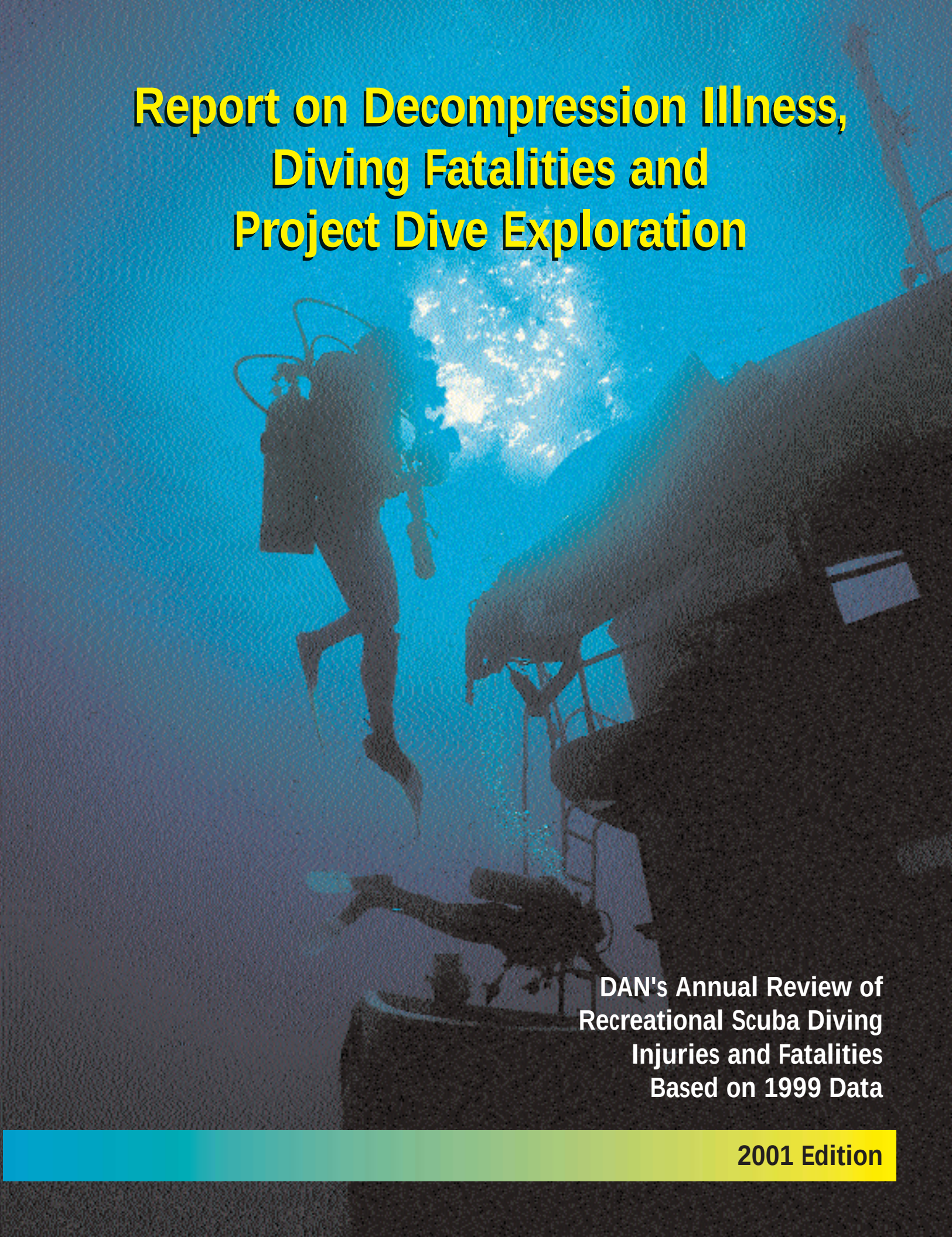
Report on Decompression Illness, Diving Fatalities and Project Dive Exploration



DAN's Annual Review of Recreational Scuba Diving Injuries and Fatalities Based on 1999 Data

2001 Edition

Report on Decompression Illness, Diving Fatalities and Project Dive Exploration

The DAN Annual Review of Recreational Scuba Diving Injuries and Fatalities Based on 1999 Data

