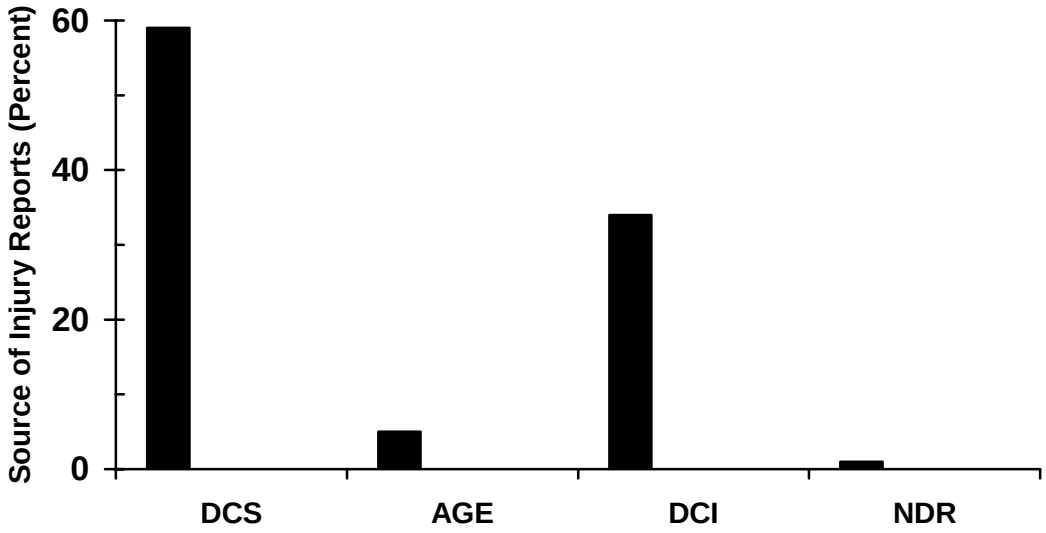

Figure 3.1-2 Percentage of cases by reported diagnoses (n=487).

The fact that someone received hyperbaric therapy does not guarantee that decompression injury occurred as there are no objective diagnostic tests for such injuries. Most reporting chambers

treat fewer than 10 cases per year making it difficult for clinicians to acquire significant diagnostic experience. Because hyperbaric treatment is generally benign, many divers are treated for uncertain indications when DCS or AGE appears possible. The SERF and MSCC allow treating physicians to express their diagnostic confidence. Figure 3.1-3 shows the treating physician judged the diagnosis to be confident for only two-thirds to three-quarters of treated patients.

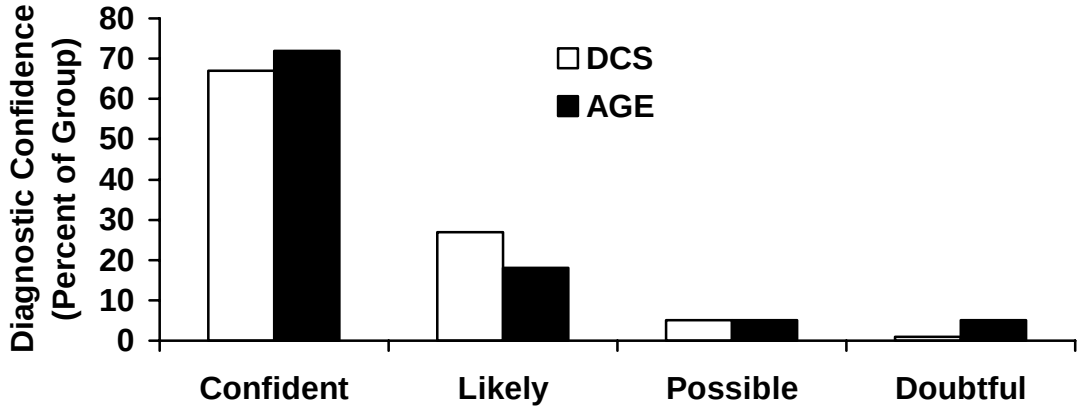

Figure 3.1-3 Confidence in DCS and AGE diagnoses.

3.2 Diver Characteristics Associated with Injuries

Age. The mean age of the divers in our injury population was 39 years, slightly younger than the mean age of 43 years in PDE divers. Figure 3.2-1 shows the distribution of age (in groups of 11.3 years) and indicates that some injured divers continued to dive well into the ninth decade.

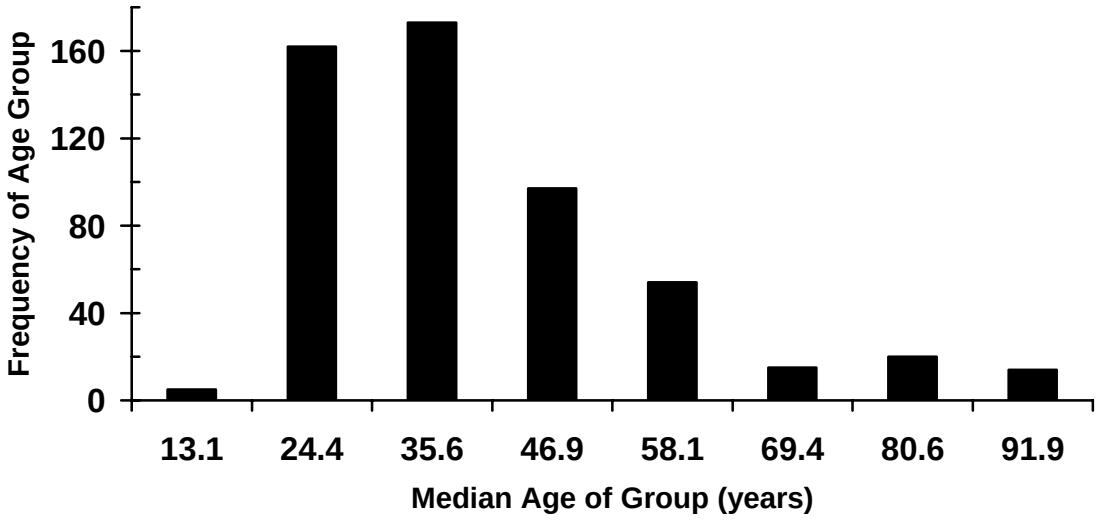

Figure 3.2-1 Diver age groups.

Medical Problems. Reliable medical history information was available for 173 injured divers among whom there were 5 with asthma, 2 with diabetes, 2 with heart disease, 10 with hypertension, 14 with back pain, and 11 who reported prior treatment for DCI. Twenty people admitted to smoking. These figures do not suggest that any of these medical conditions were over-represented in injured divers.

Certification. Figure 3.2-2 illustrates the breakdown of injured divers by certification. Because the total number of divers in each certification category is unknown, conclusions about how certification might influence the risk of injury are not possible. In addition, diving frequency may be different among the certification categories.

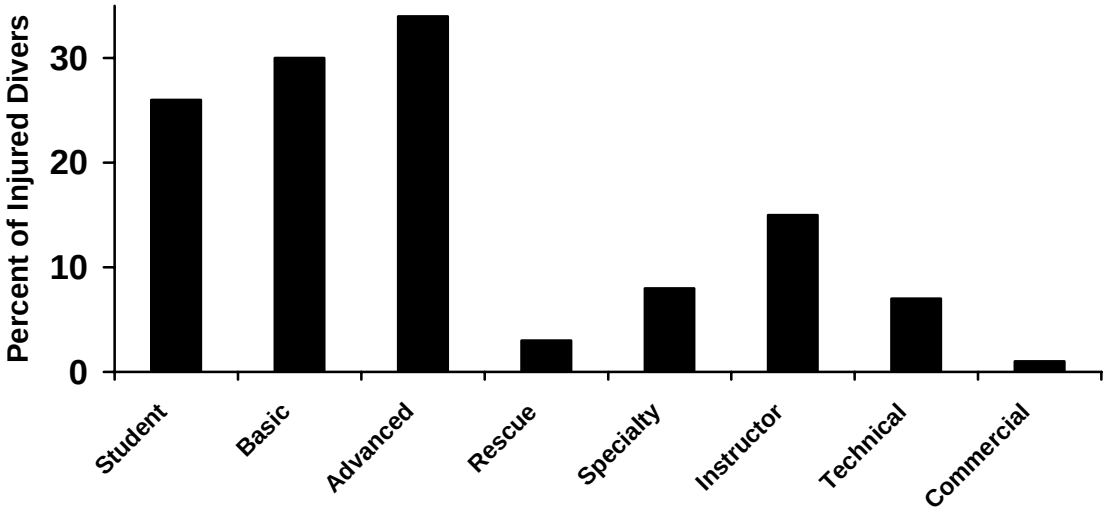

Figure 3.2-2 Certification Level.

3.3 Dive Characteristics Associated with Injuries

Rapid ascent and omitted decompression were commonly associated with injuries as indicated in Table 3.3-1. A diagnosis of AGE was most frequently associated with rapid ascent and DCS with omitted decompression. No relationship of breathing gas to the type of injury sustained was apparent.

Table 3.3-1 Omitted decompression and rapid ascent.

	Subgroup (%)	
Diagnostic Category	Omitted Decompression	Rapid Ascent
AGE	29	71
DCS	38	38
Unsure (DCI)	33	52
Not diving related	0	0

The frequency of dives, by days and number of dives, is given for each diagnostic category in Table 3.3-2. The median is a better measure of central tendency than the mean because of the presence of outliers (extreme values).

Table 3.3-2 Days of diving and dives in series.

Diagnosis		Days In Dive Series	Dives In Series
AGE	Mean	2.2	2.8
	N	18	18
	Median	1	2
DCS	Mean	2.5	4.6
	N	146	145
	Median	1	2
DCI	Mean	6.8	11
	N	137	132
	Median	2	2
NDR	Mean	2.3	2.8
	N	6	6
	Median	2	3

Table 3.3-3 indicates that AGE occurred at shallower depths than DCS. This may be because AGE can occur at any depth where as DCS requires some degree of inert gas loading, a process that happens more rapidly with deeper immersions. When dives are examined by gender, males tended to dive deeper than females (Table 3.3-4).

Table 3.3-3 Maximum depth (fsw) of last dive by diagnosis.

Diagnosis	Mean (fsw)	N	Median (fsw)
AGE	45	18	28
DCS	52	217	36
NDR	19	4	19
DCI	33	149	22

Table 3.3-4 Maximum depth (fsw) of the last dive before injury by gender.

Gender	Mean (fsw)	N	Median (fsw)
Male	46	354	30
Female	39	126	27

Consensus recommendations allow flying within 12 hours of a single no-decompression dive and within 18 hours of multiple no decompression dives (Sheffield P, Vann RD (eds). Flying After Recreational Diving: Workshop Proceedings. Durham: Divers Alert Network; 2004.) Divers appear to heed these warnings because at least 63 percent of the injured divers waited longer than 24 hours to fly, but from the 2004 data, it was not established if they had symptoms before or after flight.

3.4 Symptom Characteristics

DCS symptoms are often subtle and difficult to characterize by both diver and physician. Thus, it is possible that the symptoms for which some (Fig. 3.1-3) people were treated may not have been DCS. Fourteen percent of divers with DCS reported having had symptoms before their last dive. Forty percent of divers categorized as having non-diving related symptoms had symptoms before their last dive. The following is a description and frequency analysis of symptoms reported by divers in this sample.

Most divers reported only one symptom, but some had multiple and varied complaints. Only the first three occurring symptoms were considered in investigating the most common complaints. Figure 3.4-1 shows the number of individual complaints logged by divers in our injury sample.

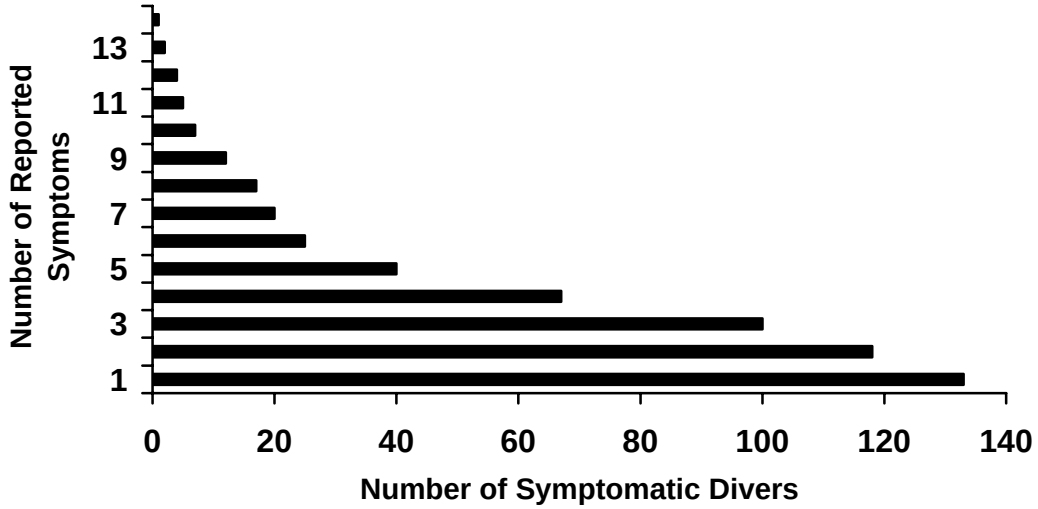

Figure 3.4-1 Number of symptoms per diver (n=264).

Figure 3.4-2 shows that pain and sensory symptoms were most common. Figure 3.4-3 shows the frequency of reported symptoms indicating that pain was by far the most common. Figure 3.4-4 shows that the hands, head and arms were the most common symptom locations.

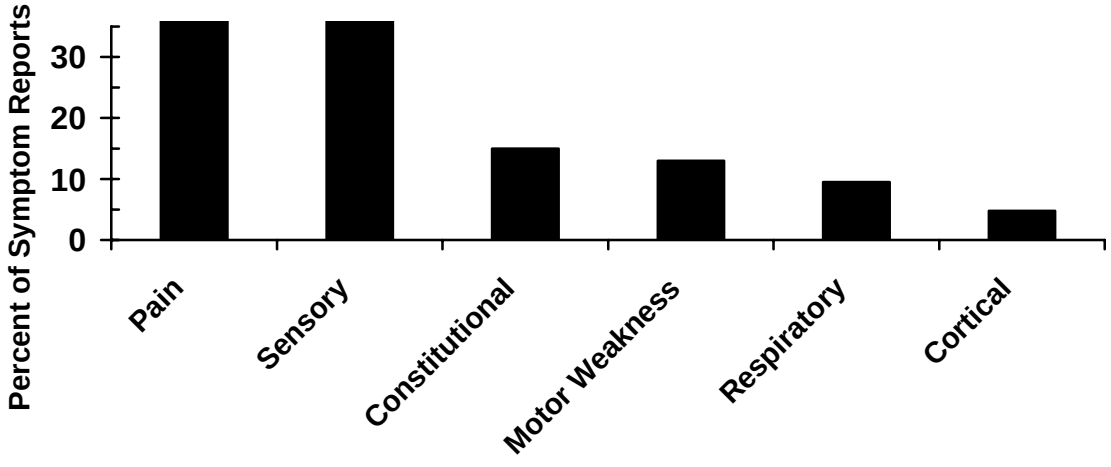

Figure 3.4-2 Percent of reports by individual symptom (n=264).

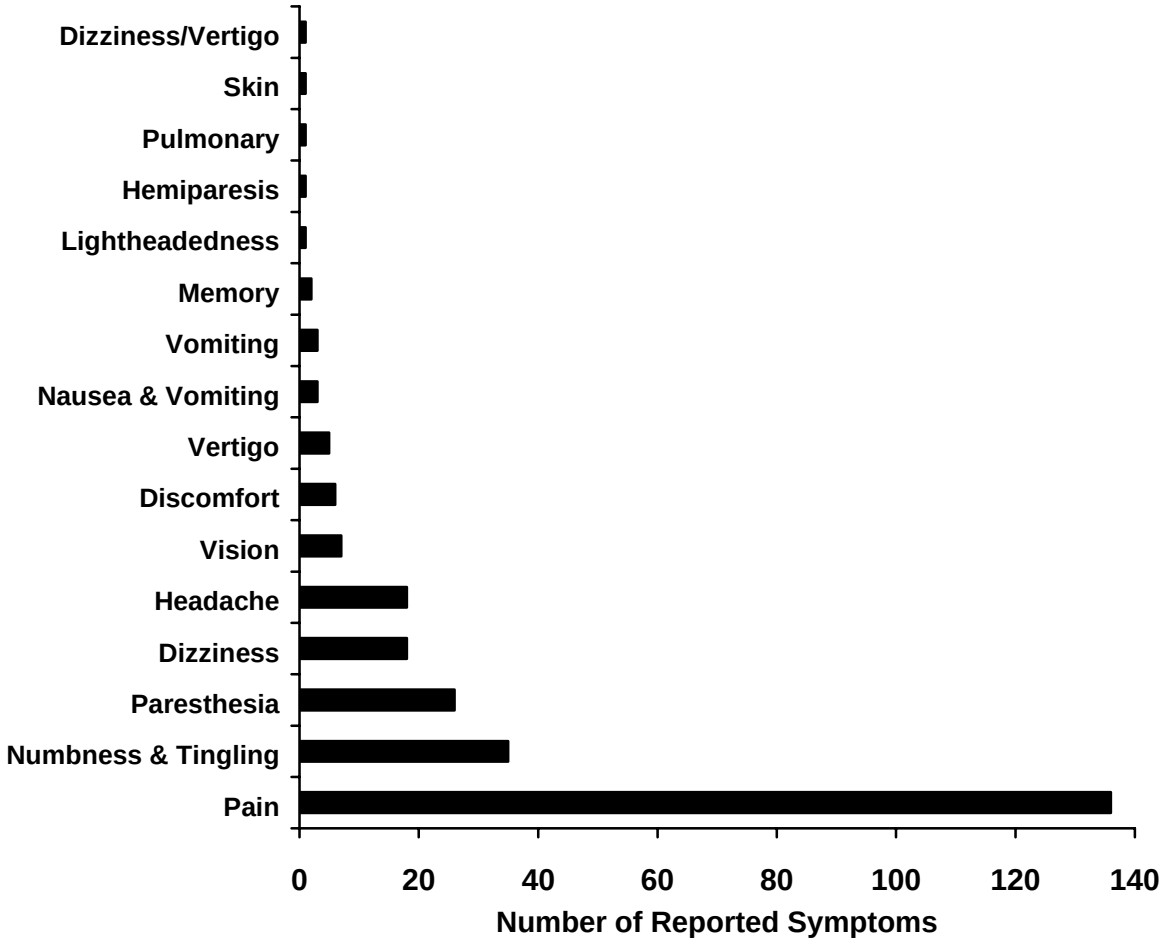

Figure 3.4-3 Specific symptoms by frequency of reports (n=551).

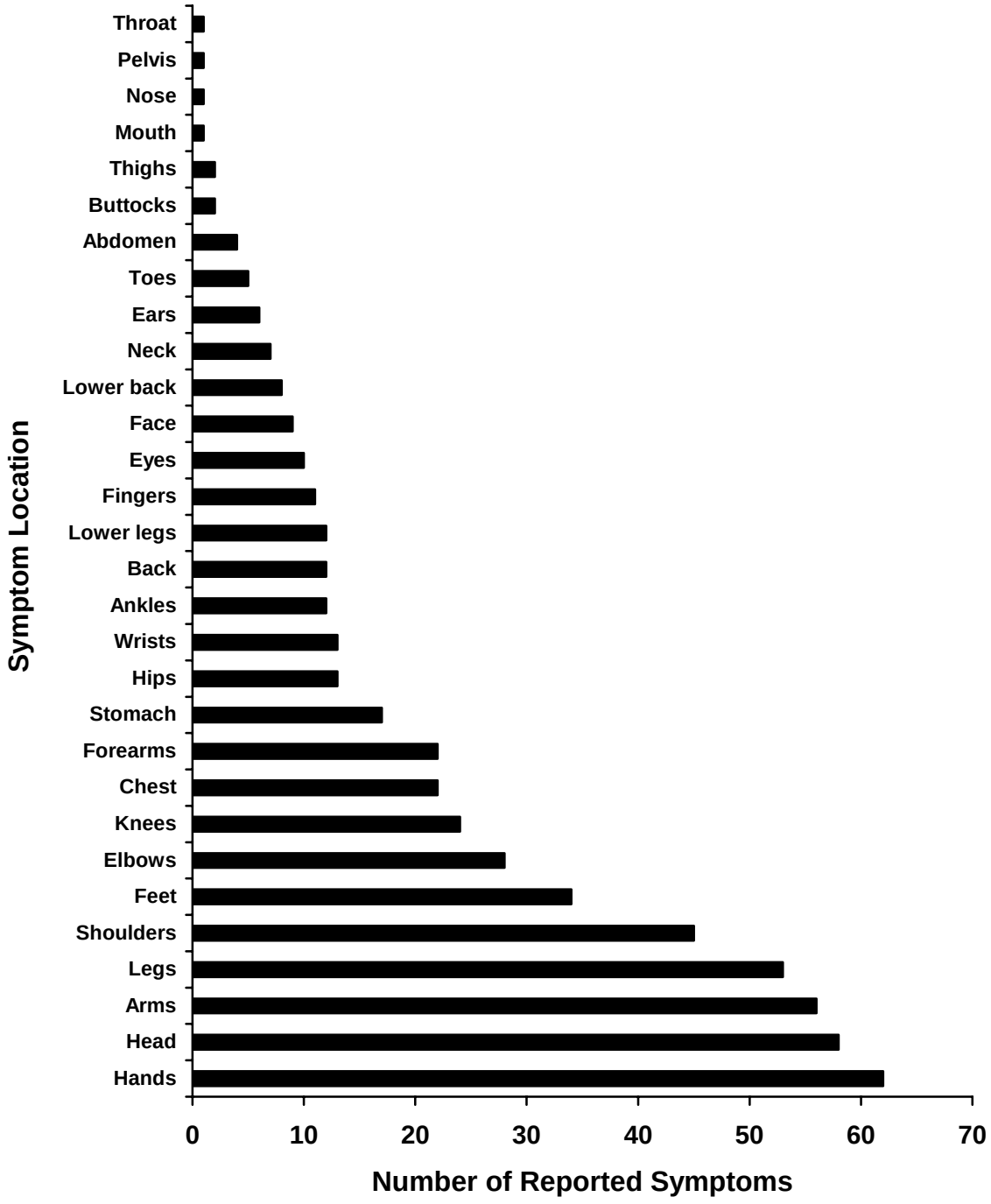

Figure 3.4-4 Location of specific symptoms by frequency of reports (n=551).

