DAN

Divers Alert Network

1990 Report on Diving Accidents and Fatalities

Divers Alert Network, Box 3823, Duke University Medical Center, Durham, North Carolina 27710

Acknowledgments

Data for the *1990 Report on Diving Accidents and Fatalities* was collected and assembled by DAN employees and staff. These contributions ranged from accident follow-up calls, data entry, editing, proofreading, and compiling the final report. DAN wishes to recognize the following people for their important contributions:

Peter Bennett Ph.D., D.Sc.
Petar Denoble M.D., D.Sc.
Guy Dear M.B., F.F.A.R.C.S.G.
Yancey Mebane M.D.
Richard Moon M.D.
Richard Vann Ph.D.
Jeffrey Bertsch DMT
Karen Corson MPH
Paige Dickson
Jeffrey Hodson EMT-D
Conrad Ireland EMT
Richard R. LaReno EMT
Natalie Lew B.S.
Heather McCabe B.S.
Michele Nealen
Sally Reiser B.S.
Randy Sitzes EMT
Philip Trommel B.A./EMT

Editor — Joel Dovenbarger
Layout and Design — Gary Nichols & John Rorem

Direct financial support for this report was provided by the National Oceanic and Atmospheric Administration (NOAA) and the Diving Equipment Manufacturers Association (DEMA). DAN also recognizes the dive clubs, stores, instructors, and many individual members who support DAN and diving safety.

DAN is indebted to the many hyperbaric physicians, nurses, and technicians from the national network of chambers who fill out DAN reporting forms and send them in for follow-up. DAN also wishes to thank the local sheriff, police, emergency medical personnel, U.S. Coast Guard, medical examiners, and coroners who submitted information on scuba fatalities. DAN could not perform its reporting service without the support and contributions of these concerned individuals.

The National Underwater Accident Data Center at the University of Rhode Island and its Director, Mr. John J. McAniff, have joined with DAN to produce this year's report on scuba fatalities. This joint venture is made possible through NOAA Grant NA88AA-D-UR048.

Table of Contents

Introduction to Divers Alert Network

Divers Alert Network (DAN) is the United States' safety organization for recreational scuba diving. DAN is a 501(c)3 not-for-profit company that relies on dues from its membership association to support DAN services and scuba diving safety research. The membership of DAN includes individual divers, dive clubs, retail scuba operators, equipment manufacturers, scuba certification agencies and special individuals who donate their services, time and money to support diving safety.

Scuba diving like most other recreational sports has a potential for personal injury. Breathing compressed gas underwater creates a certain amount of risk. This risk, however, is considered to be relatively low. DAN's mission is to enhance diving safety for the recreational diver by helping them to avoid injury and provide assistance when injuries occur. DAN supports this mission by:

1. Providing information on health and safety issues in scuba diving.
2. Providing assistance to injured divers for evaluation, transportation and treatment.
3. Collecting, analyzing and publishing data on diving accidents and fatalities.

DAN is now the largest diving safety organization in the world, with 80,000 members currently enrolled. It recently organized the first international federation of diving safety organizations. The goals are to provide worldwide assistance for information, air evacuation and acceptance of insurance programs. Similar organizations now exist with the same mission under International DAN or IDAN such as DAN Europe, DAN Japan, and DAN Australia.

Divers Alert Network is best known in the diving community for its medical emergency and advisory telephone services to recreational divers and physicians. The telephone service handles over 10,000 combined calls annually. ***These telephone services are supported by membership dollars and are provided free to all callers.*** Divers depend on DAN's safety services when they need information and assistance.

24-Hour Medical Emergency Hotline (919) 684-8111 —
DAN maintains a 24-hour emergency service 365 days a year to provide injured divers with medical consultations and referrals.

Non-Emergency Advisory Line (919) 684-2948 —
DAN maintains an information hotline to provide answers for commonly asked questions about scuba diving medicine and safety. Calls are answered 9 a.m. to 5 p.m., EST, Monday through Friday, except holidays.

Alert Diver —
Alert Diver is the bimonthly magazine of Divers Alert Network sent to each DAN member. *Alert Diver* provides the latest in diving medicine and safety information.

Diving Safety Courses —

DAN provides courses for divers, instructors and physicians who wish to increase their awareness and understanding of scuba diving injuries and treatment. Many divers attend DAN's one-day courses and over 1,500 physicians have been introduced to diving medicine through DAN's one-week seminars. The DAN *Oxygen First Aid in Dive Accidents* program trained over 1,850 oxygen providers and 280 instructors in this, its first year.

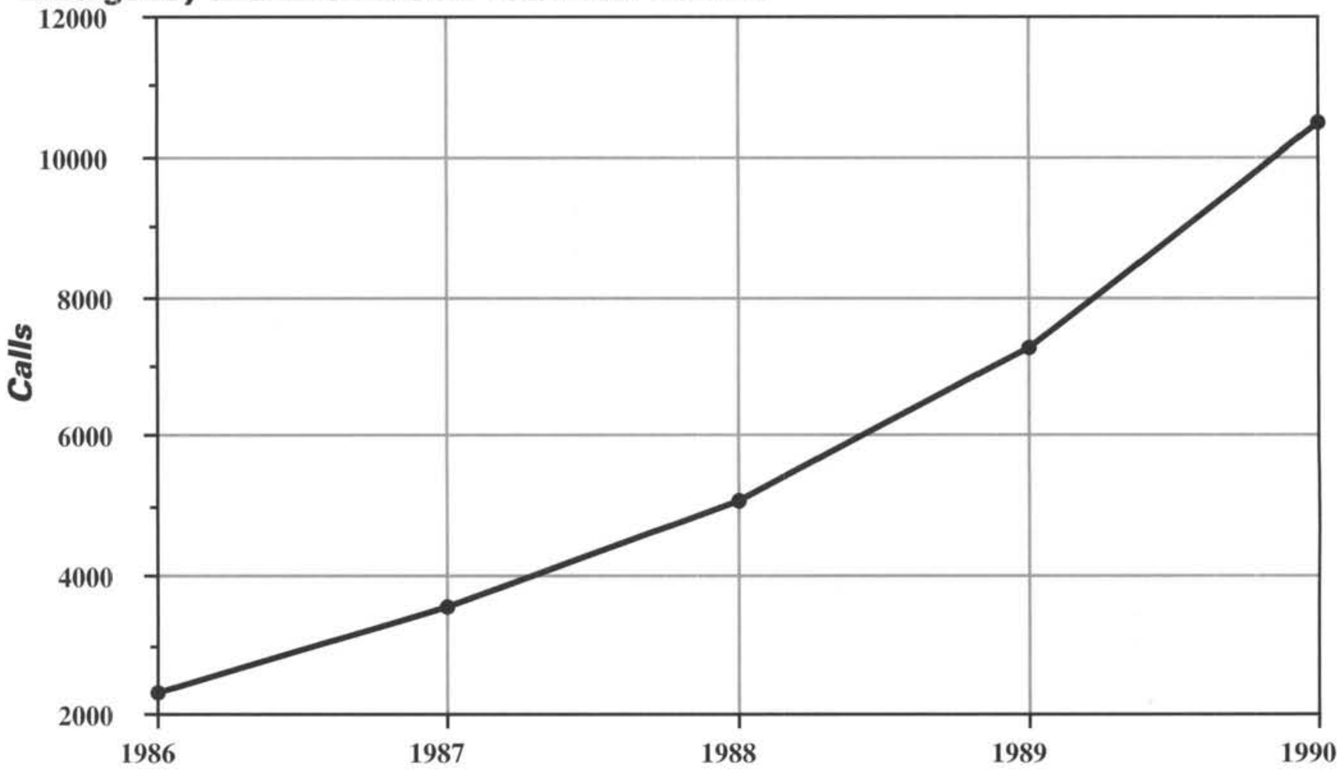
Dive Accident Insurance —

DAN pioneered and implemented the first diving injury insurance for recreational divers in the United States. For those who choose this DAN benefit, air evacuation and treatment are assured. DAN members are covered anywhere in the world for all in-water injuries. Regular membership now includes guaranteed worldwide coverage for air evacuation.

Annual Report on Scuba Diving Accidents —

DAN collects the details of recreational dive injuries and fatalities. This data is analyzed for common injury trends and divided into descriptive and possible risk attributes.

Emergency and Information Total Call Volume



1.0 Introduction to Dive Accidents

Divers Alert Network has completed its tenth year of safety service to the scuba community. This is the fourth annual report on recreational scuba accidents and the second to include scuba fatalities. The communication network, composed of hyperbaric chamber personnel and physicians, has increased over the past ten years.

DAN now receives information from over 130 treatment facilities in the United States, Caribbean Basin Islands and the Pacific territories. Because DAN receives the cooperation of the staff at these hyperbaric facilities when reporting the number of treated recreational divers, we believe the total number of treated cases in this report is fairly accurate. Some divers with decompression illness do not report for evaluation and treatment so the actual number of cases is probably higher.

The importance of injuries in any given sport is related to the total number of participants. It is extremely difficult to determine the number of active scuba divers. A true incidence is thus difficult to determine. Table 1.1 lists popular sports for comparison of the number of participants, their reported injuries and incidence. It is difficult to compare an injury in one sport to another because some sports injuries could be much more severe than others. Scuba diving differs not only in the type of injuries that may occur, but also in the surrounding physical environment.

To determine the number of sports injuries, the National Safety Council uses the National Electronic Injury Surveillance System (NEISS) which surveys injuries from 90 emergency departments annually. This NEISS reporting system was updated in 1990. The number of participants is based on a 20,000 household survey done by the National Sporting Goods Association (NSGA). Scuba diving is no longer included in the safety commission's report, but information is available from these organizations. NSGA estimates 2.6 million active divers, and the NEISS system reported 1,044 injuries for 1990. This gives an estimated incident rate of 0.04 percent, which is roughly the same as bowling. Using a second estimate of 2.45 to 3.1 million active divers (see Introduction Section 6) and the reported 738 decompression illness cases, an incidence rate of 0.03 to 0.023 percent can be obtained.

Scuba	2,600,000	1,044	0.04%

There are several factors which limit the use of the above methods of estimating injury numbers and population size in scuba diving. Participants are not necessarily active if they only participate twice in a given year. Divers may re-enter the sport after not having dived for several years. Even though the incidence of injury is very low, it may appear inflated because of intermittent divers who participate. There are also resort courses where individuals learn to dive but receive no certification. Some uncertified divers may also appear in the number of total yearly injuries but are not counted as participants by any study of the industry.

One of the biggest drawbacks to the NEISS system is that anyone receiving emergency hospital care for a scuba related injury is counted. For example, people who drop a tank on their foot may be counted using this system. Raters who record the injuries are not asked to decide about the nature of the injury or outcome. Scuba injuries are separated by type and relationship to the underwater environment. DAN reports on both decompression illness (DI) and scuba fatalities in separate sections of this report. A diver cannot be counted in both the injury and fatality sections.

In 1990, 645 DAN Diving Accident Reporting Forms (DARF) were sent in to DAN for analysis by September 1, 1991, for cases occurring during the 1990 calendar year. Of the 645 forms sent to DAN, 459 cases were followed completely and included in our computer database. DAN excluded 28.8 percent (186) from analysis, including 63 commercial divers and 123 divers classified as "other." The 123 "other" cases were accidents which could not be followed to complete the form, were in litigation, had symptoms which mimicked decompression illness but were not dive related, or non-decompression illness injuries (such as ear squeeze, mask squeeze).

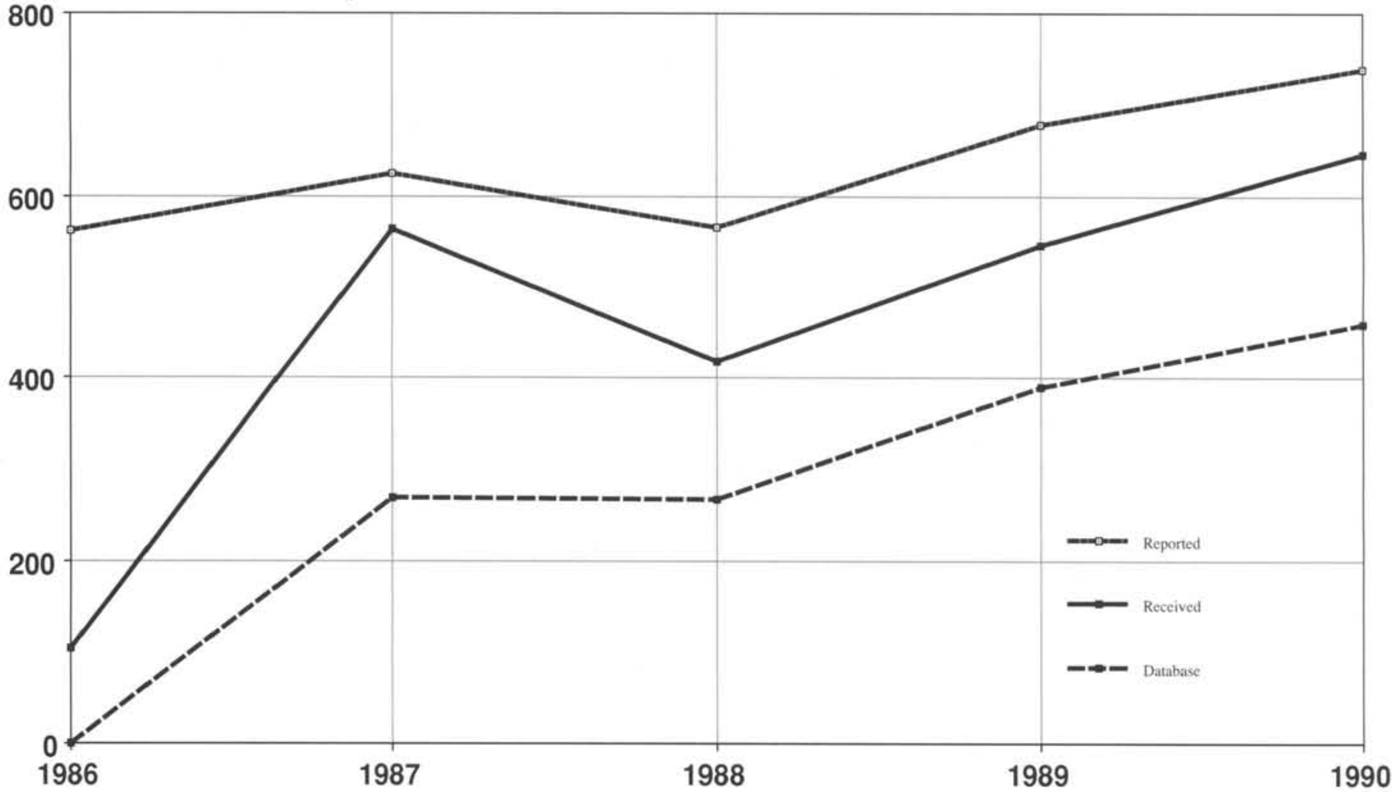
The 459 cases included were based upon the diagnosis being decompression illness and the case reports being complete and verified. There were some cases which may have had one or two missing answers on the form which the diver could not recall. Cases missing a few responses were included because the major portion of information was available and considered useful. In these cases the denominator was reduced to show that not all cases in the data base were used to calculate this percentage, thus, it would not give an exaggerated total number for that question. Because of this, "*Frequency Missing*" may be seen throughout the report to indicate that a response was not given. For example, in Table 2.9 Current Medical History there were 475 different current medical problems listed. Thirty-three did not respond to this question out of the total 459 population, thus 426 persons had 475 current medical problems. In some places "n=x" denotes the size of the population to which a table or graph refers (If n were used in Table 2.9, it would read "$n = 426$").

Table 1.1 Occurrence of Injuries in Various Sports

Sport	Number of Participants	Reported Injuries	Incidence
Football	14,700,000	319,157	2.17%
Baseball	15,400,000	321,806	2.09%
Basketball	26,200,000	486,920	1.86%
Soccer	11,200,000	101,946	0.91%
Volleyball	25,100,000	92,961	0.37%
Water Skiing	10,800,000	21,499	0.20%
Racquetball	8,200,000	13,795	0.17%
Tennis	18,800,000	22,507	0.12%
Swimming	70,500,000	65,757	0.09%
Bowling	40,800,000	17,351	0.04%

Source: *Accident Facts, 1991 Edition; National Safety Council. Numbers represent individuals who participate in this sport more than one time during the year, and injury represents someone who was treated in an emergency room for an accident relating to the sport or involving sporting equipment.*

Table 1.2 Decompression Illness Cases from 1986-1990



In many tables there were very few respondents to certain questions which led to a small number divided by a large number resulting in a very small percentage (i.e., 0.036 percent). When calculated, the computer rounds up (or down) to the nearest tenth or the nearest hundredth. It is because of rounding that you may see some percentages which do not total 100 percent exactly.

Some hyperbaric chambers do not send DARF forms to DAN. Other chambers give the patient the form to send in, and often these forms are not received. The number of cases reported by the different DAN regions is always higher than the number of forms received at DAN, as can be seen in the graph above. The top line indicates total cases reported by DAN regions. The middle solid line indicates total cases received by DAN, and the bottom line represents total cases completed and verified which are included in DAN's accident database.

DAN collects cases from network hyperbaric chambers and persons who have experienced decompression illness. DAN also receives reports from members who were at the site of an accident and who later have the victim fill out a report. Once each case is received which fits the appropriate criteria (recreational, decompression related), it is then logged into the DAN database. If a patient has residual symptoms, he or she is contacted by telephone and followed until they no longer have residual symptoms or for up to three months if they continue to have residual symptoms. If a patient has no residual symptoms, he or she is contacted by telephone only if there is incomplete or incongruent information on the reporting form. Some patients cannot be followed because they have moved and left no forwarding address or telephone number.

The Dan Diving Accident Reporting Form used to collect accident information is presented in Appendix A. The names and identifying personal information are confidential and are not available for publication. Accident data cannot be used to imply individual fault or blame in determining the cause of scuba injuries.

Case Collection

Divers Alert Network utilizes a regional system of accident reporting. Each region has a coordinator who assists in the triage and treatment of divers in their region. They also assist in the collection of cases from the hyperbaric chambers. The increased and improved collection efforts by DAN are due to the cooperation of the many hyperbaric facilities in the referral network and to the regional coordinators. In 1990 several chambers reported record years for treating scuba diving injuries. Comparisons may be made from year to year, by region, or by diagnosis. The Southeast (SE) region contains Florida and the Caribbean Islands where a large part of the world's diving is done. The Southeast has always led the national regions in scuba diving accidents. A breakdown of the location of dive accidents by country and state is shown in Tables 1.5 and 1.6.

Some divers are treated at two or three different facilities, but they are only counted as one dive accident. Divers can only be counted twice if there were two separate episodes of decompression illness. These numbers represent only non-fatal decompression illness. Chambers in the regions may have reported more cases of decompression illness, but Table 1.3 only represents cases of recreational decompression illness.

Table 1.3 shows the number of decompression illness cases reported being treated over the last five years. The total number of treated cases has been slowly increasing since 1986 with the exception of 1988 when the number of cases declined. Regions in Table 1.3 refer to certain states and areas of the country. States are listed by region in Table 1.4. The Caribbean basin islands are shown separately but are part of the southeast region.

Note: *In Table 1.3 and 1.4, "*" represents DCS Types I and II cases combined; ** SE includes Caribbean basin; + Hawaii only reports number of cases treated; and ++ "No Treatment" represents cases in which patient refused treatment or had spontaneous resolution of symptoms.*

Table 1.3 Total Reported Cases in 1990

1990	SW	NW	MW	GU	PA+	NE	SE**	TOTALS
DCS-I	48	8	17	31		28	111	243
DCS-II	64	8	10	37		34	193	346
AGE	35	1	2	7		15	58	118
No DX reported					31			31
No Treatment++								
TOTALS	**147**	**17**	**29**	**75**	**31**	**77**	**362**	**738***

1989								
DCS-I	48	12	18	11		14	78	181
DCS-II	64	15	17	29		47	156	328
AGE	35	3	3	1		4	65	111
No DX reported					58			58
No Treatment++								
TOTALS	**147**	**30**	**38**	**41**	**58**	**65**	**299**	**678**

1988								
DCS-I	14	9	11	13		22	68	137
DCS-II	43	27	10	25		32	151	288
AGE	25	6	2	1		10	38	82
DCS-AGE combined	1			4			5	10
No DX reported					36			36
No Treatment++		3		1	1	2	5	12
TOTALS	**83**	**45**	**23**	**44**	**37**	**66**	**267**	**565**

1987								
DCS-I	15	4	2	15		30	61	127
DCS-II	58*	25	12	20		26	199	340*
AGE	20	4	2	6		6	59	97
No DX reported					38			38
No Treatment++	2					3	17	22
TOTALS	**95**	**33**	**16**	**41**	**38**	**65**	**336**	**624**

1986								
DCS-I		6	2	1			68	77
DCS-II	69*	11	13	8	7	33	133	274*
AGE	28	2				10	41	81
No DX reported					25		97	122
No Treatment++	3					1	4	8
TOTALS	**100**	**19**	**15**	**9**	**32**	**44**	**343**	**562**

Table 1.4 Total Cases Treated and Reported in 1990 by DAN Regional Coordinators

Southwest Region	DCS-I	DCS-II	AGE	TOTALS
Arizona	1	3	0	4
California	29	55	13	97
Utah	1	2	0	3
TOTALS	**31**	**60**	**13**	**104**

Northwest Region				
Oregon	4	2	0	6
Washington	4	6	1	11
TOTALS	**8**	**8**	**1**	**17**

Midwest Region				
Illinois	3	3	0	6
Michigan	5	1	0	6
Minnesota	5	3	1	9
Ohio	3	2	1	6
Wisconsin	1	1	0	2
TOTALS	**17**	**10**	**2**	**29**

Gulf Region				
Arkansas	1	0	0	1
Colorado	0	3	0	3
Louisiana	10	5	5	20
Mississippi	1	1	0	2
Missouri	3	4	0	7
Texas	16	24	2	42
TOTALS	**31**	**37**	**7**	**75**

Pacific Region	DCS-I	DCS-II	AGE	TOTALS
Hawaii*				31
TOTALS				**31**

Table 1.5 Accidents by Country and U.S. Territories

Northeast Region	DCS-I	DCS-II	AGE	TOTALS
Connecticut	1	5	1	7
Maryland	3	6	2	11
Maine	4	5	3	12
New York	2	9	4	15
Pennsylvania	17	7	5	29
Virginia	1	2	0	3
TOTALS	**28**	**34**	**15**	**77**

Southeast Region				
Alabama	6	2	1	9
Florida	82	124	33	239
Georgia	6	5	2	13
North Carolina	2	9	1	12
TOTALS	**96**	**140**	**37**	**273**

Caribbean Basin				
Bahamas	1	3	0	4
Barbados	2	3	1	6
Belize	0	2	0	2
Bermuda	0	1	0	1
Bonaire	0	1	0	1
Cayman	1	13	6	20
Curacao**	-	-	-	-
Honduras	1	3	1	5
Jamaica	0	1	1	2
Mexico	3	11	5	19
Panama	0	0	0	0
Puerto Rico	0	2	1	3
St. Thomas	6	10	6	22
Turks and Caicos	1	3	0	4
TOTALS	**15**	**53**	**21**	**89**

*** Did not report for 1990.*

Country	Frequency	Percentage
Philippine Islands	1	0.2
Egypt	1	0.2
Fiji	1	0.2
New Guinea	1	0.2
Barbados	2	0.4
Antilles	2	0.4
Bonaire	2	0.4
Other	2	0.4
Israel	2	0.4
Jamaica	3	0.7
West Indies	4	0.9
Canada	6	1.3
Belize	6	1.3
Honduras	10	2.2
U.S. Territories	12	2.6
Bahamas	20	4.4
Caymans	24	5.3
Mexico	36	7.9
USA	319	70.3
TOTAL	**454**	**99.7**

Frequency Missing = 5

Tables 1.5 and 1.6 show the location of diving for the 459 reported cases in 1990. Improved collection techniques and assistance from overseas chambers have led to more dive accidents by Americans being tracked. With the assistance of the local chamber personnel, non U.S. citizens and local fishermen who dive commercially are excluded from reported cases. Tables 1.5 and 1.6 show the location of the dives that led to symptoms but do not necessarily indicate the site of treatment. Many divers delay in reporting symptoms until they return home or to the U.S.

Table 1.6 Accidents by State and U.S. Territories

State	Frequency	Percent
Alaska	1	0.3
Arizona	1	0.3
Arkansas	1	0.3
Illinois	1	0.3
Maryland	1	0.3
New Hampshire	1	0.3
Ohio	1	0.3
Oklahoma	1	0.3
Virginia	1	0.3
Wisconsin	1	0.3
Maine	2	0.6
Missouri	2	0.6
Pennsylvania	2	0.6
Rhode Island	2	0.6
South Carolina	2	0.6
Guam (U.S.)	2	0.6
Hawaii	3	0.9
Texas	3	0.9
Georgia	4	1.2
Massachusetts	4	1.2
Michigan	4	1.2
Minnesota	4	1.2
New York	4	1.2
Puerto Rico (U.S.)	4	1.2
Washington	6	1.8
U.S. Virgin Islands	6	1.8
Unknown State	9	2.7
North Carolina	14	4.2
New Jersey	21	6.3
California	30	9.1
Florida	193	58.3
TOTAL	**331**	**99.8**

Frequency Missing = 128

2.0 Diver Characteristics

Table 2.1 shows the age distribution of reported decompression illness cases from 1987 to 1990. There have been no significant population shifts in any of these age groups. Only the 35-39 year- old varied by more than 5 percent in the four years shown. This breakdown of injuries by age most likely represents the age distribution of the population who are currently diving. Approximately 75 percent of all injuries occur between the ages of 25 to 44 years of age. Fewer accidents reported may indicate that there are not as many certified divers in these age groups, or that divers in these age groups may have different dive patterns.

Table 2.2 illustrates the severity of illness in males and females using the DAN severity coding system (Appendix C). This system rates a decompression related injury in terms of severity. Few divers under twenty or over 45 years of age appear to have suffered serious injury.

Table 2.1 Age Distribution of 1987-1990 Accident Cases

Age	1990 Frequency	1990 Percent	1989 Percent	1988 Percent	1987 Percent
10-14	1	0.2	0.3	0.7	0.7
15-19	15	3.3	2.8	1.5	4.1
20-24	41	9.0	8.2	10.1	10.4
25-29	105	22.9	24.0	23.1	19.3
30-34	103	22.5	22.0	23.9	23.3
35-39	94	20.5	14.6	14.6	22.2
40-44	54	11.8	12.3	13.1	11.9
45-49	23	5.0	7.4	7.1	4.1
50-54	14	3.1	4.3	4.1	1.1
55-59	5	1.1	2.8	0.7	1.1
60-64	3	0.7	1.3	1.1	1.9
TOTALS	**458**	**100.1**	**100.0**	**100.0**	**100.0**

Frequency Missing = 1 | $n = 391$ | $n = 268$ | $n = 270$

Table 2.2 Disease Severity by Age and Sex

Male

	SEVERITY						
AGE	1	2	3	4	5	6	TOTALS
10-14	0	1	0	0	0	0	1
15-19	2	0	1	3	6	0	12
20-24	3	5	0	9	10	2	29
25-29	9	6	8	27	19	9	78
30-34	12	13	8	21	15	3	72
35-39	14	16	1	22	10	5	68
40-44	2	4	1	14	12	8	41
45-49	3	2	0	5	7	3	20
50-54	1	0	0	3	3	2	9
55-59	2	0	0	1	1	0	4
60-64	0	1	0	2	0	0	3
> 64	0	1	0	0	0	0	1
TOTALS	48	49	19	107	83	32	338

34.3 65.7

Female

	SEVERITY						
AGE	1	2	3	4	5	6	TOTALS
10-14	0	0	0	0	0	0	0
15-19	0	0	1	0	2	0	3
20-24	0	1	0	6	5	0	12
25-29	1	3	1	10	9	3	27
30-34	4	10	2	10	3	2	31
35-39	0	5	4	11	4	2	26
40-44	0	1	3	3	6	0	13
45-49	1	0	0	1	1	0	3
50-54	0	2	0	1	2	0	5
55-59	0	0	0	1	0	0	1
60-64	0	0	0	0	0	0	0
> 64	0	0	0	0	0	0	0
TOTALS	6	22	11	43	32	7	121

32.2% 67.8%

Table 2.3 Sex of 1987-1990 Accident Cases

Sex	1990 Frequency	1990 Percent	1989 Percent	1988 Percent	1987 Percent
Female	121	26.4	26.1	21.6	24.1
Male	338	73.6	73.9	78.4	75.9
TOTAL	**459**	**100.0**	**100.0**	**100.0**	**100.0**
			$n = 391$	$n = 268$	$n = 270$

The average number of females in the dive injury population over four years was one in four cases or 24.5 percent. The percentage of active female divers is not known so it is difficult to determine if the percentage shown in Table 2.3 is representative of the active female scuba population or just females who were injured.

Table 2.4 Number of Divers by Years of Diving Experience

Years Diving	Sex	1990	1989	1988	1987
< 2 Years	Male	81	37	35	56
	Female	55	21	25	29
2 to 5 Years	Male	106	79	62	46
	Female	44	32	17	14
6 to 9 Years	Male	55	36	37	31
	Female	8	9	12	14
≥ 10 Years	Male	96	98	76	72
	Female	14	8	3	8

Diver Experience

Lack of experience seems to play a role in dive injuries, but this is a common factor in other types of injury. A smaller percentage of women are represented in the "6 to 9 years" and "10 years or more" diving experience categories shown in Table 2.4. The percentage of females diving who are in the five years of diving or less category has ranged from 66 to 82 percent while the population of males in the five years and under category has ranged from 46 to 55 percent. Diver experience is broken down in Table 2.5 by total years of diving and reported number of dives. It is difficult to determine how good a diver is just by looking at how long they have been diving or how many dives they have made. Twenty-three percent of the injured male divers in 1990 had been active for only one year compared to 41 percent of the injured female divers. Seventy percent of first year males and 67 percent of females had dived 20 times or less.