2001 Edition

by

Divers Alert Network

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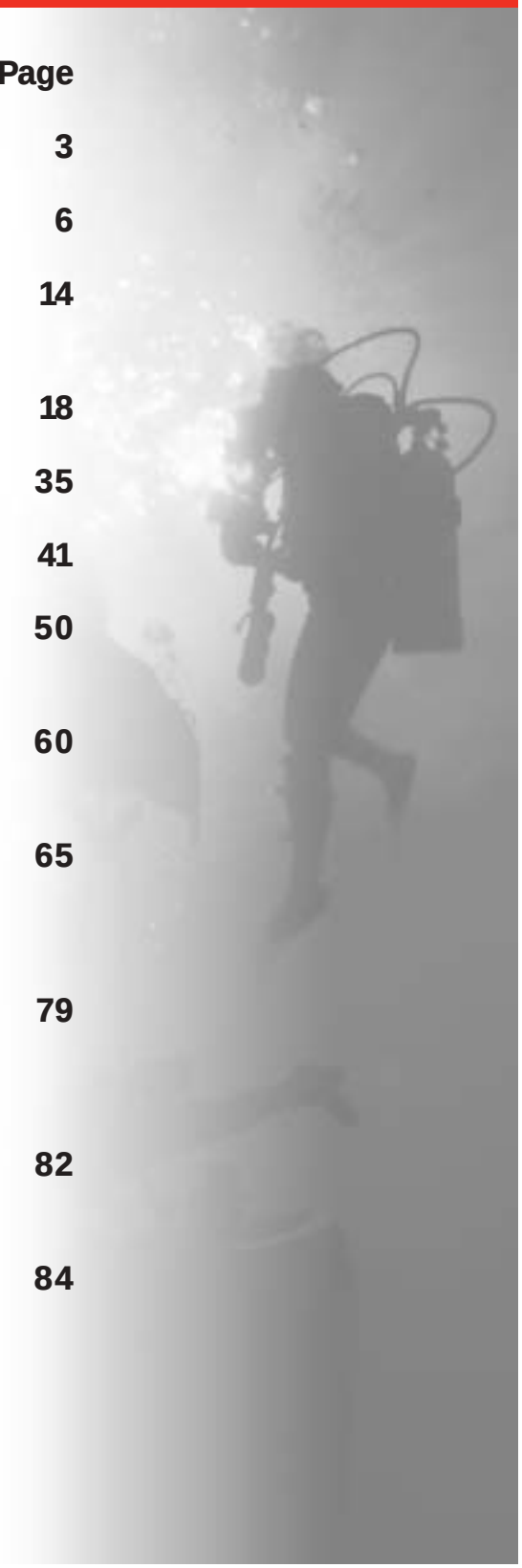

DAN Report on Decompression Illness, Diving Fatalities and Project Dive Exploration: 2001 Edition

Cover photo by DAN member Dave Haas.
Layout and design by Rick Melvin.

Acknowledgments

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David Hendricks, M.D.
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Project Dive Exploration Dive Profile Collection (collectors and number of dives)

DATA COLLECTION CENTERS

Nekton Pilot	6,621
Paradise Divers	741
Dutch Springs	454
Diveshop II	178
Discovery Diving	117

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Peter Winkler	327
Daniel Nord	194
Petar Denoble	136
Ivana Gabrielova	54

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Charley Coffey	440
Paul Joyner	390
Marc Dragon	154
Kathy Coulombe	905

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Andi Nendwich	741
Jon Schneiderman	424
John LaPere	347
Michael Johnson	234
Daniel Millikovsky	192
William Charlton, Jr.	166
Scott McClary	178
Terry Laraman	165
Larry Hill	133
Scott Winners	131
Terry Loar	112
Denis Burlage	101
Elbert Wilcher III	78
Daniel Hartman	75
Kendall Broxson	68
Kelly Rockwood	68
Brian Basura	67
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Edrianna Stilwell	62
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Rick Gifford	55
Robert Hildebrand	47
Martin Naaktgeboren	34
John Scruggs	32
Peter Mueller	24
Robert Eichholtz, Jr.	20
Amy Juried	19
Darrel Seale	15
Eileen Weinstein	13
John Sloan	11
Christopher Owen	10
Philip Weber	8
Bill Sawyer	2
Daniel Moore	2

DAN Regions and Regional Coordinators for Hyperbaric Treatment

Divers Alert Network uses a network of 258 hyperbaric chambers in the United States and around the world to report decompression illness (DCI) injuries. The DAN network is now divided into eight regions, each overseen by a Regional Coordinator.