Figure 3.4-5 indicates that symptom onset was on the order of minutes for malaise, confusion, respiratory trouble, and motor weakness but an hour or more for pain and paresthesia. Median values were reported to minimize the effect of outliers. The median times for AGE, DCS, DCI, and NDR were 0, 1.8, 4.0, and 4.3 hours, respectively.

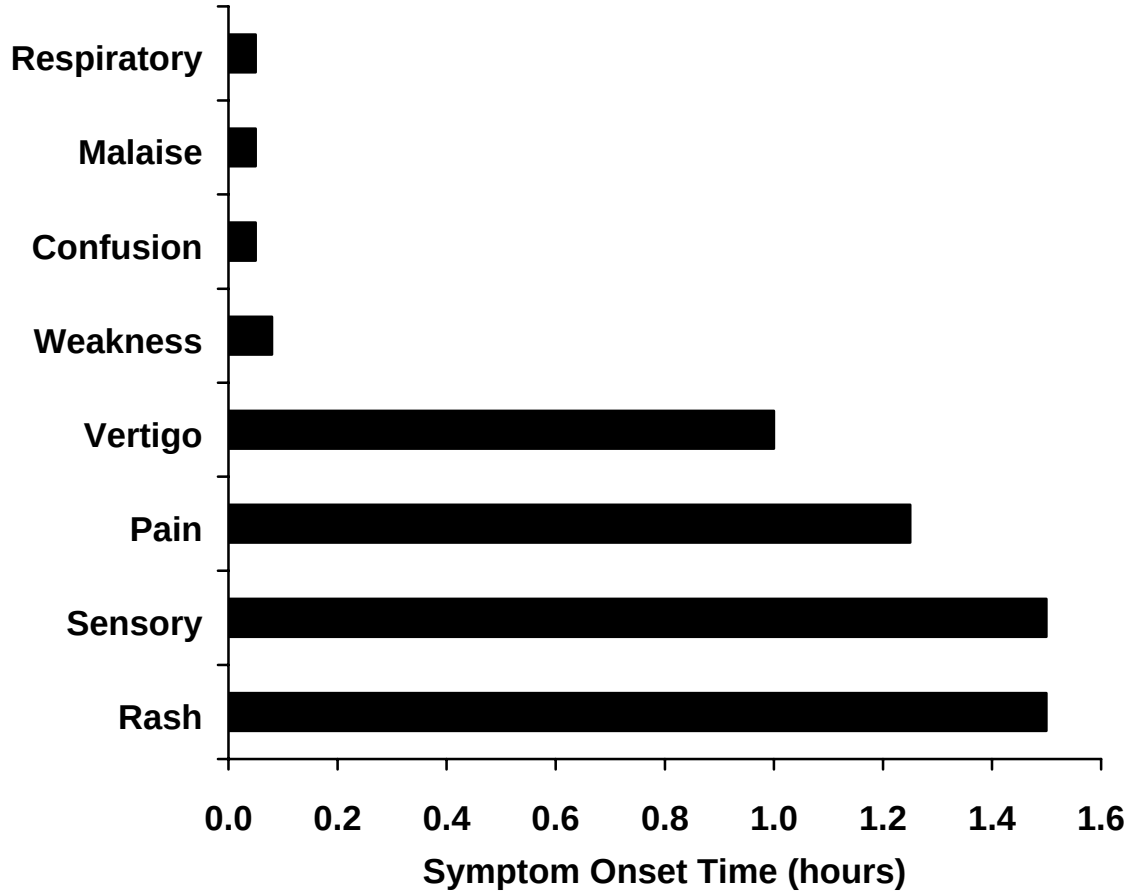

Figure 3.4-5 Onset time of specific symptoms.

3.5 Treatments and Outcomes

Divers in our sample received between 1 and 17 recompressions. Figure 3.5-1 illustrates the breakdown by the number of treatments. Most divers received 2 recompressions. When all treatments are considered, more divers received non-standard HBO therapy for DCS than the standard USN Table 6 (Figure 3.5-2).

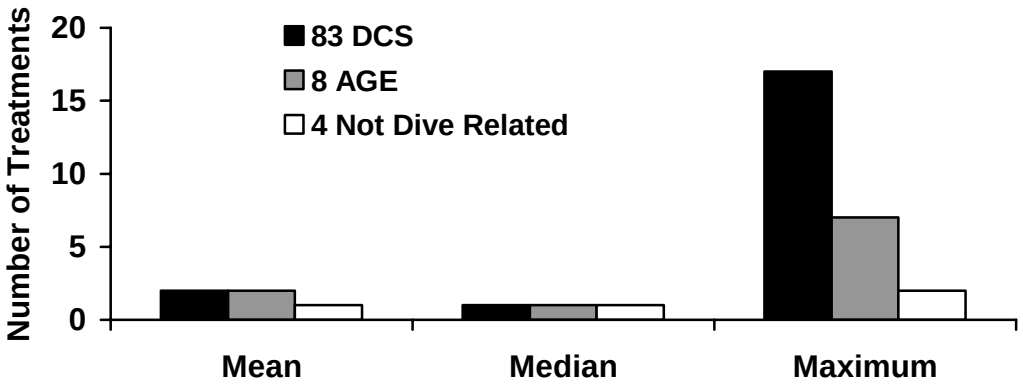

Figure 3.5-1 Number of treatments per diver.

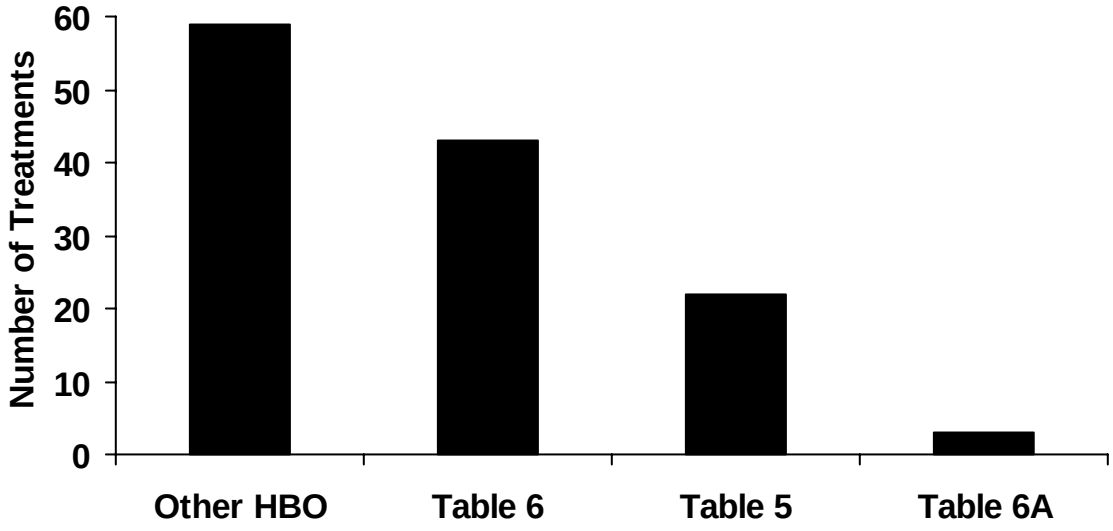

Figure 3.5-2 Recompression tables used (n=132).

Seventy percent of the divers had complete relief or improvement of symptoms after recompression (Figure 3.5-3). Only seven percent had no response, but outcome was not reported in 23 percent.

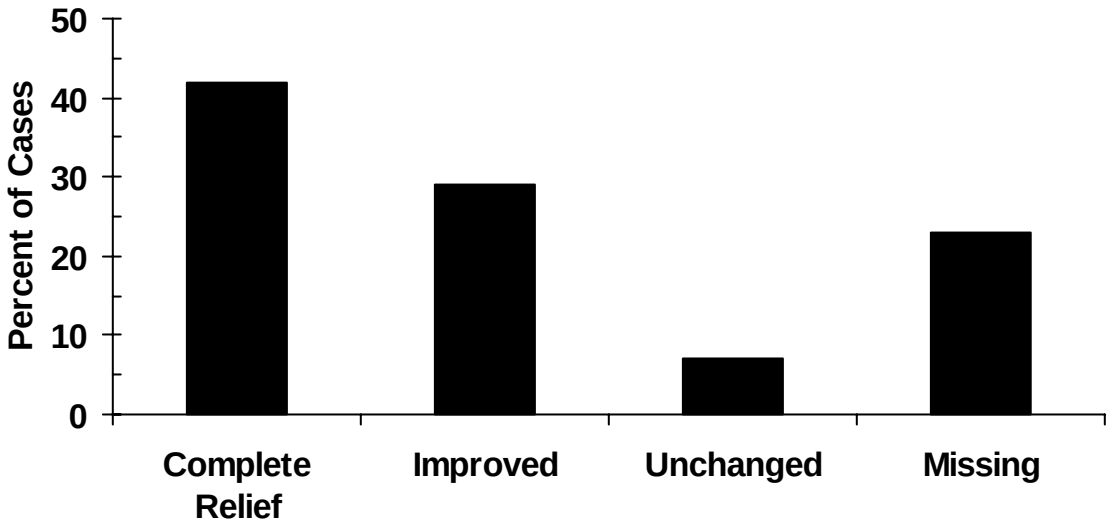

Figure 3.5-3 General outcome (based on DIRF data only; n=173).

Serious symptoms were rare in this sample. Table 3.5-1 lists the cases with serious symptoms and their outcomes after treatment. Relief was complete in 83 percent and improved in 6 percent. There was no change in 10 percent.

Table 3.5-1 Specific outcomes.

Symptom	Frequency	Outcome after All Treatments
Bladder or bowel	1	NC
Deafness	4	2CR, 1IM, 1NC
Confusion	7	5CR, 2NC
Respiratory	6	5CR, 1NC
Malaise	30	28CR, 2IM
CR= complete relief, IM= improved, NC= no change		

4. DIVE FATALITIES

DAN fatality surveillance is an external voluntary notification system with an internal collection process. Voluntary notification comes from divers who may have witnessed an accident, family members, dive businesses, investigative agencies, and government agencies. DAN also actively monitors newspapers and the internet for news about diving fatalities. Once notification is received, DAN researchers start an inquiry to collect available data. The inquiry is limited to recreational scuba fatalities involving US and Canadian citizens diving in US, Canada or abroad. Despite all investigative efforts, information on fatalities is often incomplete, especially in cases that occurred abroad.

In this section, we present the fatality surveillance data as basic descriptive statistics that can be compared to the statistics in PDE and Injury sections and discussion of situations and hazards. A separate description of each accident appears in Appendix B.

A forensic pathologist trained in dive medicine reviewed all cases. When the autopsy was inconclusive, the autopsy findings and surrounding circumstances sometimes made it possible to elucidate a likely sequence of events that resulted in death.

4.1 Fatality Statistics

Table 4.1.1 shows the frequency of diving deaths by country of occurrence.

Table 4.1-1 Number of reported diving deaths by country.

Country	Decedents	
	All	US & Canada Residents
United States	53	53
United Kingdom	18	
Australia	12	1
Canada	11	11
Japan	8	2
Mexico	6	5
Philippines	5	1
New Zealand (Aotearoa)	4	
South Africa	3	
Thailand	3	1
Fiji	3	
Netherlands Antilles	3	3
Guam	3	
Ireland	3	1
Malaysia	2	2
Turkey	2	
Spain	2	
Bahamas	2	
Brazil	1	
Cayman Islands	1	1
China	1	
Costa Rica	1	
Dominican Republic	1	1
Ecuador	1	
Egypt	1	1
El Salvador	1	1
Estonia	1	
French Polynesia	1	1
Israel	1	
Korea (North)	1	1
Malta	1	
Myanmar	1	1
Palau	1	1
United Arab Emirates	1	
Virgin Islands (U.S.)	1	
Total	**160**	**88**

Out of 88 cases involving USA and Canadian divers, autopsies were performed in 59 cases, and reports were available in 37. In ten cases, an autopsy was not performed, and death was documented by coroner's summary or death certificate. In five cases, a body was not found, and in 14 cases, it was not known whether an autopsy was performed. In 47 out of 88 cases, there were no witnesses of the critical event.

Ninety-one cases were U.S. or Canadian residents who were followed-up and 88 cases (14 women and 74 men) were included in this report. Three cases were rejected due to lack of data. Seventy-two percent (n=64) of these cases occurred in the U.S. or Canada and 28 percent (n=40) abroad.

Figure 4.1-1 shows the geographic distribution of U.S. fatalities by region. Most cases (42 percent) occurred in the Southeast Region (North Carolina to Florida, Tennessee and Alabama).

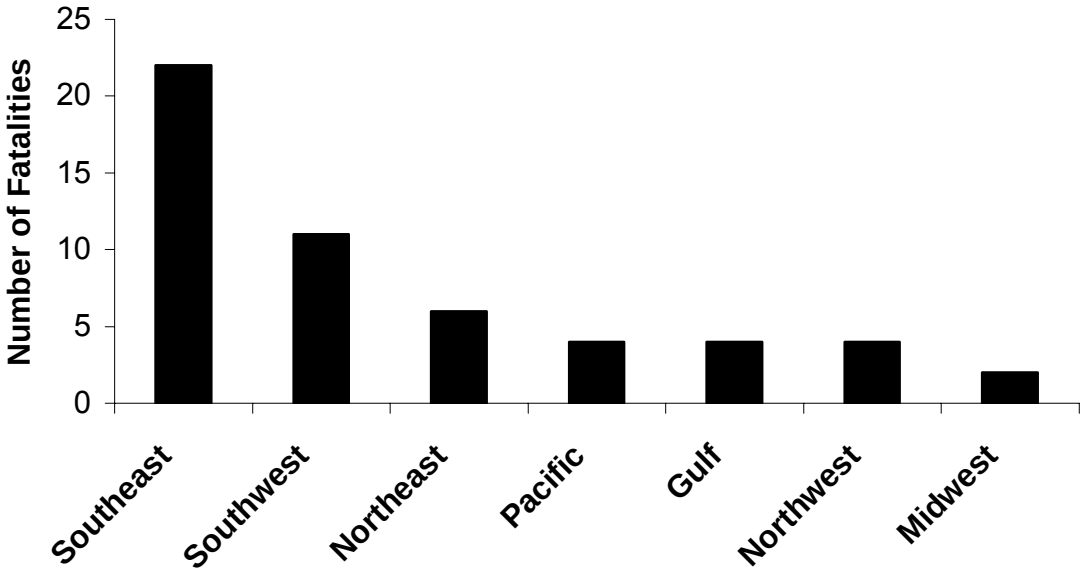

Figure 4.1-1 Regional distribution of fatalities in the U.S. (n=53).

4.2 Characteristics of Divers Who Died

Figure 4.2-1 shows the age distribution for dive fatalities. Seventy percent of males and 80 percent of females were 40 years or older. The age range of females was 30-69 years, with a median of 53 years. The range of males was 14-72 years, with a median of 47 years.

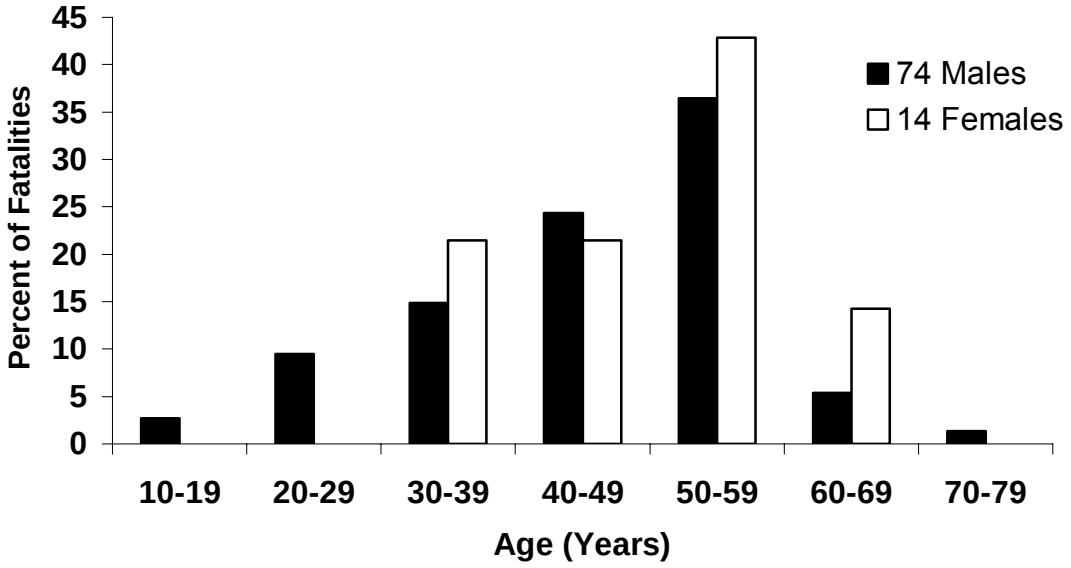

Figure 4.2-1 Distribution of fatalities by age and gender (n=88).

Medical history was available in 35 cases (40 percent), although it was rarely complete. The most frequently reported medical conditions were heart disease (13 cases, 15 percent) and high blood pressure (8 cases, 9 percent). Two decedents were diabetic and one was asthmatic who used inhalers. Other health conditions included breast implants, drug addiction, detached retina, glaucoma, heart surgery 1.5 years before, hysterectomy, cholecystectomy, lymphoma, post-traumatic stress from the Vietnam War, prostate cancer, coronary artery bypass, and history of seizures (two divers). Smoking history was known for 51 cases in which seven were known smokers and three were ex-smokers.

Figure 4.2-2 shows obesity in the fatality population as measured by body mass index (BMI; weight in kg divided by height in meters squared). Except for individuals with increased muscle mass, the level of obesity increases with BMI. BMI data available for 49 fatalities indicated that 26 percent were classified as normal weight (18.5 to <25 kg/m^2), and 74 percent were overweight (BMI 25 to <29.9 kg/m^2) or obese (30 kg/m^2 or higher).

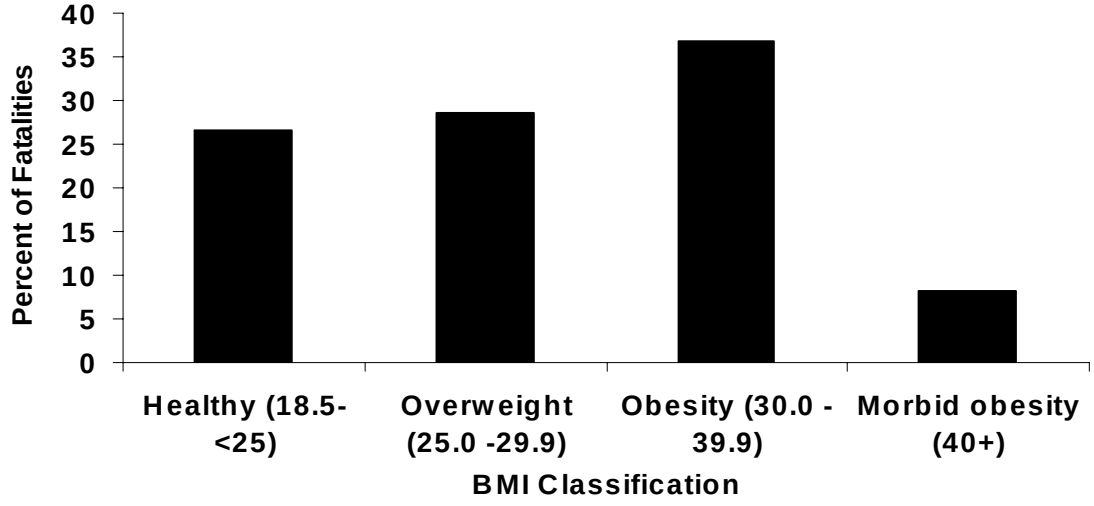

Figure 4.2-2 Classification of fatalities by BMI (n = 49).

The National Center for Health Statistics reports that 35 percent of U.S. adults aged 20 years and older are classified as overweight (BMI 25 – 29.9 kg/m^2) and approximately 30 percent are classified as obese (BMI ≥ 30 kg/m^2) (1999-2002 National Health and Nutrition Examination Survey). Among diving fatalities in 2004, 45 percent had BMI ≥30 kg/m^2 (including obese and morbidly obese in Figure 4.2-2), representing higher proportion than in the National Survey. If the distributions of obesity in the National Survey and the recreational diving population are similar, this would suggest that obesity may be a risk factor for death while diving.

Figure 4.2-3 shows the certification levels and gender for 47 male and 10 female fatalities. Most had open water or advanced certification. Of six student fatalities, three were males and three females. One had no formal training.