Table 2.5 Diver Experience

Male

	Total Dives							
Years Diving	0-20	21-40	41-60	61-80	81-100	100-120	121+	TOTALS
0-1	57	14	5	3	1	0	1	81
2-3	14	17	6	7	2	2	19	67
4-5	7	3	4	2	3	1	19	39
6-7	3	1	1	2	5	2	14	28
8-9	3	1	1	1	2	0	19	27
10-11	0	1	2	1	0	0	16	20
12-13	3	2	0	0	3	0	10	18
14-15	0	1	1	0	0	0	18	20
16-17	0	0	0	1	1	0	5	7
18-19	2	0	1	0	1	0	4	8
20-21	0	0	1	0	1	0	21	23
TOTALS	**89**	**40**	**22**	**17**	**19**	**5**	**146**	**338**

Female

	Total Dives							
Years Diving	0-20	21-40	41-60	61-80	81-100	100-120	121+	TOTALS
0-1	37	10	4	0	2	2	0	55
2-3	9	2	6	5	3	1	5	31
4-5	2	1	2	0	0	0	8	13
6-7	0	1	0	2	0	0	2	5
8-9	0	0	0	0	0	0	3	3
10-11	0	0	0	0	1	0	2	3
12-13	0	1	0	0	0	0	0	1
14-15	1	0	0	0	0	0	1	2
16-17	0	0	0	0	0	0	3	3
18-19	1	0	0	0	0	0	0	1
20-21	0	1	0	0	0	0	3	4
TOTALS	**50**	**16**	**12**	**7**	**6**	**3**	**27**	**121**

Table 2.6 Certification Level of 1987-1990 Accident Cases

Certification	Male	Female	Totals	1990%	1989%	1988%	1987%
Student	2	1	3	0.7	3.1		
Basic	34	12	46	10.0	7.7	13.4	15.6
Open Water	141	61	202	44.0	41.4	35.4	35.9
Advanced	73	23	96	20.9	27.9	26.9	22.2
Divemaster	27	4	31	6.8	6.1	4.9	5.6
Instructor	36	12	48	10.5	10.5	11.2	11.1
Commercial	4	0	4	0.9	0.3	4.1	
Other	14	7	21	4.6	1.5	3.0	1.1
None	6	1	7	1.5			4.1
Unknown	1	0	1	0.2	1.5	1.1	4.4
TOTALS	338	121	459	100.0	100.0	100.0	100.0

Table 2.6 refers the level of certification of 1990 accident cases. Case collection and follow-up, which have improved over the years, have resulted in better information about certification levels. The commercial divers listed here were all diving recreationally at the time of injury. They may also have had other certifications but did not list them. The "other" category refers to individuals who chose to list a specialty certification such as rescue diver or master diver which are not choices on the reporting form. (The student category were divers performing their check-out dives when an injury occurred.) The "none" category refers to active divers who had not received certification. Several had dived successfully for years, but two were injured on their first or second dive.

The number of noncertified injured divers is counted in the yearly totals because their treatment is reported by hyperbaric treatment centers; however, the total number of noncertified divers is unknown. It is important to note that noncertified divers make up a very small portion of the total injury population and also, most likely, of the active diver population. However, diving without proper training may place an individual and their companions at increased risk for injury and possibly death.

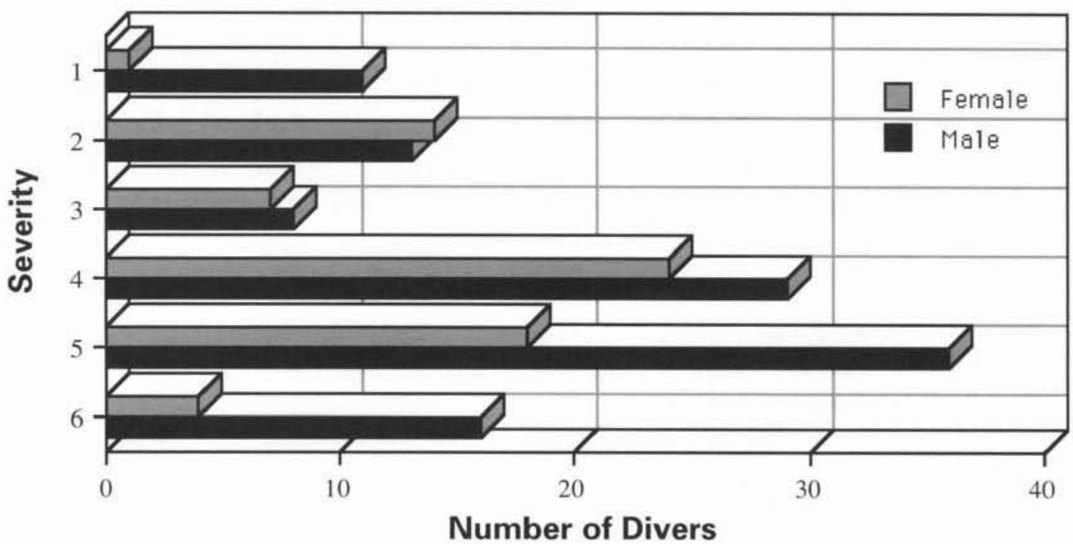
Table 2.7 New Diver Profile Attributes

Traits	1990 Frequency	1990 Percent	1989 Percent	1988 Percent
Outside Limits	43	23.8	18.0	31.0
Rapid Ascent	69	38.1	43.0	41.0
Square Dives	92	50.8	51.0	61.0
Diving ≥ 80 fsw	117	64.6	46.0	61.0
Repeat Dive	117	64.6	59.0	50.0
≤ 20 Dives	139	76.8	72.0	75.0

Frequency Missing = 278 — $n = 181$ — $n = 114$ — $n = 78$

New divers are defined by DAN as divers who have not dived more than 20 dives *and* have less than two years experience. New divers as a separate group were not studied until 1988. The above table shows that most new divers made no more than 20 dives. Most new divers are also repetitive divers, but this is common to the sport. More than half of all new divers over the past three years did at least one dive to 80 feet of sea water on the day of injury. Between 79 and 82 percent were diving within the limits of the repetitive dive tables in use at the time.

Graph 2.8 New Divers with Less than Two Years of Experience for 1988-1990



Between 65 and 82 percent of all injuries to new divers for the last three years had a severity code of four or higher indicating more serious symptoms of decompression illness or arterial gas embolism (AGE). A higher percentage of new divers appears to be more seriously injured than the rest of the injury population.

Table 2.9 Current Medical History and Disease Severity Code of Decompression Illness

	Severity						
Problem	**1**	**2**	**3**	**4**	**5**	**6**	**TOTALS**
Chest-lung	1	0	2	3	6	2	14
Asthma	1	0	1	5	0	1	8
Chest-heart	0	1	0	1	1	0	3
GI/Abdomen	0	0	1	3	7	1	12
Brain	1	0	0	1	0	0	2
Spine/Back	0	5	3	9	2	0	19
Limb/Joint DCS	0	2	1	6	1	0	10
Circulation/Blood	0	0	0	2	2	1	5
Neuro/Nerv system	0	0	0	1	3	1	5
Muscl/Skel system	0	2	1	3	5	2	13
Eye	1	0	0	0	0	0	1
Mental/Emotional	0	1	1	5	2	0	9
Other	3	7	3	10	6	3	32
None	46	54	23	110	80	29	342
TOTALS	**53**	**72**	**36**	**159**	**115**	**40**	**475***

Frequency Missing = 33

** Divers may have had more than one current problem.*

DAN uses a coding system (Appendix C) to describe the severity of decompression illness from pain only (Code 1) to unconsciousness or seizures (Code 6). Table 2.9 shows how many divers were diving with a health problem within the last two months and the severity of the injury. One hundred thirty-three current illnesses were reported by 84 divers. Table 2.10 shows that the frequency of injured individuals diving disease free has been steadily increasing. There could also be an under-reporting of current illnesses by divers. There is no specific correlation between any particular illness and the severity code.

Table 2.10 Percentage of Divers Without Current Health Problems

Current	1990	1989	1988	1987
Frequency	342	282	180	174
Percent	74%	72%	67%	64%
	n = 459	*n* = 391	*n* = 268	*n* = 270

Table 2.11 Previous Illness and Disease Severity Code of Decompression Illness

	Severity						
Problem	**1**	**2**	**3**	**4**	**5**	**6**	**TOTALS**
Chest-lung	0	4	1	8	8	4	25
Asthma	2	1	0	6	5	1	15
Chest-heart	0	1	1	8	4	1	15
GI/Abdomen	1	5	2	18	20	3	49
Brain	1	0	0	1	3	1	6
Spine/Back	3	5	3	15	13	1	40
Limb/Joint DCS	7	6	5	9	6	2	35
Circulation/Blood	0	2	0	0	1	0	3
Neuro/Nerv system	0	0	1	2	5	1	9
Muscl/Skel system	9	6	3	29	10	6	63
Eye	1	0	0	2	2	2	7
Mental/Emotional	0	0	0	2	1	0	3
Other	5	13	5	26	16	11	76
None	30	40	15	71	47	16	219
TOTALS	**59**	**83**	**36**	**197**	**141**	**49**	**565***

Frequency Missing = 1

** Divers may have had more than one illness.*

Past illness may represent an incident occurring as recently as two months prior to the scuba injury or many years prior. Although many divers have a history of illness, injury or surgery, these disease processes may be unrelated to the episode of decompression illness. Alternatively, any previous illness or injury that limits an individual's ability to perform physical activity, or inhibits gas exchange, may contribute to decompression illness in that individual. Table 2.12 shows that more than half of the individuals in the injury population had experienced a previous health problem.

Table 2.12 Percentage of Divers Without Past Health Illness

Past Illness	**1990**	**1989**	**1988**	**1987**
Frequency	219	184	129	131
Percent	48%	47%	48%	48%
	$n = 459$	$n = 391$	$n = 268$	$n = 270$

Table 2.13 Physical Fitness of Divers in Accident Cases

	1990		1989		1988	
Sex	Frequency	Percent	Frequency	Percent	Frequency	Percent
Male	299	88.5%	270	93.4%	184	87.6%
Female	105	86.8%	90	90.0%	49	84.5%
TOTAL	**404**	**88.0%**	**360**	**92.5%**	**233**	**86.9%**

$n = 459$ $n = 389$ $n = 268$

A high percentage of divers felt they were physically fit at the time they had decompression illness. Fitness is necessary in scuba to meet the physically challenging underwater environment and to be able to rescue one's self if necessary. For example, Table 2.14 shows that strenuous exercise was performed during the dive in 24 percent (112 of 459 divers) of all cases. An unfit individual may not have been able to physically respond to a situation which requires a period of strenuous exertion. Table 2.14 represents 29 percent of the female divers and 23 percent of the males. These percentages are greater than the percent of individuals who were not physically fit so the conditions of the dive were strenuous even for some fit individuals. Seventy five percent actually stated they exercised on a weekly basis averaging 3.5 days a week per diver. Accidents happen despite physical fitness.

Table 2.14 Strenuous Exercise Before, During or After Diving in 1990

	Prior to Dive	During Dive	After Dive
Male	59	77	27
Female	18	35	10
TOTAL	**77**	**112**	**37**

Additionally, many individuals chose to perform strenuous activity prior to their dive and sometimes after their dive on the dive day. Strenuous activity is subjective for each diver and does not mean the activity exceeded the ability of the diver to perform that activity. This activity may have been a sports activity such as jogging or lifting and carrying numerous tanks off a dive boat. Exercise to the point of muscle fatigue has been reported to contribute to the development of decompression illness. Thirty one males and thirteen females are counted in at least two categories of strenuous exercise. The numbers in the table represent 178 divers.

Table 2.15 Medication Use of the 1988-1990 Accident Cases

1990 Prescription Use		Nonprescription Use	
Frequency	Percent	Frequency	Percent
132	30.0	66	18.7

$n = 440$ $n = 353$

1989 Prescription Use		Nonprescription Use	
Frequency	Percent	Frequency	Percent
93	24.9	25	7.7

$n = 374$ $n = 325$

1988 Prescription Use		Nonprescription Use	
Frequency	Percent	Frequency	Percent
58	21.9	71	27.2

$n = 265$ $n = 261$

The percentage of divers using prescription medication has increased over the last three years. This is not an unexpected result since more than half of all divers have some past health illness (Table 2.11) which may be chronic and require medication. The "$n =$ " represents the number of people who responded to these questions. There were a substantial number of people who neglected to respond.

A partial review of these medications indicated that most individuals were taking antibiotics, antihistamines, specific medication prescribed for motion sickness or birth control. Other medications were related to heart and hypertension disorders, ulcers, muscle strain or injury and menopause. Some medications which may cause drowsiness could impair alertness during diving.

The most common nonprescription medications taken were decongestants and antihistamines. Decongestants are commonly used to prevent difficulty in equalizing the middle ears and sinuses. Over the counter antihistamines are used in an attempt to prevent motion sickness on the boat. Divers are not specifically asked about allergies so some may be taking medications for this condition as well. Aspirin was the other major nonprescription drug.

Table 2.16 Percentage of Alcohol Use in 1988-1990 Accident Cases

Time of Use	1990	1989	1988
Night before	39.9	40.9	43.3
Pre-dive	8.7	1.8	1.5
Between dives	1.1	1.9	2.2
Post-dive	16.1	15.6	10.4
None	53.6	48.3	51.9
TOTALS	**119.4***	**108.5***	**109.3***

Frequency Missing = 2   *n* = 459   *n* = 391   *n* = 268

* *Some divers engage in drinking in more than one category.*

Alcohol use is the number one contributing factor in many types of accidents, especially in motor vehicle accidents. Alcohol consumption can lead to an altered state of personality and impaired judgment. Perhaps the most significant aspect of alcohol use in diving is its dehydrating effect. Without appropriate rehydration fluids, repetitive drinking for days may lessen the body's ability to offgas nitrogen accumulated during scuba diving.

Table 2.17 Alcohol Use up to 12 Hours Before Diving

	Number of Drinks							
Severity	**1**	**2**	**3**	**4**	**5**	**6**	**≥7**	**TOTAL**
1	4	7	3	0	0	2	0	16
2	8	11	1	1	0	2	1	24
3	3	4	2	1	0	0	0	10
4	17	19	4	7	3	3	8	61
5	9	20	7	8	3	2	3	52
6	2	6	2	3	1	1	4	19
TOTAL	**43**	**64**	**19**	**20**	**7**	**10**	**16**	**182***

Frequency Missing = 276

* *One diver did not report a number of drinks.*

Table 2.17 shows the severity of injury in individuals who drank prior to their dive. These 182 divers consumed a total of 585 drinks. There appears to be a relationship between an increased number of drinks and the severity of decompression illness.

Table 2.18 Nausea, Hangover, Diarrhea, and Recreational Drug Use

Sex	Nausea	Hangover	Diarrhea	Drug Use
Male	3	4	9	3
Female	6	1	7	0
TOTALS	**9**	**5**	**16**	**3**

Frequency Missing = 13

Table 2.18 shows acute conditions that occurred during the dive trip prior to injury. Nausea and diarrhea have been the most common acute conditions affecting the diver on the dive day for the past several years. Both conditions contribute directly to diver dehydration and physical ability. Some recreational drug use and excessive alcohol use are reported, but these numbers may be low because divers do not wish to admit this behavior. These figures may also be low because divers generally avoid these conditions and behaviors.

Table 2.19 Lack of Sleep and/or Fatigue Prior to Last Dive

Sex	1990 Frequency		1990 Total	'90%	'89%	'88%
Male	84	of	338	24.9	30.1	32.9
Female	41	of	121	33.9	39.4	27.6
TOTAL	**125**	**of**	**459**	**27.2**	**32.5**	**31.7**

$n = 385$ $n = 268$

Fatigue is believed to be one of the personal attributes which may affect nitrogen offgassing after diving. Fatigue can also impede optimal physical performance and lead to inappropriate decision making. Forty percent of those divers who listed being fatigued on the last dive day had dived on the previous day before becoming symptomatic. The fatigue of those divers could have been a sign of decompression illness from the day before. According to the data shown in Table 2.19, 27 percent of the 1990 injury population began the injury dive day fatigued or with less than an adequate amount of sleep.

Table 2.20 Smoking History of 1988-1990 Accident Cases

Smoke	1990 Frequency	1990 Percent	1989 Percent	1988 Percent
Present	74	16.3	15.3	13.1
In past	122	26.8	24.8	17.5
Never	259	56.9	59.8	68.7
TOTALS	**455**	**100.0**	**100.0**	**99.3**

Frequency Missing = 4 $n = 391$ $n = 268$

The Center for Disease Control Office of Smoking and Health* reports that 51.9 percent of the population are either current smokers or smoked sometime in the past. Twenty-eight percent of the national population are current smokers. The percentage of current and past smokers is lower in injured divers than that of the national average. This low result may be expected because smoking and a potentially occluded airway are seen as an obvious scuba risk factor.

Twenty-four percent of the injured divers were current smokers and were diagnosed as having a gas embolism. Most gas embolisms in smokers occurred after rapid ascents (64 percent) or after buoyancy problems (29.4 percent). These events are considered starting causes of pulmonary overpressurization which can lead to gas embolism. Smoking would most likely not be considered contributory in these situations since there was a more provocative cause for the embolism.

Seventy six percent of the current smokers were diagnosed as having decompression sickness. Only 19.9 percent of the decompression sickness cases had a rapid ascent, and 5 percent had a buoyancy problem.

** National Health Interview Survey 1988 Center for Disease Control*

3.0 Dive Profile

The dive activity, frequency of diving and diver attribute trends make up the dive profile section. Data from previous years are presented in many of the tables to demonstrate those attributes which show little change over the years or those characteristics which may be increasing or decreasing. In order to accurately describe this population of injured divers, dive profile information should be considered in terms of how different attributes relate to each other. Few single pieces of data are representative of the entire injury population.

Sightseeing is likely the most common primary dive activity in scuba diving. Wreck diving and spearfishing were also popular primary and secondary dive activities. After collecting this information for the past three years, the data shows that approximately 86 percent of all dive accidents reported occurred in saltwater. This could be a reflection of the amount of diving done in saltwater.

Graph 3.1 Primary Dive Activity When Injury Occurred

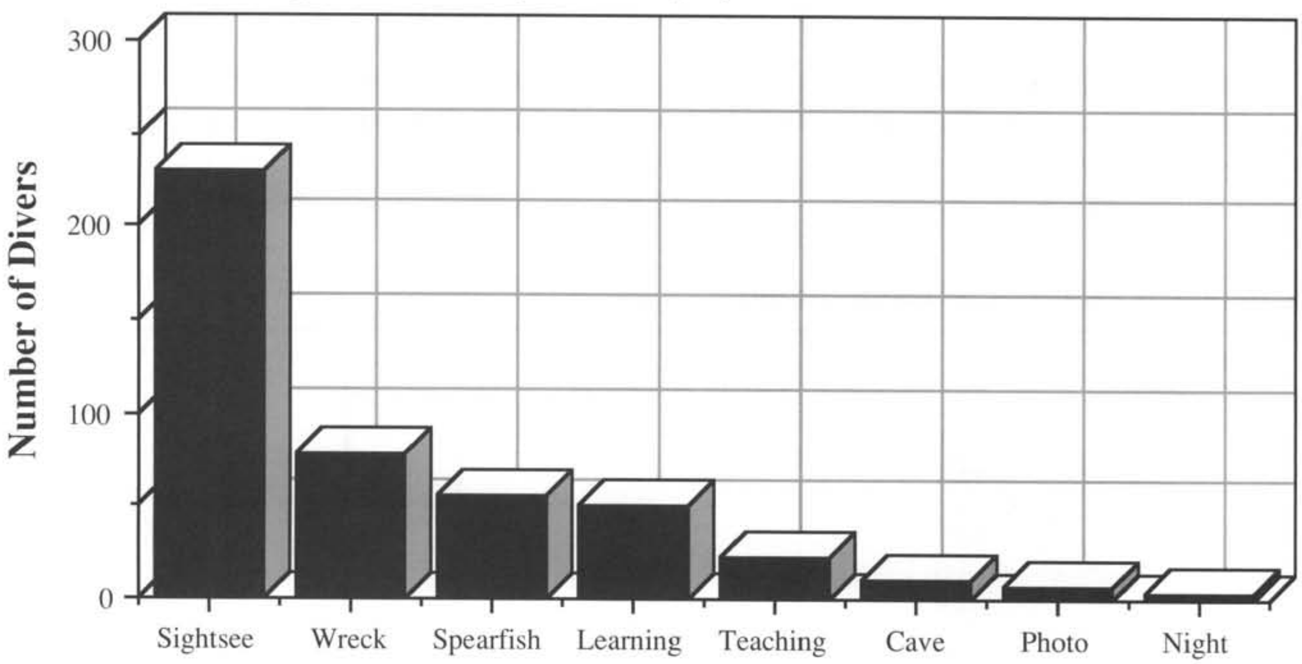
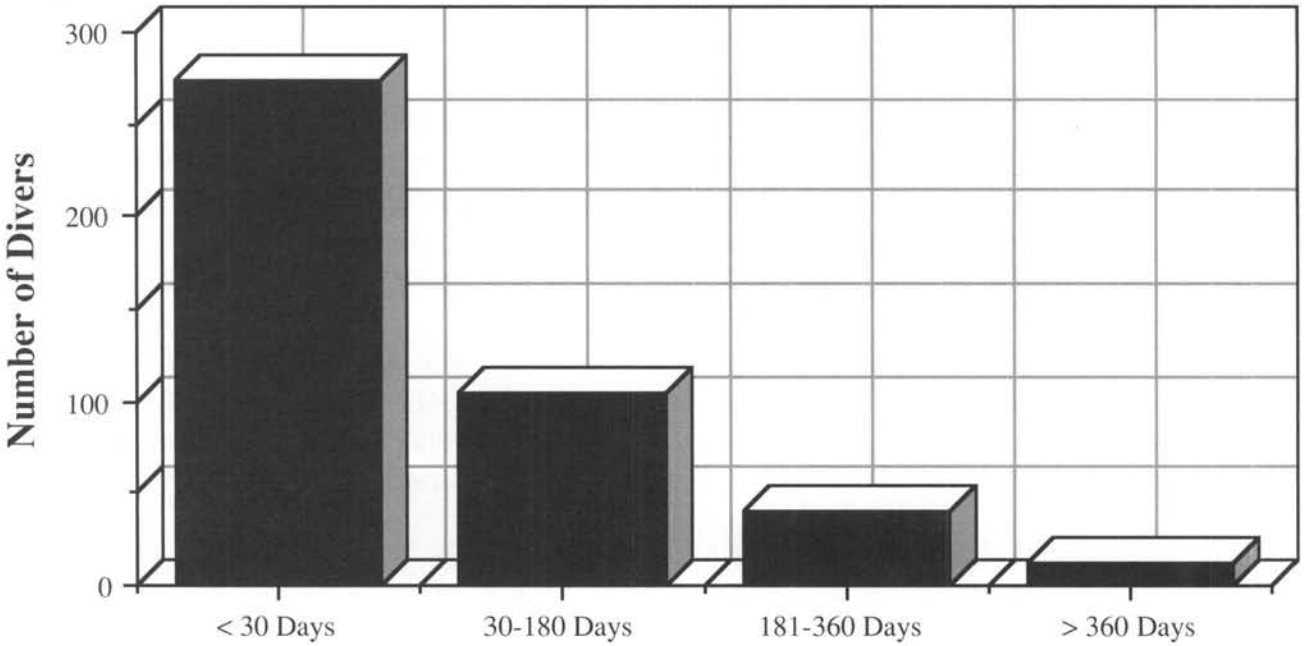


Table 3.2 Type of Water Environment

Type	1990 Frequency	1990 Percent	1989 Percent	1988 Percent
Freshwater	59	12.9	12.5	15.0
Saltwater	399	87.1	87.5	85.0
TOTAL	**458**	**100.0**	**100.0**	**100.0**

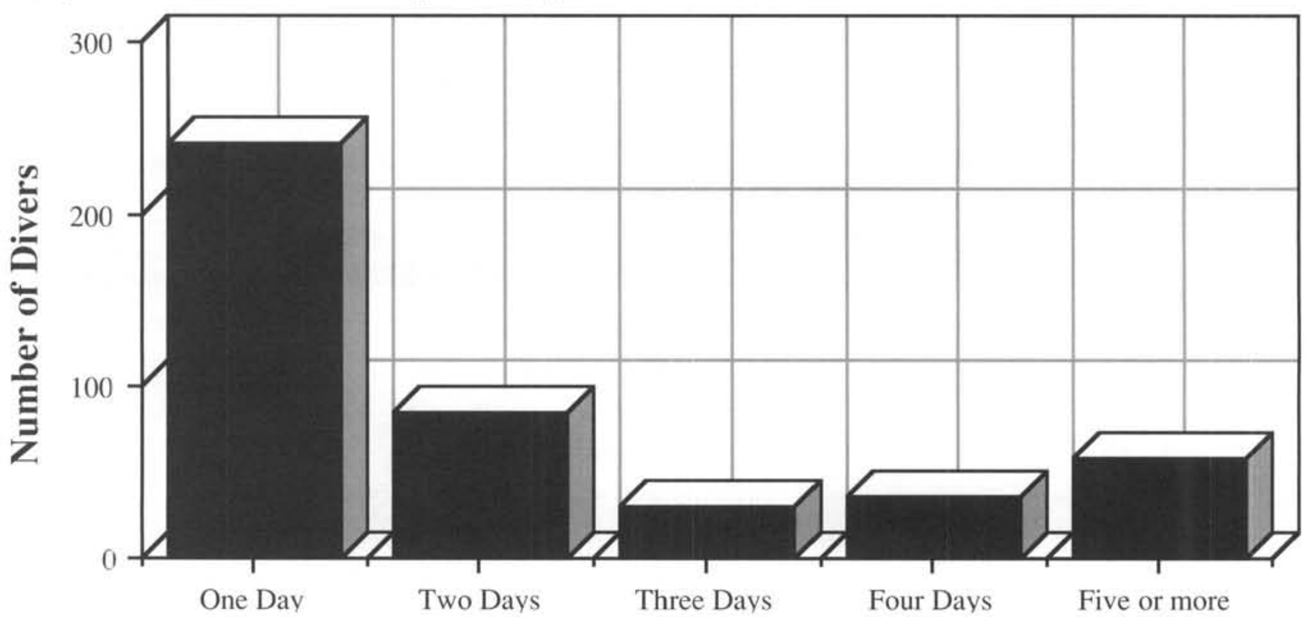
Frequency Missing = 1 $n = 391$ $n = 267$

Graph 3.3 Days Since Last Safe Dive



Two hundred and seventy three (59 percent) of all injuries occurred within 30 days of the last safe dive that had been performed. This group includes not only experienced divers who dive frequently but the new, inexperienced divers.

Graph 3.4 Number of Days Diving



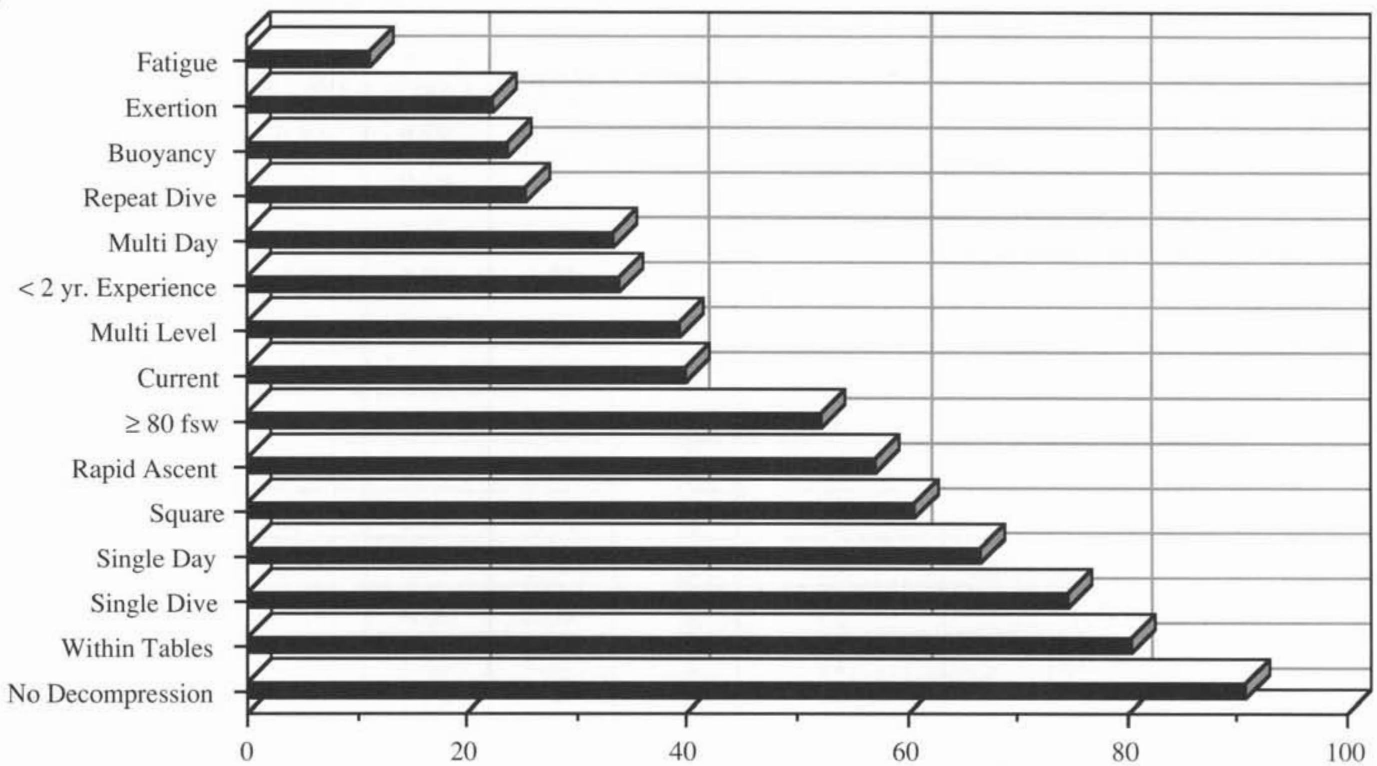
Single day dive injuries have increased over the last four years of data collection (see Tables 3.6 and 3.8). This was especially true in reported AGE cases. The overall percentage of single day decompression illness cases for 1990 was 52.7 percent.

Diver Characteristics

Dive characteristics for both types of decompression illness, decompression sickness (DCS) and arterial gas embolism (AGE) are broadly the same. Gas embolism can occur in any diver who ascends through the water column regardless of depth with any area of air trapping or voluntary breathholding on the part of the diver. On the other hand DCS results from a significant time exposure to a depth of 30 feet or greater. Both conditions result in bubble formation producing symptoms in the individual.