International Headquarters and Southeast Region – Alabama, Georgia, North Carolina, South Carolina and Tennessee
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Northeast Region – Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia and West Virginia
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Pacific Region – Guam, Hawaii and U.S. Territories
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DAN - '*Your* Dive Safety Association'

For scuba divers worldwide, DAN means safety, health and peace of mind. DAN is a 501(c)(3) non-profit safety organization associated with Duke University Medical Center in Durham, N.C., and is supported by the largest membership association of divers in the world.

DAN was founded in 1980 to provide an emergency hotline to serve injured recreational divers and the medical personnel who care for them. Originally funded by government grants, DAN today relies on membership, dive industry sponsors, product sales and fund-raising to provide the high level of service the dive community has become accustomed to receiving.

DAN America's Services to the Recreational Diving Community

Over the years, divers have made increasing use of DAN's Medical Services.

DAN is best known for its 24-Hour Diving Emergency Hotline, the 9-to-5 Dive Safety and Medical Information Line and its dive-related medical research programs. DAN America and its affiliates in Europe, Japan, Southeast Asia-Pacific and Southern Africa also serve the recreational scuba community with dive first aid training programs, dive emergency oxygen equipment, affordable dive accident insurance, and books and videos about scuba safety and health.

The 24-Hour Diving Emergency Hotline at +1-919-684-4236 (collect) or +1-919-684-8111 is DAN's premier service. The DAN medics and physicians offer emergency consultation and referral services to injured divers worldwide. In 1999 DAN answered more than 2,600 calls for emergency assistance from its members and divers on the diving emergency hotline.

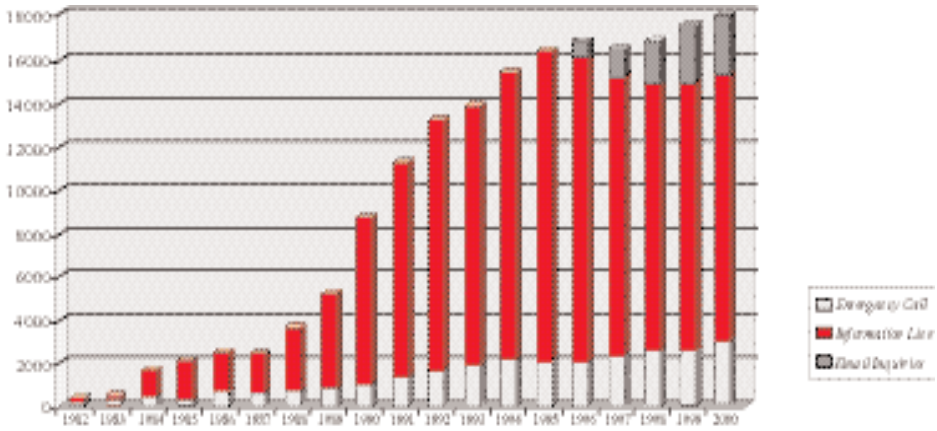
DAN's Medical Information Line at +1-919-684-2948 (or 1-800-446-2671 in the United States and Canada) is available weekdays from 9 a.m. to 5 p.m. Eastern Time (1400-2200 Greenwich Mean Time).

Also, divers may visit the medical pages of the DAN website — www.DiversAlertNetwork.org — where they can find answers to general questions on diving fitness and health. For a more detailed response, callers may make non-emergency medical inquiries of a more specific nature.

When divers have questions about their health in relation to diving, if they need to find a dive physician in their area, or if they have questions on medicines and diving, diving after surgery or other dive-related issues, DAN's medical information specialists are there to help. The Medical Information Line and DAN's website allow divers to talk to a specially trained diving medical technician about non-emergency diving safety and health concerns. Respondents include DAN medics with the resources of DAN's senior medical staff, on-call physicians, dive researchers at DUMC's Center for Hyperbaric Medicine and Environmental Physiology and other experts in dive medicine.

In some cases, DAN may refer callers to a diving medical specialist in their region for further evaluation. In 1999, DAN's Medical Department received 15,714 information calls (including 2,886 emails). Since its beginnings in 1980, DAN has helped more than 192,332 callers through these telephone services.

The annual record of emergency, information, and email inquiries to the DAN Medical Department since 1981 are shown below.