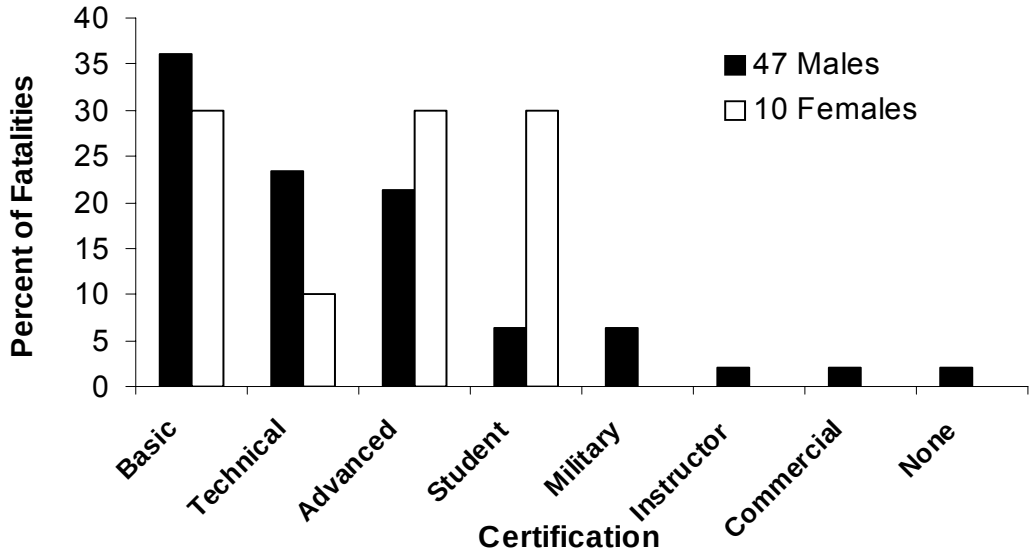

Figure 4.2-3 Certification of divers who died (n=57).

Figure 4.2-4 shows the number of years since initial certification. Twenty-five percent had been certified 10 or more years earlier, and 45 percent had one year or less.

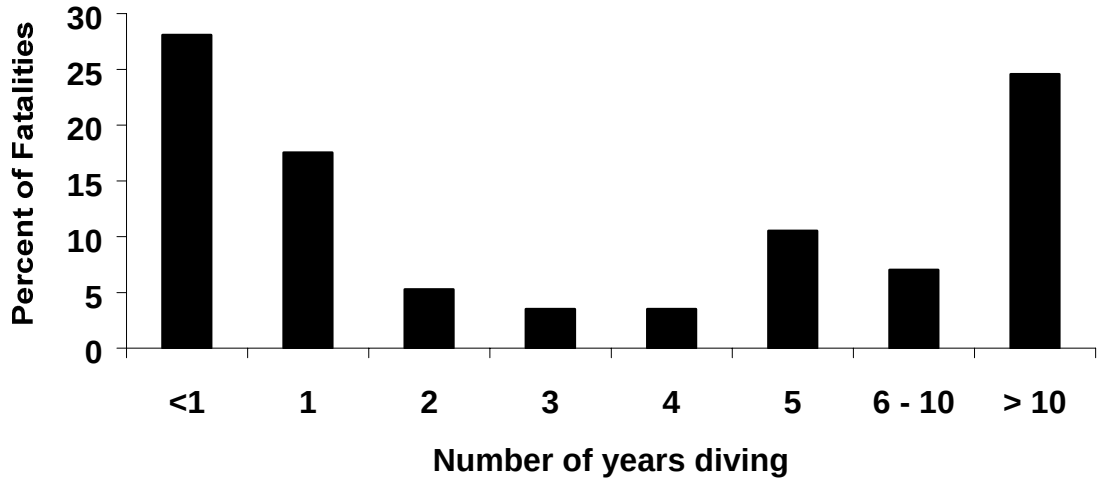

Figure 4.2-4 Number of years since initial certification of divers who died (n=57).

Figure 4.2-5 shows the number of dives performed in the 12 months prior to death which was available in 44 cases. Seven percent of divers had not dived in the previous 12 months, and 43 percent had less than 20 dives in the past year and less than 20 lifetime dives.

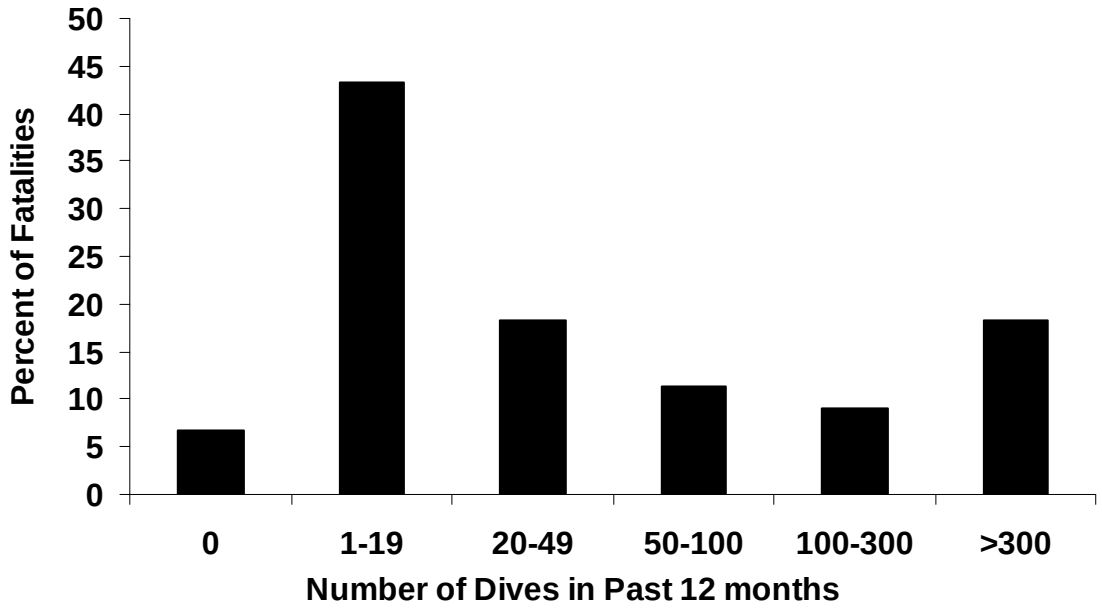

Figure 4.2-5 Number of dives in 12 months prior to death (n = 44).

Figure 4.2-6 shows the period between the previous dive and the fatal dive (n=40). In 68 percent of the 2004 cases, the fatal dive occurred only days after the preceding dive. This differed from previous years when 56 percent of fatalities had not dived for one or more years suggesting that conclusions based on a single year must be viewed cautiously.

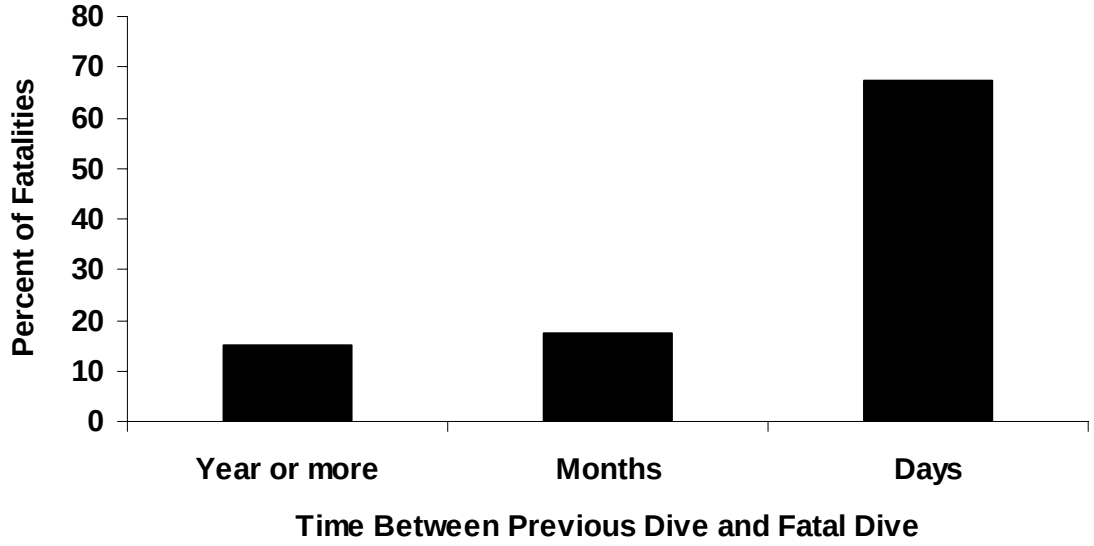

Figure 4.2-6 Time between last dive and day of accident (n = 40).

4.3 Characteristics of dives

Information about diving activity in fatalities is often limited to the last day of diving and is usually not complete. Figure 4.3-1 shows the month of death. Most fatalities occurred during summer months.

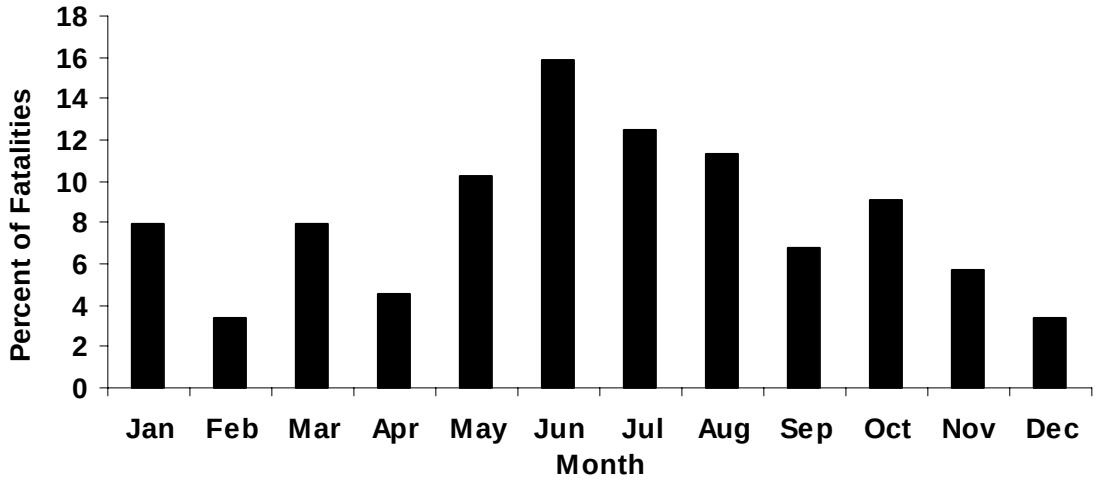

Figure 4.3-1 Month when diver deaths occurred (n=88).

Eighty-four percent of diving deaths occurred during daylight. Nine deaths (12 percent) attributed to drowning occurred during night diving and three occurred at dusk. Sixty-eight percent occurred in the sea or ocean, 14 percent in rivers, 12 percent in lakes or quarries, and 4.5 percent in other environments including one case in a pond while cleaning a clogged drain, one in a canal during a public safety search, and two in cenotes.

Figure 4.3-2 shows the reason for diving. Sixty-three percent of fatalities (n=55) involved pleasure or sightseeing, 14 percent involved wreck diving, 13 percent were in training, and seven percent were fishing or collecting game. Two died while retrieving an anchor or lost property. One was crushed by a boat he was repairing in shallow water. One was sucked into a drain and one drowned in a strong current while collecting sharks teeth in a river. Ten percent of the cases occurred during cave diving. Four of these divers were trained and experienced in cave diving, two were novices, and there was no information on training or previous experience for three divers. One case occurred in a lake partly covered with ice but not under the ice.

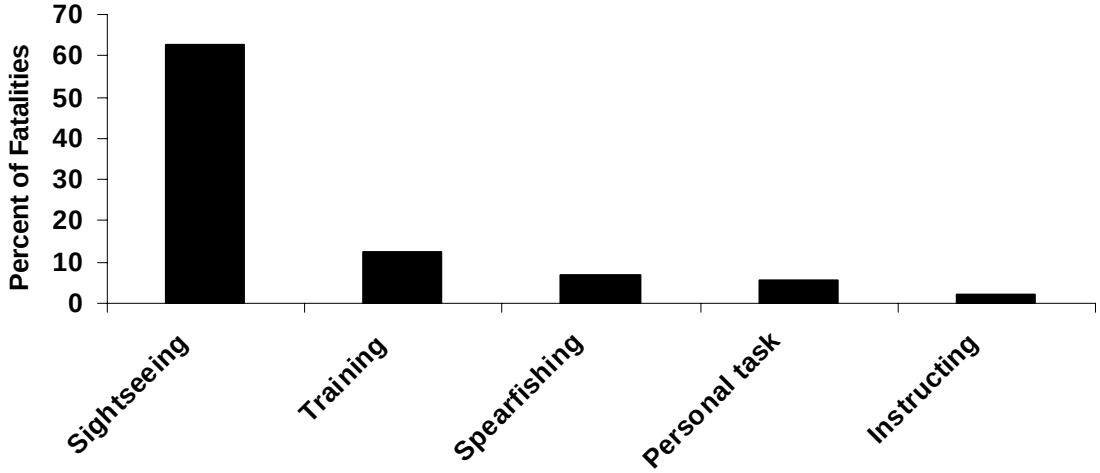

Figure 4.3-2 Diving activity (n=55).

Figure 4.3-3 shows the platform from which the fatal dives began. Fifty percent began from a charter or private vessel, consistent with previous reports. Forty percent dived from shore. Of these, 40 percent dived alone while only 17 percent of charter or private boat fatalities dived alone. Strong current or rough seas were present in 30 percent of shore diving and 15 percent of charter boat diving. Half the diving fatalities wore wetsuits, 37 percent wore drysuits, and 13 percent wore swimsuits. Death occurred on the first dive of the day in 50 percent of cases while 20 percent occurred on a repetitive dive. This information was not available in 30 percent of cases.

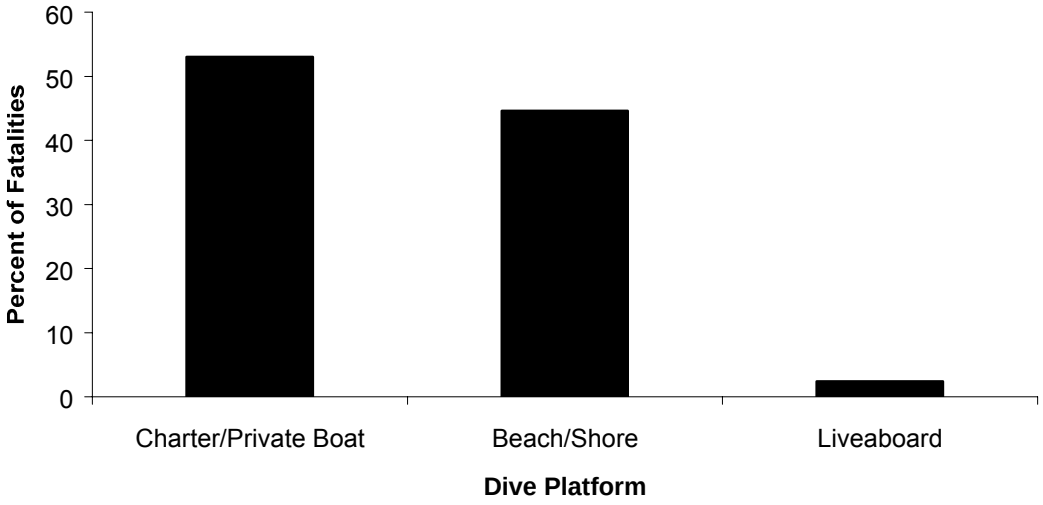

Figure 4.3-3 Dive platform (n=88).

Figure 4.3-4 shows the maximum dive depth reported for 59 fatalities. Three cases (3.5 percent) occurred on the surface before diving. Seventy-six percent occurred in less than 90 fsw (27 msw) and 24 percent on deeper dives. Four occurred at deeper than 200 fsw (61 msw).

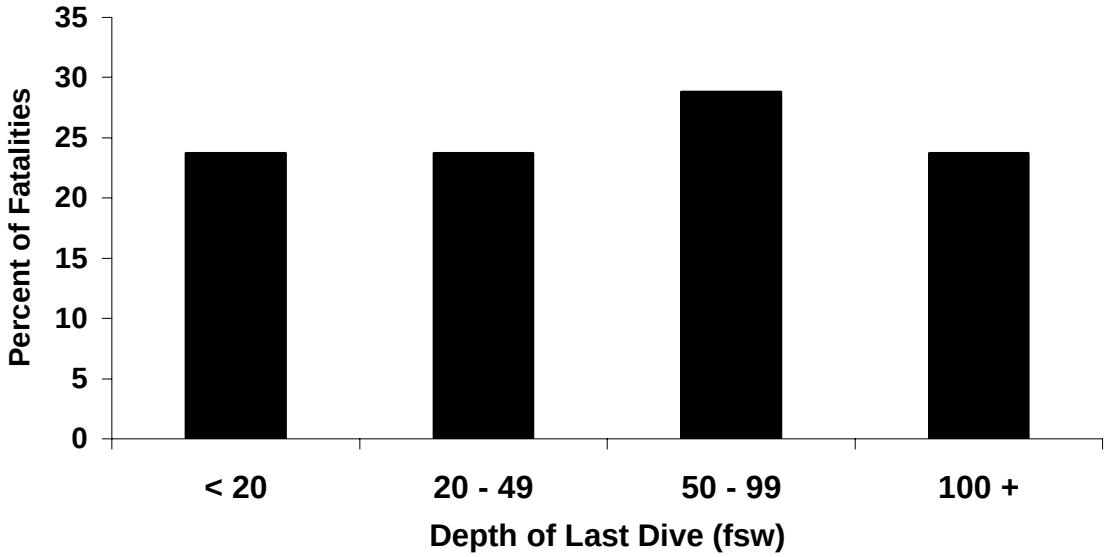

Figure 4.3-4 Maximum dive depth (n=59).

Figure 4.3-5 shows breathing gear and breathing gas. Scuba was used in 94 percent of cases and most frequently with air (78 percent). Nitrox and trimix were used in six cases each. Rebreathers were used in four cases and surface-supply in one.

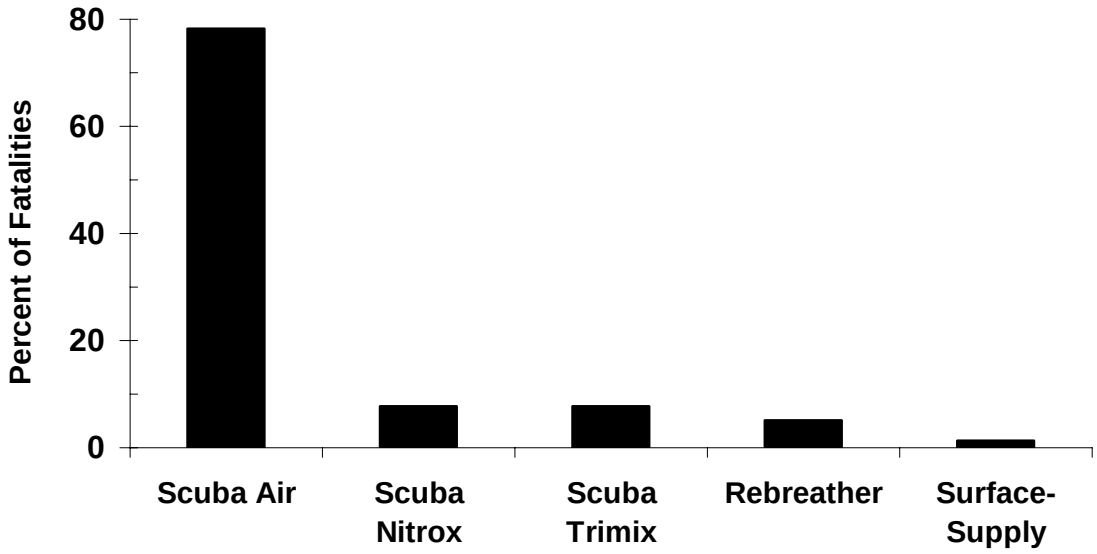

Figure 4.3-5 Breathing gear and gas for U.S. cases (n=73).

4.4 Analysis of situations and hazards

We explored each case according to: (a) the phase of the dive in which it occurred; (b) the chronological chain of events ending in death; and (c) the buddy system used.

Cause of death (COD) was usually the best defined characteristic of a diving fatality, but preceding events were frequently more relevant to understanding what happened. In reverse chronological order, we defined the key events as COD, disabling injury, disabling agent, and trigger. Where possible, we attempted to identify these events for all cases. The disabling injury was not necessarily the COD but was ultimately responsible for death. The disabling agent was the cause of the disabling injury, and the trigger was the event that began the sequence that ultimately culminated in death.

4.4.1 Fatalities by dive phase

Dive phases included: (a) on the surface before diving, (b) descent, (c) on the bottom, (d) ascent, and (e) on the surface after diving. Figure 4.4.1-1 shows the distribution of fatalities by dive phase and indicates that most deaths appeared to occur for divers on the bottom. Fatalities often began and evolved over several dive phases. Table 4.4.1-1 shows the phase when problems started and when the diver lost consciousness. Forty-two divers lost consciousness underwater, but their problems may have started earlier. No information was available in 34 percent of cases.

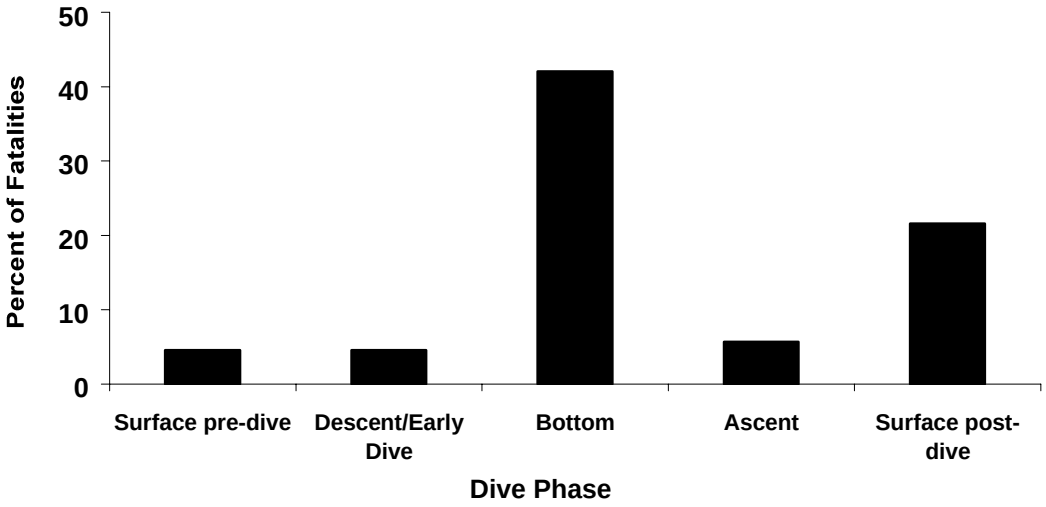

Figure 4.4.1-1 Distribution of fatalities by dive phase (n = 88).