These two injuries are reported on separately because the mechanism of injury is different between the two diagnoses. Although the attributes of both injuries are the same, the frequency of occurrence is different. Attributes from previous years are also presented in order to demonstrate trends in the yearly results.

Graph 3.5 1990 Percentage of Divers With AGE Attributes



No decompression diving within the dive table limits in a single day and single dive seem to be the most prominent characteristics in AGE cases. The most important change has been a decreasing trend of AGE in inexperienced divers. Sixty percent of all AGE occurred using a square dive profile, and 56.3 percent of all AGE cases were related to a rapid ascent which can cause pulmonary barotrauma and lead to AGE. These dive attributes have consistently been associated with AGE dive profiles over the last four years.

Table 3.6 shows the comparison of previous years data in AGE. The number of AGE cases completed for analysis has increased due to better collection efforts. As the number of cases has increased, some trends have become more apparent. A contributory rapid ascent has slowly increased from 48 to 56.3 percent in four years. Since time and depth are not commonly associated with AGE, most AGE cases are within their dive tables and only about half are diving at 80 feet or greater compared to 68 to 76.8 percent of DCS cases who dove to 80 feet or more.

Tables 3.6 and 3.8 list dive attributes in the order in which they occurred in 1990. In this manner direct comparisons can be made between DCS and AGE. For example, rapid ascent occurs in only 22.4 percent of DCS cases but contributes to 57 percent of all AGE cases.

Table 3.6 AGE Dive Attributes

Attribute	Frequency	1990%	1989%	1988%	1987%
No Decompression	59	90.8	92.2	97.8	88.5
Within Tables	57	80.3	84.8	87.0	78.8
Single Dive	53	74.6	67.3	71.7	-
Single Day	46	66.7	53.8	69.6	88.5
Square	37	60.7	60.4	84.8	90.4
Rapid Ascent	40	57.1	55.8	54.3	46.2
≥ 80 fsw	37	52.1	46.2	45.7	51.9
Current	28	40.0	40.4	30.4	26.9
Multilevel	24	39.3	39.6	15.2	9.6
< 2 yr. Experience	24	33.8	47.1	54.3	38.5
Multi Day	23	33.3	46.2	30.4	11.5
Repeat Dive	18	25.4	32.7	28.3	25.0
Buoyancy	17	23.9	9.6	28.3	26.9
Exertion	16	22.5	15.7	21.7	21.2
Fatigue	8	11.3	25.5	28.3	34.6
		$n = 71$	$n = 52$	$n = 46$	$n = 52$

Decompression sickness has been associated more with deeper, multilevel, single day dives than has AGE. A record number of DCS cases involved repetitive diving within the tables, 80 feet or greater, with multilevel profiles. Some characteristics such as depth of dive and multilevel diving may reflect the increasing percentage of computer divers in the accident population.

Graph 3.7 1990 Percentage of Injured Divers With DCS Attributes

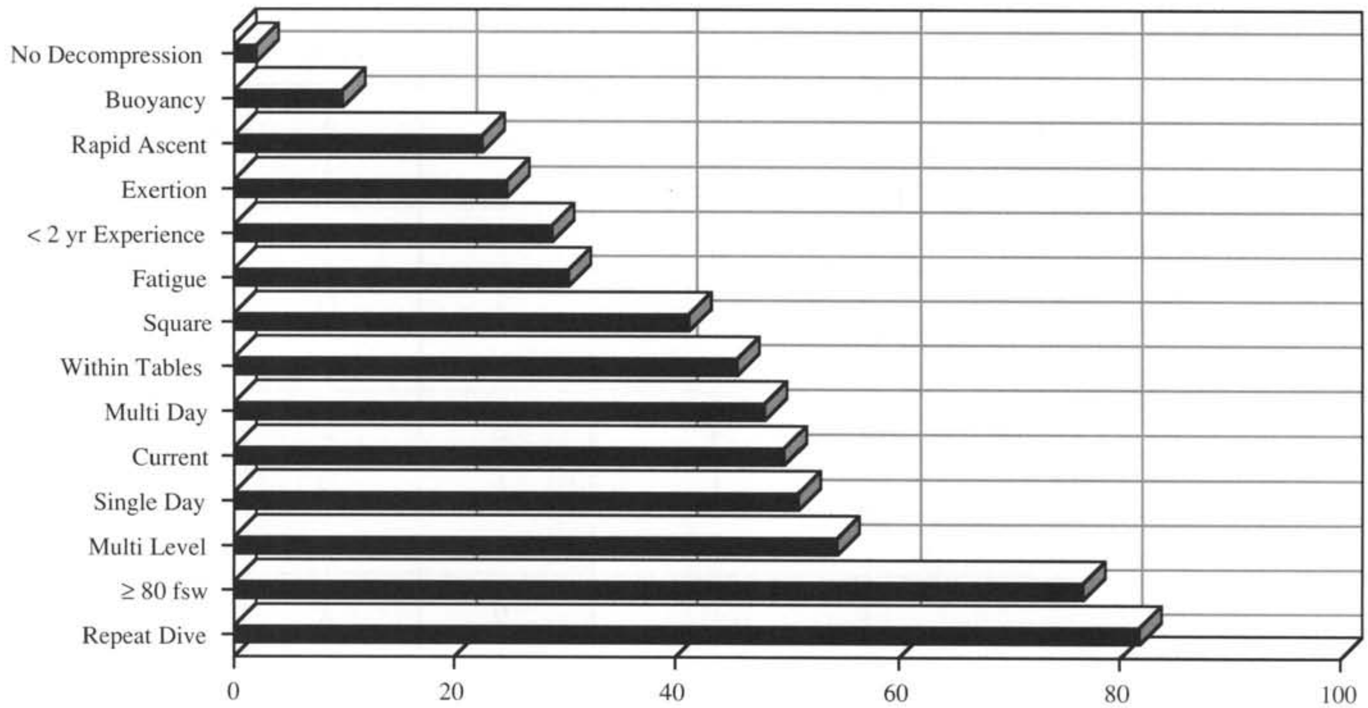


Table 3.8 DCS Dive Attributes

Attribute	Frequency	'90%	'89%	'88%	'87%
Repeat Dive	317	81.7	68.5	65.3	63.1
No Decompression	306	78.9	78.2	70.3	70.6
≥ 80 fsw	298	76.8	68.2	72.1	68.3
Multilevel	212	54.6	52.1	45.5	29.0
Single Day	203	52.9	50.6	48.2	61.9
Current	193	49.7	42.1	39.2	39.9
Multi Day	181	47.1	49.4	51.8	38.1
Within Tables	176	45.4	54.1	58.1	58.3
Square	160	41.2	42.6	54.5	71.1
Fatigue	117	30.2	32.9	32.4	37.6
< 2 yr Experience	112	28.9	11.5	23.9	29.8
Exertion	96	24.7	29.4	24.8	35.3
Rapid Ascent	87	22.4	25.3	23.9	23.4
Buoyancy	38	9.8	15.3	11.7	12.8
		$n = 388$	$n = 339$	$n = 222$	$n = 218$

Table 3.9 Equipment Problems

Equipment	Frequency	DCS	AGE
Regulator	12	4	8
BC Vest	11	6	5
Weight Belt	3	1	2
Dry Suit	3	3	0
DC Computer	8	6	2
Inflator Hose	4	2	2
Contaminated Air	1	1	0
Unfamiliar Equip.	8	6	2
Other	11	9	2
TOTALS	**61**	**38**	**23**

Frequency Missing = 398

Scuba is an equipment intensive activity, and proper maintenance and knowledge of equipment is essential to diver safety. Thirteen percent of the 1990 cases in this report involved equipment problems. The percentage of equipment problems has varied from 12 to 15 percent over the last four years.

Equipment problems do not necessarily mean equipment malfunction or failure. It could also mean unfamiliarity with equipment. These problems were a contributing factor to the development of decompression illness and in the cases of AGE may have caused the injury. Factors relating to buoyancy control and air supply most generally were associated with AGE. The other category of problems involved six gauge problems, a leaking mask, leaking octopus hose, failure to turn on computer, assisting another diver with an equipment problem and one unspecified problem.

Equipment problems were listed in 37 percent of the 1990 AGE accident cases. The percentage of equipment problems in AGE cases has steadily increased from 19.5 percent in 1987 to 26 percent in 1989. This trend suggests that a subset of divers may be able to prevent serious injury with better equipment maintenance and knowledge.

Table 3.10 1990 Computer Diving and Table Diving Comparison

	Computer Diving		Table Diving	
Attribute	**Frequency**	**Percentage**	**Frequency**	**Percentage**
≥ 80 fsw	174	85.7	161	62.9
Repeat Dive	167	82.3	180	70.3
Single Day	105	51.7	139	54.3
Multi Day	97	47.8	112	43.8
Square	65	32.0	132	51.6
	n = 203		*n = 256*	

A direct comparison is made between five common dive attributes associated with decompression illness in Table 3.10 among table and computer divers. Because computers adjust for multilevel diving by crediting divers for spending time at shallower depths, divers with computers can begin dives deeper, have a longer total bottom time and do more repetitive diving.

Table 3.11 Decompression Illness in Computer and Table Divers

	Computers					Tables			
	1990%	1989%	1988%	1987%		1990%	1989%	1988%	1987%
DCS I	28.1	31.0	31.0	26.8		17.2	18.5	18.5	15.8
DCS II	64.0	62.7	60.7	61.0		61.3	64.9	60.3	63.6
AGE	7.9	6.3	8.3	12.2		21.5	16.6	21.2	20.6
TOTAL	**100.0**	**100.0**	**100.0**	**100.0**		**100.0**	**100.0**	**100.0**	**100.0**
	n = 203	*n* = 126	*n* = 84	*n* = 41		*n* = 256	*n* = 265	*n* = 184	*n* = 228

In the DAN database there are twice as many arterial gas embolism cases occurring in table users than computer users. There was almost twice as much pain only limbs bends (DCS I) in computer users compared to table users. Part of the explanation for this may be that many computer users are more experienced divers and are less likely to run out of air or make a rapid ascent leading to neurological decompression illness (including AGE). Only 23 percent of the 1990 computer users had less than two years' experience and/or made 20 or less dives since certification. Multilevel profiles allow for longer bottom times at shallower depths which in turn decreases the partial pressure of nitrogen in the faster neural tissues but not necessarily slower peripheral tissue groups which is where DCS I is thought to occur. Interestingly, despite the difference in percentages of divers with DCS I who use tables versus computer users, the percentage of DCS II for computer and table users is approximately the same.

Table 3.12 Attributes of Computer Divers from 1987-1990

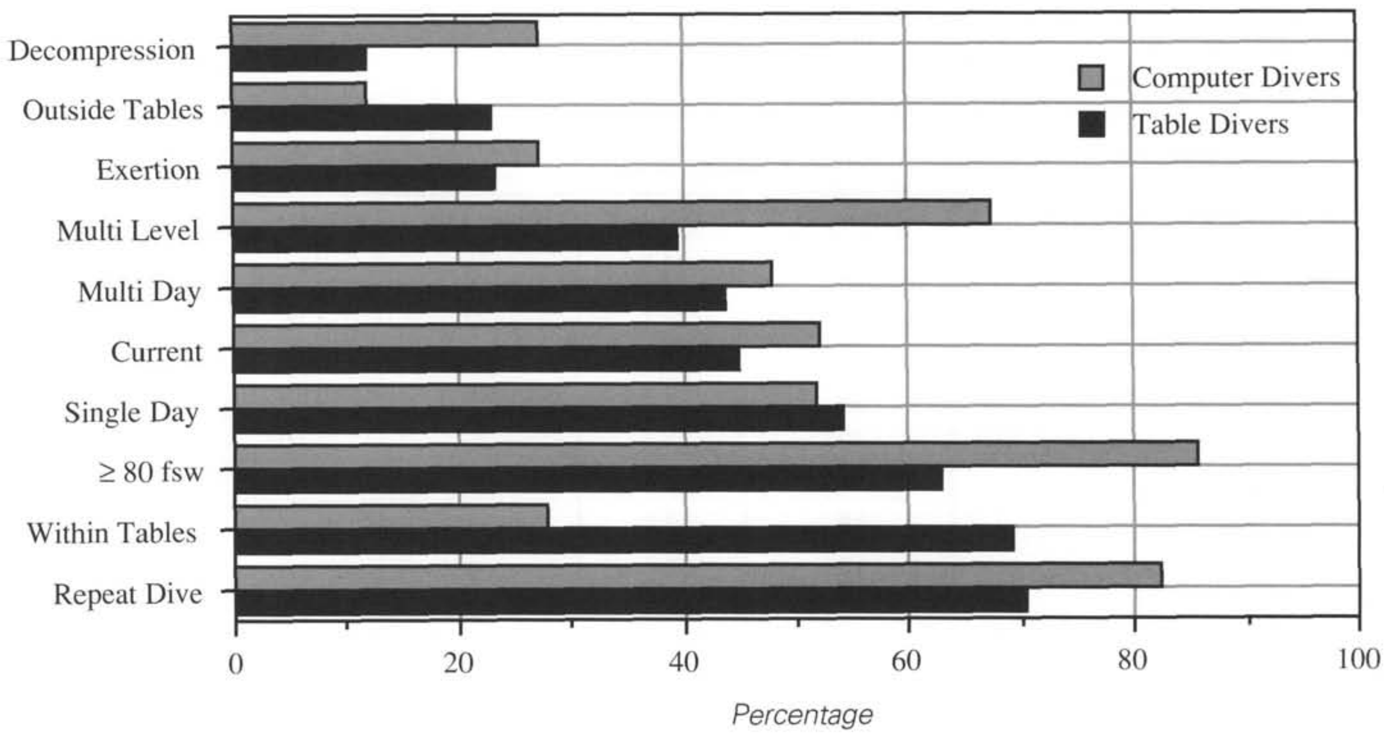
Attribute	1990 Frequency	1990%	1989%	1988%	1987%
≥ 80 fsw	174	85.7	81.0	82.0	92.7
Repeat Dive	167	82.3	73.0	80.5	73.2
Multilevel	137	67.5	68.3	58.4	56.1
Current	106	52.2	44.4	42.9	43.9
Single Day	105	51.7	48.4	45.5	48.3
Multi Day	97	47.8	51.6	54.5	51.7
Exertion	60	29.6	31.0	26.2	34.1
Within Tables	56	27.6	26.2	44.0	29.3
Decompression	55	27.1	20.6	36.9	48.8
Outside Tables	44	21.7	18.3	56.0	70.7
Frequency Missing = 256		$n = 203$	$n = 126$	$n = 84$	$n = 41$

Comparison of trends in table or computer use from 1987 to 1990 may be done using Tables 3.12 and 3.13. There have been increases in repetitive diving, single day diving and multilevel diving in table users. Among dive accident victims who use tables, there has been a steady decrease in the percentage of individuals who dive outside table limits. Staged decompression diving has decreased in computer users.

Table 3.13 Attributes of Table Divers from 1987-1990

Attribute	1990 Frequency	1990%	1989%	1988%	1987%
Repeat Dive	180	70.3	58.5	57.0	52.4
Within Tables	177	69.1	73.6	71.7	68.1
≥ 80 fsw	161	62.9	57.4	69.0	60.3
Single Day	139	54.3	59.6	52.0	49.7
Current	115	44.9	40.9	35.3	37.9
Multi Day	112	43.8	40.4	47.6	50.3
Multilevel	101	39.5	43.4	38.6	19.7
Exertion	60	23.4	26.6	23.4	32.3
Outside Tables	59	23.0	26.4	28.3	31.9
Decompression	31	12.1	16.7	19.6	21.8
Frequency Missing = 203		$n = 256$	$n = 265$	$n = 184$	$n = 229$

Graph 3.14 1990 Comparison of Computer and Table Diver Attributes



Graph 3.14 compares attributes of diving in both table and computer users in 1990. Dive computer use in individuals with decompression illness increased to 44.8 percent of all cases in the 1990 database. This is a 12.5 percent increase from 1989 and represents a threefold increase in computer use since 1987. This increase in computer use probably indicates the popularity of dive computers rather than an increased risk associated with computer use. The way in which computers and tables are used and individual diver decisions are more likely to account for an injury.

4.0 Symptoms

Table 4.1 1990 Most Frequent Symptoms of Decompression Illness

	First Symptom		Second Symptom	
Symptom	Frequency	Percent	Frequency	Percent
Pain	188	41.0	91	21.8
Numbness	82	17.9	102	24.5
Dizziness	36	7.8	21	5.0
Weakness	26	5.7	49	11.8
Headache	26	5.7	29	7.0
Nausea	18	3.9	22	5.3
Extreme fatigue	18	3.9	18	4.3
Other	15	3.3	0	0.0
Itching	8	1.7	9	2.2
Unconscious	7	1.5	8	1.9
Difficult breathing	7	1.5	0	0.0
Visual disturbance	5	1.1	4	1.0
Rash	4	0.9	3	0.7
Personality change	3	0.7	0	0.0
Bowel problem	3	0.7	1	0.2
Paralysis	3	0.7	8	1.9
Restlessness	2	0.4	11	2.6
Speech disturbance	2	0.4	3	0.7
Semi-conscious	2	0.4	4	1.0
Convulsion	1	0.2	0	0.0
Hemoptysis	1	0.2	1	0.2
Hearing loss	1	0.2	1	0.2
Difficult walking	1	0.2	0	0.0
Bladder problem	0	0.0	0	0.0
Muscle twitch	0	0.0	2	0.5
Reflex change	0	0.0	0	0.0
Ringing ears	0	0.0	0	0.0
TOTALS	**459**	**100.0**	**387**	**92.8**

Table 4.2 Decompression Illness Symptoms Prior to Last Dive

Sex	1990 Frequency		1990 Total	1990 Percentage	1989%	1988%
Male	47	of	338	13.9	12.4	14.8
Female	23	of	121	19.0	25.3	26.6
TOTAL	**70**	**of**	**459**	**15.2**	**15.7**	**17.5**
					$n = 381$	$n = 268$

Table 4.3 Disease Diagnosis

Final Diagnosis	1990 Frequency	1990 Percent	1989%	1988%	1987%
DCS I	101	22.0	22.5	22.4	17.4
DCS II	287	62.5	64.5	60.4	63.3
Air Embolism	71	15.5	13.0	17.2	19.3
TOTAL	**459**	**100.0**	**100.0**	**100.0**	**100.0**
			$n = 391$	$n = 268$	$n = 270$

The frequency of symptoms in decompression illness is listed in Table 4.1 The most common initial symptom in the 1990 accident population was pain.

Table 4.2 demonstrates that between 15 and 17.5 percent of divers with decompression illness continued to dive after developing the first symptom of decompression illness. The reasons for this are not apparent. However, this may have been due to a lack of symptom recognition or possibly reluctance to mention symptoms in a group of peers. It can be seen that the majority of divers in this accident population reported neurologic symptoms at some time prior to recompression.

The diagnoses DCS I, DCS II or Air Embolism were assigned either by the treating physician or by DAN after careful review of all records. DCS I includes cases of pain only bends occurring in the extremities or skin bends. DCS II includes all cases of decompression illness with neurological or cardiopulmonary symptoms except those diagnosed as air embolism. The diagnosis of air embolism was assigned to those individuals with an acute onset of neurological symptoms within 30 minutes of surfacing in the presence of a risk factor (rapid ascent, breath hold, lung disease) or if the depth-time profile is such that no significant inert gas loading could have occurred. As in previous years DCS I in 1990 forms a minority of total cases of decompression illness. This is in contradiction to previous reports for professional or military divers. Possible reasons for this might be:

1. Recreational divers often dive in areas which do not have a hyperbaric chamber immediately available. Cases of decompression illness which might otherwise have been classified as Type I may progress to Type II because of the delay. Evidence and support of this is found in Table 4.1 which indicates that the first symptom of decompression illness in the DAN experience is most commonly pain. Second and third symptoms are usually neurological in nature.

2. In professional or military diving Type II decompression illness has a greater "penalty" in terms of time off work or potential disqualification than Type I and, therefore, may be underreported.

Table 4.4 DAN Disease Severity Code

Severity Code	1990 Frequency	1990 Percent	1989 Percent	1988 Percent	1987 Percent
Code 1	54	11.76	12.00	14.55	11.48
Code 2	71	15.47	11.80	12.31	20.74
Code 3	30	6.54	6.40	10.82	9.63
Code 4	150	32.68	36.10	28.73	30.37
Code 5	115	25.05	22.00	24.63	15.19
Code 6	39	8.50	11.80	8.96	12.59
TOTAL	**459**	**100.00**	**100.00**	**100.00**	**100.00**
			$n = 391$	$n = 268$	$n = 270$

Symptomology in recreational divers is quite often severe as evidenced by the fact that over 65 percent of divers are in severity codes 4, 5 or 6. There have been small yearly fluctuations in the distribution of divers' symptoms within the DAN severity codes, but the percentages have not changed appreciably from 1987 to 1990. This data represents 43 to 62 percent of the yearly total of treated cases. The DAN Severity Coding System is shown in Appendix C.

Table 4.5 Percentage of Decompression Illness in Males and Females and the Total Population

Sex	1990	1989	1988
Male	12.7%	15.1%	12.4%
Female	10.7%	11.8%	8.6%
Total Population	12.2%	14.1%	11.6%
	$n = 459$	$n = 391$	$n = 268$

Table 4.5 shows that few divers get decompression illness twice. A smaller percentage of females reported a previous episode of decompression illness than males.

Table 4.6 Current Injury Severity Code vs. Previous Dive Injury Diagnosis

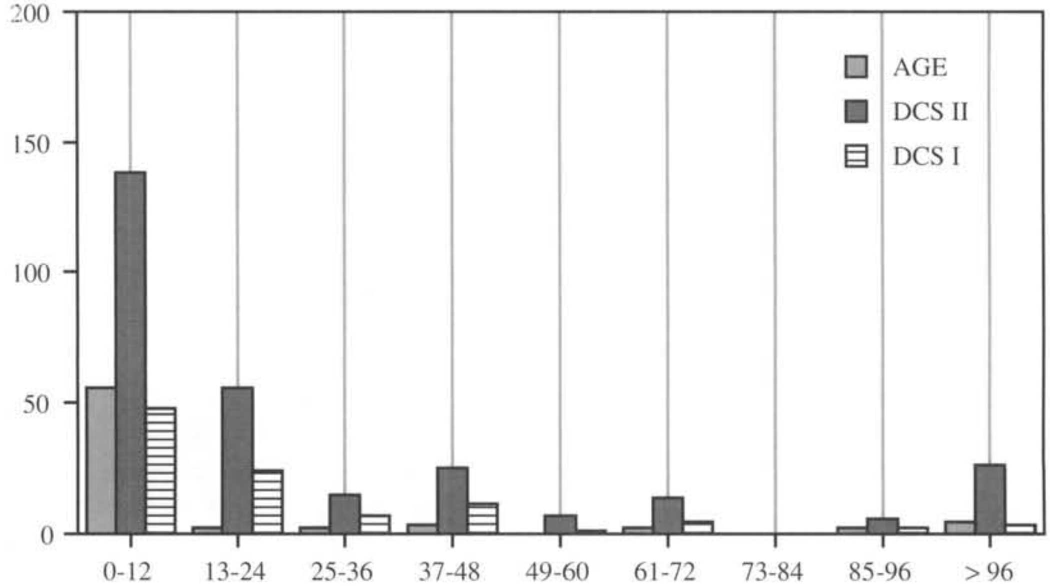
Current	Previous		
Severity	AGE	DCS	Total
1	1	12	13
2	0	8	8
3	0	4	4
4	0	15	15
5	0	13	13
6	1	2	3
TOTAL	**2**	**54**	**56**

Previous injuries are shown as either AGE or DCS, and the totals for each injury are shown at the bottom of Table 4.6. The second injury is represented by one of the severity codes. Of the three cases of previous decompression illness that had a severity code of six, one had a previous AGE and the other two had been diagnosed as decompression sickness. The individual with the previous AGE had been restricted from ever diving again by a physician within 30 days of the second incident.

It is of note that a total of 56 individuals (12.2 percent) had a previous episode of decompression illness. The results of our prospective study performed in 1989 indicated that only 2.5 percent of randomly selected insured DAN members had a previous episode of decompression illness. These data suggest that recreational divers who experience decompression illness may be predisposed either due to physiological factors or behavior patterns (e.g., depth-time profiles, heavy diving exposure or inappropriately high ascent rates).

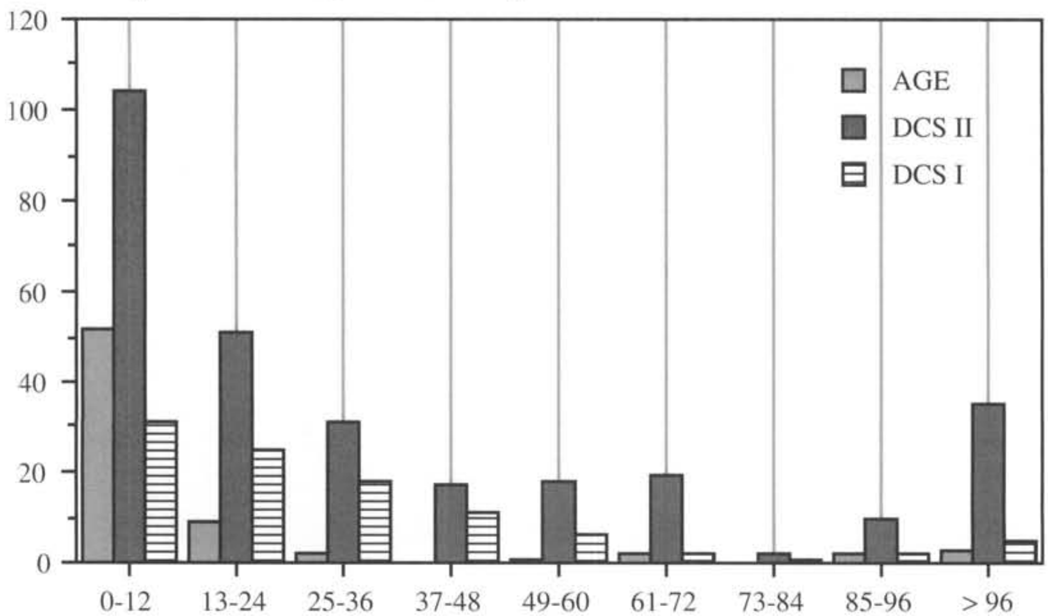
5.0 Treatment

Graph 5.1 Delay to Calling for Assistance

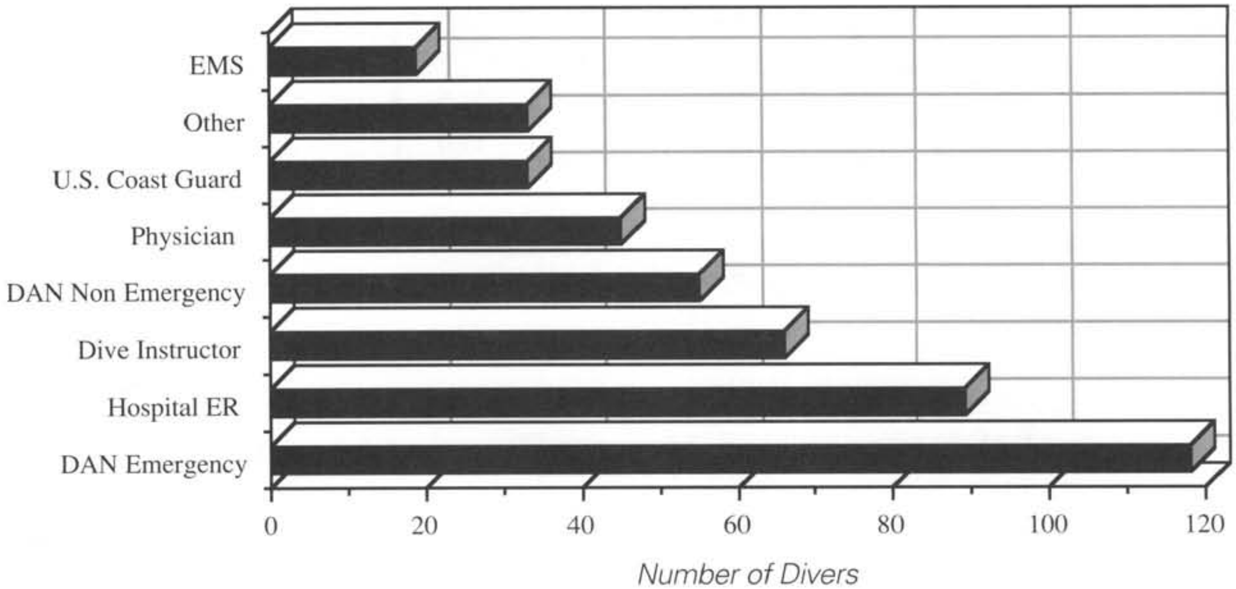


There are many reasons divers delay seeking medical evaluation or assistance. As mentioned in Section 3.0 symptoms, symptoms can be very subtle and go unnoticed for some time. Decompression illness pain can be mistaken for normal aches and pains common to exertion. Some individuals may prefer not to seek evaluation due to remote locations or do not feel their symptoms are serious enough to seek treatment. The delay in seeking assistance creates the delay in treatment shown in Graph 5.2 and may decrease the possibility of immediate and complete resolution.

Graph 5.2 Delay to Recompression



Graph 5.3 First Contact for Assistance



A total of approximately 182 divers out of 459 (40 percent) used DAN as their first contact for assistance. This appears to indicate that DAN is providing a useful service to individuals with decompression illness. Additionally, DAN is contacted by many hospital emergency departments, local EMS, personal physicians and the U.S. Coast Guard when emergencies arise. Assistance may consist of arranging transportation to a hyperbaric chamber or medical management advice to a non- diving medicine trained physician. Sixteen divers contacted a hyperbaric chamber directly in the "other" category while some contacted friends, certifying agencies and other health service providers.