DAN Dive Health and Safety Research

DAN's Research Department is dedicated to the study of diving health issues. Prospective experimental research, such as the Ascent Rate Study, is conducted in the pressure chambers of the Center for Hyperbaric Medicine and Environmental Physiology at Duke University Medical Center. Field research, such as Project Dive Exploration, and the Diving with Diabetes projects, is conducted at diving locations all over the world.

The research conducted by DAN requires the use of specialized hypo-hyperbaric scientists and physicians, software development and technical staffing. DAN projects are privately funded through DAN membership and dive industry support.

Medical information specialists and DAN physicians offer emergency consultation and referral services to injured divers worldwide.

Injury and Fatality Data Collection

This report is based on annual data collection of diving injury and fatality data. In 1998, DAN revised the old injury form, the Diving Accident Report Form (DARF) with the Diving Injury Report Form (DIRF) in an effort to describe DCI symptoms more completely and accurately. In 1999, DAN began promoting the use of an electronic version of the DIRF (eDIRF). In 2001, DAN research plans to revise all of the data collection forms in current use (DIRF, fatality and safe dives) so that they match and can be analyzed together. Also, DAN Research plans to increase the use of the eDIRF in hyperbaric chambers that treat decompression illness.

Copies of the DIRF and the fatality and dive incident reports are available through DAN's Research Department at 1-800-446-2671 toll free in the United States in Canada, or +1-919-684-2948, or on DAN's website at www.DiversAlertNetwork.org. An electronic version of the DIRF (eDIRF) is available from the DAN website (www.DiversAlertNetwork.org).

The Diabetes and Diving Project was started to determine the safety of persons diving with insulin-requiring diabetes.

Diabetes and Diving Project

In 1996, DAN Research began a project to determine the relative safety of people diving with insulin-requiring diabetes. Approved by DUMC's institutional review board, this project was launched in 1997. As of December 2000, 561 dives had been collected from 41 divers with insulin-requiring diabetes. Data collected on control divers (non-diabetics) was 504 dives from 43 divers.

Supporters of the project include: Aggressor Fleet, Inc.; Nekton Cruises Inc.; Peter Hughes Diving, Inc.; Underwater Explorers Society (UNEXSO) in the Bahamas; and these DAN Sponsors in Cozumel, Mexico: Buceo Medico Mexicano Hyperbaric Chamber, Casa del Mar, Del-Mar Aquatics, AquaWorld, Albatros Charters, Blue Bubble Divers, Caribbean Divers, Cozumel Equalizer SA, Dive Paradise, Mako Tours, Scuba Club Cozumel, Sand Dollar, Cha Cha Cha Divers, Scuba Du, Dive Palancar and Aldora Divers.

Bayer Corporation and Can Am Care have also supported this project with equipment and supplies. The study is testing guidelines for blood glucose monitoring and collecting data on blood glucose levels before and after diving. Data collection was completed in 2000. Data was presented at the Undersea and Hyperbaric Medical Society (UHMS) Annual Scientific Meeting and the American Society of Exercise Physiologists. Data are being analyzed and a final scientific paper will be written in 2001.

Project Dive Exploration

Project Dive Exploration (PDE) uses recording dive computers to collect information on dive profiles. As of September 2000, PDE had collected 19,000 dive profiles. PDE goals are to create a database of both safe dives and dives that result in injuries. This will help provide insight into the behavior, dive profiles and characteristics of recreational divers associated with decompression illness (DCI). Dive computer manufacturers Cochran, Suunto and Scubapro/Uwatec have strongly supported this project. Volunteer Field Research Coordinators (FRCs) and Data Collection Centers (DCCs) also are integral to collection of dive data. For a list of FRCs and DCCs, see Page 3.

Flying After Diving Study

One of DAN's most ambitious research programs, a study of flying after diving, was completed in December 1998. The goal was to develop guidelines for recreational divers for safe intervals between diving and flying aboard a commercial airliner. A scientific paper will be submitted for peer-review in 2001.

Aging Diver Study

Begun in 1999, DAN's Aging Diver Study uses PDE methodology to identify special concerns or issues for divers who are 50 or older. Of particular interest is the occurrence of equipment problems, diving medical problems, non-diving medical problems and other diving-related incidents. In addition to PDE data collection, this study includes an additional medical history form and a dive lifestyle survey.

DAN's Aging Diver Study uses the methodology of Project Dive Exploration (PDE) and seeks certified divers who are 50 or older.