Table 4.4.1-1 Accidents by stage of dive.

Problem started	Diver Lost Consciousness					
	Surface pre-dive	Under-water	Surface post-dive	Out of water	Unknown	Total
Surface pre-dive	3	1				**4**
On descent/early in dive		4			1	**5**
At the bottom		27	6		4	**37**
Ascent		3		1	1	**5**
Surface post-dive			16	1	2	**19**
Unknown		7			11	**18**
Total	**3**	**42**	**22**	**2**	**19**	**88**

Surface pre-dive. Problems began on the surface before submersion in four cases.

- A 55-year-old, obese diver struggled while donning his equipment, became fatigued during a surface swim from shore, was separated from his buddy, and was found drowned in shallow water without indication of having been diving.
- A healthy 61-year-old diver on a night dive with a group returned to the boat for unknown reason and was recovered from the water unconscious.
- A 48-year-old diver started a dive alone in a strong current, tried to return after removing some of his gear including his fins, and drowned before reaching shore.
- A 58-year-old diver panicked upon entering rough seas, returned to the boat out of breath, but decided to follow the other divers down the anchor line to a wreck at 80 fsw (24 msw). He was last seen descending at 20 feet and never arrived at the wreck.

On descent or early in dive. Problems began on descent or at an early stage of the dive in four cases.

- A 15-year-old novice diver on medication for attention deficit disorder entered shallow water off the beach, had a flooded mask at 8 fsw (2 msw), panicked, and drowned.
- A diver with a history of seizures and cocaine use was found entangled in an anchor line immediately after descent.
- A 55-year-old female diver experienced problems with her regulator immediately upon descent to 117 fsw (36 msw) and drowned. Examination of the regulator revealed a missing diaphragm seal.
- A 40-year-old diver spearfishing on a wreck at 196 fsw (60 msw) made a rapid ascent to 80 fsw (25 msw), and found convulsing at 150 fsw (46 msw) where he drowned.

At the bottom. Problems started on the bottom in 42 percent of cases (n=37). Twenty-seven divers (31 percent) lost consciousness at the bottom, eight divers were trapped, three were entangled, two may have had heart problems, and four lost consciousness for unknown cause.

Ascent. Problems started during ascent in 15 percent of cases (n=13), sometimes even after completing a 10-foot safety stop. In one case, a diver was lost in shallow water after his safety stop. Inspection of his rebreather indicated malfunctions due to poor maintenance and assembly.

Surface post-dive. Twenty-two divers lost consciousness after surfacing. The longer a diver is at the surface without symptoms, the less likely it is that death was due to injury on the bottom or during ascent.

Post-dive, out of water. Two deaths occurred after dives without obvious problems.

- A 63- year-old experienced diver with a history of heart disease collapsed on the boat after exiting the water.
- A 51-year-old experienced diver completed a 100 fsw (30 msw) dive and collapsed minutes later in the locker room. He was transferred to a hospital and treated for AGE but died of hypoxic brain injury a few days later.

4.4.2 Cause of Death

Figure 4.4.2-1 shows the distribution of COD in the judgment of the DAN pathologist who reviewed each case. Fifty-six cases (64 percent) were designated as drowning; acute heart condition was cited in 10 cases (8 cardiac dysrhythmia, one myocardial infarction, and one severe atherosclerosis). Arterial gas embolism was judged as COD in 9 cases (10 percent). COD was unknown in 10 percent (n=9) because the body was not found (n=4), or COD was not specified by the medical examiner.

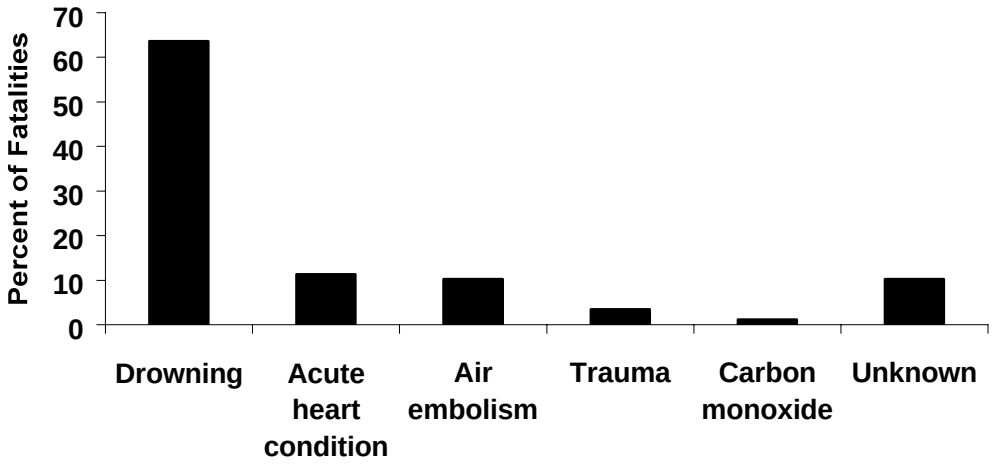

Figure 4.4.2-1 Cause of death (n=88).

4.4.3 Disabling injury

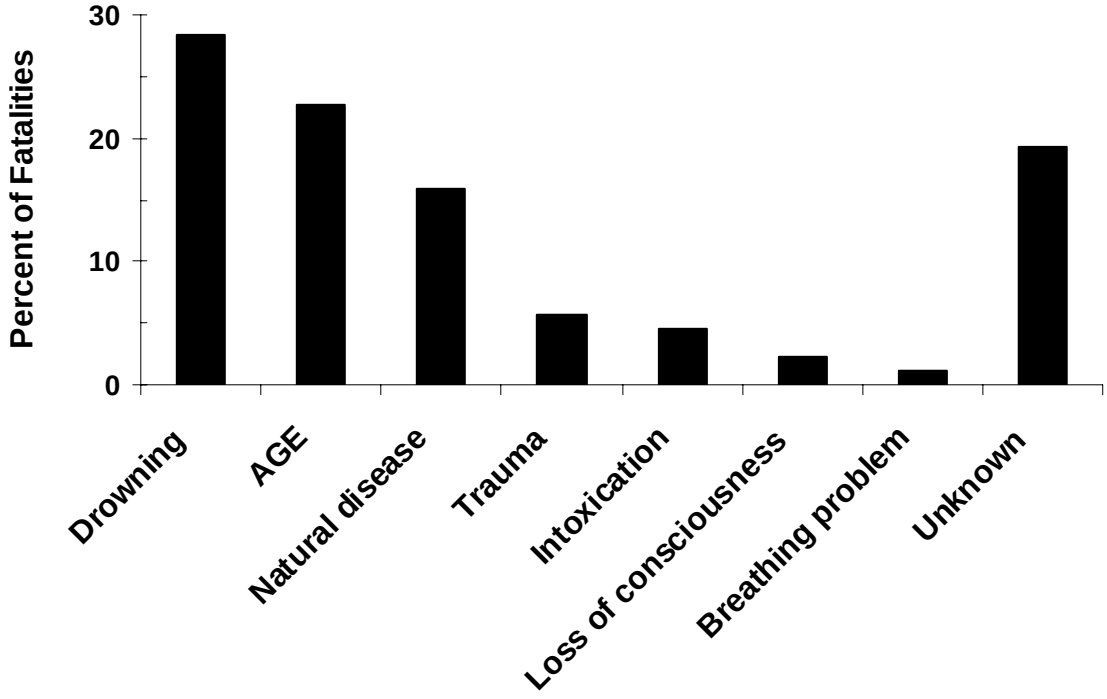

Figure 4.4.3-1 Disabling injury (n=71).

Drowning (25 cases). Drowning was cited as the COD in 64 percent of cases, but we identified drowning as the disabling injury in only 29 percent and only in circumstances where asphyxia and/or aspiration appeared to have immediately preceded death. For example, disabling injuries

were classified as drowning for divers who ran out of air in a cave, were entrapped, or sank to the bottom due to overweight or inability to inflate their BCs. Even if drowning was the COD, the disabling injury was classified as unknown if another disabling injury could not be excluded.

AGE (20 cases). AGE was identified as the disabling injury in 23 percent of cases, double that indicated by COD.

Trauma (5 cases). Two divers were struck by a boat, two were injured in rough seas near shore, and one was crushed under a boat in shallow water.

Intoxication due to unsuitable breathing gas (3 cases).

- One diver lost consciousness at depth and drowned after breathing gas that was contaminated with carbon monoxide.
- One diver using a rebreather was reportedly seen seizing at the bottom.
- One diver using a full face mask and breathing trimix was found unresponsive on the bottom. He appeared to have switched to oxygen while at depth.

Loss of consciousness due to unknown causes (2 cases).

- A 55-year-old experienced female diver made a dive to 296 fsw (90 msw) and lost consciousness at 107 fsw (33 msw) during an apparently normal ascent. Her body was retrieved an hour later. The autopsy was inconclusive.
- A diver at 110 fsw (34 msw) on a wreck in a cold lake signaled his buddies that he wanted to ascend and started toward the ascent line but lost consciousness and drowned before his companions were able to get him to the surface. Autopsy results were not available.

4.4.4 Disabling agent

Figure 4.4.4-1 shows disabling agents. Emergency ascent, entrapment or natural diseases were the disabling agents in 50 percent of all fatalities.

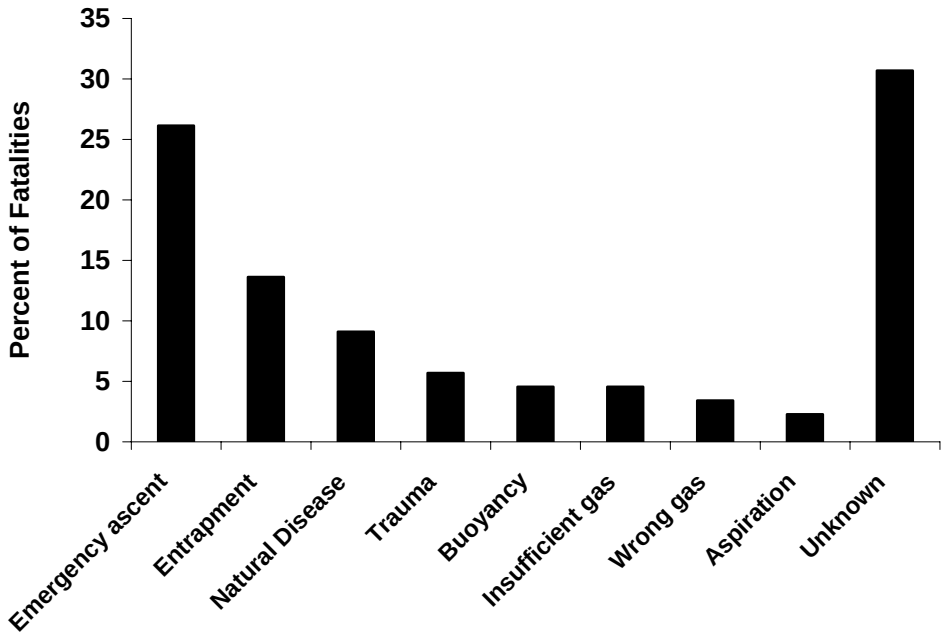

Figure 4.4.4-1 Disabling agents (n=88).

Emergency ascent (22 cases). Autopsies were done in 16 cases and reports available for 13.

- Eight divers had autopsy reports with objective findings of AGE (gas in brain circulation) or likelihood of pulmonary barotrauma such as subcutaneous emphysema, extra-alveolar air, or gas in the circulation).
- One diver had made many brief excursions (yo-yo diving).

4.4.5 Initial triggering event

Figure 4.4.5-1 shows the initial triggering event that began the sequence ultimately leading to death. The most frequent initial event was insufficient gas (14 percent) followed by rough seas and strong current (10 percent), natural disease (9 percent), entrapment (9 percent), and equipment problems (8 percent). The triggering event could not be established for 20 percent of the cases.

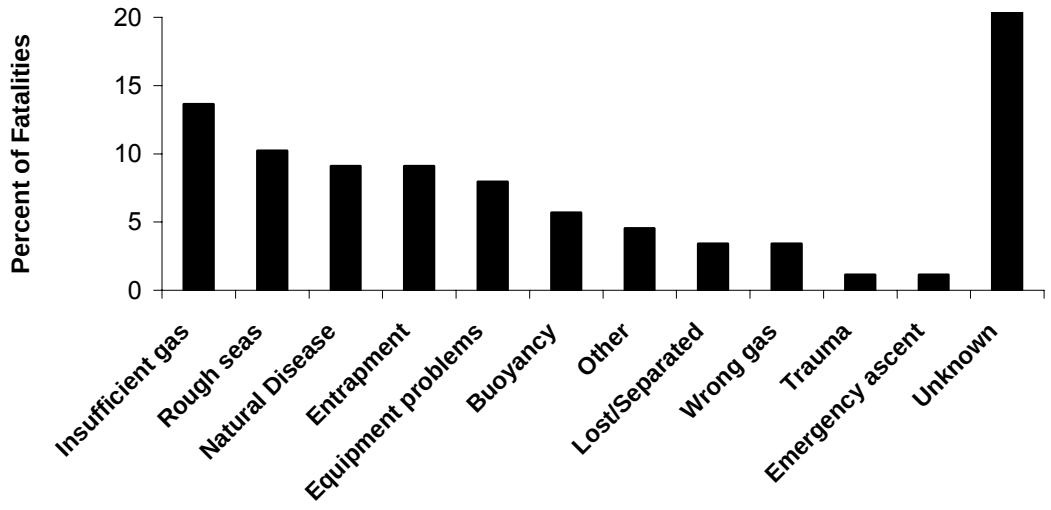

Figure 4.4.5-1 Initial triggering event (n = 88).

Insufficient gas (12 cases).

- Three divers ran out of air in a cave and drowned.
- Five divers ran out of gas or became low on gas at the bottom.
- Three divers made unsuccessful emergency ascents and two drowned at the bottom.
- An older diver with a history of heart disease completed a safety stop and surfaced in rough seas, but without enough gas to inflate his BC, he drowned.
- Three divers were reported to be out-of-air by witnesses or were assumed to have run out of air by the investigator without supporting evidence.

Rough seas, surf or strong current (9 cases). Six divers, either alone or in small groups, entered rough water from the shore. Three divers dived from boats.

Natural disease in favorable diving conditions (8 cases).

- Six divers were in their fifties and sixties.
- A 37-year-old male diver lost consciousness at the bottom which the medical examiner ascribed to an abnormally enlarged heart.

- A 47-year-old male died of an apparent heart attack while climbing a ladder after diving. He had ignored shortness of breath after diving on the previous day.

Entrapment in situations with known hazards (8 cases).

- Two divers were trapped in narrow caves.
- Two divers were entangled or trapped while wreck diving.
- One diver was crushed while inspecting a tug boat in shallow water.
- Two divers were trapped in drains, one in a pond and one in a canal.
- One diver was trapped under an ice-covered part of a lake.

Equipment problems (7 cases). The true incidence of equipment failure is uncertain because equipment was tested in only 35 cases, and test results were available only for 15. Equipment was not retrieved in six cases, and in 47 cases, there was no record of equipment testing. One or more equipment problems were documented in seven cases.

- Five divers had BC problems.
    - Three divers appeared to have made errors using their equipment.
    - Two divers could not inflate their BCs because of malfunction. Both sank to the bottom and drowned.
- One diver drowned due to inhalation of water from a missing diaphragm seal on his regulator.
- One diver using surface-supplied air had a knot in the supply hose that may have contributed to his death by reducing air flow.

4.4.6 Buddy system

A common diving safety recommendation is for divers to dive as buddy pairs. Figure 4.4.6-1 shows the number of divers in the dive party or group that included the diver who died. In 10 percent of accidents the diver was diving alone. In another 10 percent, the diver was with a group but dived alone.

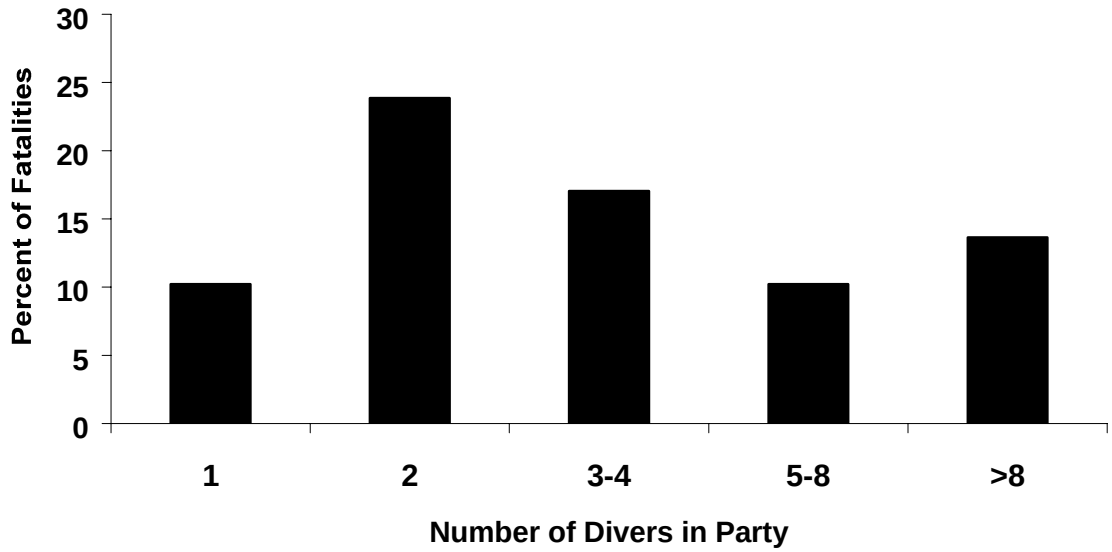

Figure 4.4.6-1 Number of divers in party (n=66).

The number of divers in the diving team is shown in Figure 4.4.6-2. The dive started with a formal buddy system in 45 percent of cases and with three or more divers in 19 percent. Fifty-three percent of the buddy teams separated during the dive and so really did not follow the buddy system. Separation of divers was sometimes a matter of choice and sometimes accidental. In some cases divers separated at the beginning of the dive because one diver delayed descent due to difficulty equalizing or needed some kind of equipment adjustment. Another typical separation occurred towards the end of the dive when one diver got low on breathing gas and ascended to the surface leaving the buddy behind.

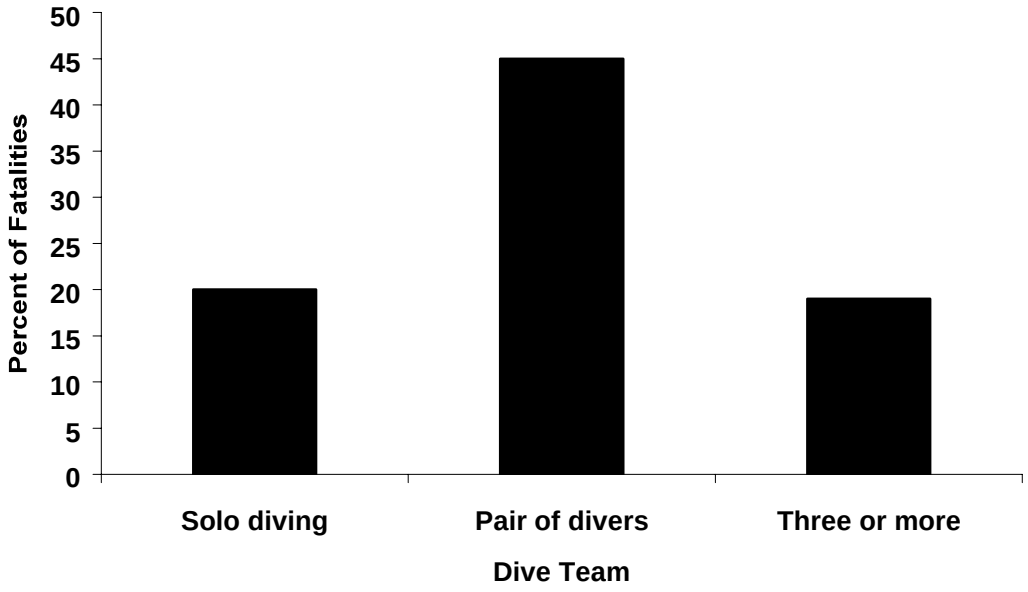

Figure 4.4.6-2 Number of divers in team (n=66).

5. BREATH-HOLD DIVING

5.1 Introduction

Breath-hold diving is defined as in-water activity without 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, weight belt, mask, snorkel and/or fin(s).

Breath-hold diving continues to experience a marked growth in popularity as an underwater sport. Potentially physically challenging, serious injury or death can result from problems encountered during the exposure. A database dedicated to breath-hold diving was established in 2005 to collect and disseminate information regarding breath-hold incidents, both fatal and non-fatal, and to improve awareness, training, and procedural development.

The purpose of incident data collection and analysis is not to assign blame but to learn from past events. Some accidents are just that - unfortunate events that can occur even when sound experience, planning, equipment and support are in place. These cases serve as a reminder of the fundamental risks and remind us to take as much care as we can in all things. Other accidents arise from flaws - flaws in equipment maintenance, equipment use, training, or procedures. Incident analysis and reporting can reduce the risk for all participants in the future. One of the challenges of accident investigation is that all of the facts are very rarely known. The effort can require a substantial amount of deductive reasoning and occasionally some guesswork to interpret events. In this review, we summarize the available data and speculate when reasonable. The case reports found in Appendix C provide brief summaries of documented information. The reader will be left to interpret these cases - hopefully with critical consideration of his or her own practices.

5.2 Cases in 2004

Most cases were initially identified through internet searches, typically in online newspaper articles. Some cases were reported to DAN directly by individuals involved in or aware of incidents. Cases were excluded if the available information was too limited to be evaluated.

Twenty-three cases are included in this summary. All but one (96 percent, n=22) involved fatalities.