Graph 5.4 First Aid Used

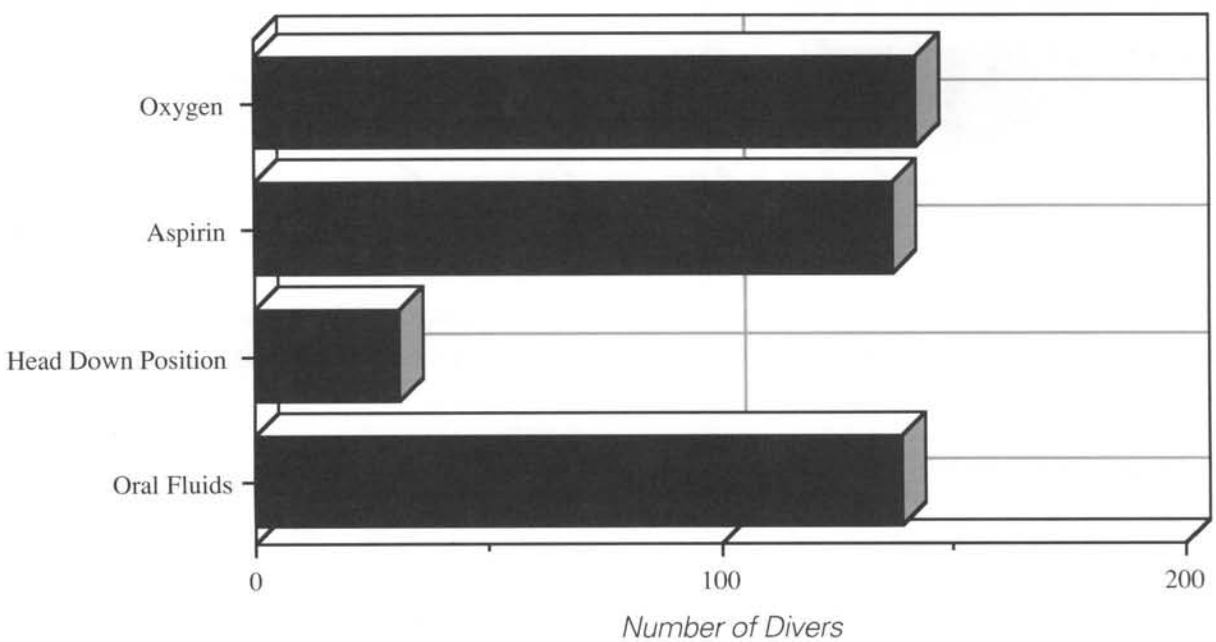


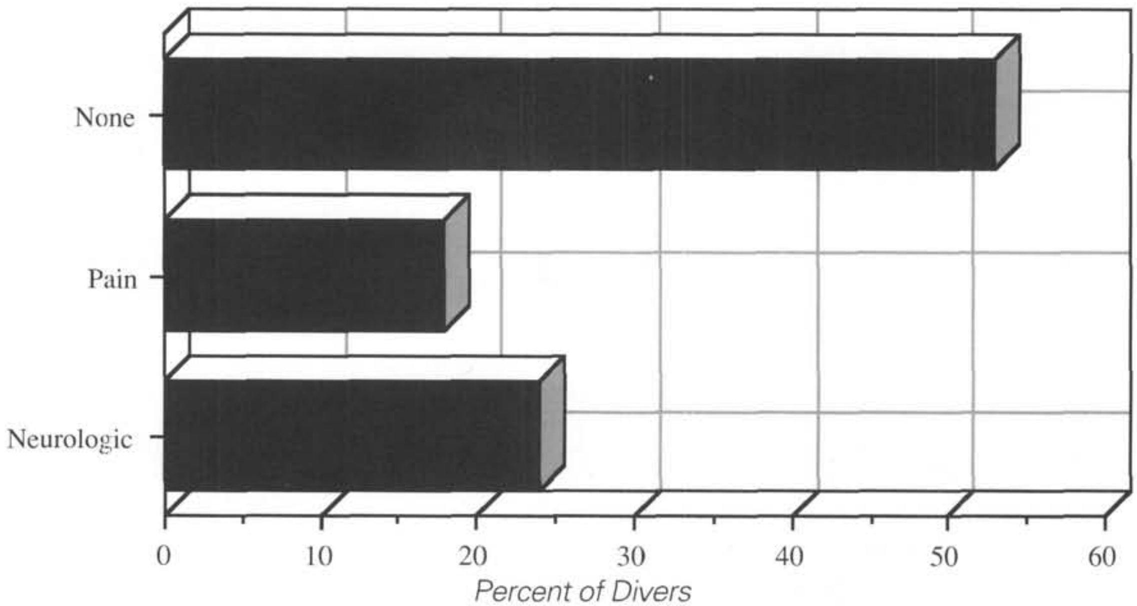
Table 5.5 Accident Management

	1990 Percent	1989 Percent	1988 Percent	1987 Percent
Oxygen	30.9	33.2	34.0	35.6
Oral Fluids	30.3	23.8	18.7	17.0

The trend in the use of oxygen and oral fluids as a first aid measure is shown in Table 5.5. Percentages are shown for those cases where a diver received the first aid mentioned. Some first aid fields on the DAN reporting form were not marked.

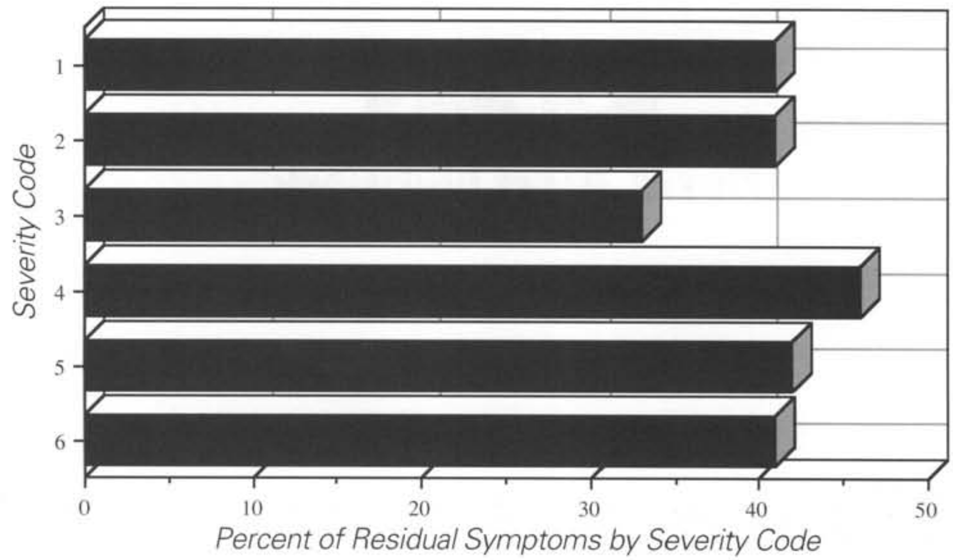
Reassuringly, oxygen is being used in approximately one third of all cases. However, this percentage has been slowly decreasing since DAN began collecting this information. Approximately one third of injured divers are also receiving oral fluids. Interestingly, despite their limited value, analgesics and/or head down position are still used in a significant number of cases.

Graph 5.6 Post-Treatment Residuals

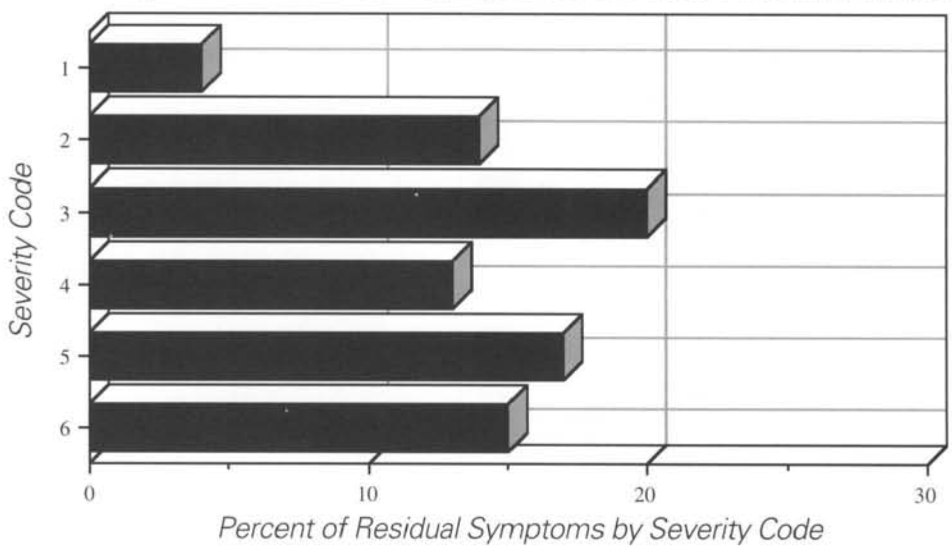


Fifty-three percent of all decompression illness cases who received treatment stated there was complete resolution of symptoms at the end of hyperbaric therapy. Resolution may have occurred after a single treatment or after multiple hyperbaric exposures.

Graph 5.7 Residual Symptoms after Completion of Hyperbaric Therapy



Graph 5.8 Residual Symptoms at Three Months Post Treatment



Post treatment residual symptoms are present in approximately 40 percent of all injured divers. Like similar types of trauma with more visible signs of injury, time is needed to resolve the effects of a dive injury. This fact may be overlooked because decompression illness does not manifest itself with any external signs of injury.

According to the 1990 injury data, divers with neurological symptoms of decompression illness were the most likely to still have symptoms three months after being treated. The degree of disability cannot be inferred from Graph 5.8 since no detailed information on residual symptoms severity is available.

DAN

Divers Alert Network

1990 Report on Diving Fatalities

6.0 Introduction to Diving Fatalities

The 1990 report on scuba fatalities represents a joint effort by Divers Alert Network (DAN) and the National Underwater Accident Data Center (NUADC) at the University of Rhode Island (URI) to collect and study underwater diving fatalities. This report covers those fatalities which occurred to United States citizens who were recreational divers. These fatalities occurred in U.S. waters, U.S. territories, the Caribbean basin islands and throughout the world. Deaths of divers involved in commercial or scientific pursuits are included in the Occupational Diving Fatalities in Appendix H.

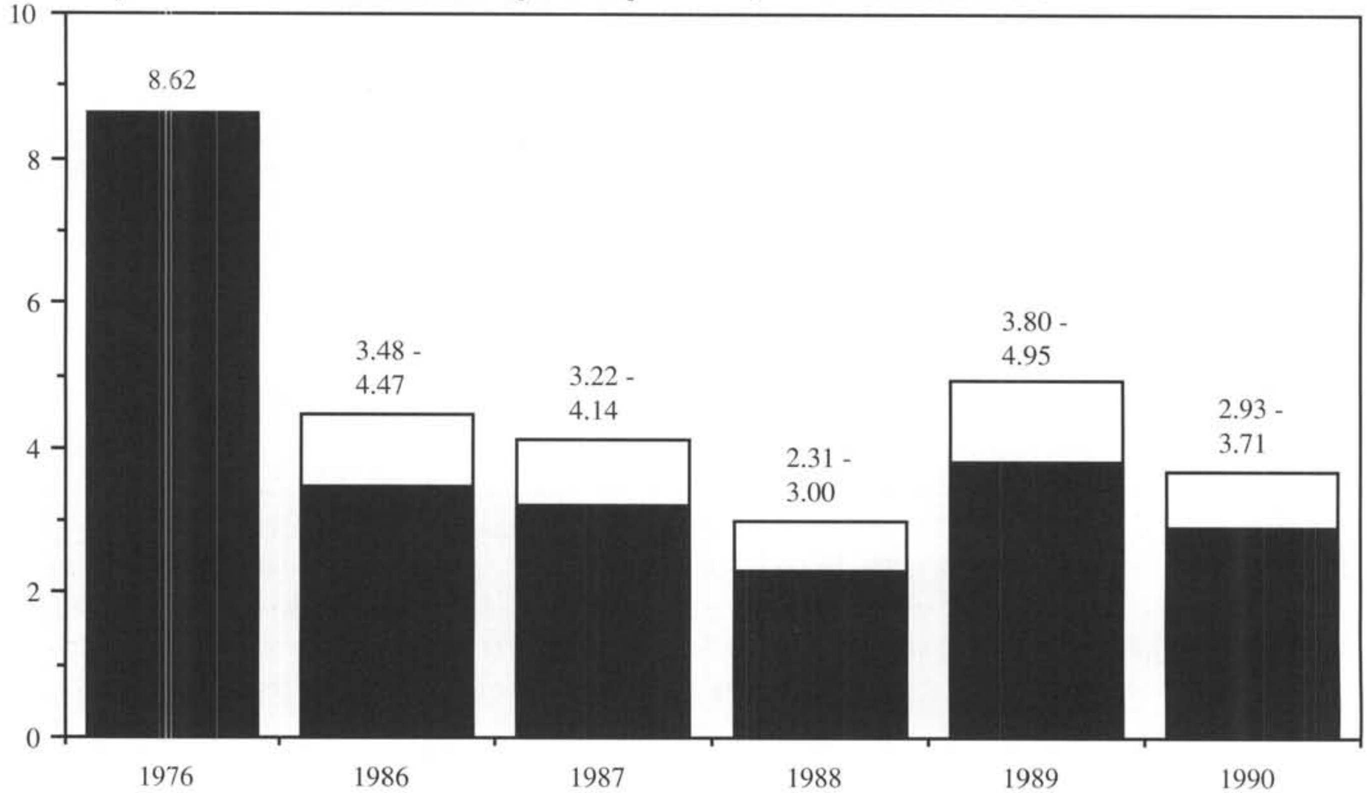
NUADC has been collecting scuba fatality information and attempting an analysis of the active diver population in the United States for the past twenty years. Since 1989 DAN and NUADC have been collaborating in this effort. In order to estimate the fatality risk for scuba, the surveys of three national research firms were reviewed by NUADC. These firms were Diagnostic Research Inc., Mediamark Research Inc., and the National Sporting Goods Association (NSGA) (as a part of "Sports Participation in 1990, Series II"). NUADC has combined the information from these studies and the data collected by its staff in order to determine an estimated range of active scuba divers for 1990. All three studies dealt with recreational (nonoccupational) divers. NUADC has done a careful review of the studies and has established an estimated active diver population in the United States of 2.45 to 3.1 million at the end of 1990.

The major difficulty of comparing these studies was the lack of a consistent definition for an "active" diver. Divers may be excluded in one study because they were under 18 years of age or included in another study if they dove more than twice a year. Certification was not necessarily a criteria for being an active diver. Although common characteristics used to establish an active diver varies from study to study, several common attributes exist. All three studies include individuals engaged in training for entry level certification while excluding those taking introductory (resort) sessions. Another activity known as technical diving is included in the active diver population but is not considered recreational and is discussed separately. Technical diving can be loosely defined as an avocation which uses specialized techniques, equipment, training and skills to advance beyond the present limits of recreational diving.

For 1990, 95 recreational (nonoccupational) scuba diving fatalities were reported. Four of these deaths were foreign nationals which leaves a total of 91 scuba fatalities of U.S. citizens. Further analysis of the 1990 data shows that eleven (12 percent) of the 91 fatalities involved victims who had not been certified. This leaves only 80 certified diver fatalities. Certified and uncertified divers are reported on separately except where noted.

There are several reasons why a range is used when describing the number of active divers. No reliable numbers are available to determine how many new divers are certified each year. NUADC estimates there could be 550,000 newly certified divers yearly. Not all will remain active after the first year of diving. Drop out continues for several years adding to an unknown cumulative drop out rate. Although 550,000 individuals may have received a first time certification, the total active diver increase in 1990 was between 100 to 150 thousand certified divers due to the overall drop out rate. Additionally, divers may choose to reenter the active diver population anytime after being certified which will also cause the

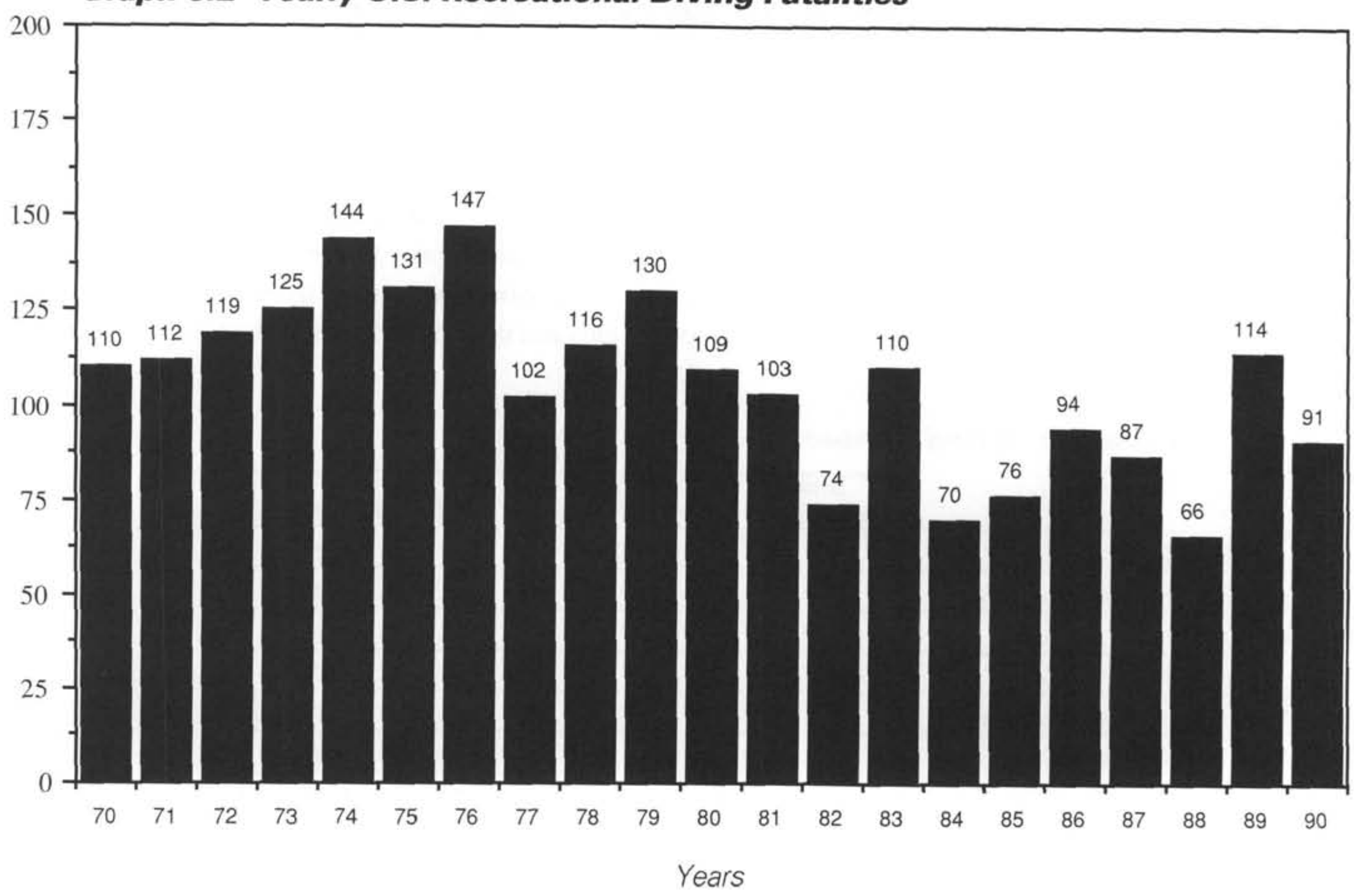
Graph 6.1 Estimated Fatality Rate per 100,000 Active Divers



number of active divers to vary. There is no way to track the number of divers who reenter the sport. It is possible that during the course of a calendar year, the "active diver" population could vary by several hundred thousand divers. For these reasons an estimated range is best suited to describe the U.S. active diver population.

Graph 6.1 shows a comparison of estimated fatality rates per 100,000 divers for recent years. These rates are based on data collected by NUADC. If calculated on the basis of 2.45 to 3.1 million active divers, the fatality rate for 1990 is 2.93 to 3.71 fatalities per 100,000 active divers. Although this is an estimated fatality rate for scuba diving, it suffices to say the rate is very low. Since we are unable to determine the number of noncertified divers in the active population, it is impossible to give an accurate fatality rate per 100,000 certified divers.

Graph 6.2 Yearly U.S. Recreational Diving Fatalities



A review of the scuba fatalities since 1970 reveals a decreasing trend in yearly scuba fatalities. The 1970s were by far the worst years for fatalities in recreational scuba diving. Increased training standards and diver awareness are believed to have led to a decrease in fatalities in the 1980s. The reported number of deaths in the eighties is much lower than those reported for the 1970s. The 1970s averaged 130 deaths per year compared to an average of 90 deaths per year in the 1980s. The first two years of the 1990s have produced an average of 78.5 fatal dive accidents per year. More importantly, scuba deaths have shown a decreasing trend in the last several years. The peak year for scuba fatalities was in 1976 when there were 147 deaths, and there was a recent peak in 1989 with 114 deaths. There were record lows of 66 scuba deaths in 1988 and 67 in 1991.

According to the NUADC estimate, the number of active certified divers is increasing each year, and the number of fatalities is decreasing. Therefore, the decreasing number of fatalities represents a dramatic decrease in the fatality rate since the 1970s.

7.0 Methods of Fatality Data Collection

DAN relies on several sources for information on possible scuba diving fatalities. Table 7.1 shows the individuals or agencies that served as initial contacts in 1990 scuba deaths. Reports from the DAN network accounted for 35.2 percent of initial contacts, including 18.7 percent from general DAN membership, 11.0 percent from network chambers, and 5.5 percent on the DAN 24-hour emergency line service. Subscription services accounted for 31.9 percent of initial contacts. Other contributions were made by law enforcement agencies, newspaper staff, medical examiners, private physicians and the United States Coast Guard.

Table 7.1 Initial Contacts

	Inside United States	Outside United States	Total	Percentage
DAN Network*	25	7	32	35.2
Subscription Services**	20	9	29	31.9
Legal/Agency	10	5	15	16.5
Newspaper	7		7	7.7
Medical Examiners	4	2	6	6.6
USCG	2		2	2.2
TOTAL	**68**	**23**	**91**	**100.0**

* *General membership, network chambers and emergency line*
** *Luce, Compuserve, Burrell's*

After receiving a report that a scuba diving fatality may have occurred, DAN verifies the incident through local authorities, medical services, or regional newspapers. Following verification of each incident, DAN requests copies of autopsy reports, investigation reports and, when possible, witness statements. Using information from these sources, DAN analyzes the cumulative database to identify contributing conditions and common trends. The detail and accuracy of the annual report depend on the quality of information

obtained by the reporting agencies and individuals. DAN can most accurately identify the factors involved when it receives an autopsy report, a thorough investigation report, and witness/family statements.

Table 7.2 shows information sources for 1990. In the table we do not distinguish between the reports containing witness statements and those that do not. Where family or witness interviews have been noted, DAN has either spoken directly with an individual or received a written statement not included in an investigation report.

DAN received an autopsy report in 64.8 percent of the cases (59 of 91). In 49 of the 59 cases, DAN also obtained an investigation report. An autopsy report was not available in 32 fatality cases, which includes 16 cases where the autopsy report could not be released. Additionally, in six cases, family members requested that no autopsy be performed, or an autopsy could not be done. Rescuers were not able to locate nine bodies. Main sources of information in these 32 cases included investigation reports, local

Table 7.2 Information Sources

Autopsy, investigative/coroner report & family/witness interview	9
Autopsy and investigative/coroner report	40
Autopsy and local contact/family or witness interview	9
Autopsy and news clippings	1
Investigative report	13
Local contact	8
Witness	7
Newspaper only	4
TOTAL	**91**

contacts, witness/family interviews and news clippings. When used as a sole source of information, news clippings generally do not provide adequate information. The media highly publicized three of the four cases where news clippings were the only source of information, and no additional information could be obtained. Scuba certification agencies were able to verify the fatalities in these cases. In the fourth case, a single news clipping was the only source of information. This report could not be verified by a second source.

Determining contributing factors such as medical history and current health status is a difficult aspect of fatality data analysis. Information on individuals' health conditions is difficult to obtain. Medical information was lacking in many cases, but health conditions may have contributed to some scuba deaths. Autopsy information such as levels of alcohol, recreational drugs, anti-depressants and cardiac medications may indicate the diver's mental or physical condition at the time of the incident. Currently, a detailed toxicology report is only available in a small number of cases. Family members, close friends, and diving partners sometimes have this information when a detailed toxicology analysis is not available. In the future, public awareness of DAN's efforts to analyze fatalities will increase information from these sources.

Location of Diving Fatalities

Tables 7.3 and 7.4 show the location and distribution of scuba diving fatalities occurring in each of the fifty United States and in areas outside of the United States. The tables show the total number of fatalities along with the percentage of the 1991 total. This percentage compares fatalities by location to the total of 1990 fatalities. This is not an incident rate. An incident rate would relate the number of fatalities at a particular location to the number of divers visiting the same location. Thus, a high number of fatalities may represent a popular diver distribution. Alternatively, it may represent a high number of unqualified individuals who perform a hazardous type of diving that artificially increases the number of deaths in a certain state. For example, cave diving deaths in Florida are artificially high because recreational divers attempt dives they are not qualified to perform.

The state of Florida recorded 22 scuba fatalities during 1990, seven of which occurred in underwater caves. This is a considerable reduction from the 1989 tabulations which showed 29 deaths with nine deaths in caves. California had a 33 percent reduction in fatalities in 1990 with 14 deaths as compared to

Table 7.3 Location of Diving Fatalities by State

	Certified	Uncertified	Total	Percentage
Florida	14	8	22	24.2%
California	12	2	14	15.4%
Washington	4		4	4.4%
Hawaii	3		3	3.3%
Maine	2	1	3	3.3%
New York	3		3	3.3%
Massachusetts	2*		2	2.2%
New Jersey	2		2	2.2%
Pennsylvania	2		2	2.2%
Rhode Island		2	2	2.2%
Wisconsin	2		2	2.2%
Connecticut		1	1	1.1%
Illinois	1		1	1.1%
Louisiana	1		1	1.1%
Montana	1		1	1.1%
Ohio		1	1	1.1%
Oregon	1		1	1.1%
South Dakota	1		1	1.1%
Texas		1	1	1.1%
Utah	1		1	1.1%
TOTAL	**52**	**16****	**68**	**74.7%**

* *It is unknown if these people are certified divers.*
** *Includes six people taking initial instruction.*

21 in 1989.
Washington state reported four deaths for 1990, while the states of Hawaii, Maine, and New York had three fatalities. Several states recorded two scuba fatalities each. These were Massachusetts, New Jersey, Pennsylvania, Rhode Island, and Wisconsin.

Nine states recorded one scuba fatality each: Connecticut, Illinois, Louisiana, Montana, Ohio, Oregon, South Dakota, Texas, and Utah. In addition, one death each was noted for Puerto Rico and the U.S. Virgin Islands during 1990.

For the reader's convenience, a table is presented in Appendix E which displays U.S. Underwater Diving Fatalities by state, U.S. territory and foreign areas 1970-1990. In the United States scuba diving activity is concentrated in Florida and California. No conclusions can be drawn about diving being more dangerous in one state versus another since the number of fatalities includes state residents and nonresident

Table 7.4 Location of Diving Fatalities Outside the United States

Mexico	4	4.4%
Bahamas	3	3.3%
Italy	2	2.2%
Jamaica	2*	2.2%
Belize	1	1.1%
Bequia	1**	1.1%
Bermuda	1	1.1%
Cayman Islands	1	1.1%
Egypt	1	1.1%
Honduras	1	1.1%
Martinique	1*	1.1%
Micronesia	1	1.1%
Okinawa	1	1.1%
Panama	1	1.1%
Puerto Rico	1	1.1%
St. Thomas, USVI	1	1.1%
TOTAL	**23**	**25.3%**

* *Triple fatalities, only U.S. citizens included in analysis.*
** *Limited information on this case could not be verified by a second source.*

divers. The number of fatalities per state is more likely to represent the popularity of diving in the state and frequency of diving. The total number of fatalities among U.S. citizens in foreign countries greatly exceeds any individual state except Florida. As in the U.S., this most likely represents the popularity and frequency of diving at these locations.

Twenty five percent (23 deaths) of 1990 U.S. citizen scuba fatalities occurred in foreign countries or U.S. territories. There were four such deaths in Mexico during 1990. Two occurred in the Gulf of California, one off Cozumel and the fourth in a cave system near the Yucatan Peninsula. The three deaths in the Bahamas occurred at different locations.

The fatalities in Jamaica and Martinique were both triple fatalities. Multiple diver scuba fatalities are covered in Section 11.0. Only the American members of the dive party are included in this analysis. In Jamaica, two U.S. citizens died while scuba diving with their Jamaican divemaster and several other Americans. The divemaster also died. In Martinique, one U.S. citizen died with two French nationals while scuba diving. One double fatality at Lake Garda near Verona, Italy involved two U.S. servicemen doing a recreational scuba dive. These cases are discussed in more detail later.

Nine other foreign countries also recorded the deaths of U.S. citizens during 1990. These include Belize, Bermuda, Bequia, Cayman Islands, Egypt (the Red Sea), Honduras, Japan (Okinawa), Micronesia, and Panama.

8.0 Dive Profile

Divers can participate in numerous activities and at different skill levels while on scuba. The activity can be as easy as diving on a warm, clear reef or as physically and mentally challenging as diving on a wreck with a strong current and limited visibility. Since these dive activities can be quite stressful, the conditions of the dive should be consistent with the diver's training, experience, and level of comfort.

Table 8.1 shows the number of certified and noncertified divers by the primary activity in which they were involved. Here, "certified" means that the person has received at least the minimum open water training. An analysis of certification level is located in Section 9.0 (Table 9.2). The "primary activity" is defined as the main objective of the dive. For example, if a diver was hunting on a wreck, the primary activity is hunting although the activity occurred around or possibly on the wreck.

The Dive Profile section is divided into two separate categories. The first category includes individuals who were certified or under supervision of a qualified instructor. The second category includes individuals who dive without any certification credentials. In the first category there are 80 divers. Seventy-two people were certified to dive, and six were undertaking their initial training. DAN was unable to confirm certification in three instances; however, circumstances in two of the cases suggest that these individuals were certified to dive so they are included in the primary category. The second category contains the accident scenarios for eleven people, ten of whom dived without proper certification or supervision and one unconfirmed certification.