DAN Research Internship Program

Begun in 1999, the DAN Research Internship Program is designed to expand Project Dive Exploration data collection and to provide experiences that may motivate young people towards careers in diving or diving-related fields. The Internship Program runs from June through August, and interns are recruited largely from undergraduate and graduate students at colleges and universities across the United States. (Non-student candidates and periods other than summer will be considered, if appropriate.) Interns are trained at DAN and placed with supportive DAN sponsors.

The goals of the internship are to: (a) collect dive profile data for Project Dive Exploration; (b) provide the Interns with an experience in diving safety research and potentially earn college credits; (c) educate the diving public about DAN; and (d) educate the diving public about PDE.

If anyone is interested, please contact the DAN Research Department for further information at 1-800-446-2671, +1-919-684-2948, or on DAN's website at www.DiversAlertNetwork.org.

DAN's Doppler Field Studies

DAN Doppler studies also incorporated the methodology of PDE. Conducted on liveaboard dive boats in the Caribbean and in the Pacific, 281 repetitive, multiday dive profiles were collected and analyzed. This work seeks to estimate the relationship of Doppler-detected bubbles to the dive profile. The final Doppler trip was conducted in 1999. That year DAN also submitted a manuscript on open-water Doppler monitoring to the Journal of Undersea and Hyperbaric Medicine. The manuscript is in review.

Supporters of the Doppler Field Study include Aggressor Fleet, Peter Hughes Diving, Inc., Mike Ball, Nekton Cruises, Caribbean Explorer Ventures, Borneo Divers, Thorfinn and Caribbean Marine Research Center.

The goal of DAN's Ascent Rate Study is to determine an appropriate rate of ascent for recreational divers.

Dive Computer ID Program

Recently, DAN Research started a program of mutual support with the dive computer manufacturers. The program is open to all manufacturers that have implemented DL7 standard (DAN designed) in their dive log software. This standard was developed specifically to enhance data collection for Project Dive Exploration, but it is applicable in any other project that involves dive data collection.

The purpose of the Computer Identification Program is to increase participation in PDE by increasing awareness of all dive computer users. The three manufacturers (Cochran, Suunto and Uwatec) involved with this program are distributing their products worldwide.

Ascent Rate

The Ascent Rate Study is designed to evaluate the interaction between depth, bottom time and ascent rates on decompression safety. Its goal is to determine if differences exist in the incidences of decompression sickness and venous gas embolism between 10 and 60 foot-per-minute ascents after dives to 100 feet/30 meters. Study dives are conducted at the Center for Hyperbaric Medicine and Environmental Physiology (Hyperbaric Center) of Duke University Medical Center.

NASA

Another chamber project is a NASA-funded study to determine how exercise and microgravity affect decompression illness in astronauts during "space walks," or extravehicular activity (EVA). This is in preparation for the construction of the International Space Station.

Information about DAN Research Projects and Project Dive Exploration are available by calling DAN's Research Department at 1-800-446-2671, +1-919-684-2948, or on DAN's website at www.DiversAlertNetwork.org.

DAN Online — http://www.DiversAlertNetwork.org

DAN's website on the World Wide Web provides a wealth of information on scuba health and safety and the many benefits of DAN membership. This might include answers to frequently asked dive medical questions, oxygen course listings or the location of a DAN retail Sponsor near you. Members can order DAN products, and newcomers to DAN will be able to sign up online.

DAN's Research Department uses the website to communicate information on DAN Research, particularly Project Dive Exploration, Ascent Rate, and Diabetes and Diving. Interested participants can, at no cost, download software for collecting information about dive profiles and diving injuries.

DAN America Membership Services

In addition to supporting diving's only 24-hour diving emergency hotline, DAN members receive a number of valuable benefits, including emergency travel assistance, a subscription to the award-winning *Alert Diver* magazine, DAN's *Dive and Travel Medical Guide*, and dive and travel discounts.

DAN members are also eligible for affordable dive accident insurance and the exclusive DAN Tag™, diving's medical emergency ID, and the DAN Dog Tag, modeled after the popular military dog tag.

As of December 2000, approximately 208,000 members support DAN in the United States, the Caribbean, Canada and Mexico. Additionally, as of September 2000, approximately 52,000 members are International DAN affiliates. DAN America members receive the following dive and travel benefits:

DAN *TravelAssist*

One of the automatic benefits of membership with Divers Alert Network is DAN *TravelAssist*. This service provides up to $100,000 emergency medical evacuation assistance for any injury or illness — dive-related or not — incurred at least 50 miles from home by a DAN member or a DAN family member.