Incidents were reported from nine different countries. Fifty-two percent (n=12) occurred in the United States. The U.S. incidents occurred in three states: California and Hawaii (each with 42 percent), and Florida (17 percent). The preponderance of U.S. incidents likely reflects a bias in the available reports rather than a true world-wide pattern. The distribution of U.S. incidents may partially reflect the popularity of breath-hold activities in certain states but could also include a reporting bias. It is anticipated that case identification will improve in all areas as our initiative becomes more recognized.

Details on the diving environment were available for 87 percent (n=20) of the known cases. The vast majority (90 percent) occurred in the ocean. One case occurred in a swimming pool and one in a freshwater lava tube.

Categorical descriptions of the primary activity of the incident victim were available in 96 percent of the known cases (n=22). The breakdown in shown in Figure 5.2-1. Snorkeling is the most commonly applied designator. Snorkelers may remain completely on the surface or participate in some breath-hold diving from the surface. Freedivers typically wear a mask and some form of fin or fins and direct their activity to breath-hold diving from the surface. Increasing dive depth and/or breath-hold time are common goals. The nature of the dives will vary dramatically with the individual skill and training level of participants. Spearfishing incorporates the act of underwater hunting for food into the breath-hold exercise. Collecting refers to underwater hunting without spear devices. Maximizing 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.

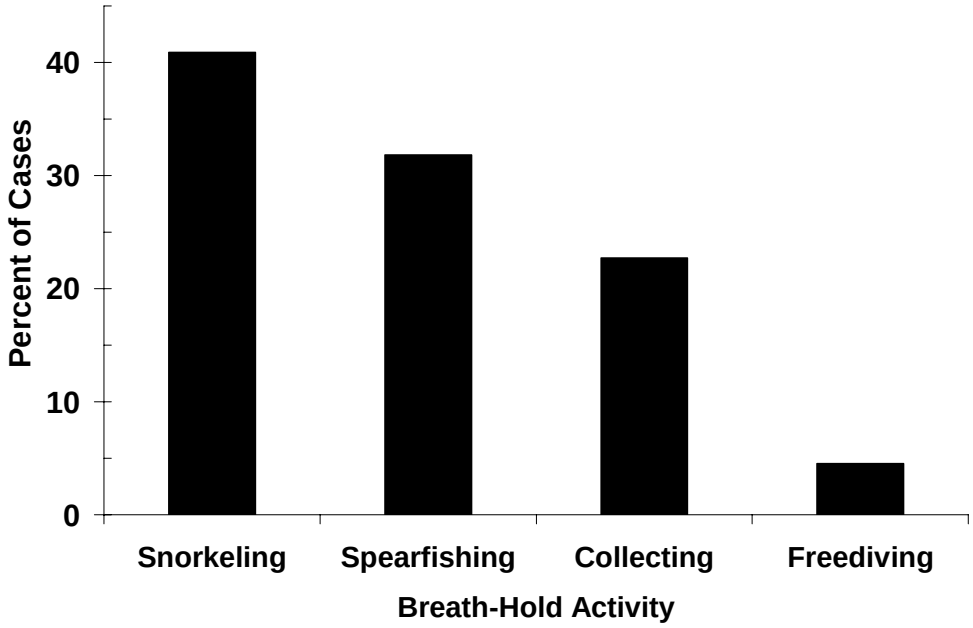

Figure 5.2-1 Distribution (percentages) of described primary activity for breath-hold incident victims in 2004 (n=22).

Figure 5.2-2 describes the information known regarding gender and age. Gender was available in all cases (n=23). All but one of the victims was male (96 percent; n=23). Age was available in 96 percent (n=22) of cases. The average age of victims (± standard deviation) was 41±16 years, ranging from 14 to 77 years.

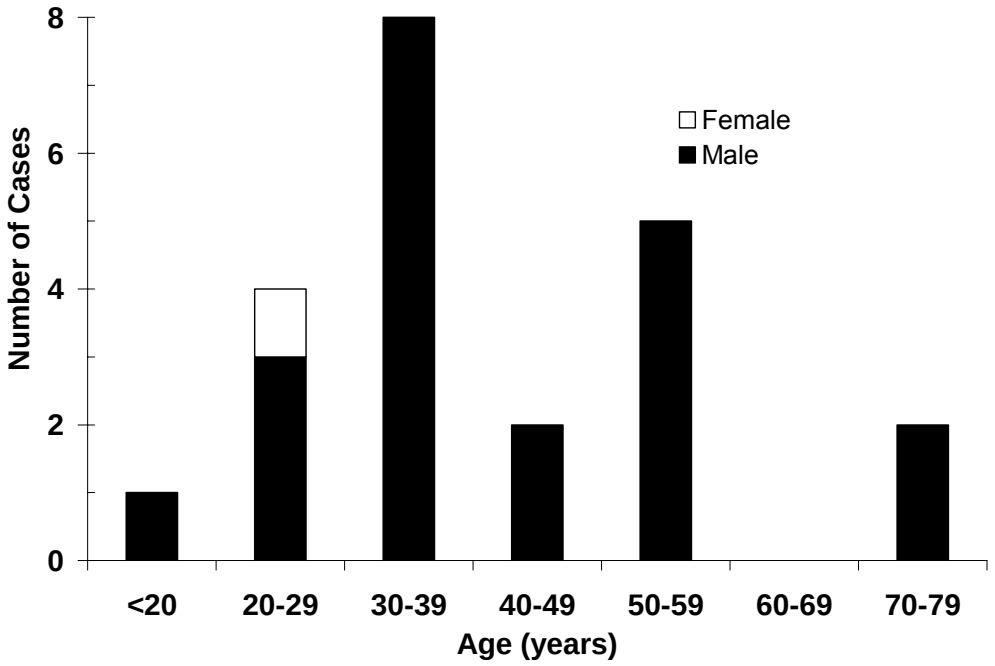

Figure 5.2-2 Age and gender distribution of breath-hold incident victims in 2004 (n=22).

Information regarding the support available to the diver was available in 91 percent (n=21) of cases. Dive partners were present in 52 percent, groups in 29 percent, and 'other support' (poorly documented) in five percent of the known cases. Solo diving was conducted in 14 percent of the known cases.

Assessments on the victim's experience with the activity were available in 43 percent (n=10) of cases. Victims were described as 'expert' in the majority of cases, and 'novice,' 'intermediate' or 'advanced' in one-each of the known cases.

Eyewitness presence was established in 83 percent (n=19) of the known cases. Witnesses were present for 53 percent. The availability of assistance to the victim was established in 91 percent of known cases. As expected, the pattern is similar to the presence of witnesses, with assistance available in 52 percent.

The record of body recovery was available for 91 percent (n=20) of the known cases. Bodies were recovered in 85 percent of the fatal incidents. The recovery depth was available in 61 percent (n=14) of the cases. Seven victims were recovered at the surface with others recovered from as deep as 85 fsw (26 msw) (Figure 5.2-3).

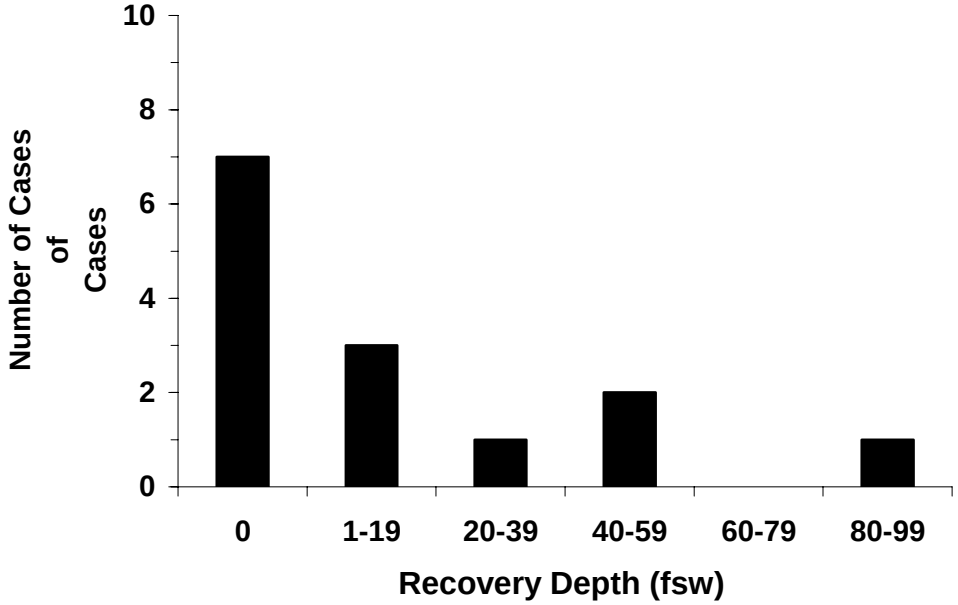

Figure 5.2-3 Recovery depth of body by depth for fatal breath-hold incident victims in 2004 (n=14).

5.3 Contributing Factors

The official cause of death is typically determined by medical examiners, but the usefulness of the findings is often limited, particularly for drowning. More important is the effort to identify the problem or problems that created the situation in which drowning, for example, could occur. The search for contributing factors can be challenging, particularly in the case of unwitnessed events. When fatal case files are completed as best can be done at DAN, they are forwarded to the DAN medical examiner (Dr. Caruso) who is experienced in diving medicine. He reviews all the data to confirm or, if warranted, expand upon the conclusions drawn by the initial medical examiner.

Records from initial medical examination were available for 59 percent (n=13) of the known fatal cases. The primary cause of death was determined to be drowning in most cases (9/13), followed by heart disease (2/13) and shark bite (1/13). Secondary medical examination was not completed for these cases.

Trigger events were documented in 43 percent (n=10) of the known cases. These included animal interactions (shark attacks; 4/10), weather conditions (undertow [1/10], rip current [1/10], and rough seas [1/10]), and one case classified under each of health problems (severe coronary arteriosclerosis) and boat interaction (propeller strike). Animal interactions may be relatively overrepresented given the ease of recognizing signs in many of these cases. Shallow water blackout was suspected in two other cases without supporting documentation.

5.4 Breath-Hold Diving Wisely

Breath-hold divers must be respectful of their limits. Voluntary breath-hold can be a simple effort, but also a dangerous one. The one fatal swimming pool incident in this sample stands as a good example. The victim was a 33-year-old male diving instructor practicing with no supervision. The specific factors leading up to his death cannot be determined, but the lack of apparent injury suggested that an unexpected loss of consciousness was involved. Pool breath-hold is often conducted as a challenge or training activity, with the primary focus on improving breath-hold time during resting (static) or swimming (dynamic) breath-hold. A variety of techniques, including relaxation and voluntary hyperventilation, may be practiced to increase performance. Pools can provide a relatively controlled setting to try new techniques and test personnel limits. The apparently benign nature of the environment, however, quickly turns if adequate safeguards are not in place. The most important practices to protect freedivers are direct supervision and access. Access is not usually a problem given the shallow water and good visibility. The absence of direct supervision was the critical problem in this case. Unconsciousness can result from seemingly modest efforts to prolong breath-hold time in many circumstances. The lack of warning that can precede unconsciousness is not something that can be 'overcome' by motivation or certifications. This is a prime example of how complacency can kill. Adequate safeguards are always required to ensure safety. The risks are dramatically reduced by close monitoring of a partner throughout his or her pre-breath-hold workup, the breath-hold and the first 30 seconds post- breath-hold (the risk continues post-breath-hold since it takes time for the oxygen in an inspired breath to reach the brain). A simple two-person, one-up-one-down buddy team with committed direct supervision will be sufficient to manage most potentially serious problems in a pool. While additional safeguards are required to ensure the same monitoring capability in more complex environments or breath-hold diving operations, the core concept is simple. Direct supervision during the pre-breath-hold, breath-hold, and post-breath-hold saves lives.

The case reports found in Appendix C provide additional opportunity to reflect upon how easy it can be to run into problems. They can be useful to think about when reviewing individual practices and procedures.

5.5 Summary

A dedicated program is in place to collect data on breath-hold diving incidents. The current report is predominantly comprised of fatal incidents. Documentation of non-fatal incidents remains elusive. Data from both fatal and non-fatal cases would provide valuable information to improve awareness, facilitate training and promote procedural evaluations. Further effort will be directed at expanding case reporting.

APPENDIX A. DIVE INJURY CASE REPORTS

Case 1 – Infrequent teenage diver with pain and sensory symptoms that became worse during flight and partially resolved on recompression.

A very fit 16-year-old male in excellent health had made 10 dives in his one year of certification. On the day of his injury, he made four dives during which he followed the divemaster. His morning dives were to 50 fsw (15 msw) for 30-35 minutes with a short safety stop, less than 45 minutes on the surface, and a second dive to 30 fsw (9 msw) for about 30 minutes with a 2 minutes safety stop at 15 fsw (5 msw). After a 5.5 hour surface interval, he dived to 50 fsw (15 msw) for 35 minutes with no safety stop. After a 10 minute surface interval, he again dived to 50 fsw (15 msw) for approximately 30 minutes with a 3 minute safety stop. The day was trouble-free.

He awoke the following morning with mild joint aches that increased in the early afternoon. The aching was most noticeable in his hands, knees, ankles and feet. He then developed an uncomfortable sensation in his arms and legs and did not feel well for the remainder of the day. He had never experienced similar symptoms.

At 42 hours after his last dive and 30 hours after the onset of symptoms, he flew home with his family at a cabin altitude of 6,000 ft (1,829 m). His joint pain was constant with position and movement, and he developed a slight swelling in his extremities. During the flight, the discomfort increased from a 5 to a 7-8 on a 0-10 scale. He was seen in the local hospital emergency department upon arrival that night. The odd skin sensations had resolved at the time of evaluation and no other signs or symptoms were found by the examining physician.

He was recompressed on a 5 hour, U.S. Navy Treatment Table 6 with incomplete symptom relief. There was no significant change the following morning during a 2 hour treatment. His symptoms improved over the following week.

Case 2 – Student diver diving at altitude with multiple symptoms that resolved with recompression 48 hours after onset.

The diver was an active 32-year-old female in good health except for smoking a pack-a-day for 15 years. She was taking an open-water certification course at an altitude of approximately 4,000 ft (1,219 m). Her first dive was to about 20 ffw (6 mfw) for 25 minutes with a slow normal ascent followed by a 15 minute surface interval. The next dive was to 60 ffw (18 mfw) for 10 minutes with a slow ascent to 20 ffw (6 mfw) and a 3 minute safety stop followed by a 90 minute surface interval. Her final dive began at 20 ffw (6 mfw) for 5 minutes, progressed to 45 ffw (13 mfw) for 10 minutes, and then to about 55 ffw (18 mfw) for 3 minutes. She surfaced after a slow ascent to 20 ffw (6 mfw) over 3 minutes and a 10 minute safety stop. The total bottom time was approximately

31 minutes with 60 ffw (18 mfw) the deepest depth. She returned home to an altitude that was 500 ft (152 m) higher than the dive site.

About one hour after her last dive, she noted tightness in her chest and pain on inhalation on the right side and in her right shoulder. She also had some shortness of breath with exertion. She slept well but had numbness on the surface of her entire left arm the following morning. In the afternoon, she developed tingling over her entire right leg.

The second morning, her symptoms had lessened but persisted, and she decided to seek evaluation 48 hours after onset. A local clinic ruled out pneumothorax despite continued chest discomfort and found no objective neurological signs despite continuing complaints of numbness and tingling. She was recompressed on a 5-hour Table 6 with full resolution during treatment. The final diagnosis was pain and mild neurological DCS.

Case 3 – Joint aches followed by numbness and tingling that became worse when flying and resolved with recompression.

A 25-year-old male diver, in good health, a non-smoker, and fit and active, had been certified for five years with advanced open water and mixed gas training. He had made seven dives in the past year and 40 since certification.

While on vacation, he made seven dives in four days. On the first three days he made 6 dives using a nitrox mix to a maximum depth of 90 fsw (27 msw). On the fourth day, he dived on air to 85 fsw (26 msw) for approximately 35 minutes with a brief safety stop at 15 fsw (5 msw). Upon exiting the water at noon, he began drinking alcohol with friends and by 4 pm, felt generalized joint aches with an unusual awkward feeling in his left arm. He went to bed and awoke the next morning with the same aches and pains that were not relieved by over-the-counter pain medications. He flew that afternoon and experienced new aches and pains which diminished on landing. After spending the night, he flew again with continuing symptoms.

He was evaluated by a dive physician at which time he complained of joint aches and tingling in his left hand. He experienced complete relief of symptoms half way through a 2.5-hr USN Treatment Table 5.

Case 4 - Instructor doing deep dive training developed numbness and tingling in hands and feet which resolved upon recompression.

A 33-year-old female instructor in good health and well rested had made over 200 dives in the past year and more than 600 in the past five years. She and a student made a shore entry air dive in 60^{o}F (16^{o}C) water wearing drysuits and using a dive computer. After a long surface swim, they descended to 160 fsw (49 msw) where they remained for 4 minutes before descending to 200 fsw (61 msw). They surfaced after a total dive time of 20 minutes and did a 4 minute stop at 15 fsw (5 msw) with followed by a long surface swim and walk up the beach. Both divers had been affected by nitrogen narcosis at depth and were fatigued after the long swim and walk. To avoid urinating in her drysuit, the dive instructor had limited her fluid intake.

She had a bad headache, which was common for her after cold water diving, with unusual fatigue and tingling in her hands and feet which she attributed to being cold even though it persisted longer than usual. Nine hours later, she was still symptomatic and was evaluated at a local hospital and transferred to another hospital with a chamber where she was recompressed on a

Treatment Table 6 with improvement. A second treatment the next day relieved all symptoms except fatigue that resolved the following day. She was diagnosed as having had neurological DCS.

Case 5 – Experienced recreational diver performed a single cold water dive and developed subjective symptoms that were largely relieved by recompression 48 hours after the dive.

A 32-year-old experienced male recreational diver had performed 15 dives in the past 12 months with a lifetime total of more than 200 dives, frequently in cold fresh water. He was in good physical condition, and his only medical problem was elevated cholesterol for which he took a prescription medication.

He made an uneventful air dive to 95 ffw (29 mfw) for 35 minutes with a safety stop on open circuit scuba. He wore a drysuit as the water temperature was 36°F which was 5-10 degrees colder than he was used to. He finished about 1 PM and carried his gear from the shore to his vehicle requiring significant exertion. There were no symptoms.

Upon awaking more than 48 hours later, he had numbness and tingling in the index finger and thumb of both hands which progressed to his forearms and biceps. He also felt mentally unclear and complained of pain in both shoulders and neck. The symptoms worsened during the day, and he sought medical attention at a local hospital with a hyperbaric unit.

The Emergency Room physician found no objective signs and referred the diver for evaluation by the hyperbaric physician whose findings were similar but decided to recompress the diver for his subjective complaints. Most of the symptoms cleared with the extended Table 6, and residual numbness in his fingers and thumbs resolved gradually over the next two weeks.

Case 6 – Blurred vision and motor weakness after 27 dives over 13 days resolved with first aid oxygen and recompression.

An experienced 57-year-old recreational diver had participated in 70 dives during the past year with a lifetime total of over 400 dives. He had a history of hypertension for which he took two medications. He occasionally took medication to aid sleep.

He was on a vacation at a resort where he participated in a total of 27 dives over 13 days. All his dives had been uneventful with a maximum depth of 82 fsw (25 msw) and a last dive depth of 62 fsw (19 msw). He dived according to the recommendations of his dive computer and performed safety stops on every dive.

Within 5 minutes of surfacing from the last dive, he noted blurred vision and then generalized motor weakness (more pronounced on the left than right) and decreased sensation in all extremities with the weakness being more pronounced on the left side. He was unable to stand without assistance. The boat crew placed him on first aid oxygen, and within 30 minutes, the blurred vision resolved, and his right extremities had returned to normal, but his left side remained weak although deep sensation had returned. He remained on oxygen for almost an hour and was taken to a local chamber where he was treated (exact treatment unknown) and experienced complete resolution of his symptoms.

Case 7 – Divemaster candidate experienced joint pain within three hours following six dives which were relieved by three recompressions.

A 26-year-old male divemaster candidate participated in six training dives over three days in which the deepest was to 70 fsw (21 msw), and the maximum depth of the last dive was 53 fsw (16 msw) with 34% nitrox. Dives were conducted in accordance with his dive computer. The last dive ended at approximately 1 PM. At about 4 PM, he noted right knee pain at a 7 on a 0-10 scale. Within an hour, he developed pain in his right wrist, left knee, and ankle pain which he rated 7 on a scale of 0 to 10. The symptoms did not improve during the day, and he became anxious with chest discomfort and difficulty on deep inspiration. He presented to the local Emergency Room at 1:30 AM and was referred for evaluation to the hospital hyperbaric unit. An initial treatment on Table 6 reduced the pain to 3 out of 10 in all affected joints, and he became pain free during a second treatment the same day with on Table 9 (45 feet for 102 minutes). He noted slight discomfort by next morning which resolved completely with another Table 9.

Case 8 – A diver with back trouble developed pain and motor weakness in his back and legs after 11 dives over three days complicated by altitude exposure. He had partial resolution during a long series of recompressions.

A 63-year-old male divemaster had made 50 dives during the past year and more than 200 lifetime dives. He had a history of degenerative lumbar disc disease and hypothyroidism for which he took synthetic thyroid hormone. He was on a liveaboard vacation and had made 11 dives over a 3 day period with a maximum depth of 128 fsw (39 msw) and a last dive depth of 100 fsw (30 msw). All dives were uneventful and used 32% nitrox with dive times according to an air computer.

He performed five dives the first day, four the second, and two morning dives on the third day. He stated he was well hydrated, well rested and had not consumed any alcohol. While returning to the boat after the second morning dive, he developed pain in his lower back consistent with his pre-existing disc condition, but he was able to climb onto the boat without assistance. He did not make another dive but opted to rest, have a back massage, and eat lunch. Feeling better, he participated in a walking tour of a local island which took him to an altitude of about 2,000 ft (610 m). During the tour, the back pain returned, and he had difficulty walking due to numbness in his legs but was able to return to the vessel where a physician also on vacation was concerned that might have neurological DCS. They informed the boat captain who placed the diver on first aid oxygen while they traveled to a nearby island with a hyperbaric chamber.