Table 8.1 Primary Dive Activity

	Certified to Scuba Dive	Not Certified to Scuba Dive	Total	Percentage
Sightseeing	33*	7	40	44.0%
Overhead Environments**	15		15	16.5%
Under Instruction	3	6***	9	9.9%
Spearfishing/Hunting	8		8	8.8%
Collecting/Work/Task	3	3	6	6.6%
Wreck - no penetration	6		6	6.6%
Photography	3		3	3.3%
Night	2		2	2.2%
Providing Instruction	1		1	1.1%
Unknown		1****	1	1.1%
TOTAL	**74**	**17**	**91**	**100.0%**

* *Unable to verify two certifications, but due to other facts, they are included here.*

** *Diving in caves, under ice or penetrating a wreck.*

*** *Undertaking initial training.*

**** *News clipping only, unable to verify any information regarding this fatality.*

Table 8.2 Fatalities in Overhead Environments

	Total Fatalities	Certified in Specialty Yes	No	Violated Standard Practices*
Cavern	1	1		
Cave	8**	4	4	7**
Ice	4	1	3	4
Wreck Penetration	2			2***

* *NACD/NSS/Respective agencies*

** *Includes two technical divers*

*** *Limited training exists for wreck penetration.*

Forty four percent of the 1990 fatalities occurred during pleasure dives. Since sightseeing is the most popular activity, it is expected that most fatalities would happen to individuals engaging in this activity.

Some activities in scuba, such as overhead environments, require special training and equipment to be performed safely. Overhead environments include caves/caverns, wreck penetration, and diving under the ice. Recreational overhead environment divers are trained to safely enter these overhead environments; however, they remain within the limits set by the respective agencies. Fatalities in overhead environments accounted for 16.5 percent of the 1990 deaths, including eight while cave diving, four while ice diving, two while penetrating a wreck, and one while cavern diving. Two of the cave divers were considered technical divers.

Divers under instruction accounted for the third highest fatality activity at 9.9 percent. In 1990 there were 9 such cases. Six of the divers were taking their initial training while the remaining three were taking advanced level classes. One of the advanced training fatalities was also a night dive.

Spearfishing is popular among many divers. Struggling with a fish can add stress to the already physically challenging environment. The same can be said of task oriented diving such as collecting golf balls or retrieving lost articles. Even photography can divert a diver's attention from keeping an open airway, maintaining proper buoyancy control and monitoring air pressure and depth gauges. Successful dives generally indicate diver control over the many aspects of the dive profile. Most of these fatalities were the result of the individual being unable to control some aspect of the dive.

There was one instructor fatality while providing scuba training for the first time since 1986. NUADC has recorded only four instructor deaths while providing instruction in twenty years of data collection. According to the autopsy report, this individual died of a myocardial infarction.

Overhead Environment Accident Scenarios

As seen from Table 8.2 seven of the overhead environment fatalities had no specialty training. Thirteen fatalities, including the seven without appropriate training, failed to follow standard procedures. Of the thirteen, six failed to maintain a continuous guideline to the surface, two used homemade reels and became entangled in them, two became entangled in their guideline that had become detached from its initial tie-off, two exceeded the recreational 130-foot depth limit, and one dived without a buddy. The remaining two divers adhered to safety rules, but inexperience and human error seem to have been the major factors.

Cave and Cavern Scenarios

A 38-year-old fully certified cave diver had been exploring an underwater cave system with three associates in two, 4-man groups. On the second dive of the day, group one became disoriented and had difficulty determining the direction out of the cave system. Group two became worried when the first group did not appear and cancelled the dive. A search was immediately begun. One diver was found alive in an air pocket, and the victim was found later with empty air tanks at a depth of about 40 feet and 170 feet from the entrance.

A 46-year-old certified cave diver died while diving alone in a spring in Florida. When recovered, his 80 cubic foot buddy bottle was empty, but his twin 100 cubic foot tanks showed 1200 psi of air remaining. The primary regulator was free flowing upon inspection, and the second opening on the tank manifold was not completely turned on. He was recovered almost four hours later at a depth of 62 feet and about 200 feet into the cave. It is speculated that he may have had a faulty regulator.

Four fatalities in underwater caves involved victims who did not have a cave specialty certification. The first incident among the noncertified victims who died in caves cost the lives of two males, aged 18 and 19, in Florida. One source quoted the boys as saying they intended to go just "a little way" into the cave which was located about 80 feet down in a sinkhole. They were found more than 50 feet into the cave completely entangled in their makeshift guideline.

A 55-year-old man was certified to the level of rescue diver but had no cave diving experience or certification. Despite warnings, this victim chose to dive alone without using a guideline to the surface. His body was recovered from a position 200 feet into the cave at a depth of 70 feet.

May of 1990 marked an unprecedented event in diving history — the heroic rescue of not one but two cave diving victims. Unfortunately, a third victim became one of the statistics for this report. An instructor was accompanied by four of her former open water certified students in a dive at Otter Springs, Florida. The participants were repeatedly admonished against entering the cave, but when the instructor and one other diver left the water, the three others remained behind. A certified cave recovery diver happened to be at the scene and was able to lend assistance when the instructor realized the three were missing. He immediately suited up and within minutes had located two of the victims unconscious at a depth of 50 feet and well into the cave. He pulled one of them down through the cave and to the surface where CPR proved successful. In the meantime he returned to the second victim who apparently had recovered consciousness and used his octopus regulator to bring this man to the surface. On his third trip he found and retrieved the body of the third man who had been down at least 30 minutes. The victim had run out of air and drowned.

There was a single certified cavern diver fatality reported in 1990. This 53 year-old man died in Florida while diving with a certified cavern diver and the latter's 10 year-old son. The incident is alleged to have occurred when conditions became silty. While exiting the cavern, the dive team leader passed the victim who was not on the guideline.

Technical Diving Scenarios

A 25-year-old man died in an underwater cave in Florida. This man was reported to have had about five years diving experience but had been certified as a cave diver only six months before his demise and had logged about 75 cave dives in that period. He was unfamiliar with this specific cave but was diving with a group of expert cave divers. He apparently went to a depth of 250 feet, more than 20 feet deeper than his deepest previous dive, and was breathing compressed air. He is believed to have succumbed to the effects of nitrogen narcosis and drowned.

In the second technical diving case for 1990, the 29-year-old male, who was a fully certified cave diver with extensive experience, was found unconscious at the entrance to a 200 foot deep cave formation in the same Florida county as the previous case. Since the autopsy revealed no other physical problems, this victim may have also suffered from the effects of nitrogen narcosis. He was not using a guideline to open water.

Wreck Penetration Scenarios

One incident took the life of a 40-year-old man who was an open water instructor with perhaps hundreds of wreck dives logged and at least 30 dives on this wreck. He apparently experienced a severe silt-out and ran out of air before he could find his way out from deep within the ship. The body was not recovered until five days later.

While diving in Micronesia, a 67-year-old man failed to follow his guide, left his dive buddies, penetrated the wreck, and became lost deep in the stern section of the wreck. When found at a depth of 110 feet, he had wandered hundreds of feet into the stern.

Ice Diving Scenarios

Diving under the cover of ice resulted in two double fatalities in 1990. The first event took place in January in a Pennsylvania quarry. The two 43 year-old victims were considered to be excellent, experienced divers, one of whom was a certified instructor. Their bodies were located two weeks after the incident in 60 feet of water. About 200 feet of rope was found with them with one end frayed and the other end cut. On the surface there was no evidence of a tied off safety line nor could it be established that any tender had been present. Sources close to the two victims still consider it a mystery that they would have violated the safety principles which the two believed in so strongly.

Two brothers, aged 33 and 26, died in the second ice diving fatality incident in Okauchee Lake, Wisconsin. There was no safety line, and no surface tenders were present. Both victims were reported to be experienced divers, and both were certified to an advanced level. They were not trained for ice diving.

Training Case Scenarios

During advanced open water training, a night dive off the California coast resulted in the death of a 49-year-old woman. She had already completed three dives that day. On the last dive, she apparently became entangled in heavy kelp but was rescued. Initial CPR was successful, but she died four days later.

A deep reservoir in Utah was the site of the death of a 29-year-old woman who was making a deep dive planned for 80 feet. The instructor allegedly lost sight of the victim and her buddy in the silt disturbed from the bottom. He found the buddy partner in distress and assisted him to the surface then had to make two more dives before finding the victim on the bottom. Extensive efforts at resuscitation were unsuccessful, and the death was attributed to drowning by asphyxiation. She had 1,500 psi remaining her tank.

The third 1990 case of a fatality during advanced training was that of a 54-year-old man who developed distress during the ascent of his second dive off the coast of Puerto Rico. The autopsy report indicated the individual was intoxicated.

During 1990 six fatalities were recorded while the victims were undergoing entry level training. Two of these six cases occurred off the Atlantic coast of Florida and involved a 50-year-old man and a 62-year-old woman. The autopsies on both of these cases concluded that a myocardial infarction was the cause of death.

The death of a 39-year-old man off Jamestown, Rhode Island in June of 1990 was attributed to asphyxiation due to drowning. An examination of this 280 pound victim's equipment by the University of Rhode Island determined that he was wearing 37 pounds of weight attached with a jury-rigged suspender-type harness (under his buoyancy compensator) which could not be removed during the emergency.

A 32-year-old, 275 pound man died during his first open water dive of an entry level program near Nubble Light, Maine in August of 1990. While on the bottom in 25 feet of water and having completed an escorted bottom swim with his instructor, this victim signaled "out of air" to his student-buddy partner who assisted him with an alternate regulator part way to the surface. He then panicked and made a rapid ascent. On the surface he stated he could not breathe and continued in a panic state until he lost consciousness and was towed to shore. Despite extensive resuscitation efforts he was pronounced dead at the local hospital. The autopsy resulted in a finding of drowning.

A deep pond behind a dive shop in Ohio was the location of the death of a 35-year-old man in September of 1990. This victim indicated that he had only 500 psi of air just prior to making a descent to 35 feet. An immediate head count on the bottom discovered him missing. The body was located by a recovery team about three hours later. This case was also ruled as drowning.

After surfacing from an uneventful fourth certification dive, a 65-year-old female complained of being tired. The instructor towed her to shore during which time she lost consciousness. The autopsy listed her cause of death as drowning.

Six Open Water Dive Scenarios

Scuba diving is done in the open water for various reasons. Divers frequent wreck sites which provide opportunities to dive a historical site, observe different species of fish, find ocean debris or gain experience. Six typical cases are given here which demonstrate the nature of scuba fatalities.

In May a 23-year-old man lost his life in Seneca Lake in central New York state. This victim had been basic open water certified three years earlier and had logged about ten dives in the previous year; however, none of these dives were deeper than 50 feet. He and his two companions had planned to dive down the steep slope of the lake to explore three sunken barges which rested in a line on the slope at depths of 30 feet, 60 feet and 90 feet, then bounce to 140 feet. At about 135 feet the victim's regulator began to free-flow causing panic and a rapid ascent. The autopsy suggested that he suffered a massive air embolism.

The wreck of the "IDA" about ten miles off shore of Monmouth, New Jersey was the site of the death of a 49-year-old male. This man was open water certified and had several years of sport diving experience. He was in the water with six other divers at depths between 85 and 115 feet. His body was located on the surface about two hours after the start of the dive and his tanks were out of air. None of his companions were aware of any specific problem that might have caused this accident, and cause of death was simply listed as drowning.

In October a 35-year-old man certified as an open water diver died on the USS San Diego. This victim was found lying on the upturned hull of the wreck at a depth of about 70 feet after being separated from his buddy. Reports indicate that he became entangled in his ascent line and ran out of air.

A 50-year-old man died off the coast of Honduras while on his first open water dive to a wreck 100 feet deep. This fatality occurred during the victim's trip on a cruise ship. He signaled out-of-air and buddy-breathed to about 30 feet. He then broke away from assistance and made a rapid ascent.

At the site of a wreck off St. Thomas in the U.S. Virgin Islands, a 50-year-old man completed his 60 foot dive and returned to the boat. With the help of the captain he was taken on board and began vomiting. He collapsed and despite resuscitation efforts was pronounced dead at the hospital. The cause of death was said to have been a myocardial infarction.

Another case attributed to a myocardial infarction took the life of a 56-year-old man who was exploring an 80-foot deep shipwreck in Bermuda with his son as a buddy. This victim was said to have been a certified diver with more than 60 dives to his credit.

Tables 8.3 and 8.4 refer to the dive platform used by certified divers and how many divers were in the dive group. Among the eleven non-certified divers, seven (63.6 percent) made dives from shore, three (27.2 percent) made dives from a private boat, and one entry was unknown. All of the non-certified deaths occurred in dive groups of four or less. One diver was diving solo with a shore observer, and four deaths occurred in groups of two divers while both divers were in the water. The remaining deaths occurred in groups of three or four individuals but with two or three divers in the water at one time.

Table 8.3 Dive Platform

Entry	1990 Frequency	Percent
Shore	36	45.0%
M/V* Private	16	20.0%
M/V Charter	28	35.0%
TOTAL	80	100.0%

** M/V = Motor Vessel*

The percentage of 1990 charter boat fatalities dropped by 4.5 percent from 1989, and the number of deaths decreased by seventeen. Private boat fatalities decreased by 14.2 percent and 23 deaths. Scuba fatalities from shore based dives increased from 24.6 percent to 45 percent and from 28 to 36 fatalities. This increase may seem alarming while scuba fatalities are currently showing a decreasing trend. It most likely can be explained by yearly variances in the number of double fatalities. There were only four double fatalities in 1990 which was down from six in 1989, but all four were shore based divers. The lack of appropriate experience for the water conditions and lack of general diving experience also seemed to affect shore based diving.

Diving in small groups may suit the style of diving or behavioral characteristics of some individuals, but it also limits the emergency and rescue assistance available to these individuals. Lack of access to communication in a small dive group could make it impossible to support a dive accident victim in a remote location.

Table 8.4 Number of Divers in a Group

Number in Dive Party	Frequency	Percent
1	3	3.8%
2	15	18.8%
3	9	11.3%
4	8	10.0%
5	3	3.8%
6	4	5.0%
7	4	5.0%
8	8	10.0%
9	1	1.3%
10 or more	8	10.1%
Unknown	17	21.3%
TOTAL	**80**	**100.0%**

Table 8.4 shows the number of individuals in the dive group at the time of the incident. This includes all divers and associated shore or boat personnel. Generally, this also represents the total number of people at the scene of the fatality; however, in some instances there are actually more people present. For example, a group may be one of several groups at a quarry. Only the number of participants that relate to the fatality are considered.

As seen from Table 8.4, 43.9 percent of the fatalities had been diving in small groups (one to four divers). In 1990, three divers died while diving solo with no topside observer present. Fifteen fatalities occurred in a dive group of two people. Four of these fatalities were also solo diving with a surface observer.

Three of five double fatalities occurred in dive groups of only two people with no surface assistance. Buddy separation occurred in two of the five remaining two-member dive party cases.

Nine fatalities occurred in dive groups of three people. Three of these fatalities were solo diving. One double fatality occurred in a dive group of three people. Buddy separation occurred in all the remaining cases. Eight fatalities occurred in dive groups of four people. Buddy separation occurred in seven of these eight instances.

Accident Scenarios for Noncertified Divers

The oldest victim in 1990 was a 73-year-old man who was reported to have succumbed while diving off Bequia Island in the Grenadines. Verification of this event and diver certification were not possible. No additional information was available.

An uncertified 22-year-old male made a shore entry dive with a certified dive buddy. The uncertified diver was missing ten minutes into the second dive. The dive profiles were 25 feet for 10 minutes with a 2-hour surface interval followed by a 25-foot dive. He was found on the bottom about 20 minutes later with 2,000 psi left in his tank.

While a friend observed from shore, a 32-year-old male made a 10-15 foot dive alone. He was using equipment that was borrowed. Although instructed to only use the equipment in his backyard pool, the victim went diving in a river. The witness on shore saw the diver in distress at the surface and then sink. It took twelve hours to locate him at which time he was found to have 1500 psi in his tank. He was not using a BC, and his tank and backpack were found away from his body. His mask and fins were not located. His urine was positive for methamphetamines and cannabinoids.

Four young men had been drinking and diving. After the dive a 20-year-old man developed distress at the surface. His friends on the boat could not pull him in due to a strong four knot current. He also could not inflate his BC with a power inflator or CO_2 cartridge. The newspaper stated that there were no equipment problems, and there was air left in his tank. He had 14.5 pounds of lead weight and was not wearing a wet suit. His body was found four days later. The newspaper reported that the autopsy indicated the diver was legally intoxicated.

An uncertified 62-year-old male with two years of diving experience and about 40-50 dives was an active individual with a history of heart disease. He had been diving one month prior to his death using his own boat. He made a 60-foot dive for about 5 minutes with his son, came back to the surface and lost consciousness. His son reported that he had not made a rapid ascent. The autopsy reported hypertensive cardiovascular disease was present.

A 35-year-old male was collecting artifacts around a pier at a depth of about 10-20 feet with 5-foot visibility. There was a moderate current. He was not wearing a BC but had on a full wet suit and 21 pounds of weight. He was diving with a friend, but they were not diving as buddies. He surfaced and yelled for help. A surface observer threw a float to him which he was unable to reach. He did not release his weight belt and submerged again. His body was located 14 days later. Upon inspection, his regulator was found to free flow and be in need of repair. The autopsy showed that he was legally intoxicated at the time of death.

An uncertified 39-year-old male was collecting artifacts off the Florida Keys when he came up to tell the people on the boat that he found something. They next noticed him floating face down at the surface. He had a medical history of chest trauma with a punctured lung.

Two certified adults were diving with a 14-year-old male in about 10-15 feet of water. The youth was using a steel 90 and horse collar BC but no power inflator. The mechanism that holds the diaphragm down was shown to be bent, possibly allowing water to enter. His buddy saw the diver panicked with his regulator out of his mouth trying to get to the surface. The dive buddy's attempt to assist the diver was unsuccessful.

A 21-year-old male was diving with a friend who was certified. His friend set up the equipment with the BC backwards. They were gathering golf balls from a course pond and were not using fins or a depth gauge. The visibility was poor, and they were not using the buddy system. A topside witness saw the diver surface, take off his mask and go back under. The witness also saw that the rope which secured the bag of golf balls was wrapped around the victim's neck. He had air left in his tank.

A 35-year-old male had dived approximately 20-30 times. He had been drinking and made a shore entry with a certified diver. He signalled to his buddy that he was returning to shore. When his buddy returned, he found a law officer performing CPR on the victim. The regulator was shown to be hard breathing, the victim was overweight, was not wearing a wet suit and was wearing 18 pounds of lead weight. His blood was positive for alcohol, and urine was positive for cannabinoids.

A 20-year-old male, who had made about six dives, made a shore entry with two certified divers in a calm cove. They swam toward the opening of the cove and surfaced because of increasingly rough water. The waves knocked the victim into rocks causing him to lose his regulator. He was unable to perform self rescue and drowned.

9.0 Certified Diver Population

The data contained in this section relates only to those divers who were trained in a formal certification course or currently involved in a training program.

Table 9.1 shows the distribution of scuba fatalities by age. A comparison of fatality age ranges to that of decompression illness (Table 2.1) reveals some interesting data. There were six fatalities over the age of 60 but only three reported decompression illness (DCI) cases. There were only four less fatalities (18) than DCI cases (22) in the fifty-and-over age group.

A total of 18 of the 80 fatalities in 1990 (22.5 percent) involved persons over the age of fifty. This compares to 21 percent of the case load in 1989 and only 10 percent of the case load for the five years prior to 1989. Because there is no accurate incidence rate for scuba fatalities, it is difficult to determine the exact meaning of the older (greater than 50 years of age) fatalities. It is known that there is a higher incidence of other illness and disease in this population. This emphasizes the need for good physical condition and thorough medical examinations for older candidates in scuba classes.

Table 9.1 Age and Sex Comparison of 1990 Fatalities

Age Group	Male	Female	Percent	Total
10 - 19	3	2	6.3	5
20 - 29	14	1	18.8	15
30 - 39	17	6	28.8	23
40 - 49	14	5	23.8	19
50 - 59	11	1	15.0	12
60 - 69	4	2	7.5	6
TOTAL	**63**	**17**	**100.0**	**80**

Seventeen of the 80 fatalities in 1990 were female (21.3 percent) as compared to ten of the 104 certified diver deaths in 1989 (9.6 percent). A review of the female cases does not reveal an obvious or simple explanation for this increase in the percentage of female fatalities. Studies have shown that more women than ever are participating in scuba diving each year. This is the largest number of female deaths since 1986 when there were 19. The record year for female deaths was 1978 when there were 21 female deaths of 144 total scuba fatalities. The noncertified divers are not shown in Table 9.1, but in both 1990 and 1989 all of these individuals were male.

Table 9.2 shows the distribution of the highest levels of certification for fatal dive accidents. Forty six percent of the fatality population held basic certification or were taking their initial training. Lack of experience most likely played some role in individuals with entry level training only. Divers who complete an open water certification are not complete divers. New divers are ready to learn the skills required

Table 9.2 Certification Level of 1990 Fatalities

Student	6	7.5%
Basic/Open Water	31	38.8%
Advanced	13	16.3%
Rescue	3	3.8%
Dive Master	1	1.3%
Instructor	4	5.0%
Cavern	1	1.1%
Cave	4	5.0%
Unknown level	17	21.3%
TOTAL	**80**	**100.0%**

for special situations such as open ocean, currents, cold water, zero visibility and other dive variables. Accidents can occur when individual or group diving skill level and ability to respond to underwater situations do not match dive conditions and the skill required to successfully complete a dive.

Table 9.3 shows the distribution of overall diver experience by total number of dives that were made by the individual. Diver logs are rarely available to analyze experience or an exact number of dives done by any individual. It is also difficult to determine the length of time since an individual's last dive. Information is generally obtained secondhand through investigation reports, a dive buddy or someone who knew the diver.

Thirty seven and one half percent of all divers had dived twenty times or less since certification. Although lack of experience may have played a role in the newer divers, it does not explain the 32.5 percent of the cases who were very experienced with a minimum of 61 dives. Fifteen of the experienced divers died of drowning, three of cardiovascular disease, three of embolism, two were diving without a buddy, one trauma case and two unknown cases.

Table 9.3 Overall Diving Experience in Fatalities

Novice (≤ 5 dives)	10	12.5%
Inexperienced (6 - 20 dives)	20	25.0%
Intermediate (21 - 40 dives)	4	5.0%
Advanced (41 - 60 dives)	2	2.5%
Experienced (≥ 61 dives)	26	32.5%
Unknown	18	22.5%
TOTAL	**80**	**100.0%**

Table 9.4 Experience Within Activity in Fatalities

No specialty certification	7	8.8%
Novice (≤ 5 dives)	11	13.8%
Inexperienced (6 - 20 dives)	21	26.2%
Intermediate (21 - 40 dives)	3	3.8%
Advanced (41 - 60 dives)	2	2.5%
Experienced (≥ 61 dives)	21	26.2%
Unknown	15	18.8%
TOTAL	**80**	**100.0%**

Table 9.4 shows the dive experience of individuals for the activity they were involved in at the time of death. Experience within specialty activities is as important as overall diver experience. The largest difference between overall experience and dive activity experience was in individuals who were not trained in specialty activities such as cave and ice diving. Individuals without specialty dive training are separated out to show that seven of the 80 deaths may have been prevented with proper training. These seven individuals may have dived 20 dives or more but would have been included in the novice category because they were new to the activity. The same is true for any experienced divers who may have had hundreds of total dives but only a few within spearfishing or night diving. Almost 49 percent of all certified fatalities had made twenty dives or less in their current activity when they died.

10.0 Medical Issues in Scuba Fatalities

Table 10.1 Known Medical Conditions

Age	CVD*	Pulmonary Problem	Seizures	Diabetic	Personality Changes	Chemical Dependency	Total
20-49	3	1	1	1	1	1	8
50-79	7			1			8
TOTALS	**10**	**1**	**1**	**2**	**1**	**1**	**16**

** Cardiovascular Disease*

Table 10.1 shows sixteen individuals with known medical conditions at time of death. Autopsy revealed additional health problems unknown to the diver in some cases. For instance, ten fatalities knew they had a cardiovascular problem, but cardiovascular disease may have contributed to at least thirteen scuba fatalities according to autopsy reports. This section examines all divers, certified and uncertified, to determine the role of physical fitness and health in fatalities.

Recreational diving guidelines exist to protect the individual from injury or death. When training and certification are bypassed, individuals not only miss the appropriate training but health screening as well. Scuba diving requires physical and mental fitness. Individuals may be restricted from participation due to disease or illness. Some illnesses such as medication dependent diabetes are considered disqualifying for scuba diving due to unpredictable hypoglycemia or long-term vascular and physical changes in the diver.

Many of the medically related deaths were in individuals who developed an illness or disease after being certified. The medical guidelines for scuba diving apply to all divers, but there is no process to screen for disease and illness in divers who are certified. Medical evaluation and laboratory tests give the physician a great deal of information about divers' health. Individuals who choose to ignore medical advice and continue diving may place not only themselves but a dive buddy at risk for injury or death.

The fatalities in this report were assigned causes of death and contributing factors using the *International Classification of Diseases — 9th Revision — Clinical Modification* (ICD-9-CM) based on the World Health Organization's *International Classification of Diseases*. The ICD-9-CM codes which were used are in Appendix I. The cause of death as listed on the death certificate was accepted when the death certificate or autopsy report was available. In other cases the cause of death was determined based on the information available. In a few cases there was insufficient information available to make a determination.

Discussion of Autopsied Cases

Autopsies were performed on 75 cases during 1990 by various medical examiner jurisdictions. Reports on sixteen of these autopsies were not available to DAN due to local policies restricting access to the information. This discussion will be limited to the 59 cases where autopsy reports or summaries are available. The reported immediate cause of death for 46 of the 59 autopsied cases available to DAN was drowning as a result of various factors. Fourteen of the 49 divers who drowned resulted from entrapment or entanglement as in caves, under ice or entanglement in ropes. One death of unknown cause was most likely due to drowning. However, postmortem mutilation by sharks made a diagnosis at autopsy impossible. Three divers suffered injuries at the surface and drowned. Two were struck by boats in separate incidents, and one struck his head on rocks near shore in rough seas. One case was due to anoxic brain damage as a result of near drowning with survival for two months before death. This diver was in a group of students on a certification dive.

There were five deaths due directly to a cardiovascular event such as acute myocardial infarction, heart failure or other. There were three drowning deaths due to myocardial infarction and there were an additional ten deaths where cardiovascular disease was present at autopsy. This group of 18 represents 30.5 percent of the autopsied cases. Most of these individuals had a known history of either hypertension or coronary artery disease. One individual with severe coronary disease also had bubbles in the coronary system at autopsy. Death in this case was due to drowning as a result of myocardial infarction possibly due to air embolism of the coronary artery as well as the coronary artery disease.

There were four deaths due to cerebral arterial gas embolism, and rapid ascent was observed in three cases. In at least one case a panic state occurred and prevented rescue assistance due to struggling. Another case was also probably complicated by panic preventing buddy breathing and rescue. There were five drowning deaths as a result of cerebral arterial gas embolism. One of these involved a diver attempting to assist another diver who was out of air. The diver in trouble survived, and the rescuer died.

There were eight cases in which alcohol or other drugs were found in significant blood concentration. Several of these individuals had more than one substance detected. One uncertified, but "experienced" diver had a blood alcohol level of .15 gms/dl at autopsy. Another individual was diving in fresh water at 110 feet with a 35-pound weight belt. His body was discovered on the bottom with his buoyancy compensator fully inflated and air tank empty. Blood alcohol level was .19 gm/dl. A 20-year-old uncertified, untrained diver attempted to dive in an area of strong current. He developed unknown difficulties at the surface and drowned. His blood alcohol was above the legal intoxication level.

One 34-year-old female was a drowning victim with blood levels of two prescribed psychotropic and two prescribed analgesic medications. Three of the medications have strong addiction potential. A 26-year-old uncertified, inexperienced diver was searching for sharks' teeth in an inlet. He experienced unknown difficulty and drowned. There were detectable levels of ethanol, cannabinoids, and carbon monoxide at autopsy. One of the unqualified cave diver fatalities occurred in an individual with a history of depression. Benzodiazepine and fluoxetine were detected at autopsy.

Drowning Deaths

A drowning death follows some other mishap which prevents the diver reaching or remaining at the surface. It would seem that these deaths would not be difficult to prevent given the sophistication of present day diving equipment, especially buoyancy compensators. Nevertheless, drowning remains the number one cause of death for divers.

Table 10.2 Contributing Factors to Drowning Deaths

Contributing Factors	Number of Divers
Insufficient air	26
Entrapment	17
Cardiovascular	16
Alcohol/drugs	9
Air embolism	6
Nitrogen narcosis	3
Boat accident	1
Diabetes mellitus	1
Panic state	1
Head injury	1
Carbon monoxide	1
Seizure disorder	1

Table 10.2 lists the contributing factors to drowning deaths. The only contributing factors which may not be under the divers' control are the boat accidents, head injury, and possibly contaminated air. All of the other factors can be eliminated. There were multiple factors for some deaths such as panic and cardiovascular disease in one individual.

The majority of the drowning cases were associated with running out of air. Sometimes this was due to the situation such as entrapment in a cave, a wreck, under ice or being lost. Many cases appear to have simply run out of air unexpectedly and were unable to perform self-rescue. There were several inexperienced divers in this category. There were other drowning victims who had air available in their cylinders but did not use it. There were also many cases in which the cylinder pressure was not reported.

There were several drowning incidents involving a mismatched buddy pair consisting of an experienced diver with a novice. An example was a father diving with his daughter on her first open ocean dive. While the father was spearfishing, the daughter disappeared. The daughter's body was not recovered. A similar incident occurred with a buddy team of father, son and mother. The mother was inexperienced and became separated from the other two, ran out of air and drowned. An experienced diver was diving with his fiance who had been certified four months. They surfaced 200 feet or more from the boat and resubmerged to swim to the boat. They became separated, and she was discovered later on the bottom at 73 feet with an empty tank. A 14-year-old child was untrained and diving with his stepfather. The child developed an unknown problem followed by panic, unconsciousness and drowning.

Sudden Death in Diving

The question of sudden, unexplained death in scuba diving appears in publications from time to time. Sudden cardiac death strikes 200-400,000 Americans per year and is responsible for 15-20 percent of deaths in adults. In the age group 1-20 years, sudden death accounts for 2-20 percent of all deaths with a three-fold variability year to year.

A definition of sudden death is as follows: (1) sudden event rendering the patient unconscious until death; (2) death occurring within 24 hours of the sudden event; (3) patient participating in regular activities until the event; and (4) not hospitalized when event occurred.

A proposed definition of sudden death as applied to scuba diving for this report is as follows: (1) sudden death diving; (2) death during the dive or within the following 24 hours; and (3) no obvious explanation for cause of death.