Upon evaluation, the hyperbaric physician found the diver had abnormal skin sensations bilaterally from his navel down to his toes, exhibited profound difficulty walking, and unsteadiness while standing. The diver was recompressed on Table 6 with extensions but had minimal improvement of his symptoms. Another Table 6 administered the following morning provided only slightly greater relief. Given the history of disc problems, the hyperbaric physician arranged for transfer to a hospital with greater diagnostic capability than on the island. As weather delayed air evacuation until the third day, the diver was treated again on a Table 5.

He was taken by air ambulance pressurized to one atmosphere to a larger hospital, but further diagnostic tests were inconclusive, and it was decided to continue hyperbaric therapy. The day after arrival, the diver received two treatments at 33 fsw (10 msw) for two hours with no improvement and later that day, a Table 6. Over the next seven days, he received 1-2 wound-care hyperbaric treatments (33 ft/10 msw) for 2 hours during which he reached a clinical plateau with no further improvement. His symptoms decreased over the next few months but intermittent symptoms continued, perhaps because of the existing disc problem.

Case 9 – An instructor had pain, numbness, and motor weakness after 14 dives at altitude over two days. The signs and symptoms improved with recompression and resolved completely with time.

A 52-year-old male recreational scuba instructor completed a series of 14 open-water training dives in two days. The first day involved six dives to a maximum depth of 60 ffw (18 mfw), and there were eight dives on the second day, three to a maximum depth of 103 ffw (31 mfw). All dives were completed using compressed air with corrections for an elevation of 5,000 ft (1,524 m). He made frequent ascents for training maneuvers and admitted to exceeding the limits specified by his computer.

Between his dives on the second day, he noted persistent right knee and ankle pain and later numbness and tingling of his right arm and leg that he hoped would go away and did not report. His drive home 24-hours later involved an additional ascent to 10,500 ft (3,200 m) which worsened his symptoms. He also noted mild right arm and leg weakness. At home, he again hoped his symptoms would resolve. When his symptoms persisted after 36 hours and he also developed right sided chest pain, he contacted the DAN Diving Emergency Hotline and was referred to a local hospital with a hyperbaric center.

On exam, the physician found weakness in the right arm, areas of decreased sensation to pinprick on the right arm and leg, and an unsteady tandem gait (heel to toe walking). A chest x-ray and cardiac workup were negative. He was recompressed on an extended Table 6 after which only mild right neck and right wrist pain remained. In total, the diver received four hyperbaric oxygen treatments over three days and was discharged with transient paresthesia of the right hand and wrist. Follow-up exams ruled out a patent foramen ovale (PFO), and he was cleared for return to diving after six-weeks if he remained asymptomatic and avoided severe exposures. After persisting for 12 months, the paresthesia was relieved by a surgical procedure to remove a ganglion cyst.

Case 10 – Subjective neurological symptoms on Day 9 during 18 dives over 12 days were relieved nine days after onset by three recompressions.

An experienced 41-year-old female diver was vacationing in Cozumel where she completed 18 multi-level dives over 12 consecutive days. Her maximum depth was 120 fsw (37 msw), and her dives were executed according to a dive computer. She admitted to several dives during which her computer displayed obligated decompression stops that she omitted because the computer had “locked-out.” She followed her dive buddy’s profile.

On day nine, she noted paresthesia in her left calf which persisted through the balance of her dive trip and during her flight home at 33 hours after her last dive although she denied an

increase in symptoms during flight. In the five days after arriving at home, she developed mild persistent tingling in her right arm and leg and right cheek. On the sixth day, she presented to her local hospital for evaluation.

Her physician was unable to elicit objective findings, and she received a Table 6 without extensions during which her symptoms resolved. Over the next three days, she had a gradual return of mild numbness and tingling for which received two additional HBO treatments at 2.4 ATA for 90 minutes. Her facial tingling resolved first followed by complete and sustained resolution of all other symptoms.

Case 11 – Mild neurological symptoms after omitted decompression resolved completely during recompression.

A 57-year-old male public safety diver with basic open-water certification made a series of two air dives at an elevation of 1,100 ft (335 m) in a single day for a body recovery. The depths were 91 ffw (28 mfw) and 61 ffw (19 mfw), and the bottom time of the second dive was seven minutes after which he made a rapid ascent and omitted required decompression but was asymptomatic at the surface.

Upon awaking the following morning, 16 hours following his final dive, he noted mild right calf tingling which gradually increased over the next 24-hours to the upper posterior aspect of the right thigh and persisted for the next four days. On the fifth day, he presented to his local hospital for evaluation, but the examining physician was unable to elicit any objective findings. The patient was given surface oxygen for one hour without effect and was treated on a Table 6 without extensions which resulted in complete resolution of symptoms within 10 minutes during his first oxygen breathing period. The patient was discharged asymptomatic.

APPENDIX B. DIVE FATALITY CASE REPORTS

B.1 Proximate Cause: Air Embolism

04-65 Diver with unknown certification and experience, collapsed on ladder after dive

Cause of Death: Air Embolism

Little information is available on the death of this 56-year-old male who was diving while on vacation. His certification status and experience level are unknown. The diver apparently collapsed while on the ladder exiting the water after the dive. While one report states that this was a cardiac event, there was no evidence to substantiate that and the history is more consistent with an air embolism.

04-01 Obese diver with moderate experience, separated from buddy, ran out of air and made rapid ascent

Cause of Death: Air Embolism due to Rapid Ascent

This 58-year-old male had advanced certification and a moderate amount of diving experience. Medical problems included glaucoma and obesity. He was making a series of dives on Nitrox. During his second dive of the day he spent 34 minutes at 70 fsw (21 msw) and became low on gas. There was a problem during ascent and the diver became separated from his buddy as they approached the safety stop. His buddy reported seeing him being assisted into the boat. The diver had dropped his weight belt and removed his mask. He was unconscious in the boat and could not be resuscitated. An autopsy was performed but the report was not made available. The cause of death was reported to be drowning but the circumstances are much more consistent with an air embolism. The diver's tank was empty.

04-03 Inexperienced, obese diver made solo dive, made rapid ascent, surfaced in distress and quickly lost consciousness

Cause of Death: Air Embolism due to Rapid Ascent

This 56-year-old male was a certified diver who had made two dives in the previous twelve months. He was obese and has an elevated cholesterol level. His occupation was listed as "disabled" but the disability was not further defined. The diver entered the water alone to retrieve an anchor in 17 fsw (5 msw). He surfaced in distress, called out for help, and quickly became unconscious. Resuscitation efforts were unsuccessful. The diver's equipment was incomplete and in poor repair. The reason for his rapid ascent is not known. The autopsy disclosed evidence of pulmonary barotrauma to corroborate the diagnosis of air embolism.

04-06 Experienced but infrequent diver in recertification course, multiple health problems and medications, surfaced short of breath and lost consciousness

Cause of Death: Air Embolism due to Rapid Ascent

This 62-year-old male was reported to be an experienced diver but hadn't been diving recently and was participating in a recertification course. He had multiple medical problems, including hypertension, coronary artery disease, abnormal heart rhythms, and depression. The diver took several medications for these medical problems. He surfaced short of breath after a 40-minute dive to 40 fsw (12 msw), and lost consciousness shortly thereafter. The body was embalmed prior to the autopsy, which showed moderate coronary artery disease and a thickened left ventricle. While this death was most likely due to an air embolism, a cardiac event cannot be excluded.

04-12 Inexperienced diver with multiple medical problems, trouble at beginning of dive, became separated from buddy, panicked and surfaced unconscious

Cause of Death: Air Embolism due to Rapid Ascent from Panic

This 64-year-old male received his initial open-water certification one month earlier and had completed five or six lifetime dives. He had a significant past medical history that included hypertension, elevated cholesterol levels, prior coronary artery bypass surgery, and a history of prostate cancer. After some difficulties getting suited up, the diver made a slow descent and had some trouble with his mask but eventually made it to a wreck, which was at 110 fsw (34 msw). After 10 minutes on the bottom he and his buddy ascended to 80 fsw (24 msw) where they became separated. The diver surfaced unconscious. An autopsy disclosed atherosclerosis of the coronary arteries, the cerebral arteries, and the aorta and evidence of old myocardial infarcts. The coronary grafts were patent. There was also intravascular gas and subcutaneous and mediastinal emphysema. The cause of death was an air embolism.

04-25 Experienced, obese instructor and technical diver, on multiple medications, made deep dive to wreck, panicked on ascent and missed decompression stops, lost consciousness at 30 feet

Cause of Death: Air Embolism due to Rapid Ascent from Panic

This 42-year-old female was a very experienced dive instructor and technical diver. The diver was on multiple medications, including benzodiazepines, antidepressants, an inhaler, medication for high blood pressure, and numerous over-the-counter drugs and herbal supplements. She was also obese. She and three other divers were making a dive to 205 ffw (63 mfw) in a freshwater lake to examine a wreck. During the ascent phase of the dive, the decedent panicked and skipped her decompression stops. She refused assistance from her dive buddies and lost consciousness at approximately 30 ffw (9 mfw). She was taken to the surface by her dive buddy but resuscitation efforts were unsuccessful. Her buddy had omitted some decompression and was treated in a hyperbaric chamber. The autopsy showed subcutaneous air and abundant intravascular gas.

04-31 Obese diver with unknown experience, quickly ran out of air, assisted to surface where he lost consciousness

Cause of Death: Air Embolism due to Rapid Ascent from Insufficient Air

This 47-year-old male received his initial open-water certification one year earlier but his diving experience level is unknown. He was morbidly obese and took medication for hypertension. He was with a group of four other divers, including the divemaster. The group entered the water from a boat and descended to 33 fsw (10 msw). The decedent used nearly his entire tank within the first 30 minutes of the dive. He declined using the divemaster's alternate air source and he and the divemaster surfaced. The diver was sent back to the boat and the divemaster went back

down to the other divers. The decedent lost consciousness on the surface and could not be resuscitated. The autopsy disclosed intravascular air in the blood vessels of the brain and heart as well as pulmonary barotrauma. The dive computer showed several periods of rapid ascent. The medical examiner certified the death as due to an air embolism.

04-24 Poorly conditioned diver, tobacco abuse, did solo dive, surfaced in distress and lost consciousness

Cause of Death: Air Embolism due to Pulmonary Barotrauma

This 52-year-old male was a certified diver with an unknown amount of diving experience. The diver was known to be a heavy smoker. He made a solo descent to approximately 40 fsw (12 msw) to check the anchor. The diver was noted to surface, waving his arms in distress. He then lost consciousness and could not be resuscitated. The autopsy revealed large amounts of intravascular gas as well as evidence of pulmonary barotrauma. Natural disease processes included obesity, mild atherosclerosis of the aorta and pulmonary emphysema, a risk factor for pulmonary barotrauma.

B.2 Proximate Cause: Drowning / Air Embolism

04-46 Inexperienced, obese diver on weight loss medication made solo shore dive, called for help and lost consciousness, body found several hours later

Cause of Death: Drowning due to Air Embolism

This 48-year-old female received her open-water certification one month prior to her death and she had minimal diving experience. She was overweight and used phentermine and fenfluramine as a method to attempt weight loss. The diver made a shore entry solo dive and was collecting shells and other items from the bottom. She did not wear a buoyancy compensator and did not use a buoy or dive flag. She stayed in approximately 15 fsw (5 msw), making numerous excursions to depth. The diver called out for help prior to losing consciousness. Her body was recovered from the bottom three hours later. The autopsy disclosed changes associated with drowning as well as gas in the large veins and the right side of the heart. The medical examiner felt that the diver had suffered a venous gas embolism but this more likely represents an arterial gas embolism based on the history. The intracardiac and intravenous gas likely represents a postmortem change artifact.

04-54 Student in OW class on check out dive, performing towing skill, struggled and lost consciousness

Cause of Death: Drowning due to Air Embolism

This 50-year-old male was a student in an initial open-water certification class completing his fourth check-out dive. The dive was with an instructor and one other diver using a shore entry into a lake. He was practicing rescue procedures and ascended from 15 ffw (5 mfw) prior to towing a fellow diver as part of the training evolution. While towing the diver the decedent first began to struggle a little and then lost consciousness. Resuscitation efforts were unsuccessful. The autopsy disclosed changes associated with drowning as well as intravascular gas. This was most likely a drowning secondary to an air embolism.

04-56 Student in OW class with moderate heart disease, witnessed to have seizure on ascent

Cause of Death: Drowning due to Air Embolism

This 52-year-old male was a student in an initial open-water certification class who made a shore dive into the ocean with a buddy. The diver used a decongestant nasal spray prior to the dive because he was congested. His medical problems included an elevated cholesterol level and high blood pressure. The decedent suffered what appeared to his buddy to be a seizure while ascending from 51 fsw (16 msw). The problem seemed to occur at approximately 30 fsw (10 msw). He was brought to the surface but could not be resuscitated. The autopsy demonstrated changes associated with drowning as well as moderate atherosclerosis of the coronary arteries and aorta. He also had intravascular gas and mediastinal emphysema. The death was determined to be a drowning due to an air embolism.

04-29 Obese diver with heart disease on night dive for AOW certification, had problems with mask, panicked and made rapid ascent to surface and lost consciousness

Cause of Death: Drowning due to Air Embolism due to Rapid Ascent

This 50-year-old male had basic open-water certification with six lifetime dives. He was enrolled as a student in an advanced open-water class. The diver was also obese. During the day the diver completed two uneventful dives to 30 fsw (10 msw) and a night dive was planned for the evening. For the night dive the students entered the water from the boat; visibility was poor. The decedent had problems clearing his mask and spit out his regulator. Despite coaching by the instructor the student panicked and made a rapid ascent. He lost consciousness shortly after reaching the surface. The autopsy revealed changes associated with drowning as well as air embolism. He also had moderate to severe coronary artery disease and cholelithiasis.

04-63 Solo diver certified many years with unknown experience, on spearfishing dive, made rapid ascent and lost consciousness at surface

Cause of Death: Drowning due to Air Embolism due to Rapid Ascent

This 42-year-old male had been a certified diver for twenty years, but his level of experience is unknown. The diver made a solo dive from a boat for the purpose of spearfishing. He surfaced from a dive to 89 fsw (27 msw) and rapidly lost consciousness. Resuscitation efforts were unsuccessful. The autopsy disclosed changes associated with drowning, as well as pulmonary and ear barotrauma, and gas in the arteries at the base of the brain. The decedent's computer showed that he made a rapid ascent on this fatal dive profile and in fact that he habitually made rapid ascents.

04-84 Infrequent diver with unknown experience and certification level, diving on rebreather for first time, separated from buddy, made rapid ascent and sank, body recovered later

Cause of Death: Drowning due to Air Embolism due to Rapid Ascent

The certification status and experience of this 56-year-old female is unknown and she had not made a dive in the previous two years. She was using a rebreather for the first time to make an ocean dive to 50-60 fsw (15-20 msw). While she had a buddy early in the dive, she was diving solo at the end. According to her computer she made a rapid ascent to the surface and then sank back down. Her body was recovered 30 minutes later. An autopsy was performed but only the death certificate was made available. The cause of death was listed as drowning but in all likelihood the diver likely was incapacitated by an air embolism.

04-85 Diver with unknown certification and experienced, had equipment trouble, panicked and made a rapid ascent

Cause of Death: Drowning due to Air Embolism due to Rapid Ascent

The certification status and experience of this 57-year-old female is unknown. She was making a dive to 90 fsw (30 msw) with a buddy when she had trouble with her mask and regulator. The decedent panicked and made a rapid ascent. Her buddy tried to render aid and ended up sustaining decompression sickness. The decedent lost consciousness after the ascent and was pronounced dead at a local hospital. An autopsy was not performed but this appears to be a drowning due an air embolism caused by a rapid ascent.

04-33 Experienced, but obese technical diver and instructor on spearfishing wreck dive using trimix, lost consciousness at depth and had seizures entire way to surface

Cause of Death: Drowning due to Seizure due to Air Embolism

This 50-year-old male was a very experienced technical diver and instructor. His only known medical problem was obesity. The diver made a wreck dive using trimix for the purpose of spearfishing. The original descent was to 192 fsw (60 msw). The diver then ascended to 80 fsw (24 msw) before heading back down to 150 fsw (46 msw). At that point he suffered a witnessed loss of consciousness and began to seize. The diver seized the entire time he was assisted to the surface, where he died. The autopsy disclosed gas in the blood vessels of the brain, neck, and chest. While these may be indicative of an air embolism, the findings may also be artifact from performing such a deep dive. The death was signed out as a drowning due to an air embolism. The breathing gas used would have had a low risk of causing a seizure but that is also a possibility.

B.3 Proximate Cause: Cardiac

04-40 Diver with unknown certification and experience, diving on wreck and lost consciousness at depth

Cause of Death: Cardiac Dysrhythmia

Information about the certification and experience of this 53-year-old male is unavailable. He was diving in a river on a wreck with a group of divers. The decedent lost consciousness at depth and an instructor quickly brought him to the surface. Resuscitation efforts were unsuccessful. Autopsy information was not made available but this most likely represents a cardiac event. The instructor was evaluated for a possible air embolism.

04-71 Student in OW resort class, surfaced with trouble breathing and lost consciousness

Cause of Death: Cardiac Dysrhythmia due to Coronary Atherosclerosis

This 41-year-old male was making his first lifetime dive in an open water certification class. As the decedent was on vacation this may have been a resort course. There were a total of five divers making a dive from a boat. One of the other students became low on air and the instructor took him to the surface. The decedent then surfaced and was complaining of having trouble breathing. He lost consciousness during the surface swim and could not be resuscitated. The death was attributed to a cardiac event.

04-79 Diver with unknown experience and certification, heart disease and on medication, shortness of breath on previous day's dive and surface this dive, lost consciousness on boat

Cause of Death: Cardiac Dysrhythmia due to Coronary Atherosclerosis

This 47-year-old male was a certified diver but his level of experience is unknown. He took medication for hypertension and was also a heavy smoker. The diver was making a series of dives from a boat over a period of multiple days. After his last dive of the previous day the decedent complained of severe shortness of breath. During his first dive of the next day the diver went to 101 fsw (30 msw) for 20 minutes with a buddy. He signaled to the buddy that he wanted to ascend. The buddy accompanied the diver to the ascent line but decided to stay on the bottom as the decedent ascended. The diver again complained of severe shortness of breath after surfacing. He was assisted into the boat where he lost consciousness a short time later and could not be resuscitated. The autopsy findings included severe coronary atherosclerosis and hypertensive heart disease. The cause of death was determined to be a cardiac event.

04-86 Unknown certification and experience of diver making a dive to gather lobster, had unknown problem at depth, surfaced and lost consciousness

Cause of Death: Cardiac Dysrhythmia due to Coronary Atherosclerosis

The certification status and experience level of this 55-year-old male are unknown. The decedent was making a dive from a boat with three other divers in order to gather lobster. The decedent had some unknown problem on the bottom and surfaced early. She then lost consciousness and could not be resuscitated. In all likelihood the cause of death was a cardiac event.

04-81 Obese diver with unknown experienced, had heart disease and on medication, lost consciousness on boat after dive

Cause of Death: Cardiac Dysrhythmia due to Coronary Atherosclerosis, Severe

The certification status and experience level of this 63-year-old male diver is unknown, though a newspaper article called him an "experienced diver." He was obese and had hypertension for which he took medication. The diver collapsed on the boat after completing a dive. An autopsy disclosed severe coronary artery disease and hypertensive changes of the heart.

04-83 Obese diver with unknown certification and experience level, made a wreck dive in rough seas, spit out regulator during descent and lost consciousness on surface

Cause of Death: Cardiac Dysrhythmia due to Coronary Atherosclerosis, Severe

The certification status and experience level of this 39-year-old male is unknown. His known medical problem was marked obesity. He was making a wreck dive from a boat in rough seas several miles offshore. The story isn't entirely clear but apparently the diver spit his regulator out during descent and ascended with his buddy. He would not take an alternate air source from his buddy and subsequently lost consciousness on the surface. Initially the death was attributed to drowning due to a cardiac event, but after a complete autopsy the medical examiner decided that the death was purely cardiac. The autopsy demonstrated severe coronary artery disease, left ventricular hypertrophy, and a fatty liver.

04-04 Moderately experienced diver fatigued after dive, towed by buddy on surface and lost consciousness, heart condition found on autopsy

Cause of Death: Cardiac Dysrhythmia due to Cardiomegaly

This 55-year-old male had been certified for one year and had made 30 lifetime dives. He completed a 30-minute dive to 30 fsw (10 msw) and complained of fatigue after surfacing. During

the surface swim the decedent's dive buddy had to tow him and during that time the decedent lost consciousness. An autopsy was performed but a cause of death was not conclusively demonstrated. Significant findings included pulmonary emphysema and cardiomegaly. The medical examiner postulated that a small air embolism may have caused the diver's death and the decedent did have pulmonary emphysema, a risk factor for AGE. The history appears to be more consistent with a cardiac event, however.

04-07 Poorly conditioned diver with multiple medical problems and unknown experience, had difficulty breathing at surface before dive, found unconscious on surface

Cause of Death: Coronary Atherosclerosis

This 55-year-old male had multiple medical problems including hypertension, coronary artery disease, and obesity. He was reported to be a certified diver; his level of experience is unknown. The diver made a shore entry with his son and within a short period of time complained of difficulty breathing through his regulator. He began to head back to shore and his son submerged for a couple of minutes. It is unclear if the diver ever submerged. He was found unconscious on the surface and resuscitation efforts were unsuccessful. The autopsy demonstrated focally severe coronary artery disease, left ventricular hypertrophy, toxicology positive for hydrocodone and diphenhydramine (in urine only). The death was determined to be due to a cardiac event.

04-13 Experienced but obese diver with heart disease and tobacco abuse, spearfishing in rough seas, separated from buddies at surface, body found one hour later

Cause of Death: Hypertensive Heart Disease

This 53-year-old male was a very experienced diver with basic open-water certification. The diver was obese and smoked cigarettes. He was spearfishing with two dive buddies, making a dive from a boat to 50 fsw (15 msw) in a rough sea state. After a seemingly uneventful but short dive, the diver was seen drifting away from the boat and his dive buddies while they were all on the surface. The body was recovered one hour later. The autopsy disclosed evidence of hypertensive heart disease, mild pulmonary emphysema, and marked fatty change of the liver. The death was determined to have been due to a cardiac event.

04-18 Experienced dive instructor was training student on rebreather, separated from student at depth, body recovered later

Cause of Death: Myocardial Infarction due to Coronary Atherosclerosis

This 53 year-old, experienced, dive instructor was on a rebreather training dive with one student. Approximately 8 minutes into the dive, at a depth of 160 fsw (49 msw), the student stopped to clear his mask and the divers became separated. The student saw the instructor above him for a moment and then he lost visual contact. The instructor's body was recovered later. An autopsy report was not made available but the cause of death was reported to be a myocardial infarction.

B.4 Proximate Cause: Drowning / Cardiac

04-08 Diver with moderate experience and heart disease, made several dives in several days, surfaced out of air and could not inflate his BC, struggled and lost consciousness

Cause of Death: Drowning due to Cardiac Dysrhythmia

This 52-year-old male was a certified diver with a moderate amount of experience. He was making the last planned dive in a series of 16 dives that took place over several days. He and his buddy spent 25 minutes at 90 fsw (27 msw), completed a safety stop, and surfaced

approximately 100 ft (30 m) behind the boat. The decedent indicated that he was out of air and could not inflate his buoyancy compensator. He struggled on the surface and lost consciousness before making it back to the boat. The autopsy report was not made available but the death was determined to be a drowning due to a cardiac event. The decedent had a history of hypertension and elevated cholesterol levels. With the seemingly controlled ascent, an air embolism is less likely though still a possibility.

04-49 Newly certified diver with heart disease, planned dive to wreck but didn't reach depth, witnessed to swim away from group, found unconscious on surface

Cause of Death: Drowning due to Cardiac Dysrhythmia

This 51-year-old male had recently received his initial open-water certification and had only made 6 lifetime dives. He was making a shore entry dive down to a wreck with a group of divers. The water in the area was 50 fsw (15 msw) but the decedent only made it down to 13 fsw (4 msw) for a bottom time of 4 minutes. The decedent was witnessed swimming away from the group and then was brought to the beach by two surfers who found him unconscious on the surface. There was no evidence of pulmonary barotrauma at autopsy but there was significant coronary artery disease and left ventricular hypertrophy. The death was determined to be a drowning due to a cardiac event. An evaluation of the decedent's equipment showed that he was wearing 24 ½-pounds.

04-50 Diver with unknown experience and heart disease, made shore dive with inexperienced buddy who ran low on air and surfaced but victim did not, found unconscious on bottom

Cause of Death: Drowning due to Cardiac Dysrhythmia

This 38-year-old male had an unknown amount of diving experience but had been certified for 3 years. He made a shore entry dive to 50 fsw (15 msw) with a large group and with a somewhat inexperienced buddy. The buddy became low on air and signaled to the decedent to surface but only the buddy surfaced. The decedent was found unconscious on the bottom 30 minutes later. Resuscitation efforts were unsuccessful. The autopsy demonstrated changes associated with drowning as well as atherosclerosis of a coronary artery that supplies a critical area of the heart. He also had hypertrophy of the left ventricle of the heart, fat infiltration of the right ventricle of the heart, and fatty change of the liver.

04-78 Inexperienced, recently certified diver with multiple medical conditions and medications, buoyancy problems at depth, buddy couldn't assist to surface, lost consciousness and found on bottom

Cause of Death: Drowning due to Cardiac Dysrhythmia

This 56-year-old male had multiple medical problems including insulin-dependent diabetes mellitus, severe coronary artery disease. One and a half years earlier he required stents to be placed in his coronary arteries. The diver was on numerous medications, including an anticoagulant. Both he and his wife had received their initial open-water certification one month earlier and completed five lifetime dives (a number reported in the same newspaper article that called them experienced divers). The diver and his buddy made a shore entry dive in a lake and he had buoyancy problems while at depth. His buddy attempted to render assistance but could not physically get him the surface. The diver lost consciousness at depth and his body was brought up 30 minutes later. An autopsy was performed but the report was not made available. The death certificate lists cardiovascular disease as the cause of death, but it was signed by a Justice of the Peace rather than a physician. The accounts of rescue personnel who describe fluid in the airway and the circumstances make drowning due to a cardiac event a much more likely scenario.

B.5 Proximate Cause: Drowning / Insufficient Air

04-32 Uncertified diver on second lifetime dive from shore in poor visibility, ran out of air and was witnessed to be in distress at surface, she descended during surface swim to shore, recovered hours later

Cause of Death: Drowning due to Insufficient Air

This 38-year-old female was uncertified and making her second lifetime dive. There are conflicting stories between whether she entered the water alone or with her boyfriend, who was a divemaster. It was a shore entry dive with poor visibility to a depth of 15 ffw (5 mfw) in a lake. If she was diving with a buddy they became separated. Witnesses saw her have trouble at the surface and then she descended again during the surface swim back to shore. Her body was recovered 2 hours later. An autopsy was performed but the report was not made available. The decedent's tank was empty. The cause of death was reported to be drowning.

04-39 Inexperienced diver with asthma and heart disease, on medications, diving with buddy and separated, found later unconscious on bottom

Cause of Death: Drowning due to Insufficient Air

This 50-year-old male had been certified for less than a year and had minimal diving experience. His medical history included mild asthma for which he used an inhaler. The decedent was diving for scallops with a buddy and spent 30 minutes at approximately 60 fsw (18 msw). The divers became separated and the decedent was found on the bottom unconscious. He was pronounced dead at a local hospital. The autopsy disclosed changes associated with drowning as well as mild coronary artery disease. The diver's tank had 60 psig remaining when it was examined. The exact contribution of the natural disease processes cannot be determined, but it is more likely a drowning due to running out of air.

04-47 Diver with moderate experience but dived infrequently, diving at higher altitude with buddy, separated and found later unconscious, floating on the surface

Cause of Death: Drowning due to Insufficient Air

This 53-year-old female was a certified open-water diver with moderate experience, but she was an infrequent diver. She made a dive into a lake with a buddy to approximately 30 ffw (9 mfw). The lake was located at an altitude of greater than 8000 feet. As the dive progressed, her buddy noticed that the decedent was low on air and signaled for her to meet him at the safety stop. When she did not arrive at the safety stop the buddy searched for the diver. She was found minutes later, unconscious and floating on the surface with her buoyancy compensator inflated. Her tank was empty. An autopsy report was not made available but the medical examiner determined the cause of death to be drowning.

04-57 Diver with unknown experience made a dive with buddy to wreck, ran out of air, separated from buddy, found unconscious on bottom

Cause of Death: Drowning due to Insufficient Air

There is little information about the death of this 47-year-old female. Her dive certification status and diving experience are unknown. She and a buddy made a dive from a boat into a lake to look at a wreck. The decedent had some sort of an out of air emergency at 60 ffw (18 mfw), and the divers became separated. The diver was found unconscious on the bottom. An autopsy was performed, but the findings were not made available.

04-61 Inexperienced diver had buoyancy problems and weight problems on all dives of the day, returned to boat through kelp bed and became separated from buddy, found unconscious on the bottom

Cause of Death: Drowning due to Insufficient Air

This 37-year-old male was a certified diver with twenty lifetime dives. He was making a series of dives from a boat. The diver had buoyancy problems during the first dive of the day. During the initial stages of the second dive of the day, he first forgot his weight belt and only had weights in his buoyancy compensator pockets. The diver returned to the boat and retrieved his weight belt but he still had problems with buoyancy. The decedent and his dive buddy were returning to the boat and went through a kelp bed, where they became separated. The decedent was found by his buddy, unconscious and on the bottom. The decedent's tank was empty. The autopsy demonstrated changes associated with drowning. Additionally, there was evidence of aspirated gastric contents and while the coroner felt that this was the cause of the drowning, in reality it is most likely a result of the drowning and dying process. The diver drowned because he ran out of air while diving.

04-70 Experienced diver diving with nitrox with group but went off solo, rapid ascent according to computer, found unconscious on bottom

Cause of Death: Drowning due to Insufficient Air

This 40-year-old male was an experienced diver according to newspaper reports but there was no documented certification or experience level made available. He made a dive from a boat in a group of three divers but it was essentially a solo dive. The diver was found unconscious on the bottom and could not be resuscitated. According to the decedent's computer, he made a rapid descent to 55 fsw (17 msw), spent 30 minutes on the bottom and then rapidly ascended to 4 fsw (1 msw) before heading back to the bottom. The decedent's tank was nearly empty. The medical examiner stated that the diver must have planned a very deep dive since he was using Nitrox (demonstrating a basic misunderstanding on his part regarding how Nitrox is utilized). The death was ruled a drowning, though the history is typical for an air embolism. The autopsy did not demonstrate significant intravascular gas or evidence of pulmonary barotrauma.

04-14 Experienced divemaster and technical diver made solo dive on Nitrox to a wreck using a scooter, wreck shifted and trapped diver, body was recovered later

Cause of Death: Drowning due to Insufficient Air due to Entrapment (wreck)

This 43-year-old male was a very experienced diver with divemaster and technical certifications. He made a shore entry, solo dive in a river down to a wreck at 50 ffw (15 mfw), using nitrox. The diver was employing a scooter for mobility and also employed it to remove sediment from the wreck. Apparently the wreck shifted enough to entrap the diver. He subsequently ran out of breathing gas and drowned. The body was recovered four hours later. The autopsy report was not released.

04-15 Recently OW certified diver, made solo dive inside cave, became entrapped in cave and ran out of air, found in tight passage with equipment removed

Cause of Death: Drowning due to Insufficient Air due to Entrapment (cave)

This 27-year-old male had received his initial open-water certification two weeks earlier and had completed twelve lifetime dives. He and two dive buddies planned to enter an underwater cave system. One of the buddies could not descend and aborted his dive. The decedent and the other buddy went to depth and surfaced, but the decedent then decided to return to depth alone. Police divers recovered his body in a very unsafe, tight passage of the cave later that day. The diver had

removed his buoyancy compensator and weight belt in an attempt to either enter the tight passage or extricate himself from it. In addition to changes associated with drowning, the autopsy disclosed mild atherosclerotic cardiovascular disease and minor blunt force injuries.

04-17 Very experienced technical and cave diver completed one dive with group, made second cave dive solo without light or line, became entrapped and ran out of air, found outside of cave entrance without equipment

Cause of Death: Drowning due to Insufficient Air due to Entrapment (cave)

This 45-year-old male was a very experienced diver with technical and cave diving certifications. He completed the first dive of the day with a group of other divers without incident. The diver decided to return to depth alone while the other divers went off to get tanks filled. He apparently entered a cave system without a light or line and was using a single tank. The diver became entrapped and ran out of air. When the other divers realized that he had been at depth far too long they went down to look for him. The diver's body was found outside of the cave entrance, without his tank and regulator. The regulator and empty tank were recovered from inside the cave two days later. The autopsy findings were consistent with drowning.

04-34 Double Fatality. Experienced technical and cave diver diving with group in cave system, poor visibility, buddy and victim made wrong turn and both became trapped and ran out of gas, bodies recovered later

Cause of Death: Drowning due to Insufficient Air due to Entrapment (cave)

This 37-year-old male was an experienced cave and technical diver. He was in a group of four divers, two buddy sets, who entered a cave system. Visibility was poor and this diver and his buddy apparently made a wrong turn. The other two divers made it out of the cave system but this pair ended up sharing air and eventually died in the cave with their breathing gas exhausted. The bodies were recovered 250 ft (76 m) from the exit. The autopsy report lists drowning as the cause of death.

04-35 Double Fatality. Experienced instructor and technical and cave diver diving with group in cave system, poor visibility, buddy and victim made wrong turn and both became trapped and ran out of gas, bodies recovered later

Cause of Death: Drowning due to Insufficient Air due to Entrapment (cave)

This 53-year-old male was the dive buddy of the previously reported buddy pair who became entrapped in a cave system. He was also an experienced cave and technical diver, as well as an instructor. He was in a group of four divers, two buddy sets, who entered a cave system. Visibility was poor and this diver and his buddy apparently made a wrong turn. The other two divers made it out of the cave system but this pair ended up sharing air and eventually died in the cave with their breathing gas exhausted. The bodies were recovered 250 ft (76 m) from the exit. An autopsy was performed but the report was not available. The divers obviously drowned due to entrapment in a cave.

04-37 Double Fatality. Experienced technical and cave diver, cocaine abuse, made a dive with buddy into a complex cave system using mixed gas, body found 3 days later entangled in his line at 286 feet

Cause of Death: Drowning due to Insufficient Air due to Entrapment (cave and rope)

This 44-year-old male was a very experienced technical diver with cave diving certification. He and another experienced diver entered a complex cave system using mixed gas. When they did not exit the water at the expected time, a person on shore summoned assistance and a search was undertaken. The diver's body was located 3 days later, at a depth of 286 ft (87 m). He was

entangled in his own line and his gas supply was exhausted. The autopsy disclosed changes associated with drowning. Toxicology tests were positive for cocaine and cocaine metabolites. The significance of the cocaine cannot be determined because of the decomposition that occurred but it does indicate fairly recent use of the drug.

04-38 Double Fatality. Experienced technical and cave diver, obese with heart disease, made a dive with buddy into a complex cave system using mixed gas, body found the next day at 240 feet

Cause of Death: Drowning due to Insufficient Air Entrapment (cave)

This 38-year-old male was a very experienced technical diver with cave diving certification. He and another experienced diver entered a complex cave system using mixed gas. When they did not exit the water at the expected time, a person on shore summoned assistance and a search was undertaken. The diver's body was located the next day, at a depth of 240 ft (73 m). His gas supply was exhausted. The autopsy disclosed changes associated with drowning, along with obesity and left ventricular hypertrophy.

04-23 Poorly conditioned but experienced AOW diver with past medical history of seizures and cocaine addiction, made night dive to collect game, separated from buddy and entangled in anchor line, found that air was never turned on

Cause of Death: Drowning due to Insufficient Air due to Entrapment (anchor line)

This 33-year-old male was an experienced diver with advanced open-water certification. His past medical history included seizures that required medication for control. This was due to a cocaine addiction but according to reports he had been off medication and free of seizures for some time. The planned dive was a night dive off a boat in order to collect lobsters. As the diver and his buddy descended, the buddy saw a light on the bottom and swam toward it, thinking it was the decedent. It turned out to be just the decedent's light and weights. The buddy then saw the decedent 10 fsw (3 msw) above him and entangled in the anchor line. The buddy could not untangle the diver's equipment from the line so he removed the diver's buoyancy compensator and brought the stricken diver to the surface. The diver was taken to a recompression chamber where he was pronounced dead. When the tank was found, the pressure gauge read zero psi. An evaluation of the diver's equipment revealed that his air was turned off and that there was plenty of air in the tank. The logical conclusion is that the air was initially turned on and for whatever reason was turned off before the diver entered the water. The diver would have been able to take a few breaths before there would have been no air in his hose. He also had integrated weights as well as weights in the pockets of his buoyancy compensator, in addition to the weight belt he had dropped. The autopsy revealed an obese diver with liver steatosis, a tongue contusion, and changes associated with drowning.

B.6 Proximate Cause: Drowning / Various Causes

04-10 Diver with AOW certification, unknown experience, planned night dive but never submerged, signaled to boat with light before lost consciousness

Cause of Death: Drowning

This 61-year-old male had advanced open-water certification but an unknown amount of diving experience. He was making a night dive from a boat but he did not submerge with the rest of the divers. The diver signaled back to the boat with his light before he lost consciousness. The diver was pronounced dead at a local emergency room. The autopsy demonstrated changes consistent

with drowning as well as mild coronary atherosclerosis, mild pulmonary emphysema, and some minor abrasions.

04-19 Diver with moderate amount of experience, diving with group, had problem with regulator at depth and drowned

Cause of Death: Drowning

This 53-year-old female had been a certified diver for two years and had a moderate amount of diving experience. She entered the water with three other divers, one of whom was a paraplegic. Approximately two minutes into the dive and at 117 fsw (36 msw) the decedent had difficulty using her regulator and apparently drowned. An examination of the regulator revealed that it missing a diaphragm seal. The regulator was owned by the diver, but it is not clear if she had used it for diving since the last time routine maintenance was performed.

04-21 Inexperienced, obese diver made night dive with group, dropped regulator for unknown reason at depth, refused to share air and lost consciousness

Cause of Death: Drowning

This 34-year-old male received his open-water certification approximately one year earlier and had made fewer than eight lifetime dives. His medical problems included obesity. It was the third dive of the day for the group of divers, a planned night dive on a wreck. For unknown reason, the diver dropped his regulator from his mouth at 80 fsw (24 msw). He would not take an alternate air source from his dive buddy and proceeded to lose consciousness at depth. The other divers brought the stricken diver to the surface where resuscitation efforts were unsuccessful. In the official investigation report, a comment was made that "the repetitive dives would have caused a buildup of nitrogen, possibly causing narcosis at a shallower depth." There is no physiologic basis for the possibility of such a phenomenon and narcosis would not have played a role in this death. The autopsy showed cardiomegaly, mild atherosclerotic cardiovascular disease, and changes associated with drowning.

04-26 Inexperienced diver made series of dives with group, lost consciousness on bottom while waiting for others to go through lava tube, found with regulator out of mouth

Cause of Death: Drowning

This 46-year-old female was an inexperienced diver with open water certification. The diver made a series of four dives from a live-aboard boat with two other divers. There was a 30 ft (9 m) long lava tube that the other divers went through but the decedent did not. She apparently lost consciousness on the bottom and was found with the regulator out of her mouth. The diver was brought to the surface and resuscitation efforts were unsuccessful. The autopsy did not reveal any significant natural disease processes, and the case was signed out as a drowning.

04-27 Uncertified teenage diver with medical history of seizure disorder on medication, made shore dive with buddy in strong current, became separated, found on bottom, BC found not to hold air

Cause of Death: Drowning

This 14-year-old male was uncertified and had a history of a seizure disorder for which he took medication. He was diving with his father who was also uncertified. The two divers made a shore entry dive in a strong current. They became separated when the father surfaced to clear his mask. The father could not locate his son after they became separated. Lifeguards recovered the boy's body from the bottom. The autopsy findings were consistent with a drowning. An evaluation of the equipment revealed that the diver had weights in the pockets of the buoyancy compensator and the buoyancy compensator would not hold air.

04-58 Solo diver with advanced experience level, medical problems on multiple medications, made shore dive into river with strong current, tried unsuccessfully to abort dive, found close to shore

Cause of Death: Drowning

This 48-year-old male had open-water certification and had made approximately 50 lifetime dives. His medical problems included bipolar disorder and he was reportedly taking more than ten medications. The diver made a solo dive using a shore entry into a river, but the current was so strong that he quickly decided to abort the dive. He was found only seven feet from shore and the cause of death was reported to be drowning. The autopsy report was not made available but the coroner stated that he had removed some of his equipment including his fins. It is also very possible that he simply lost them while struggling in a rough current.

04-62 Experienced solo diver, diving for fossils in low visibility river with strong current, weighted down with heavy equipment, body found four days later

Cause of Death: Drowning

This 47-year-old male was an experienced, certified diver who was diving for fossils in a river. The current was strong and visibility was nearly zero. The diver was making a solo dive and was weighted down by the heavy equipment he used for his task. Another diver was also searching for fossils in the vicinity and he noticed that the decedent had failed to surface. His body was found in 30 ft (9 m) of water four days later. Entrapment on the bottom may have been a factor in this drowning but it could not be proven.

04-66 Recently certified diver made shore dive into strong current with poor visibility, struggled on surface with buddy who was rescued, body found later

Cause of Death: Drowning

This 32-year-old male was a recently certified diver with nine lifetime dives. He made a shore entry dive in a strong current and with poor visibility. The dive occurred 20 feet from shore and in a depth of 10 fsw (3 msw). The diver and his buddy ran into some sort of problem and were noted to be struggling on the surface. The decedent's buddy was rescued, but the diver's buddy was not recovered for another 30 minutes. While the cause of death was drowning, the contributing circumstances remain unknown.

04-68 Inexperienced diver made solo dive with homemade weight harness, surfaced and dropped weight belt, possible weight belt and harness tangled, drowned

Cause of Death: Drowning

This 48-year-old male was a certified diver with minimal dive experience. He made a solo, shore entry dive using a homemade harness to distribute the weights he wore. The diver surfaced and was heard to comment about his regulator. He dropped his weight belt but did not inflate his buoyancy compensator. After several excursions below the surface he finally submerged and did not come back up. The coroner declined to have an autopsy performed and signed the case out as a drowning death. It appears that his regulator became caught in the homemade harness, which led to his death by drowning.

04-42 Double Fatality. Inexperienced, obese diver made shore entry dive in rough seas, thrown against rocks

Cause of Death: Drowning

This 54-year-old male received his initial open-water certification 4 years previously but had minimal diving experience, with only eight lifetime dives. The diver was also obese. He also had not made an open-water dive in 3 years. The decedent and two other divers made a shore entry into rough seas in an area known for difficult diving conditions. Two of the divers in the group died in the event. The autopsy disclosed changes consistent with drowning and blunt force injuries from the diver being tossed against the rocks.

04-43 Double Fatality. Moderate experienced, obese diver made shore entry dive in rough seas, thrown against rocks

Cause of Death: Drowning

This 41-year-old male received his initial open-water certification over 5 years ago and had a moderate amount of diving experience, with twenty-eight lifetime dives. The diver was also obese. The decedent and two other divers made a shore entry into rough seas in an area known for difficult diving conditions. Two of the divers in the group died in the event. The autopsy disclosed changes consistent with drowning and blunt force injuries from the diver being tossed against the rocks.