The causes of sudden death during exercise in those age 30 or younger are mostly various cardiovascular disorders with the occasional exception of an infectious cause. The most common of these events is due to hypertrophic cardiomyopathy. One 25-year-old diver died of drowning but was found on autopsy to have hypertrophic cardiomyopathy. When recognized, hypertrophic cardiomyopathy is a contraindication to scuba diving. However, the diagnosis is difficult to make in the individual without symptoms. Only 9 percent of sudden death during exercise in the 30 or younger age group is due to coronary artery disease.

Above the age of 40 the vast majority of sudden deaths during exercise are due to coronary artery disease. Coronary artery disease was responsible for 88.7 percent of sudden deaths in those aged 40 years and older who were exercising. It is not surprising then that coronary artery disease either caused or contributed to at least 13 deaths in the group of dive fatalities over age 40.

The cardiovascular response to diving derives from several effects: exercise effects, cold stress and emotional stress. Physical stress from exercise and cold results in increased oxygen consumption and increased work load for the cardiovascular system. Emotional stress may result in an acute anxiety reaction causing tachycardia (very rapid heart rate), elevated blood pressure and hyperventilation. These stresses may result in dysrhythmia, angina and sudden death in the presence of cardiovascular disease.

These stresses demand increased output from the heart and an increased blood flow through the coronary arteries. If there is coronary artery disease producing obstruction, blood flow becomes inadequate for the working heart muscle. The result may be angina pectoris (chest pain), lethal rhythm disturbances or heart failure.

Discussion of Age Classification

It is useful to compare the group of divers under age 40 to those over age 40 in terms of immediate cause of death. In both groups the most common cause of death was drowning. However, under age 40, drowning accounted for 75.5 (40 of 53) percent of the deaths, but only 44.7 (17 of 38) percent of the deaths over age 40.

There were no fatalities of unknown cause under age 40. In the group over age 40, there were five deaths of unknown cause. In one case the body was too mutilated to establish a diagnosis. There were two cases which were autopsied and cause of death established, but the information was not released because of local restrictions. A cause of death could not be established for the remaining two due to a lack of information available to DAN. Bodies were not recovered in nine cases although drowning appears to have been the cause in at least four of the nine. The body was not located in seven instances under age 40, and two instances over age 40. See Graph 10.3.

Death from cardiovascular disease is common in the over age 40 group. There were eight deaths immediately caused by myocardial infarction and an additional three deaths from drowning after myocardial infarction. These 11 deaths represent 28.9 percent of the total in this age group. Five other victims had a cardiovascular disease as a contributing cause. These included both hypertension and coronary artery disease. Thus, at least 16 victims had cardiovascular disease severe enough to have disqualified them as divers. As coronary artery disease can usually be readily diagnosed when looked for, it would seem that this age group should be advised to have careful evaluation before participating in a strenuous activity such as diving. The diver over 40 probably makes the same mistakes as the diver under 40 and, in addition, may have the added risk of significant cardiovascular disease. See Graph 10.4.

There were two deaths in individuals over age 40 who were diabetic. Both of these individuals died of myocardial infarction. There was one death due to drowning in an individual who was diabetic, obese and who developed an acute panic reaction. This individual was on a training dive with his instructor who was unable to assist him due to the panic reaction. The student's cylinder contained less than 100 psi when tested postmortem. Insufficient air was a factor in nine of the cases above age 40.

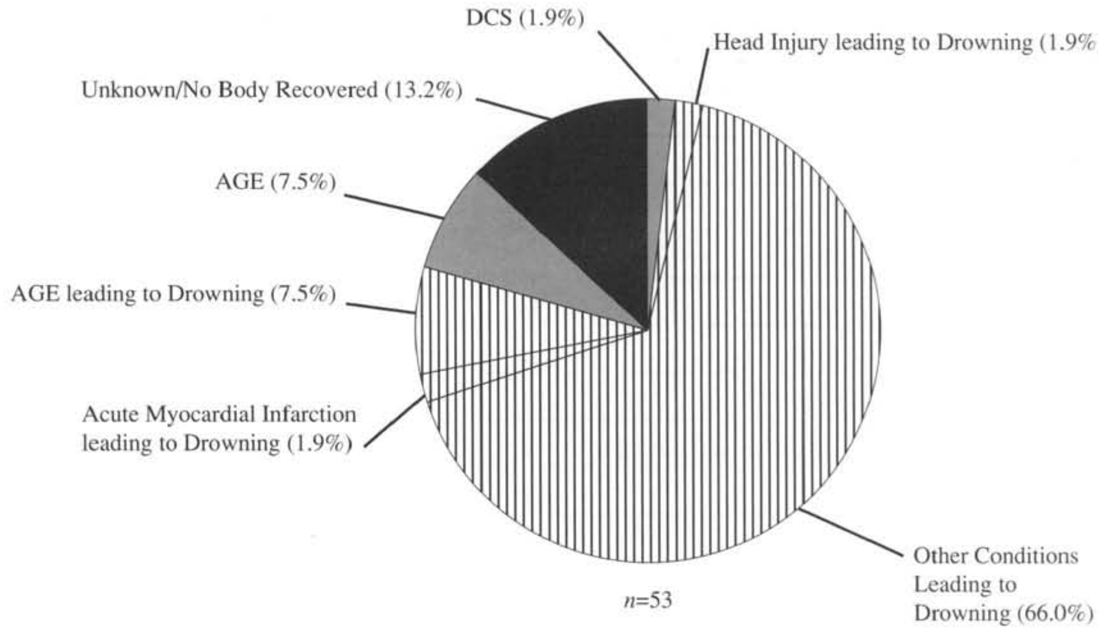
The youngest fatality was age 14, and the oldest confirmed fatality was 68 (one victim was allegedly older, but this remains unconfirmed). There were six victims age 19 or younger and seven age 60 or over.

Summary

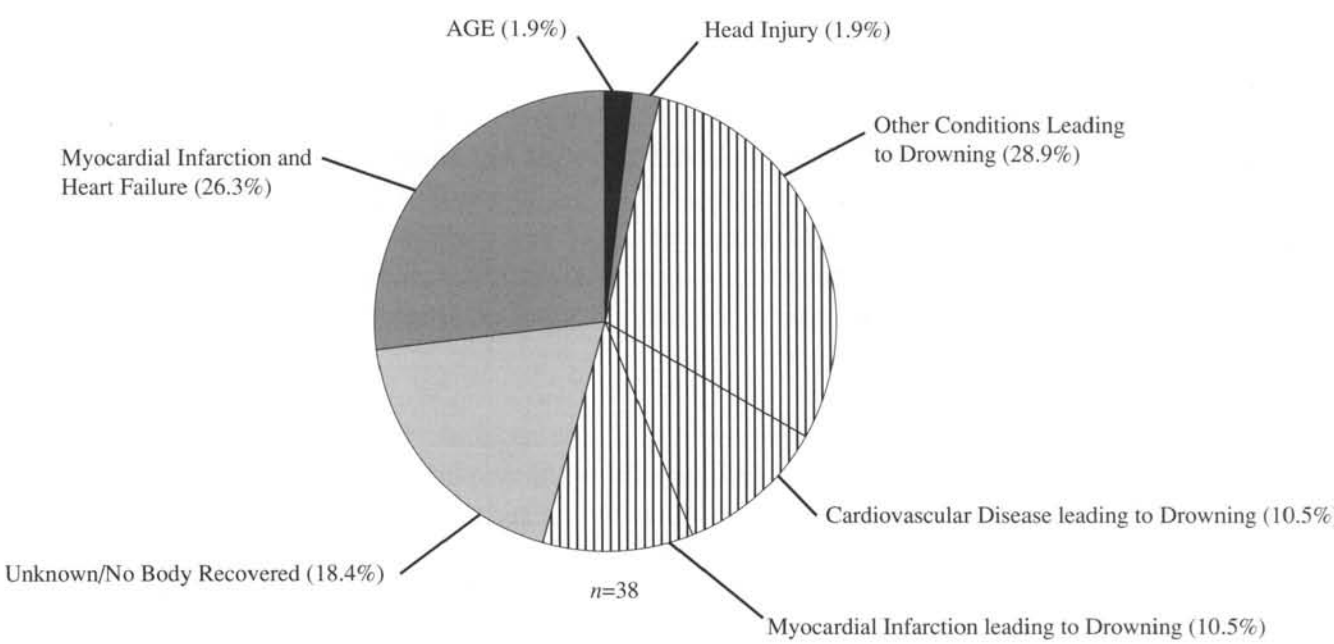
Scuba deaths are the result of many factors leading to the final event which is most commonly drowning. Some of these factors are determined long before the diver enters the water, and the eventual death can be prevented by recognizing the contributing factors. Pre-existing disease or inadequate training and experience for the situation are not difficult to recognize. Running out of air during a dive should be simple to prevent but annually accounts for several deaths. Panic, rapid ascent and arterial air embolism continue to occur, usually in a training situation or involving inexperienced divers. A significant number of cardiovascular deaths occur each year. The diver past 40 needs to be carefully evaluated for the presence of coronary artery disease especially in the presence of risk factors such as smoking, hypertension, elevated cholesterol and others.

Ultimate responsibility for safety rests with the diver, and the diver makes the decision to dive or not to dive. The diver should have sufficient training to enable assessment of each diving situation before deciding whether or not to dive.

Graph 10.3 Deaths Under Age 40



Graph 10.4 Deaths Over Age 40



11.0 Characteristics of Fatalities

Tables 11.1 & 11.2 When and Where Problem Occurred

When

Immediately	4
Early-Dive	9
Mid-Dive	7
Late-Dive	30
Post-Dive	13
Unobserved*	11
No Information Available	6
TOTAL	**80**

Where

During Descent	7
At Depth	28
During Ascent	16
Surface-Post Dive	14
Unobserved*	11
No Information Available	4
TOTAL	**80**

** No witnesses at scene.*

Tables 11.1 and 11.2 illustrate the time and phase of the dive in which the fatality occurred. The exact time trouble begins for a diver is difficult to obtain. In 61.3 percent of the deaths, no one directly observed the actual event that led to the fatality. However, in all but eleven instances a dive buddy or group member was with the victim and able to approximate the time and position of the event. In eleven cases no approximation could be made because all members of the dive team perished. These include one triple fatality (not all members of the dive team were United States citizens), three double fatalities, and four solo divers.

All phases of the dive require the diver's attention. Not being prepared to enter the water can lead to immediate and early dive problems. Late dive difficulties often evolve from low or out of air situations. The cardiovascular problems may have started at depth forcing the individual to come to the surface early where their problem was listed as "Surface-Post Dive." This was also true of the 1989 fatality data. If a diver develops a primary problem at depth or on the surface, they may still have to overcome negative buoyancy. Failure to release the weight belt directly contributed to three fatalities once the primary problem had occurred and the diver was at the surface. Eight out-of-air ascents were also complicated by a failure to release the weight belt.

There is generally more than one contributing factor in fatal dive accidents. After reviewing the documentation for every case, an initial cause or probable starting event was determined. For example, a total of ten divers became lost in overhead environments, ran out of air and then drowned. (The diver is counted only under the "lost" category and not in the "air" category since being lost was the initial contributing cause.) Running out of air contributed to the fatality, but the initial cause was getting lost. The initial contributing cause of fatalities is shown in relationship to the problem onset depth or the maximum intended depth of the dive if the exact depth of onset is unknown.

Table 11.3 Initial Contributing Cause of 1990 Fatalities

	Onset or Maximum Depth (feet)											
Contributing Causes	Surface	1-5	6-20	21-33	34-66	67-99	100-132	133-165	166-198	199-231	232+	Depth Unknown
DCS	1											
Barotrauma	1											
Fitness	2											
Injury	1	1										
AGE	1											
Anxiety					1							
Seizure					1							
Panic					1							
Fatigue					1							
Equipment					1		1					
Tangled			1		2	2						
Lost			2	1	4	2	1					
Alcohol			1				1					
Rapid Ascent			1				2				1	
Narcosis					2					1	2	
CVD*	9		1	1	1	2						
Air	2		1	1	5	1	2	1			1	
Unknown			1		4		2			1	2	3

* *Cardiovascular Disease*

Recreational divers do not have immediate access to the Emergency Medical Service (EMS) due to the remoteness of dive locations. EMS response time is considerably reduced when secondary roads must be used. Air evacuation assistance is widely available but may involve long flights. Furthermore, only U.S. Coast Guard and military helicopters have crews capable of making open ocean sea to air rescue. The U.S. Coast Guard provided search and/or rescue assistance in 33 percent of the certified diver fatalities in 1990. There were only nine air medical evacuations.

Surviving an unexpected underwater event may depend on timely and effective cardiopulmonary resuscitation (CPR). The shorter the non-breathing time interval, the better the chance of survival after an in-water event. Effective CPR in scuba diving accidents is hindered because the underwater event goes unnoticed or there is buddy team separation, prolonging initial rescue. Even after an individual is found, they must be removed from the water and placed on a hard surface capable of supporting a CPR effort. Finally, many of these individuals required a level of care found in hospital emergency departments. The diver who has had a myocardial infarction, drowning or suffered some other serious medical condition is not likely to survive with the limited medical skill and resources available at a dive site.

Table 11.4 Diver Recovery and Rescue

Time to Recovery	Number of Divers	Yes (CPR) No		Medivac	USCG * Assisted
Body not located	9		9		4
0-5 Minutes	27	25	1	5	8
20-30 Minutes	6	6		2	3
40-50 Minutes	3	3			
1+ Hours	3	1	1		1
2+ Hours	2	2			1
3+ Hours	1		1		
12 Hours to 14 days	19		19		5
Just found body	3		3		
Unknown time to recovery	7	5		2	5
TOTAL	**80**	**42**	**34**	**9**	**27**

** U.S. Coast Guard*

The delivery of oxygen is recognized as an important element of first aid in the treatment of drowning, near drowning and myocardial infarction. In its CPR Standards and Guidelines which appeared in JAMA in 1986, the American Medical Association suggests oxygen should be given during CPR as soon as it becomes available. Unfortunately, oxygen is still not widely available for emergency use by divers due to local or state laws and a lack of proper training.

Oxygen was available and given by members of the dive group in only eleven known cases. It is possible that oxygen was available in more cases but not used because of the delay to locate the body. Eight charter boats had oxygen available, two did not have oxygen, and for eighteen boats this information was not available. Oxygen was available in two private boats, two did not carry oxygen, and ten private boats had no information. One of the shore diving fatalities had oxygen available, two had no oxygen, and for 32 shore dives this information was unknown. The additional oxygen administration shown in Table 11.5 was done by EMS crews.

Multiple Fatality Events

There were seven multiple fatality events in 1990. Sixteen individuals were involved in these events; however, only thirteen were U.S. citizens. There were five double fatalities, which was one less than in 1989, and two triple fatalities. Four of the five double fatalities occurred in U.S. waters. The remaining multiple fatalities occurred in foreign waters.

Three double fatalities occurred in the overhead environment, two while diving under ice and one while diving in a cave. The incident in the cave involved two divers who held advanced open water certification but had no cave diving training. Topside assistants were not utilized in either incident associated with diving under the ice. In the first ice fatality, the divers did not properly secure the safety line at the surface. They became entangled in the line and apparently were unable to get out. The second ice fatality involved recreational divers untrained in ice diving. The divers did not use a safety line and were unable to find their way out.

Two double fatalities occurred in open water. Although the events were not witnessed, nitrogen narcosis is suspected as a factor in both incidents. The first occurred on a dive planned to 120 feet to inspect or repair a crab trap. Both individuals had made many dives. One diver died of a gas embolism, and the body of the other was not located. The other double fatality involved the two servicemen who died in Lake Garda, Italy.

The first triple fatality occurred on the French windward island of Martinique in January. The victims included two French citizens and a 24-year-old American. All three were certified instructors who attempted a dive together on compressed air that was to exceed 300 feet. None of the divers returned.

In March, a tragic triple fatality took the lives of two Americans and their Jamaican dive guide. A party of eight divers intended to go no deeper than 70 feet on a drift dive. Missing the intended ledge, the entire dive party reached a depth of 160 feet. Inexperience and nitrogen narcosis resulted in three divers continuing to well over 200 feet. An experienced member of the dive group rescued one diver who had lost consciousness. The other two divers apparently continued to sink and were never recovered.

Preliminary Report on 1991 Recreational (Non-Occupational) Fatalities

At the end of January 1992 a total of 67 recreational scuba fatalities had been reported to Divers Alert Network or The National Underwater Accident Data Center. It is possible this preliminary number may change as reports come in from remote and foreign areas. The record low for scuba fatalities was reported by NUADC in 1988 when there were 66 deaths. Scuba fatalities are beginning to show a definite downward trend. This is good news for scuba diving considering there are currently more certified divers than at any other time in history.

Table 11.5 Oxygen Use in Dive Fatalities

Time to Recovery	Number of Divers	O_2 Available	O_2 Administered
Body not located	9	1	
0-5 Minutes	27	8	10
20-30 Minutes	6		2
40-50 Minutes	3	1	
1+ Hours	3	1	1
2+ Hours	2		
3+ Hours	1		
12 Hours to 14 Days	19		
Body found by others	3		
Unknown time	7		
TOTAL	80	11	13

Fifty-four of the 1991 fatalities (80.5 percent) occurred within the United States, and thirteen fatalities occurred outside the U.S. Although the percentage of fatalities occurring in the U.S. was up from 75 percent in 1990, the total number of U.S. fatalities decreased by fourteen.

There were only three double fatalities reported in 1991 which resulted in six deaths. This compares to the seven multiple fatalities resulting in thirteen U.S. citizen deaths for 1990. All of the 1991 double fatalities were the result of recreational divers who entered overhead environments without proper training for that environment. There were only three deaths while participating in initial scuba training compared to six in 1990. Only four deaths in the total of 67 were known to have occurred in noncertified divers. This represents only 6 percent of all scuba deaths. This percentage is also down from 1989 when 9 percent of diver deaths were uncertified and in 1990 when 12 percent of all deaths were uncertified individuals. Uncertified deaths occur predominantly in the U.S. despite the efforts of responsible instructors and dive shop operators to limit the access to scuba equipment by untrained individuals.

The reduced number of scuba fatalities in 1991 has been good news for the states of Florida and California where almost half the number of fatalities which usually occur have been reported.

DAN DIVE ACCIDENT REPORTING FORM

BOX 3823 • DUKE UNIVERSITY MEDICAL CENTER
DURHAM, NORTH CAROLINA 27710
Information Mon.–Fri. 9–5 (E.T.) (919) 684–2948
Emergencies Only (919) 684–8111

DATE & TIME OF ACCIDENT
MONTH/DAY/YEAR ☐☐☐☐☐☐ Time __________ AM PM

IS THIS A FATALITY REPORT? ☐ YES ☐ NO

For DAN Office Use Only
CASE
SEVERITY CODE
BMI

1. PATIENT NAME LAST FIRST MI

2. OCCUPATION

3. ADDRESS STREET CITY ST ZIP

4. PATIENT PHONE (HOME)

5. PATIENT PHONE (WORK)

6. COUNTRY (IF NOT USA)

7. AGE YRS

8. SEX M or F

9. HEIGHT FT IN

10. WEIGHT LBS.

11. CERTIFYING AGENCY
A - PADI
B - NAUI
C - NASDS
D - YMCA
E - SSI
F - Other
G - None

12. CERTIFICATION LEVEL
A - Basic
B - Open Water
C - Advanced
D - Divemaster
E - Instructor
F - Commercial
G - Other
H - None
I - Student

13. DAN MEMBER?
Y - Yes
N - No

14. YEARS DIVING
YEARS MONTHS

15. NUMBER OF DIVES MADE
Total
Previous 12 months

16. PREVIOUS DIVE ACCIDENTS
A - Possible DCS
B - DCS
C - AGE
D - Pul. barotrauma
E - None

17. CURRENT MEDICATIONS
Y or N
☐ Prescription
☐ Non-prescription
List __________

18. CIGARETTE USE
A - Presently
B - In past
C - Never
Years Smoking
Packs per day

19. PREVIOUS MAJOR ILLNESSES/ SURGERY
(Provide up to 3 responses)

A - Chest-lung
B - Asthma
C - Chest-heart
D - Gastrointestinal/Abdomen
E - Brain
F - Spine/Back
G - Limb or joint of DCS site
H - Circulation/Blood
I - Neurologic/Nervous system
J - Muscle/Skeleton system
K - Eye
L - Mental/Emotional
M - Other __________
N - None

Past:
A - 2-6 months
B - 7-12 months
C - 1-3 years
D - 2-5 years
E - 6+ years

List and describe specific problems:

20. CURRENT HEALTH PROBLEMS WITHIN PREVIOUS 2 MONTH
(Provide up to 3 responses)

A - Chest-lung
B - Asthma
C - Chest-heart
D - Gastrointestinal/Abdomen
E - Brain
F - Spine/Back
G - Limb or joint of DCS site
H - Circulation/Blood
I - Neurologic/Nervous system
J - Muscle/Skeleton system
K - Eye
L - Mental/Emotional
M - Other __________
N - None

List and describe specific problems or additional current medications

PLEASE ATTACH SEPARATE SHEET FOR ADDITIONAL INFORMATION OR NARRATIVE.

I understand that the information in this form will be used for research purposes only, and that all personal information will be kept strictly **confidential**. I also understand that the Divers Alert Network may need to contact me in the future for clarification of information provided on this form.

____
Patient Signature

DIVE ACCIDENT

21. PURPOSE OF DIVE

☐ A - Pleasure
B - Work/Labor

22. DIVE ACTIVITY (up to 2 responses)

☐ ☐
A - Wreck
B - Cave
C - Night
D - Photography
E - Under Instruction
F - Providing Instruction
G - Spearfishing/ Game collecting
H - Sightseeing

23. ENVIRONMENT

☐ A - Freshwater
B - Saltwater

24. ALTITUDE OF DIVE

☐ A - Sea Level
B - > Sea Level but < 1000 ft.
C - > 1000 ft.

25. Was this dive or dive series typical of your normal type of diving?

☐ Y - Yes
N - No

IF NO, Explain ____________________

26. DIVER'S PERCEPTION OF TEMPERATURE

☐ A - Cold
B - Hot
C - Comfortable

27. CURRENT STRENGTH

☐ A - Strong
B - Moderate
C - Mild
D - None

28. AIR SUPPLY

☐ A - Scuba Air
B - Surface Supply Air
C - Mixed gas
D - None/Breath-hold dive

29. AIR CONSUMPTION

☐ A - Ran low
B - Out of air
C - Not a problem
D - Buddy breathing (not octopus)

30. BUOYANCY PROBLEM

☐ Y - Yes
N - No

31. RAPID ASCENT

☐ Y - Yes
N - No

32. WITHIN LIMITS-Y or N

☐ Tables (which table ________)

or

☐ Computer (type ____________)

33. TYPE OF SUIT

☐ A - Wet
B - Partial Wet
C - Dry
D - Lycra
E - Swim

34. EQUIPMENT USED ON DIVE: (please check all that apply)

☐ Depth gauge
☐ Timing device/watch
☐ Buoyancy vest
☐ BC Inflator hose in use
☐ Decompression computer

35. EQUIPMENT MALFUNCTION:

☐ ☐
A - None
B - Regulator
C - BC Vest
D - Weight belt
E - Dry suit
F - DC Computer
G - Inflator hose
H - Contaminated air supply
I - Equipment was not familiar to you.
J - Other

Reason: ____________

36. TYPE OF DIVE

Y - Yes
N - No

☐ Single

☐ Repetitive

37. WOMEN, PLEASE RESPOND (up to 2 responses)

When the accident occurred, were you:

☐ ☐
A - Menstruating
B - On birth control medication
C - Pregnant
D None of the above

38. DIVE LOCATION:

State, Province, or Island: ____________

Country or nearest country: ____________

39. How long ago was your last Dive Trip/Series?

☐☐ Circle one: Days Weeks Months

40. STRENUOUS EXCERCISE

Y - Yes
N - No

☐ 24 hours predive
☐ During dive
☐ 6 hours postdive

41. PREDIVE HEALTH

☐ A - Nausea/ vomiting
B - Hangover
C - Diarrhea
D - Other
E - No Problem

42. ALCOHOL

Please check: | Number of drinks, beers, or wine

☐ None	
☐ Night Before	☐☐
☐ Predive	☐☐
☐ Between Dives	☐☐
☐ Post Dive	☐☐

43. RECREATIONAL DRUG USE

Prior to, between, or after dive

☐ Y - Yes
N - No

44. Do you consider yourself physically fit?

☐ Y - Yes
N - No

☐ Do you excercise on a weekly basis? (Y or N)

☐ # Days per week

45. FATIGUE OR LACK OF SLEEP PRIOR TO DIVE?

☐ Y - Yes
N - No

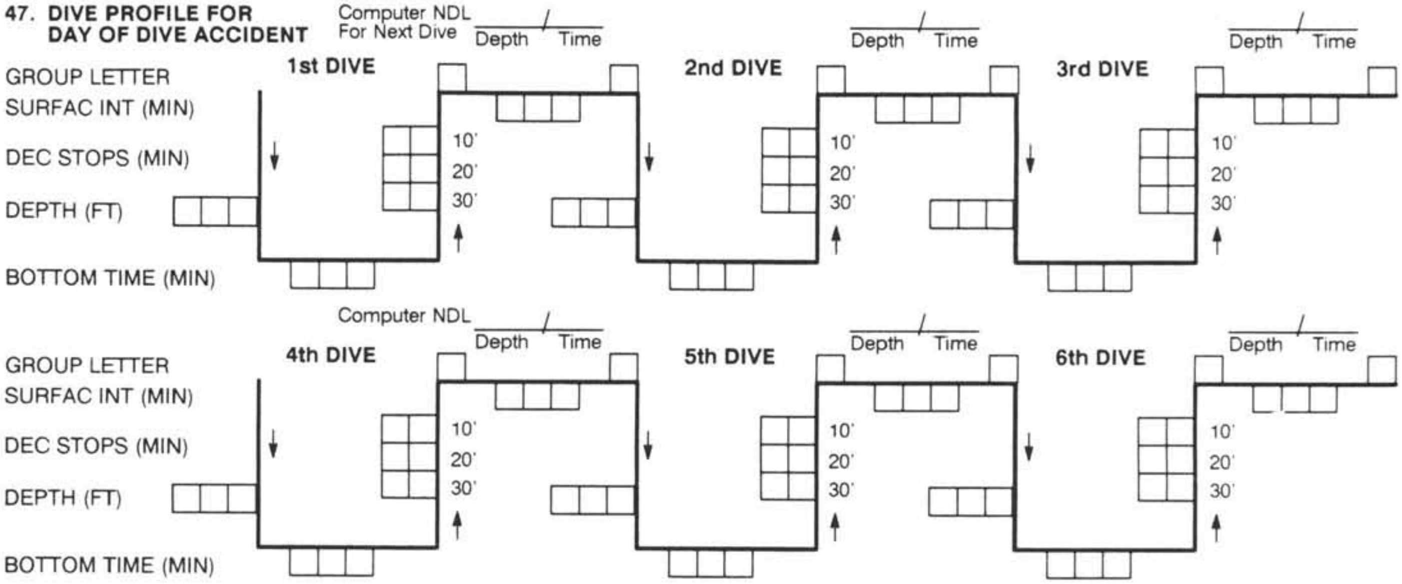
46. DIVE SERIES

Please fill in all that apply up to and including your last dive. If you skipped a day please leave that day blank.

	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7
Total # of dives	☐	☐	☐	☐	☐	☐	☐
Any night dive? (How many)	☐	☐	☐	☐	☐	☐	☐
Any symptoms? (Yor N)	☐	☐	☐	☐	☐	☐	☐
A - All no stop dive(s) B - Any safety stop C - Any dive requiring decompression stops	☐	☐	☐	☐	☐	☐	☐
A - Multilevel (time divided) B - Square	☐	☐	☐	☐	☐	☐	☐
Deepest Dive (ft.)	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐

DIVE ACCIDENT (cont.)

47. DIVE PROFILE FOR DAY OF DIVE ACCIDENT



PRE-CHAMBER INFORMATION

48. INITIAL CONTACT WAS:

A - DAN Emergency
B - DAN Non-emergency
C - Hospital emergency room
D - Emergency medical service
E - US Coast Guard
F - Physician
G - Dive instructor/shop
H - Other: ____________

49. Total delay from symptom onset to contacting DAN or other medical help:

HOURS or DAYS

50. FLYING OR INCREASED ELEVATION AFTER DIVING AND PRIOR TO TREATMENT?

A - Commercial airliner
B - Unpressurized aircraft
C - Med Evac Flight
D - Mountain elevation
E - Does not apply

Hours post dive (flew or went into elevation)

elevation (in feet)

51. SIGNS & SYMPTONS

1st Symptom
2nd Symptom
3rd Symptom
4th Symptom
5th Symptom
6th Symptom

A - Pain
B - Rash
C - Itching
D - Weakness
E - Numbness/Tingling
F - Dizziness/Vertigo
G - Semi-consciousness
H - Unconsciousness
I - Restlessness
J - Extreme fatigue
K - Visual disturbance
L - Speech disturbance
M - **Headache**
N - Paralysis
O - Difficulty breathing
P - Nausea/Vomiting
Q - Hemoptysis/coughing blood from lungs
R - Muscle twitching
S - Convulsions
T - Hearing loss
U - Ringing ears
V - Decreased skin sensation
W - Bladder problem
X - Bowel problem
Y - Personality change
Z - Difficulty walking/ standing
1 - Reflex change
2 - Other: ____________

52. LOCATION: Block A = location of symptom
Then please check (✓)
L = Left R = Right B = Bilateral/Both Sides

	A	L	R	B
1st Symptom				
2nd Symptom				
3rd Symptom				
4th Symptom				
5th Symptom				
6th Symptom				

A - Head
B - Face
C - Sinus
D - Eyes
E - Ears
F - Neck
G - Shoulder
H - Entire arm
I - Upper arm
J - Elbow
K - Forearm
L - Wrist
M - Hand
N - Fingers
O - Chest
P - Back
Q - Upper back
R - Lower back
S - Abdomen
T - Buttock
U - Groin
V - Hip
W - Entire leg
X - Thigh
Y - Knee
Z - Calf
1 - Shin
2 - Ankle
3 - Foot
4 - Toes
5 - Trunk
6 - Generalized
7 - Other: ____________

53. SYMPTOM ONSET:

	HOURS	MINUTES	or	BEFORE SURFACING FROM DIVE
1st Symptom				
2nd Symptom				●
3rd Symptom				
4th Symptom				
5th Symptom				
6th Symptom				

54. ANY OF THE SYMPTOMS FROM #51 PRIOR TO THE LAST DIVE?

Y - Yes
N - No

If yes, which symptoms?