04-55 Experienced diver with heart disease and diabetes, did drift dive in very strong current, rapid ascent, reef hook entangled, lost consciousness after surface struggle

Cause of Death: Drowning

This 69-year-old female was an experienced, certified diver with a history of diabetes mellitus as well as a cardiac dysrhythmia for which she took medication. She was making a drift dive in the ocean in a very strong current. After spending 27 minutes at a maximum depth of 71 fsw (22 msw), she unexpectedly made a rapid ascent to the surface. The diver's reef hook became entangled in the mooring line and she struggled on the surface before losing consciousness. The death was ruled a drowning, but air embolism cannot be excluded. Equipment evaluation demonstrated that the inflator for her buoyancy compensator was stuck open, and she had minimal air remaining.

04-76 Diver with intermediate diving experience made dive using nitrox, had inappropriate equipment setup and was overweighted, buoyancy problems, lost consciousness at depth

Cause of Death: Drowning

This 45-year-old male was a certified diver with 30 lifetime dives making a dive from a boat. The diver was using nitrox-34 and against advice from the boat crew, he strapped his weight belt on to his tank. He also used pocket weights, with a total of 50-pounds of weight used. The dive was made on a wall, and not surprisingly the diver experienced buoyancy problems. At first he was between 60 and 75 fsw (23 msw), then he descended to 120 fsw (37 msw), resisting his buddy's attempts to provide assistance. He was pulled up from 113 fsw (34 msw) unconscious and resuscitation efforts were unsuccessful. The autopsy findings were consistent with drowning.

04-87 Diver with unknown certification and experience level, made solo night dive to spearfish, body recovered two days later

Cause of Death: Drowning

There is little information available on the death of this 36-year-old male, including certification status and experience level. He apparently made a night dive alone and was likely spearfishing.

The diver did not return to the beach and fishermen recovered his body two days later. An autopsy was performed but the report was not made available. The cause of death was reported to be drowning.

04-36 Student in AOW course made shore dive in cold, strong current, became tangled in line and freed, separated from buddy, body recovered three months later

Cause of Death: Drowning due to Entanglement (rope)

This 21-year-old male had recently received initial open-water certification and had completed 9 lifetime dives. He was a student in an advanced open-water course and was making a dive with the instructor, another student, and two other divers. The group made a shore entry into a river, in cold water and with a strong current. Visibility was poor. The divers used a buddy line to stay together, with the goal being to tie the line off on a submerged automobile. Approximately eight minutes into the dive the decedent became entangled in the line, and his buddy cut him loose. The student became separated from the group and could not be located. Fisherman recovered the body 3 months later, with a portion of line still entangled around him.

04-50 Experienced but infrequent diver made night dive with buddy, separated and entangled in line, found unconscious later

Cause of Death: Drowning due to Entanglement (rope)

This 46-year-old male was an experienced diver with hundreds of lifetime dives but none in the past 2-years. He and a buddy made a night dive to 60 fsw (18 msw) from a boat. The diver became separated from his buddy and surfaced at one point, entangled in his own line. The diver descended again and was later found unconscious, with his regulator out of his mouth. An autopsy was performed and the death was ruled a drowning.

04-53 Experienced technical and rescue diver performing dives to try out new drysuits in ice covered lake, found one day later

Cause of Death: Drowning due to Entrapment (ice)

This 43-year-old male was an experienced diver with technical and rescue certifications. He and another diver were performing search and rescue drills and trying out new drysuits in a lake that was mostly covered with ice. They did not plan on going under the ice so a buddy line was not employed. After spending an unknown amount of time at 20 to 30 ffw (6 to 9 mfw) the diver signaled to his buddy to ascend. The buddy reached the surface but the decedent did not. His body was recovered from depth, under the ice, one day later. The equipment was tested, and it was determined that the drysuit was trimmed in such a manner that it would have fit too tight around the neck and wrists. It is unclear exactly how this may have contributed to the fatal diving accident, but the coroner thought pressure on the carotid arteries from the suit may have played a factor. The death was due to drowning secondary to entrapment below the ice.

04-59 Infrequent military diver, made series of dives to clear drainage pipe, extremity sucked into pipe and could not free himself, body recovered two hours later

Cause of Death: Drowning due to Entrapment (drainage pipe)

This 37-year-old male was reportedly a military trained diver. There was no documentation of his dive certification or experience, and he had not made a dive in at least four years. The diver made a series of shore entry dives into a pond to clear a drainage pipe. On the third excursion to depth, which was only seven feet, one of the diver's upper extremities was sucked into the drainage pipe, and he could not remove it. His body was recovered two hours later. In addition to changes consistent with drowning and some blunt force injuries, the autopsy demonstrated mild to moderate coronary artery disease.

04-69 Recently certified, unclear whether solo or separated buddy dive, found under rocks on bottom

Cause of Death: Drowning due to Entrapment (rocks)

This 26-year-old male had recently received his open-water certification. It is unclear whether he was making a solo dive or if he became separated from his dive buddy. His body was found under some rocks on the bottom. The death was ruled a downing, though it is unclear if he was entrapped under the rocks prior to death.

04-77 Technical cave diver did cave dive with group, became stuck on exit from cave, buddy could not assist, body recovered hours later

Cause of Death: Drowning due to Entrapment (cave)

The age of this male is unknown but he was reported to have been a technical diver with cave diving certification. He and two other divers entered a cave system with the decedent as the trailing diver in the group. The dive was to 35 ffw (11 mfw) and as the divers began their exit from the cave the decedent became stuck in one of the passageways. Despite assistance by one of the buddies, the diver remained trapped in the cave and his body was recovered hours later. There are unsubstantiated statements regarding the possible contribution of carbon monoxide to this death but an autopsy report, if an autopsy was performed, was not made available.

04-02 Inexperienced diver with resort course certification, obese with mild heart disease, planned shore dive but had difficulty with fins, fatigue during swim from shore, separated from buddy and never descended, found unconscious just below the surface

Cause of Death: Drowning due to Scuba Diving

This 55-year-old male had been certified for one year and had completed only four lifetime dives. His training consisted of a resort course and he had not made any dives since completion of that course. His medical problems included obesity. The diver planned a shore entry, ocean dive with a buddy. He had difficulty putting his fins on in the shallows and seemed fatigued during the surface swim away from shore. The two divers became separated and they never descended for the dive. The decedent was found by another swimmer, unconscious and just below the surface. Resuscitation efforts were unsuccessful. The autopsy revealed changes consistent with drowning, along with mild hypertensive atherosclerotic cardiovascular disease, and fatty change of the liver. The death was ruled an accidental drowning.

04-30 Inexperienced diver with health conditions and numerous medications including cocaine abuse, did solo dive using surface supplied air to perform task, did not surface and body found later

Cause of Death: Drowning due to Cocaine Intoxication

This 53-year-old male had been certified over 10-years ago but apparently had made only 5 or 6 lifetime dives. The diver's health history included insomnia, depression, and anxiety for which he took numerous medications. Coincidentally his wife had died in a diving accident five years ago. He entered the water alone to retrieve something that had gone over the side of his boat in 10 fsw (3 msw) using surface supplied air. The diver returned to the boat within a short period of time to adjust a leaking regulator. He then descended again and when he did not return others entered the water to find him. The diver's body was recovered later in the day. The autopsy disclosed focally moderate coronary atherosclerosis and changes consistent with drowning. Toxicology studies revealed cocaine and cocaine metabolites in the diver's blood, as well as diazepam, doxepin, and meclazine. The medical examiner signed the case out as a drowning with cocaine intoxication as a contributing factor. An equipment evaluation revealed that a knot in the air hose

might have prevented air from flowing to the regulator. Also, the diver was overweighted and not wearing fins.

04-80 AOW certified diver with unknown experience, did multiple solo cave dives while intoxicated, out of air, body found in cave one hour later

Cause of Death: Drowning due to Ethanol Intoxication

This 24-year-old male had been a certified diver for 2 years with advanced open-water certification. His level of experience is unknown but he did not have documented cave diving training or certification. The diver was in a boat with three friends at 2 AM. Two friends stayed in the boat and the other snorkeled in the area. The diver made three short, five to ten minutes each, excursions to a depth of approximately 50 to 60-feet, entering a freshwater cave system. Prior to diving and in between dives he was drinking beer, as were his colleagues. After the fourth excursion to depth the diver did not surface. A rescue diver recovered the body from the cave an hour later. The autopsy disclosed changes associated with drowning. Toxicology studies revealed a blood alcohol concentration of 110 mg/dL (80 mg/dL is considered too intoxicated to drive in most states). The decedent's tank was also empty. He had used it for all four dives and began the last dive with 500 psi remaining.

04-60 Experience divemaster, made deep solo dive, possible nitrogen narcosis, body recovered one hour later

Cause of Death: Drowning due to Decompression Sickness

This 55-year-old female was a very experienced divemaster who was known to make very deep air dives. She made a solo descent from a boat to a maximum depth of 262 fsw (80 msw). According to the profile on her computer the diver had a normal descent and spent 11 minutes at depth before ascending. She then had a relatively normal ascent to 101 fsw (31 msw) where she stopped and sank back to 107 fsw (33 msw). After other divers returned to the boat, the decedent was noticed to be missing during roll call. Here body was recovered one hour later at 107 fsw (33 msw). The autopsy showed abundant intravascular bubbles in the cerebral circulation and elsewhere. Microscopic sections of her brain were consistent with changes seen in decompression accidents. Nitrogen narcosis likely played a role as well. An equipment evaluation only demonstrated that the diver was low on air.

04-75 Experienced technical diver, on solo wreck dive using trimix and scooter, found unconscious on bottom, possible seizure

Cause of Death: Drowning due to Oxygen Toxicity

This 59-year-old male was an experienced technical diver making a series of solo dives to a wreck. His first dive was to 125 fsw (38 msw), and he was using a full face mask, trimix, and a scooter. During the second dive, he was last seen going down the descent line at 80 fsw (24 msw) before being found unconscious on the bottom at 115 fsw (35 msw). There was debris within the mask, indicating a breach of the protective value of a full face mask. The decedent had a previous episode where he suffered a seizure at depth due to erroneously using a decompression mix at depth. One report indicates that the same situation contributed to his death.

B.7 Proximate Cause: Unspecified or Body Not Recovered

04-45 Experienced technical diver, diving with group on rebreather, witnessed to have seizure at depth, unconscious at surface, limited information and no specified cause of death

Cause of Death: Unspecified Cause of Death

There is little information about the death of this 47-year-old male. He was an experienced technical diver using a rebreather among a group of other divers but without an assigned buddy. It is not known what gas mixture he was diving, but the decedent had a witnessed seizure at approximately 80 fsw (24 msw). He was brought up to the boat where he was unconscious and could not be resuscitated. The decedent had some equalization problems prior to the dive, but there is no other information about his health status. As the death occurred overseas, the cause of death cannot be determined with the minimal information available.

04-52 Unknown certification and experience, diving with group in cold water, indicated problem on bottom, lost consciousness and brought to surface, received recompression treatment, limited information regarding cause of death

Cause of Death: Unspecified Cause of Death

Little is known about the death of this 53-year-old male. His dive certification status and diving experience are unknown. He made a dive from a boat with two other divers down to a wreck at 102 ffw (31 mfw) for 14 minutes in a lake. The water was cold and the diver indicated some sort of problem on the bottom. The diver signaled to his buddies that he wanted to ascend and headed to the anchor line. He lost consciousness on the bottom, and his buddies brought him to the surface. Resuscitation efforts were unsuccessful, and one of the buddies was treated at a recompression chamber for possible decompression sickness. The autopsy report was not made available, but an unreliable source stated that the diver died from a perforated ulcer. That would be an unlikely cause of sudden incapacitation and rapid death. A cardiac problem is much more likely.

04-09 Elderly, inexperienced diver with basic OW certification, limited information, body never recovered

Cause of Death: Unknown Cause of Death, Body not Recovered

This 72-year-old male had basic open-water certification and had made four lifetime dives. There is scant information available on this death, but the diver was last seen approximately 10 fsw (3 msw) below the boat. His body was never recovered.

04-22 Diver with basic OW certification and unknown experience, panicked at surface pre-dive in rough seas, boarded boat then reentered water and descended, body never recovered

Cause of Death: Unknown Cause of Death, Body not Recovered

This 58-year-old diver had open-water certification but an unknown level of experience. He was preparing to make a dive down to a wreck sitting at 80 fsw (24 msw). After the diver initially entered the water, he panicked in rough surface seas and returned to the boat out of breath. The diver's buddy thought that he was going to stay in the boat and descended to catch up with the group of other divers. The decedent entered the water shortly thereafter and began descending down the anchor line. He was last seen at approximately 20 fsw (6 msw) and never returned to the boat. One diver recalled seeing the decedent on the anchor line, but no one saw him on the wreck. A thorough search was conducted but the missing diver's body was never recovered.

04-64 Experienced diver training on rebreather, separated from instructor and body never recovered

Cause of Death: Unknown Cause of Death, Body not Recovered

This 25-year-old male was an experienced diver with numerous advanced certifications. He was diving with an instructor in a course designed to learn how to use a rebreather. The divers became separated, and the decedent's body was never recovered.

04-72 Double Fatality. Experienced diver, made shore dive in strong current with buddy, never returned and body was found four months later

Cause of Death: Unknown Cause of Death, Body not Recovered

This 53-year-old male was an experienced diver who was diving with his son. The son had only been certified one week earlier. The two divers made a shore entry dive in a strong current. Neither diver returned to the shore. This diver's body was recovered four months later and required identification by matching a DNA profile, because of extensive decomposition. His son's body was not recovered.

04-73 Double Fatality. Newly certified diver, made shore dive in strong current with buddy, never returned and body not found

Cause of Death: Unknown Cause of Death, Body not Recovered

This 29-year-old male had only been certified one week earlier. He was diving with his father, an experienced diver. The two divers made a shore entry dive in a strong current. Neither diver returned to the shore. The body of this diver's father was recovered four months later. This diver's body was not recovered.

B.8 Proximate Cause: Other

04-05 Diver with unknown certification and experience, made multiple cave dives with tanks contaminated with carbon monoxide, lost consciousness

Cause of Death: Carbon Monoxide Poisoning

This 45-year-old male was making multiple cave dives with a group of fellow divers. Minimal information is available on this fatality. The diver had unknown experience and certification level. His reported health problem was an elevated cholesterol level. Some of the tanks used in the dives were apparently contaminated with carbon monoxide, and this diver's death was attributed to carbon monoxide poisoning. While in the cave, two of the four tanks he was using were tainted. According to witnesses, he realized it, but while searching for untainted air, he lost consciousness. There was one other fatality in this group of divers, and the other divers reported symptoms like headache and nausea.

04-16 Inexperience diver with resort course certification, made strenuous dive in cold water, separated from buddy and found unconscious on surface, received hyperbaric therapy and died six days later

Cause of Death: Anoxic Encephalopathy

This 39-year-old male had completed a resort course for basic certification and had made three or four lifetime dives, all in warm, tropical water. He made a pair of dives with a buddy in cold water under fairly strenuous conditions. The first dive was apparently uneventful, with a 47 fsw

(14 msw) for 37 minute profile. During the second dive, the diver became separated from his buddy on the bottom and was found floating on the surface unconscious, without his buoyancy compensator or regulator. The diver was taken to a medical treatment facility where he received hyperbaric oxygen therapy, but he remained comatose. He died six days after the event and no autopsy was performed. The cause of death was determined to be anoxic encephalopathy due to near-drowning, but air embolism cannot be excluded.

04-74 Diver with intermediate experience, made shore dive with buddy to practice skills, lost consciousness on surface swim back to shore, received hyperbaric therapy but died four days later

Cause of Death: Anoxic Encephalopathy due to Near Drowning

This 61-year-old female had received her initial open-water certification 3 months earlier but had already completed nearly 50 dives. She and her husband made a shore entry dive to 26 fsw (8 msw) for 44 minutes, practicing dive skills. They made a safety stop at 15 fsw (5 msw) then ascended to the surface. The diver lost consciousness during the surface swim back to shore and was brought to the beach. The decedent received hyperbaric oxygen therapy at a local hospital, but her condition progressively deteriorated, and she died 4 days later. The cause of death, after an autopsy, was determined to be brain injury due to near drowning, but HBO therapy and the time between the accident and death would have masked autopsy findings that would corroborate air embolism.

04-82 Experienced public service diver, made canal dive to recover wheelchair, poor visibility and suction drain, became entrapped under gate and lost consciousness

Cause of Death: Anoxic Brain Injury due to Near Drowning due to Entrapment (canal gate)

This 43-year-old male was a public service diver and an experienced recreational diver. He made a shore entry dive with three other divers into a canal where the depth was 5 ffw (1.5 mfw) in order to recover a wheelchair. There was poor visibility and some kind of suction drain on the bottom. The diver became entrapped under a gate and lost consciousness. He was brought to the surface and resuscitated but died at a hospital two days later. In addition to anoxic brain injury, the autopsy revealed a fatty liver and mild glomerulosclerosis.

04-28 Moderately experienced diver with hypertension, diving on wreck with nitrox, low on air and made a rapid ascent, died four days later, after recompression treatment

Cause of Death: Hypoxic Brain Injury due to Air Embolism due to Rapid Ascent

This 52-year-old male was a moderately experienced diver with advanced open-water certification and a history of hypertension. He was diving on a wreck with a large group to a maximum depth of 108 fsw (33 msw). The diver used nitrox as a breathing gas, and he became low on air. The diver made a rapid ascent. The sea state was fairly rough, but he was able to get back into the boat. Shortly thereafter the diver became short of breath and collapsed. He was taken to a hospital where he received hyperbaric oxygen therapy but died after four days. An autopsy was not performed. The history and course are typical for an air embolism.

04-20 Student in OW class panicked while performing buddy breathing skill, brought to surface coughing through regulator, died after five days on life support

Cause of Death: Ischemic Encephalopathy due to Air Embolism

This 55-year-old female was a student in an initial open-water certification class making her second lifetime dive. Her first dive was to 17 fsw (5 msw) for 10 minutes, during which she lost some of her weights. During the second dive the student was involved in a buddy breathing drill

at 15 fsw (5 msw) when she panicked and descended to 29 fsw (9 msw). The instructor brought the student to the surface slowly, and it was reported that she coughed through her regulator. Upon reaching the surface, the student lost consciousness and was taken to a medical treatment facility. After five days on life support, during which she received hyperbaric oxygen therapy, she died. The autopsy lists the cause of death as ischemic encephalopathy. The initial event was most likely an arterial gas embolism.

04-41 Recently certified diver, made solo night dive with improper surface support, found on surface, struck by boat

Cause of Death: Multiple Injuries due to Struck by Boat

This 24-year-old male was recently certified and had minimal diving experience. He made a shore entry alone for a night dive into a lake, without using a dive flag, buoy, or any surface support. The diver was found floating on the surface and had been struck by a boat.

04-48 Student in basic OW class, made certification dives in poor visibility and rough seas, had difficulty with buoyancy, surfaced and hit by speeding boat

Cause of Death: Open Head Wounds due to Struck by a Boat

This 30-year-old female was a student in an initial open-water certification course completing her second dive toward certification. She was part of a large group of students in a lake where visibility was poor and the water was choppy. The diver had much difficulty with controlling her buoyancy. At one point in the dive, the decedent surfaced and was struck in the head by a speeding boat. She died nearly instantly. Of note, a dive buoy/flag was being used, though with the rough water, it could not be determined how visible the marker was. The boat that struck the diver was never identified.

04-44 Commercial diver with unknown experience, did solo dives to perform personal task, never surfaced and body found 10 days later

Cause of Death: Blunt Force Injuries due to Entrapment (under a wreck)

This 33-year-old male was reported to have been a commercial diver. His actual levels of training and experience are not known. The diver entered the water alone to perform some ship's husbandry work on a sunken tugboat. After making 3 excursions to 60 fsw (18 msw), he did not ascend after the third time at depth. A search found the body 10 days later. The tugboat apparently shifted, resulting in blunt force injuries of his head and neck.

APPENDIX C. BREATH-HOLD INCIDENT CASE REPORTS

Case 1

An experienced 52-year-old diver was freediving from a charter boat during the surface interval between dives on a wreck in 75 fsw (23 msw) of ocean water in the Florida Gulf. He was located by scuba divers and recovered from the bottom approximately 30 minutes after being missed. Cardiopulmonary resuscitation was unsuccessful.

Case 2

A 14-year-old male was snorkeling with his father from a private vessel in the Florida Gulf. The teenager dived down in a four to five knot current to unhook the anchor. His legs became tangled during the effort. He could not be freed by those on board. He was brought to the surface approximately 20 minutes later by a rescue crew. Cardiopulmonary resuscitation was unsuccessful.

Case 3

A 34-year-old male freediver was attacked by a shark while spearfishing in Hawaii. He received a non-fatal bite to the shoulder while swimming back to shore towing a bag of fish. He was able to stand and strike the 12 ft (4 m) shark with his speargun as it returned. He was assisted from the water by local residents.

Case 4

A 38-year-old freediver was spearfishing from a small boat on the Great Barrier Reef when he was attacked by a shark. His two companions on the boat became aware of the problem when he screamed. They were able to pull him into the boat after the shark swam away. The victim expired before rescue services arrived on site.

Case 5

Two experienced male freedivers, one 33 years of age and one 77 years of age, went abalone diving in rough conditions. The 77-year-old had been working all day and was tired from the outset. The men began in a partially protected cove, but bystanders observed a current carrying the older diver offshore. The younger diver swam out to assist him but was only able to bring him part way to shore before letting go. The younger diver then swam towards a rock and disappeared from view behind it. He was later seen floating. Both bodies were later retrieved by divers.

Case 6

Two males entered the water from an anchored boat to freedive for abalone off the California coast. Shortly after entering, one of the men felt a pressure wave beneath him and, looking down, saw a large dorsal fin. After dropping his weight belt and swimming rapidly back to the boat, he turned to see only a large pool of blood in the water. His partner's body was recovered shortly after in 15 fsw (5 msw). An autopsy confirmed that the injuries were caused by a great white shark.

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