1st
2nd
3rd
4th
5th
6th

Other

Explain: ____________

55. FIRST AID ADMINISTERED BEFORE HOSPITAL OR CHAMBER HELP WAS RECEIVED?

Y - Yes
N - No

Oxygen
Aspirin
Oral fluids
Head down position/ Trendelenburg

If oxygen was received was delivery by:
A - Demand valve
B - Freeflow valve
C - Don't know

PRE-CHAMBER INFORMATION (cont.)

56. HOSPITAL TREATMENT ADMINISTERED
(Please check all that apply):

- [ ] None
- [ ] Oral fluids
- [ ] IV fluids
- [ ] Oxygen
- [ ] Steroids
- [ ] Anticoagulant
- [ ] Aspirin
- [ ] Other medication ______________

57. RELIEF BEFORE CHAMBER TREATMENT?

[ ] A - Complete
B - Partial
C - Temporary
D - None

58. IF ANY RELIEF OCCURRED, WHICH SYMPTOMS FROM #51 ABOVE?
(Please check):

1st [ ]
2nd [ ]
3rd [ ]
4th [ ]
5th [ ]
6th [ ]

59. PRE-CHAMBER RELIEF OCCURRED:

[ ] A - Without first aid or medical care
B - Following first aid
C - Following pre-chamber hospital care
D - No relief occurred

CHAMBER TREATMENT

60. CHAMBER TREATMENT FACILITY LOCATION

CITY

STATE COUNTRY

Date & Time of Treatment

MONTH/DAY/YEAR

Time __________ AM PM

Name of hyperbaric facility

Treating doctor

Form Completed By

____

61. TYPE OF CHAMBER
(please check)

Initial Treatment	Retreatment Chamber
[ ] Monoplace	[ ] Monoplace
[ ] Dualplace	[ ] Dualplace
[ ] Multiplace	[ ] Multiplace
[ ] No chamber treatment given	

62. TOTAL DELAY FROM SYMPTOM ONSET TO RECOMPRESSION

HOURS or DAYS

63. INITIAL TREATMENT

[ ] A - USN TT4
B - USN TT5
C - USN TT6
D - USN TT6A
E - HART Protocol
F - KINDWALL Protocol
G - 45 fsw 90 min
H - 33 fsw 120 min
I - Other ______________

64. TABLE EXTENSIONS REQUIRED?

[ ] Y - Yes
N - No

65. RELIEF AFTER INITIAL TREATMENT OF SYMPTOMS FROM # 51?

1st [ ]
2nd [ ]
3rd [ ]
4th [ ]
5th [ ]
6th [ ]

Please indicate:
A - Complete
B - Partial
C - Temporary
D - None

66. RETREATMENT GIVEN
(Provide up to 3 responses)

TABLE	NUMBER OF TREATMENTS
[ ]	[ ]
[ ]	[ ]
[ ]	[ ]

A - USN TT4
B - USN TT5
C - USN TT6
D - USN TT6A
E - HART Protocol
F - KINDWALL Protocol
G - 45 fsw 90 min
H - 33 fsw 120 min
I - Other ______________

67. RELIEF AFTER HYPERBARIC THERAPY COMPLETED?

[ ] A - Complete
B - Partial
C - Temporary
D - Hyperbaric therapy not completed
E - None

68. RESIDUAL SYMPTOMS AFTER HYPERBARIC THERAPY COMPLETED?

[ ] A - Pain only
B - Neurologic
C - Hyperbaric therapy not completed
D - None

69. DURATION OF RESIDUAL SYMPTOMS

(Circle one)

[ ] DAYS
WEEKS
MONTHS

70. FINAL DIAGNOSIS:

[ ] A - DCS I
B - DCS II
C - Air Embolism
D - Pulmonary Barotrauma
O - Other ______________

I WOULD LIKE TO RECEIVE DAN INFORMATION.

[ ] Y - Yes
N - No

Appendix B DAN Fatality Worksheet

Deceased Diver Profile

Name ______________________ Date / Time of death ______________
Birth date ______________ Age ________ Sex ________ Race ________
Height ________ Weight ________
Occupation ______________________ Marital status ______________
Was deceased certified? Yes No Years diving ________ Certification level ______________
Total number of dives ________ Dives in last 12 months ________
General experience level (see back) ______________________
Experience level within activity (see back) ______________________

Dive Conditions

Location (city / state / country) ______________________
Water entry (please circle) shore private boat charter boat
Altitude (please circle) sea level < 1,000 feet between 1,000 feet and 3,000 feet > 3,000 feet
Water type (please circle) salt fresh Water temp ________ °F Water depth ________ feet
Seas (please circle) calm moderate rough Visibility ________ feet
Current (please circle) none mild moderate strong
Surge (please circle) none mild moderate strong
Weather conditions ______________________
Bottom type ______________________
Diver's first time at this location Yes No Type of exposure suit ______________
Dive tender? Yes No Number in dive party ________
Dive buddy? Yes No Number in buddy team ________ Buddy separation? Yes No
Dive activity ______________________
Specialty dive? Yes No If yes, specialty certified? Yes No

Diver Health

Panic? Yes No Physically fit? Yes No
Predive health (see back) ______________
Mental status (see back) ______________
Previous dive accidents? Yes No Previous major illness ______________________
Undiagnosed health problems ______________ Current health problems ______________
Prescription medications ______________ Nonprescription medications ______________
At the time of accident, was diver influenced by (please circle) Fatigue Alcohol Recreational drugs

Other Dive Problems

Equipment problems? Yes No (please list) ______________________
Buoyancy problem? Yes No Weight belt ________ lbs. Weight belt dropped? Yes No
Familiar with equipment? Yes No Nitrogen narcosis? Yes No Rapid ascent? Yes No
Air supply (please circle) Scuba Surface-supplied Mixed gas Breathhold diving Bad air supply
Air consumption (please circle) Not a problem Low air Out of air Buddy breathing/sharing air
Diver lost? Yes No Diver trapped? Yes No Diver entangled? Yes No

Dive Profile

Dive type (please circle) Single Multi Bounce Decompression
Last dive series ______________ Dive computer? Yes No
Dive 1 Depth ______ feet Bottom time ______ minutes Surface interval ______ hours/minutes
Dive 2 Depth ______ feet Bottom time ______ minutes Surface interval ______ hours/minutes
Dive 3 Depth ______ feet Bottom time ______ minutes Surface interval ______ hours/minutes

Recovery and First Aid

Was the event witnessed? Yes No

Problem occurred at (please circle) Surface / Pre-dive Descent Bottom Ascent Surface / Post-dive

How long into dive did the problem occur __________ minutes At what depth __________ feet

Signs diver was in distress? Yes No

Immediate search? Yes No Not applicable

If no, after _______ days _______ hours _______ minutes

Was body recovered Yes No If yes, after _______ days _______ hours _______ minutes

CPR performed? Yes No Not applicable

Was oxygen available at dive site? Yes No Was oxygen administered? Yes No Not applicable

USCG assistance? Yes No Medivac? Yes No

Location of death registration ____

Report of Investigation by Medical Examiner

Probable cause of death ____ Due to __________________

Contributory conditions ____

Manner of death (please circle) Natural Accidental Homicide Suicide Pending

Autopsy done Yes No If yes, please attach copy.

Accident Scenario (use additional sheets if necessary)

____

____

____

____

____

____

____

____

____

____

____

____

____

Fatality Worksheet Instructions and Key

Please answer all questions to the best of your knowledge. If you do not know the appropriate response, enter '"?" into the blank. Responses for questions not listed below are self-explanatory.

General and activity experience level

(includes certification dives)

1 = Noncertified

2 = Novice (0 to 5 dives)

3 = Inexperienced (6 to 20 dives)

4 = Intermediate (2 to 40 dives)

5 = Advanced (41 to 60 dives)

6 = Experienced (61 or more dives)

Predive health

1 = Nausea/Vomiting

2 = Hangover

3 = Pre/Postdive alcohol

4 = Diarrhea

5 = No problem

6 = Other, please list

Predive mental status

1 = No problem

2 = Stressed

3 = Anxious

4 = Quiet

5 = Talkative

6 = Agitated

7 = Other, please list

For Office Use Only

DAN Case Number ____________ *ME Case Number* ____________ *IR Case Number* ____________

First contact ______________________________ Second contact ______________________________

Third contact ______________________________ Fourth contact ______________________________

To report a diving-related fatality, please call DAN at (919) 684-2948, or send this worksheet to: DAN, Box 3823, Duke University Medical Center, Durham, North Carolina 27710.

Appendix C DAN Diagnosis Coding for Disease Severity

Code = 0 *Asymptomatic*

Code = 1	*DCS-I*	*Location*	*Side*
Pain		G - N, U - Z	Any
Rash		Any	Any
Itching		Any	Any

Code = 2	*DCS-II*	*Location**	*Side*
Pain		D, F, Q - T, 4, 5	Any
Numbness / Tingling		Any	L/R
Restless		Any	Any
Headache		Any	Any
Skin sensation		Any	L/R
Muscle-twitch		Any	Any

Code = 3	*DCS-II*	*Location**	*Side*
Ringing ears		Any	Any
Dizziness		Any	Any
Pain		O	Any
Fatigue		Any	Any
Reflex		Any	Any

Code = 4	*DCS-II*	*Location*	*Side*
Weakness		Any	L/R
Numbness / Tingling		Any	Both
Breathing difficulty		Any	Any
Nausea / Vomiting		Any	Any
Hearing loss		Any	Any
Skin sensation		Any	Both
Personality change		Any	Any
Walk / Standing difficulty		Any	Any

Code = 5	*DCS-II*	*Location*	*Side*
Visual disturbance		Any	Any
Speech disturbance		Any	Any
Weakness		Any	Both
Paralysis		Any	Both
Bladder		Any	Any
Bowel		Any	Any

Code = 6	*AGE*	*Location*	*Side*
Semiconscious		Any	Any
Unconscious		Any	Any
Paralysis		Any	L/R
Convulsions		Any	Any

**Location of symptom is used in differential diagnosis and refers to question #52 on the DAN Dive Accident Reporting Form in appendix [A].*

Appendix D Flying After Diving 1987-1990

Petar Denoble M.D., D.Sc., International DAN Research Associate

In 1990 there were 109 DAN database reports listed flying after diving (FAD). Ninety six of these cases were classified as decompression sickness, and twelve cases were classified as arterial gas embolism (AGE). One case of AGE was believed to have been triggered by takeoff in a commercial airplane 24 hours after diving. The other AGE-flying after diving cases involved medical evacuation flights. Table 1 compares the diagnosis in flying after diving cases reported to DAN since 1987.

Among the 96 decompression sickness flying after diving cases (Type I and II) from 1990, 46 divers developed symptoms before they flew, 26 developed symptoms in flight or post flight, and the rest involved medical evacuation flights. Seventy eight percent of all flying after diving cases had flights originating abroad, and 22 percent flew within the United States.

A comparison was made between non-flying induced decompression sickness cases and those induced by flying. Flying after diving decompression sickness cases involved more women, and divers had on average less experience. In the group who developed symptoms during or after flying, there were more divers using computers who dived within the no decompression limits than in the other groups. Divers who developed symptoms during or after flying also dived repetitively more often than divers who had symptoms before they flew. Both flying after diving groups were involved more often in repetitive and multi-day diving than non-flying after diving cases. There was no apparent difference in the time of symptom onset in divers who developed symptoms before they flew and those who did not fly after diving. The delay to call by divers who had symptoms before they flew was on average twice as long as that of non-flying after diving cases.

Nearly one-third of all cases in which divers developed symptoms during or after flying had a symptom onset that coincided with takeoff. In some cases, symptoms manifested as late as 96 hours after surfacing and 72 hours after takeoff. This would seem to indicate that flying after diving was the most important event triggering decompression sickness in cases with prolonged latency.

Table D.1 Flying After Diving Cases by Diagnosis and Year of Accident

	Year				
Diagnosis	**1990**	**1989**	**1988**	**1987**	**Total**
DCS Type I	14	18	13	9	54
DCS Type II	82	70	59	54	265
AGE	12	26	2	15	55
Other	1	2	1	1	5
Total	**109**	**116**	**75**	**79**	**379**

Table D.2 Flying After Diving Cases by Group and Year of Accident

	Year				
Symptoms	**1990**	**1989**	**1988**	**1987**	**Total**
Prior to Flight	6.2	3.7	6.2	6.1	5.7
In/Post Flight	11.4	10.8	20.0	15.5	14.0
Medevac	8.2	15.0	6.2	8.4	10.2
Total FAD	**26.0**	**29.4**	**32.7**	**29.5**	**29.9**

Surface interval was less than 24 hours in 76.9 percent of all divers who developed symptoms in flight or post flight, and 27.7 percent had a surface interval less than 12 hours. Observing the DAN recommendation for waiting a minimum of 12 to 24 hours before flying after diving might have prevented the majority of reported cases in which divers developed symptoms during or after flying and reduced the total number of decompression sickness cases by almost 5 percent.

Eighty five percent of all decompression sickness symptoms occurred within six hours after diving, and 95 percent of all symptoms occurred in 12 hours or less post dive. One would suspect that most divers would not choose to fly within the first 12 hours after diving. However, half of the 26 divers (13) who developed symptoms during or after flight in fact flew within the first 12 hours post dive.

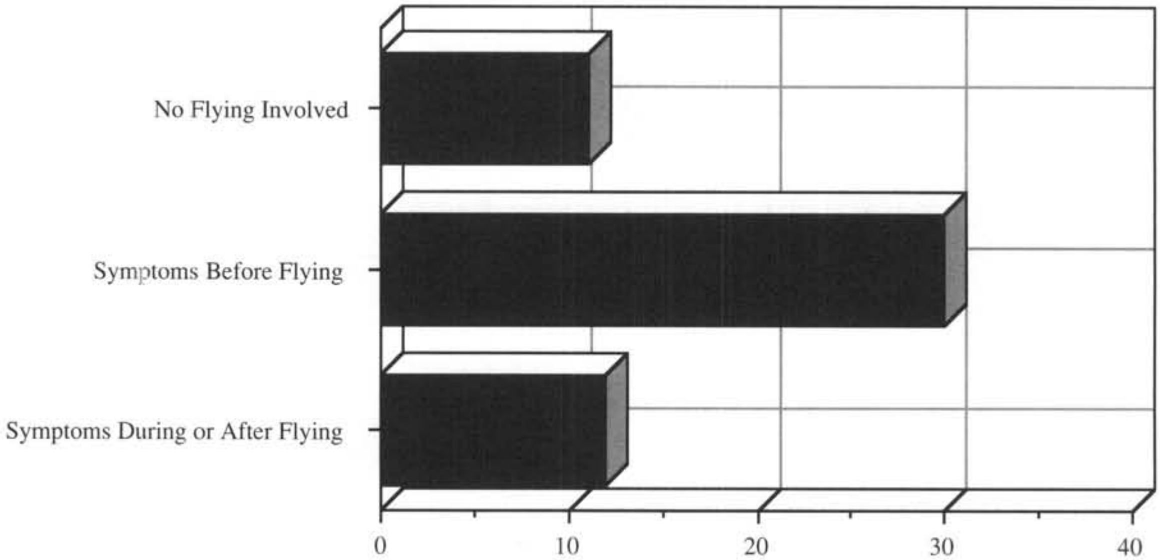
Among the cases with a delay to symptom onset of 12 to 24 hours, were 17 divers who developed symptoms during or after flying, and 49 were divers who developed symptoms before they flew or non-flying after diving cases. In cases where symptoms began 24 hours or more after diving, there were 35 divers who developed symptoms in flight or post flight and 28 divers who developed symptoms before flying and non-flying after diving cases.

Neurologic symptoms were the most common presentation of decompression sickness in all flying after diving cases. Neurological decompression sickness (Type II) accounted for 82.1 percent of the cases where symptoms were present prior to flying. This was greater than the 78.8 percent reported in the divers who developed symptoms during or after flying and the 73 percent reported in non-flying after

Table D.3 Surface Interval for Divers Without Symptoms Pre-Flight

Surface Interval	Number of Divers	Percentage
< 12 hours	18	27.7
12 - 24 hours	32	49.2
24 - 48 hours	19	29.2
48 - 76 hours	3	4.6

Graph D.4 Residual Symptoms in DCS



diving. The incidence of residual symptoms (see Graph 1) was three times greater in cases in which divers had symptoms before they flew than in non-flying after diving cases at the three-month follow-up interval. The difference in divers' characteristics and dive profiles may have accounted for both the greater incidence of neurologic decompression sickness and long-term residual symptoms in flying after diving. The potential risk of long-term residual symptoms in symptomatic divers appears to be increased two-fold by flying without receiving appropriate treatment.

Nearly one-third of all cases in which divers developed symptoms during or after flying had a symptom onset that coincided with takeoff. In some cases, symptoms manifested as late as 96 hours after surfacing and 72 hours after takeoff. This would seem to indicate that flying after diving was the most important event triggering decompression sickness in cases with prolonged latency.

Divers who have symptoms of decompression sickness should be particularly careful about flying as the risk of long-term residual symptoms appears to be twice as likely as those who develop symptoms during or after their flight and the non flying after diving cases.

Appendix E Location of Fatalities

Location of U.S. from 1970 to 1990 in Foreign Areas

Country	1970-1979	1980-1989	1990	Country Totals
Anguilla		1		1
Antigua		1		1
Aruba	1			1
Australia	1	2		3
Bahamas	17	19	3	39
Barbados		2		2
Bequia			1	1
Bermuda	1	1	1	3
Belize	2	4	1	7
British Virgin Islands		4		4
Canada	7	6		13
Carribbean Area	27			27
Cayman Islands	3	5	1	9
Central America	1			1
Costa Rica		1		1
Cuba		2		2
Egypt			1	1
Fiji Islands		2		2
French Antilles		2		2
Greece	3	1		4
Honduras		2	1	4
Italy			2	1
Jamaica			2	2
Malaysia		1		1
Martinique		1	1	1
Mediterranean Area	2			2
Mexico	18	28	4	50
Micronesia			1	1
Morocco		1		1
Netherlands Antilles		2		2
New Caledonia		1		1
Okinawa	11	3	1	15
Panama			1	1
Phillipines		2		2
Portugal		1		1
Red Sea		3		3
St. Vincent/Grenadines		4		4
Saipan		1		1
Thailand		1		1
Saudi Arabia		2		2
Unknown		1		1
Decade Totals	**94**	**107**	**21**	**221**

Location of U.S. Fatalities from 1970 to 1990 by State

State	1970-1979	1980-1989	1990	State Totals
Alabama	4	2		6
Alaska	9	9		18
Arizona	2	4		6
Arkansas	5	8		13
California	262	155	14	431
Colorado	4			4
Connecticut	9	9	1	19
Delaware		3		3
Florida	297	231	22	549
Georgia	9	11		20
Hawaii	63	54	3	121
Idaho	2	4		6
Illinois	10	3	1	14
Indiana	6	1		7
Iowa	3			3
Kansas	1			1
Kentucky	3	1		4
Louisiana	6	5	1	12
Maine	17	8	3	27
Maryland	9	1		10
Massachusetts	39	32	2	73
Michigan	33	12		45
Minnesota	5	4		9
Mississippi	1	3		4
Missouri	18	3		21
Montana		2	1	3
Nebraska	4	5		9
Nevada	4	2		6
New Hampshire	4	4	0	9
New Jersey	25	15	2	42

State	1970-1979	1980-1989	1990	State Totals
New Mexico	6	4		10
New York	38	21	3	62
North Carolina	8	12		20
Ohio	9	6	1	16
Oklahoma	2	1		3
Oregon	15	11	1	27
Pennsylvania	7	7	2	16
Rhode Island	11	19	2	32
South Carolina	7	3		10
South Dakota	1		1	2
Tennesee	5	4		9
Texas	32	19	1	52
Utah	14	5	1	20
Vermont	2	1		3
Virginia	9	5		14
Washington	96	67	4	167
West Virginia	1			1
Wisconsin	20	10	2	32
Wyoming		2		2
Washington DC	1			1
Decade Totals	**1138**	**788**	**68**	**1994**

Location of U.S. Fatalities from 1970 to 1990 by U.S. Territory

U.S. Territories	1970-1979	1980-1989	1990	Territory Totals
Guam	1			1
Marshall Island	1			1
Puerto Rico	4	5	1	10
Virgin Islands	1	11	1	13
Decade Totals	**7**	**16**	**2**	**24**

Appendix F Fatal Diving Accident Investigation

G. Yancey Mebane M.D., Assistant Medical Director, Director EMS Training, Divers Alert Network.

The forensic pathologist is usually able to determine a cause of death based on the findings of the autopsy. This cause is usually expressed as a diagnosis of a disease or a pathophysiological event. However, we are interested in the factors which led up to the final event, and this requires investigation of the total incident.

Personal and Past Medical History

A most important part of this investigation is knowledge of the divers' personal characteristics and past medical history. Does the diver meet the standards for physical fitness? No matter what the nature of the accident, being unfit will lessen the chances of survival. The diver should be in a state of physical training consistent with the dive and should have no medical condition that might be aggravated by the effects of pressure or hard physical work.

Pre-existing diseases may predispose to the diving accident. Emotional instability and respiratory infections are particularly important. Medical screening of new divers to detect the presence of physical disqualifications should be required. Adequate initial training followed by further training to match the conditions of the dive is essential. Open ocean, wreck, cold water and other special diving situations require training beyond initial "open water" certification issued by training agencies. A diver who completes an open water certification is not a finished product but is now ready to learn the skills required for special situations such as the open ocean, currents, cold water, limited visibility and others.

The diver should have adequate training for the conditions of the dive. Much criticism is currently directed at some programs which certify after a superficial level of training. Other divers tend to enter specific areas of diving without specialized training. As an example, consider cave diving, wreck diving or ice diving which require special techniques and equipment. Some recreational divers are now experimenting with mixed gas diving, dives past 200 feet and self treatment with oxygen in the water. There have been fatalities reported in 1990 due to amateurish attempts at mixed gas diving and also with dives past 200 feet. The diver must be trained to at least the depth of his dive with the equipment he is to use and for the environmental conditions he will encounter.

Past diving accident history should be taken into consideration. Some disorders experienced by divers in the past are likely to be repeated under similar conditions. These may include:

1. Breath-hold after hyperventilation
2. Panic with hyperventilation
3. Pulmonary barotrauma
4. Nitrogen narcosis
5. Syncope of ascent
6. Decompression Sickness — especially involving spinal cord

7. Oxygen toxicity
8. Alcohol and drug history

Environmental Conditions

The weather and environmental conditions at the time of the accident are important. Many fatalities are associated with adverse environmental conditions. The diver may be exposed to increased risk during entry and exit as well as during the dive by any of these factors. A diver swimming against a one knot current is at his limit and probably consuming 2 liters or more of oxygen per minute and ventilating 40 liters of gas per minuter per atmosphere pressure. It is practically impossible for a diver to make headway against a 2 knot current.

The temperature of the water will influence hypothermia, decompression sickness and the function of various pieces of diving equipment. Regulators may cease to function when the temperature is at the freezing point. Limited or zero visibility may contribute to the progression of a fatal diving accident following a minor problem.

Entrapment or entanglement is common as a cause of death and includes the diver lost in a cave, wreck or under ice. There have also been open water deaths due to entanglement in lines and kelp. Accidents involving marine animals are very rare, and none were reported in 1990. There was one fatality incident involving sharks.

Dive Profile and History

Essential information includes the location, bottom time and depth of the incident dive as well as recent dives prior to the final dive. The speed of ascent and stops is important information as well as a report of the dive plan. Was there one? Was it followed? Why not?

The degree of physical exertion required by the dive is important to know as the diver unable to meet the physical requirements of the dive is at great risk. All of this is crucial information but often is not available because the divers did not make observations or did not record details.

Diving Equipment

The equipment should be impounded after an accident until a detailed written report can be completed and photographs are taken. The cause of the accident may become apparent with examination of the equipment. The equipment may have been affected by the accident. There may have been loss or displacement of movable items or damage to protective clothing. Gas spaces such as face mask or buoyancy vest may be flooded. Look for vomitus on the mouthpiece or equipment.

The weight belt should be carefully examined and weighed. Determine if it was or could be released. Record the presence or absence of watch, depth gauge, submersible pressure gauge, decompression meter and knife. Record the condition of the buoyancy compensator.

The regulator and cylinder should be examined for defects and the final tank pressure recorded. Samples of the gas within the cylinder should be analyzed for correct partial pressures and the presence of toxic substances.

Appendix G Autopsy Protocol for Victims of Scuba Diving Accidents

Eric P. Kindwall M.D., Associate Professor, Department of Plastic and Reconstructive Surgery, Director of Hyperbaric Medicine, Medical College of Wisconsin; and Jorge Pellegrini M.D., Associate Pathologist, Department of Pathology, St. Luke's Hospital, Milwaukee.

The purpose of this protocol is to assist the pathologist in establishing immediate cause of sudden death in the water. In a pressure related diving accident, the traumatic agent is a simple gas which, although causing death, is evanescent and may go undetected using the standard autopsy routine. Cerebral air embolism has often been inadvertently signed out as simple drowning. It is important to remember that cerebral air embolism can occur in water depths as little as 1.12 meters (4 feet) and can produce fatal results within less than one minute of surfacing. Postmortem bubbles often confuse the issue. This protocol should be filed for future use when performing an autopsy on a scuba diver.

Introduction

Since the advent of civilian sport scuba diving (Self Contained Underwater Breathing Apparatus) as a major recreational pastime, diving accidents have inevitably increased and of necessity, pathologists with little previous knowledge of diving, are called upon to perform autopsies when accidents cause fatality. This poses difficult problems as there have been no protocols widely disseminated for use by pathologists in carrying out these highly specialized postmortem examinations. The purpose of this protocol is to assist the pathologist in establishing the immediate cause of sudden death in the water, and little emphasis is given to long term or chronic changes associated with decompression accidents.

In a pressure related diving accident, the traumatic agent is a simple gas or mixture of gases which although causing death, is evanescent and very well may go undetected when the standard autopsy routine is followed. As a result, many cases of cerebral air embolism have been inadvertently signed out as simple drowning. It is important to remember that cerebral air embolism can occur in water depths as little as 1.12 meters (4 feet) and may produce fatal results within a minute or two of surfacing.

Sometimes bubbles are found in blood vessels at autopsy tempting the pathologist to diagnose "bends" or decompression sickness as the cause of death when in reality the bubbles were formed postmortem. With a good understanding of the mechanisms involved and knowledge of a proper autopsy technique, much more accurate assessment of the cause of death can be made.

This protocol should be filed for future use when performing an autopsy on anyone who has died while wearing a scuba apparatus or for that matter, any type of compressed air diving apparatus. This would even include a bucket worn over the head under water supplied with air from a garden hose and tire pump.

Diagnoses to Consider

Aside from obvious trauma such as propeller injury or a natural illness such as stroke or myocardial infarction, the scuba diver is most likely to suffer:

1. Cerebral air embolism with or without mediastinal emphysema and pneumothorax.
2. Drowning.
3. Decompression sickness.
4. Bites or stings from venomous marine animals.

The pathologic findings in drowning will not be considered here as they are covered in standard reference works.

Cerebral Air Embolism

The mechanism of arterial gas embolism hinges on the fact that while using a compressed air scuba apparatus the air pressure in the lungs at depth is in equilibrium at all times with the pressure of the water surrounding the diver so long as he breathes normally. Thus it is greater than atmospheric. If the diver, through carelessness or in a panic, ascends only a few feet holding his breath, the air in the lungs expands as water pressure decreases, and forces its way through alveolar walls. Dog experiments have shown that a trans-pulmonic pressure of 80 mmHg is enough to rupture the alveoli.[3] This 80 mm pressure differential between the intra-tracheal pressure and the intra-pleural pressure corresponds to a change in sea water pressure of a little more than one meter (four feet). After passing out of the alveoli, the air may migrate medially producing pneumomediastinum and in some cases pneumopericardium or it may rupture a bleb on the pleural surface causing pneumothorax, though this latter tends to be rare. The worst situation which can commonly occur is that air enters the pulmonary capillaries and is carried via the pulmonary veins to the left heart. From there it is pumped directly into the brain. Scuba tanks are filled with compressed air, never oxygen which becomes too toxic at depth, so resultant arterial bubble contain mostly nitrogen. Air embolism will produce air bubbles in the meningeal and cerebral arteries and possibly in the coronaries. However, because the diver invariably embolizes in a head up position while vertically ascending through the water, mesenteric, spinal cord and the vertebral arteries and bones are seldom involved.

It must be emphasized that this event cannot take place if the swimmer is simply breath-hold diving. The victim must have been breathing air at greater than normal pressure under water using some kind of breathing apparatus or appliance.

Because sudden death occurring in the family swimming pool while using scuba gear is not easily attributable to the scuba itself in the minds of most people, the possibility of gas embolism is often overlooked. Again, experiments have demonstrated that as little as 0.4 ml of blood-air foam delivered to the right spot in the brain stem may produce death. In the clinical situation, when death does not immediately ensue, the patient often enters the emergency room with the signs and the symptoms of having suffered a cerebro-vascular accident. This can mistakenly be attributed to ruptured berry aneurysm or some other vascular catastrophe. As a rule of thumb, anyone dying while using a scuba apparatus should be considered to have suffered an air embolism as the initiating event until proved otherwise.

Pathologic Findings in Air Embolism

1. Intra-arterial and intra-arteriolar air bubbles in the brain and meningeal vessels, with possible petechial hemorrhages in the white and gray matter.

2. Ruptured alveoli or acute pulmonary emphysema on microscopic examination. This is often hard to document because of sectioning artifact causing tears of alveolar walls.
3. Grossly hemorrhagic lungs.
4. Possible voids due to air bubbles in the capillaries surrounding the alveoli.
5. Ring and ball hemorrhages in the brain.
6. Signs of acute right heart failure. The heart, if it contains air, may float when surrounded by water.
7. Passive congestion of the kidneys.
8. Liebermeister's sign (white mottling of the dorsum of the tongue).
9. Air bubbles in the retinal and coronary arteries.
10. Mediastinal emphysema.
11. Pneumo-pericardium.
12. Subcutaneous emphysema above the clavicles to the angle of the jaw (should be palpable).
13. Pneumothorax.

It would be unusual to find changes such as softening of neural tissue, changes in Ammon's horn and gliosis because air embolism usually causes nearly instant death. If the patient survives the immediate insult, he usually does not die although he may remain severely crippled as a late result of air embolism blocking the vascular supply with its secondary consequences.

Decompression Sickness or "Bends"

When a diver breathes air under increased pressure, nitrogen from the air goes into physical solution in his blood and tissues. This causes him no difficulty while on the bottom, (aside from an increasing narcotizing effect as he exceeds 30 meters (100 feet) in depth. However, if he has dived deeper than 10 meters (33 feet) and has remained for a long enough time to absorb significant amounts of nitrogen, gas bubbles are formed in his tissues and capillaries as nitrogen comes out of solution if he returns rapidly to the surface. Nitrogen bubbles of themselves can block circulation, tear neural tissue and also initiate complex biochemical changes causing platelet aggregation, agglutination of formed elements of the blood, sludging, stasis infarction and shock. Symptoms range from pain to paresthesias, paralysis (usually the middle third of the spinal cord), asphyxia (as pulmonary capillaries are blocked), shock and death. It is important to remember that decompression sickness (especially producing fatality) *is unlikely to occur unless* the diver has been at a depth *in excess of 10 meters (33 feet).* The time required to absorb damaging amounts of nitrogen varies inversely with depth. For example, one can spend up to 200 minutes at 12 meters (40 feet) and come directly to the surface without pausing on the way for decompression stops. However, this time is reduced to 25 minutes at 30 meters (100 feet) and only 5 minutes at 50 meters (165 feet). Bottom time is reckoned as the time between leaving the surface and leaving the bottom. Normal ascent rate is never more than 18 meters (60 feet) per minute.[5]

Assuming the diver has made a safe dive, whether requiring decompression stops on ascent or not, when he arrives on the surface he will still have more than normal amounts of nitrogen in his tissues. This will slowly be lost over the next 12 to 24 hours. Should he make another dive within that time, he must take into account the residual nitrogen present in his body at the beginning of the second dive. This will be additive to the nitrogen absorbed on the second dive, and he must shorten his second dive or lengthen his decompression time in accordance with the length of the surface interval between the dives.

There are special U.S. Navy repetitive dive decompression tables for use in calculating length of stay or decompression requirements for repetitive dives within 12 hours.[5] Repetitive diving is a frequent cause of decompression sickness is recreational divers either because they miscalculate or fail to observe any decompression rules.

All of the above has relevance to the pathologist as it demonstrates that greater than normal amounts of nitrogen are present in the diver's body even during safe dives. If the diver should die from any cause either on the bottom or within 12 to 24 hours of the dive, nitrogen will cease being carried from the tissues and eliminated through the lungs. Therefore, it will gradually revert to gas phase *in situ* producing *post-mortem* bubbles which, in such cases, will have no bearing on the cause of death. Postmortem nitrogen bubble formation, however, will be minimal or absent if the victim has died during or following short exposures to depths of less than 10 meters.

The obvious pathological findings in someone dying acutely of decompression sickness can only appear as bubbles consisting mostly of nitrogen in any tissue of the body. These bubbles usually originate on the *venous* side but when blood pressure disappears, bubbles will merge even on the arterial side. During life, the blood pressure in the arteries tends to prevent bubble formation except in cases of almost explosive decompression. The lesser pressure present in the veins permits the earlier appearance of bubbles and indeed, during normal, safe and asymptomatic decompression so-called "silent" bubbles can be detected frequently with Doppler sonar over the vena cava. In decompression sickness as already discussed, the bubble will usually represent postmortem bubble formation and therefore, cannot reliably be used to certify the causes of death to be due to too rapid decompression. This is always true if the patient died while under pressure in a recompression chamber or died after spending some time at depth with subsequent recovery of the body from the bottom. The clinical history must invariably be relied upon to establish cause of death in cases of decompression sickness. Following acute death from massive decompression sickness, such as explosive decompression, there will not have been time for tissue reaction such as gliosis, etc., to take place. The pathologist's task in such cases will be to differentiate between air embolism and decompression sickness as the immediate cause of death. In other cases where death is not immediate, the history and clinical course will amply serve to establish the cause of death. Prominent will be lesions in the white matter of the middle third of the spinal cord with evidence of stasis infarction. The brain is usually spared except in cases of aviation decompression sickness.[2]

Venomous Stings or Bites from Marine Animals

1. A bite or sting on any part of the body.
2. Unexplained edema on any part of the body.
3. Pathologic change consistent with anaphylaxis or other strong allergic reaction.

In marine animal stings the history is often suggestive, but the body should be examined very carefully to detect lesions that might have gone unsuspected. Occasionally, a relatively minor bite or sting may precipitate panic or incapacitation which subsequently leads to death by embolism or drowning. A point to keep in mind, however, is that some marine animal bites may take place after death. In such cases, tissue reaction will not occur as compared to bites occurring ante-mortem.

It is important to remember that in *all* pressure related diving accidents, the presence of bubbles formed *postmortem* may tend to cloud and confuse the pathologic diagnosis. The length of time which passes between death and the autopsy as well as the amount of body tissue decomposition which takes place requires that the pathologist exercise good judgment in coming to his final conclusions as well as careful performance of the autopsy which includes an analysis of the gases found.

Preliminary Preparations for the Autopsy

1. Obtain a history from the referring physician, rescue squad and/or the victim's diving companions. This will alert the pathologist as to what he must include or may omit in his consideration of the autopsy findings. Determine the dive profile(s), whether or not the victim dropped his weight belt, inflated his vest, etc. If possible, the diving rig or scuba apparatus should be recovered and retained for future examination. Such examination would include presence of blood or vomit in the regulator or hoses, the amount of air left in the tank(s) and an analysis of the air for contaminants such as carbon monoxide or oil; whether or not the regulator functions properly, its breathing resistance, etc., the status and operability of the lifevest, depth gauge, reserve air gauge, position of the "J" valve and the status and function of the buoyancy compensator if one was used. An expert familiar with scuba equipment should assist with such examination.
2. X-ray the head, neck, thorax and abdomen of the victim for soft tissue detail (free air) as well as bone injury.
3. Prepare a number of tight fitting, well greased 10 cc. syringes equipped with 3-way stop cocks and long spinal needles.
4. Obtain a 50 cc. graduate and fill a deep sink in the autopsy room with water.
5. Provide a hose to the autopsy table so that a gentle stream of water may be directed into the area being examined. Notify the laboratory that you wish to have gas samples analyzed for oxygen and carbon dioxide. (Nitrogen content of the gases may be obtained by subtraction.)

The Autopsy

Inspect the body carefully for signs of trauma or other unusual lesions. Do not forget to look at the back. Palpate the area above the clavicles and below the angles of the jaw for signs of subcutaneous emphysema.

Make an incision through the full thickness of the skin down the midline of the sternum beginning at the second intercostal space. Continue the incision down to the origin of the xyphoid process.[4] Secondly, make two transverse incisions at the ends of the initial vertical incision carrying them a couple of centimeters. Apply towel clips to the skin edges and using blunt and sharp dissection, undermine the skin laterad. Two assistants then "tent up" the skin, and the resultant compartment created above the chest wall fills with water. The 50 cc. graduate is then completely filled with water in the deep sink, inverted with the palm or a cork occluding the open end, is brought over to the victim and the occluded end immersed in the compartment of water over the sternum. An 18 gauge needle is then inserted into the pleural space at the level of the second intercostal space. The open end of the graduate should be positioned directly above the needle so that any gas issuing from the pleural space is trapped in the graduate. The amount of gas recovered is recorded. Then, with the bottom of the graduate again occluded, it is brought over to the deep sink, and a 10 cc. syringe with a long spinal needle is inserted in the graduate so that the gas may be withdrawn for analysis. Before the syringe is removed from the water, the stop cock is closed. Should it be impossible to reach the gas pocket at the top of the graduate, the gas may be transferred to a 50 cc.

beaker, previously filled completely with water in the deep sink by upending the graduate underneath the inverted beaker. Gas may then be withdrawn from the beaker. If the water is warm and this maneuver is carried out rapidly, there will be little absorption of CO_2. Repeat the process on the other side.

The sternum is then transected at the level of the second intercostal space, and the ribs are divided just medial to the costochondral junction. The section of ribs and sternum is removed.

Observe as one goes along whether or not bubbles issue from the cut ends of any vessels. This applies throughout the autopsy. The vessels should be identified if possible as to whether they are arteries or veins. The water in the compartment formed by this skin "tent" will probably become discolored by blood making it opaque. If discrete blood leakage points can be identified, they may be cross-clamped. As the field becomes opaque, fresh water is introduced with the hose to retain visibility. The pericardial sack is opened under water after is has been determined whether or not pneumopericardium is present. A needle is then inserted into the right and left ventricles in turn again in a flooded field with the inverted graduate held over the needle so that the escaping gas may be trapped, the amount recorded an the gas analyzed.

As the mediastinal structures are dissected, note carefully the presence or absence of gas in each discrete compartment as it is opened, bubbles being apparent as they rise through the water. Dissection should be meticulous as if a major vessel is entered early, the field will become too opaque. The hose can be used to flush the blood out to produce a clear field. When the mediastinum, heart and major vessels have been examined under water for the presence of air, the water may be evacuated from the thoracic cavity, and the autopsy proceeds in the conventional manner. Carefully examine the lungs for signs of bullae or emphysematous blebs or hemorrhage (gross or petechial).

Carefully check individual lobes or broncho-pulmonary segments for evidence of bronchial obstruction which might have given rise to blockage of the affected area during decompression such as mucous plugs, broncholiths, foreign bodies, etc. Obtain blood, urine and bile samples for analysis for alcohol or other drugs.

Be sure to probe the heart for evidence of inter-atrial or inter-ventricular septal defect. As the autopsy proceeds, note if there are signs of venous congestion compatible with right sided heat failure. In a case of air embolism where autopsy takes place soon after death, and *before* postmortem bubble formation has taken place, the right ventricle should not contain gas unless there is an inter-atrial septal defect. Gas in the heart, present only in the left ventricle is pathognomonic of arterial air embolism which in the scuba diver becomes cerebral air embolism. If the victim has made a short shallow dive and has suffered air embolism, the left ventricle should contain gas with an oxygen content approaching 16 percent. If bubbles are found after a dive of a long duration or there has been considerable time lag between death and autopsy, the gas bubbles in the heart will be predominantly nitrogen or CO_2, respectively or both.

Head

Ideally, it would be best if the entire autopsy could be carried out under water, but this is not practical as when major vessels are opened, the water becomes impossibly opaque. Before opening the head, tie all of the vessels in the neck so as to preclude the entrance of air into the cerebral or meningeal vessels from below.

After careful examination of the head and neck, the scalp is reflected and the calvarium removed with a saw as is customary. As the calvarium is removed, bubbles may appear as artifacts in the superficial veins or venous sinuses. These can safely be disregarded.[1] The arteries of the meninges should be examined for the presence of gas and then after exposing the brain, gas bubbles should be looked for in the surface vessels. The frontal lobes are reflected back and after the optic nerves have been cut, carefully examine the circle of Willis for bubbles. Air appearing here is particularly significant. The middle cerebral arteries are also examined in situ by carefully spreading the insula. Photograph any bubbles found.[1] The brain is then removed and fixed.

Interpreting Results

The presence or absence of gas in any organ following a scuba diving death can never be conclusive evidence of decompression sickness. With the exception of the case where air is found only in the left ventricle (but not in the right) and in cerebral arteries (but not veins), air embolism cannot be diagnosed simply by the presence of bubbles. However, under certain circumstances gas analysis of the intracardiac air can be revealing. If there is a difference in the oxygen content of gases obtained from the right and left sides of the heart, with more oxygen being present on the left, one can only come to the conclusion that air was introduced traumatically into the arterial circulation. Postmortem bubbles contain little, if any, oxygen, and the same is true for decompression sickness bubbles. When taken in context with the circumstances of the dive and other information which may be provided to the pathologist, gas analysis can help to establish a diagnosis.

In summary, if the basic mechanisms of air embolism, decompression sickness, mediastinal emphysema and pneumothorax stemming from scuba diving are understood by the pathologist, the results of the careful autopsy may often be able to distinguish between a pressure related mechanism of death and simple drowning. The same is true for the potentially fatal consequences of venomous animal sting.

References

Edmonds C., Lowry C., and Pennefather J., *Diving and Subaquatic Medicine,* chap. 24, pp. 320-329, Diving Medical Centre, Mosman, NSW Australia, 1976.

Minckler J., *Pathology of the Nervous System,* vol. 1, McGraw-Hill Book Company, New York, NY, 1971.

Schaefer K.E., McNulty W.P. Jr., Carey C.R., and Liebow A.A., *Mechanisms and Development of Interstitial Emphysema and Air Embolism on Decompression from Depth,* J. Appl. Physiol., 13:15, 1958.

Spitz, Werner U., and Fisher, R.S., *Medicolegal Investigation of Death,* Charles C. Thomas, Pub., Springfield, IL, 1973.

U.S. Navy Diving Manual, NAVSHIPS 0994-001-9010, Sept. 1973, Navy Dept., Washington, D.C., Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

Appendix H Occupational Diving Fatalities

John J. McAniff, Director National Underwater Accident Data Center, University of Rhode Island

The following is an analysis of 14 occupational underwater diving fatalities recorded by the DAN/URI effort for the calendar year 1990. Categories for occupational underwater fatalities have been established in agreement with the National Oceanic and Atmospheric Administration (NOAA), Occupational Safety and Health Administration (OSHA) and the U.S. Coast Guard. These categories are listed on page 98.

The 14 occupational fatalities in 1990 were concentrated in four of the 13 stated categories. One death in C-I, three deaths in C-II, six deaths in C-IV and three deaths in category G. It should be noted that in four of the 1990 cases the victims were certified recreational scuba instructors, but at the time of their demise they were not engaged in teaching and are therefore included in the data for nonoccupational (recreational) fatalities. There was one instructor who died of a myocardial infarction while actively engaged in teaching recreational scuba diving. This Category J fatality is also noted in the recreational scuba fatality section because it is such a rare event.

The occupational fatality table presents the occupational fatalities for 1990 with a listing of the total number of fatalities in each category during the previous twenty years. Category C-I reflects the great improvement in safety efforts of the offshore gas and oil industry with only two deaths since 1981 as compared to an average of two deaths per year in the prior years. It is expected that the same improvement can be produced in the near future in categories C-II and C-III as those industries continue with the institution of self-regulating safety standards and procedures.

The enterprises which are embraced by category C-IV (marine harvesting) are many and varied in their specific activities. They range from geoducks and sea urchins to kelp, mussels, quohogs, sponges and commercial spearfishing. They are geographically dispersed and usually consist of two or three person endeavors which make it difficult to institute self-regulation and safety standards.

The one C-I death occurred in Texas. One C-II death took place in New York, and the other two transpired in Tennessee. The C-IV deaths were single events in each of the following locations: Alaska, Alabama, California, Tennessee, Washington and the U.S. Virgin Islands. The category G events occurred in Florida, Hawaii and Washington.

Six of the occupational fatalities in 1990 occurred while the victims were using surface-supplied air systems. Scuba equipment was in use in the remaining cases. Case scenarios follow by category.
The one C-I death was that of a 21-year-old commercial diver who was working on a pipe-laying jet machine in 90 feet of water in the Gulf of Mexico off Texas in January. He was about to investigate cable debris on the machine when communications were lost. A standby diver was down within three minutes and found the victim unconscious with his helmet having been knocked off. He was brought to the surface, but despite heroic efforts he never regained consciousness. The autopsy determined that he had

suffered a hairline skull fracture and expired due to asphyxia.

One of three C-II deaths took place in October in upstate New York where an experienced 40-year-old diver was conducting an inspection of the intake system of a water treatment plant that had become infested with Zebra Mussels. The victim became trapped and lost his helmet more than 150 feet into the pipe system. A fellow commercial diver nearly became trapped during a rescue attempt. The deceased was near the junction of two pipes, the smaller of which was producing some suction. This may have accounted for the difficulty encountered by both divers to some degree. Upon arrival on the scene the victim's body was recovered within about ten minutes by the Rochester New York Police Underwater Recover Unit.

The death of a 34-year-old commercial diver occurred in November at the site of a Tennessee Valley Authority (TVA) steam plant in Tennessee when his surface-supplied air lines became accidentally severed while he was engaged in cleaning water intake screens.

The body of a 37-year-old man was recovered a day after the incident which cost his life in March on the Tennessee River. He had been using an underwater Oxy-ARC burning torch to cut cables that were entangled in a tug boat propeller. The crew heard an explosion which rocked the boat, and the diver disappeared. It is believed that the diver ignited an oxygen gas pocket located above the propeller shaft.

Among the six fatalities in 1990 allocated to C-IV is the case of a 19-year-old man who had been harvesting sea cucumbers off the coast of Sitka, Alaska in January. He was making his third dive of the day in water depths of 30 to 70 feet when his 20-year-old partner in a skiff could no longer detect his bubbles. Having no additional diving gear on board, the partner left the scene and contacted a nearby fishing vessel. Emergency divers recovered the victim about three hours after the victim started his final dive. Reports indicate that the victim had been learning to dive through efforts of a fellow fisherman over the previous three months on surface-supplied gear. This was only the second time the victim had used scuba gear. The cause of death has been concluded as accidental drowning.

In September a man scuba diving for mussels died in an Alabama lake in about 10 feet of water. His brother who was in the boat sensed that something was wrong and tried to pull him up, but the boat tipped over and the brother had to swim to safety himself. No other details were available.

Sea urchin harvesting off the coast of Napa, California was the activity of a 42-year-old man who died while operating with a surface-supplied air system in August. In a routine procedure the boat operator had moved the vessel a short distance while three divers were on the bottom. He immediately spotted the victim on the surface on his back without his regulator in his mouth. The victim sank, and the boat operator dove in and retrieved him from a depth of about 20 feet unconscious. It was reported that the victim had been engaged in this type of work only infrequently and in fact had only dived twice this year and about five times the year before. He had received no formal training. The death was attributed to drowning and air embolism.

In July at Kentucky Lake near Houston County, Tennessee a 27-year-old man died while harvesting

Occupational Fatality Table

Categories	1970-1979	1980-1989	1990
Class I	18	6	1
Class II	40	41	3
Class III	3	4	0
Class IV	35	40	6
Class V	0	1	0
Class VI	2	0	0
Class VII	8	13	0
F	3	2	0
G	8	7	3
H	6	15	0
I	0	0	0
J	2	1	1
K	3	5	0
Decade Totals	**128**	**135**	**14**

mussels on surface-supplied air gear. It was reported that he had consumed several beers prior to his diving.

A 22-year-old man died in April in Puget Sound, Washington. This victim was harvesting geoducks while using surface-supplied air in about 60 feet of water when his air line became entangled with both his weight belt and the water-jet hose used to excavate the large mollusks. Despite treatment in a local recompression facility, he expired within two days.

At St. Thomas in the U.S. Virgin Islands in June a 38-year-old man who had been diving for about 20 years but had not been formally certified lost his life while commercially collecting conchs. It is believed that this victim had made four dives to 110 feet of 30 minutes each with only 10 minutes between dives. He was reported to have expired while undergoing recompression treatment.

In Category G one case involved a 37-year-old U.S. Navy reservist diver who expired in a hospital two days after experiencing difficulties during a training exercise at a depth of 75 feet in the Lake Washington ship canal, Seattle, Washington.

The body of the then U.S. Navy Supervisor of Diving and Salvage was located in 200 feet deep water in the Gulf of Mexico three days after he was lost while engaged in a recertification dive in November.

A U.S. Coast Guard Chief Petty Officer aged 32 died following a dive off Johnston Atoll in the Pacific Ocean in January. A newspaper item states that he was four days into a two-week mission toward the equator at the time of his death. No further details are available.

Preliminary 1991 Information on Occupational Fatalities

Only nine commercial fatalities have been reported for 1991, including three C-IV deaths, three C-II deaths, and one C-I death. Details of two fatalities are unavailable at this time so no category can be determined. There was only one double fatality. Four divers were using hookah rigs while the remaining five were using scuba gear.

The double fatality occurred to two hookah divers in northern California. The two individuals were diving off a small vessel with one tender on board. The divers started their second dives within a few minutes of each other. Shortly after the second diver had entered the water, the boat tender noticed the first diver floating face down. The tender jerked the second diver's line and, after receiving no response, pulled him up. Both divers had dropped their weight belts. The autopsies listed carbon monoxide poisoning as the cause of death for both divers. (C-IV)

A solo hookah diver with a history of heart disease experienced an unknown problem at depth while collecting sea urchins. The tender reported a rapid ascent, and the autopsy recorded an air embolism as the cause of death. (C-IV)

While on scuba, a diver was vacuuming sand off the bottom of a large tank. He experienced unknown problems and died. (C-II)

A solo commercial diver's foot became trapped in a grate while attempting to repair an inoperative turbine. He was unable to free himself and ran out of air. (C-II)

While inspecting underwater machinery at a power plant, a diver experienced an unknown problem. The rescuers found him trapped between two screens, out of air, and missing a second stage regulator. (C-II)

A 33-year-old diver had successfully anchored a helicopter which had crashed in the ocean a few days earlier in order to salvage it at a future date. While being pulled up by the helicopter that had dropped him off earlier, the diver apparently fell back in the ocean. United States Coast Guard boats were unable to relocate him. (C-I)

Occupational Fatality Category Definitions

C-I	Commercial I includes offshore construction and salvage diving, plus oil and gas-related operations.
C-II	Commercial II includes harbor and inland diving, such as construction, shallow pipe inspection, salvage and repair.
C-III	Commercial III includes ship-related diving, such as construction, repair and hull cleaning.
C-IV	Commercial IV includes all types of commercial fisheries: abalone, sea urchin, seaweed harvesting, black coral diving, etc.
C-V	Commercial V includes scientific diving for paid consulting purposes.
C-VI	Commercial VI includes diving while in training for professional diving.
C-VII	Commercial VII includes other types of commercial diving not specifically set forth in the above categories, such as underwater photography, private research, commercial treasure diving, archeological diving.

The categories which are not strictly commercial but are occupational in nature are listed as follows:

F	Academic includes scientific research by persons associated with an academic institution.
G	Government, military includes on-duty divers in the U.S. Navy, U.S. Army, U.S. Coast Guard, etc.
H	Government, civil includes local, state and federal employees, such as police and fire department search and rescue units, etc.
I	Instructor, commercial includes those actively engaged in teaching commercial and professional diving.
J	Instructor, recreational includes certified instructors actively engaged in teaching sport and recreational diving.
K	Scientific diving includes individuals who meet the OSHA definition of scientific diving or are clearly a part of a scientific diving community.

Appendix I ICD-9-CM Codes for Dive Related Incidents

245.1	Chronic thyroiditis
250.0	Diabetes mellitus
250.4	Diabetes mellitus with glomerulosclerosis
278.0	Obesity, exogenous
293.0	Nitrogen narcosis
293.0	Acute confusional state
303.0	Ethanol acute intoxication
308.0	Panic state
336.1	Intraparenchymal hemorrhage of spinal cord
348.1	Anoxic brain damage
361.0	Coronary artery bypass graft
401.9	Hypertension
402.0	Hypertensive vascular disease (HVD)
404.0	HVD with renal involvement
410.9	Acute myocardial infarction
414.0	Coronary atherosclerosis
414.9	Chronic myocardial ischemia
414.9	Coronary artery disease
425.4	Hypertrophic cardiomyopathy
428.0	Congestive heart failure
428.1	Left heart failure (pulmonary edema)
429.3	Ventricular hypertrophy (cardiomegaly)
490	Chronic obstructive pulmonary disease
492.0	Emphysematous blebs
496	COPD
508.9	Pulmonary edema due to external agent
512.0	Spontaneous pneumothorax
571.2	Cirrhosis of liver (alcoholic)
571.8	Fatty liver
780.0	Coma
780.3	Seizure disorder
786.3	Pulmonary hemorrhage
798.1	Instantaneous death, cause not discovered
798.2	Death within 24 hours, cause not discovered
798.9	Body found after 24 hours, cause not discovered (i.e., mutilated, skeletonized, etc.)
799.9	Death, unspecified cause (body not found)
815.9	Bilateral hip prosthesis
853.0	Hemorrhage, brain-traumatic
854.0	Intracranial injury

854.1	Intracranial injury, open
860.0	Pneumothorax, tension, traumatic
958.0	Air embolism
980.0	Ethanol, toxic effect
986.0	Carbon monoxide
993.0	Barotrauma, otitic
993.1	Barotrauma, sinus
993.3	Decompression sickness
993.0	Barotrauma
994.1	Drowning and non-fatal submersion
E830	Watercraft accident (overturn)
E838.5	Struck by boat
E902.2	Rapid ascent
E906.3	Shark bites
E910.1	Recreational activity with diving equipment
E910.3	Diving for purposes other than recreation with diving equipment (i.e., marine salvage, rescue, construction, etc.)
E913.2	Insufficient air
E918.0	Caught, entangled, entrapment (specify)
E918.1*	Shipwreck
E918.2*	Cave, cavern, marine or freshwater
E918.3*	Ice
E918.4*	Kelp (or other underwater vegetation)
E918.5*	Rope, line, cable, diving equipment
E918.9*	Other entrapment

* *DAN adaptation of code*

Chemical Substances

E934.4	Benzodiazepine
E935.2	Codeine
E935.8	Propoxyphene
E937.0	Butalbital
E939.0	Fluoxetine (Prozac™)
E939.0	Nortriptyline
E980.3	Cannabinoids
E980.3	Methamphetamine

Appendix J DAN Membership Benefits

How much is DAN membership?

- Individual $25 per year.
- Family $35 per year (This includes the immediate family at the same residence).

What does DAN membership provide?

- Membership card listing emergency, medical safety, and insurance telephone numbers.
- DAN's *Underwater Diving Accident Manual.*
- *Alert Diver,* DAN's bimonthly magazine.
- Tank and gear decals with DAN's emergency telephone number for quick reference.
- Guaranteed medical emergency worldwide air evacuation for you or any family member through *Assist America* — an international assistance program.

What does Assistance America provide?

- Assist America — a new plan for DAN members — is one of the one of the oldest and best assistance programs anywhere.
- Consultation calls to Assist America Alarm Centers are evaluated and referred to English speaking doctors and/or hospitals.
- Guaranteed hospital admission if you are outside the United States.
- Emergency evacuation to the nearest facility capable of providing proper care.
- Critical care monitoring by medically trained personnel.
- Medically supervised repatriation to the United States.
- Dispatch of prescribed medication (if unavailable locally).
- Emergency message transmission to and from home.
- Transportation to join patient if you are to be hospitalized for more than seven days without charge.
- Care for minor children (if left unattended as a result of your hospitalization).
- Return of mortal remains.
- Legal referrals.

What else do DAN membership dollars support?

- *24-Hour Emergency Hotline* (919) 684-8111.

DAN maintains a 24-hour emergency service 365 days a year to provide injured divers with medical consultations and referrals. DAN assists over 1,500 divers on an emergency basis each year.

- *Non-Emergency Advisory Line* (919) 684-2948.

DAN maintains an information hotline to provide answers for commonly asked questions about scuba diving medicine and safety. Calls are answered 9 a.m. to 5 p.m., ET, Monday through Friday. DAN answered over 16,200 questions in 1991.

- DAN research into diving-related health and safety issues.
- *Annual Report on Scuba Diving Accidents* — DAN collects and analyzes information about recreational dive injuries and fatalities.

What other services does DAN offer?

- Educational Seminars and Oxygen First Aid Courses — DAN provides a variety of courses for divers, instructors, and physicians about scuba diving injuries and treatment.
- DAN sponsored research trips.
- Bimonthly drawings for FREE diving equipment.
- Diver's life insurance.
- For an additional $20 per year, you will receive $15,000 of diving medical insurance coverage

What does DAN medical insurance provide?

- Coverage for any in-water diving or snorkeling injury.
- Hyperbaric chamber treatment.
- Ambulance services (including air ambulance).
- Physician and other fees for diagnostic, laboratory, and physiotherapy services.
- Hospital care, service, and supplies.

Neither DAN or Duke University is an insurance company. However, anyone may become a member of DAN and receive membership benefits including emergency air evacuation. Presently, only members residing in the U.S. or Canada may apply for medical insurance.

Where do I call for more information?

For more information about membership in Divers Alert Network, please call (919) 684-2948 extension 333 or 334. For more information about diving insurance, please call 1-800-446-2671 (residents of Minnesota please call (612) 588-2731).

Appendix K

Enrollment Form

For quick enrollment call 1-800-446-2671

Name(s) ______________________

____

Address ______________________

____

Day Phone (   ) ______________________

Current DAN Member **No** **Yes**

Member Number ______________________

I am enclosing:

- ☐ **$25 for DAN Membership** **$** ________
- ☐ **$35 for DAN Family Membership** **$** ________
- ☐ **For $15,000 medical insurance, add $20 per person** **$** ________
- ☐ **For $30,000 medical insurance, add $25 per person** **$** ________

Total Enclosed **$** ________

Only residents of U.S. and Canada are eligible for insurance. Please include an additional $5 if outside U.S.

Type of payment please circle:

Check/Money Order VISA MasterCard

Card # ______________________

Expiration Date ______________________

Signature ______________________

Date ______________________

Please return application to: ***DAN,*** *Box 3823, Duke University Medical Center, Durham, North Carolina 27710 or call* ***1-800-446-2671.***

Enrollment Form

For quick enrollment call 1-800-446-2671

Name(s) ______________________

____

Address ______________________

____

Day Phone (   ) ______________________

Current DAN Member **No** **Yes**

Member Number ______________________

I am enclosing:

- ☐ **$25 for DAN Membership** **$** ________
- ☐ **$35 for DAN Family Membership** **$** ________
- ☐ **For $15,000 medical insurance, add $20 per person** **$** ________
- ☐ **For $30,000 medical insurance, add $25 per person** **$** ________

Total Enclosed **$** ________

Only residents of U.S. and Canada are eligible for insurance. Please include an additional $5 if outside U.S.

Type of payment please circle:

Check/Money Order VISA MasterCard

Card # ______________________

Expiration Date ______________________

Signature ______________________

Date ______________________

Please return application to: ***DAN,*** *Box 3823, Duke University Medical Center, Durham, North Carolina 27710 or call* ***1-800-446-2671.***