Alert Diver Magazine

DAN members receive a subscription to award-winning *Alert Diver* magazine, the only publication dedicated to diving safety and health.

DAN's *Dive and Travel Medical Guide*

New DAN members receive a copy of DAN's *Dive and Travel Medical Guide*, a valuable reference on treating common diving and travel injuries and illnesses.

DAN Members can now order DAN products online as well as renew their membership.

DAN Dive Accident Insurance

DAN pioneered dive accident insurance in 1987; and in 1992 DAN launched medical evacuation assistance member benefits.

DAN members are eligible for three different levels in insurance — the Preferred™, Master and Standard Plans — in addition to DAN membership. DAN insurance coverage is secondary coverage. After any other medical expense insurance you may have, the DAN plan pays up to 100 percent of all remaining eligible Reasonable and Customary Charges. The cost of medical treatment for a non-diving-related illness is not covered.

DAN pioneered dive accident insurance in 1987; and in 1992 DAN launched medical evacuation assistance member benefits. These moves helped fill a medical and financial need not being met by any other organization at the time, giving DAN Members valuable additional benefits. Before these DAN programs were launched, injured divers could be saddled with large medical bills, because most health insurance would not cover some or all of the recompression and travel charges associated with a diving injury. Although this issue still exists for some divers, DAN strives to help bridge this gap through education.

DAN INSURANCE PROGRAMS	Standard Plan	Master Plan	Preferred Plan	ADDED BENEFITS of PREFERRED PLAN
Cost/year	$25	$35	✔ $70	
Limitations	130 ft/DCI only	N/A	N/A	
Medical Dive Accident Coverage	$45,000 Lifetime	$125,000 Lifetime	✔ $250,000 per occurrence	Increased benefit level for all covered in-water skin- & scuba injuries
Coinsurance for Dive Accident Medical Coverage	100%	100%	100%	
Accidental Death & Dismemberment/diving	N/A	$15,000	$15,000	
Permanent & Total Disability	N/A	$15,000	$15,000	
Extra Transportation	N/A	up to $1,000	✔ up to $2,000	
Extra Accommodation	N/A	up to $1,500	✔ up to $3,000	
Lost Diving Equipment	N/A	up to $2,500	up to $2,500	
Medical Non-Dive Accident Coverage	N/A	N/A	✔ $10,000* Lifetime maximum	For eligible charges for treatment of non-diving accident outside home country
Diving Vacation Cancellation	N/A	N/A	✔ $10,000* Lifetime maximum	Coverage for injured person's losses incurred for trip cancelled before departure+
Diving Vacation Interruption	N/A	N/A	✔ $5,000* Lifetime maximum	Coverage for injured person's losses incurred for trip interrupted after departure+
DAN Membership TravelAssist including air evacuation & transportation	Yes $100,000	Yes $100,000	Yes $100,000	
Benefits ($29/year)Ind. Membership++				
TOTAL	**$54**	**$64**	**$99**	

* Subject to a $250 deductible + Subject to terms and limitations of the group policy ++ The DAN 24-Hour Diving Emergency Hotline, Medical Information Line, Alert Diver magazine, educational seminars and oxygen courses, Recompression Chamber Assistance Program, books, videos, dive injury/fatality reporting & more. Call for availability outside the U.S. • Administered by DAN Services, Inc.

This chart is a summary of benefits only and is subject to the terms, conditions and limitations of the group policy.

DAN Dive Safety and Health Products

DAN members receive a special price on all DAN products. DAN's product line includes a variety of books and videos on the subject of dive safety and health, as well as emergency oxygen equipment and diver first aid kits. These and other DAN products are available on DAN's website. Select products are also available in the Product Listing of every issue of *Alert Diver* magazine.

DAN Tags

In 1995, DAN introduced the first medical ID tag created exclusively for divers — the DAN Tag™. Each clip-on tag is personalized with vital membership, medical and contact information in the unlikely event of a diving emergency. Only DAN members can purchase the DAN Tag. A portion of DAN Tag sales goes directly to support DAN's Diving Emergency Hotline and DAN dive research. As of December 2000, nearly 47,000 DAN tags were in use.

In December 1998, DAN introduced the DAN Dog Tag. Modeled after the popular military dog tag, the front is imprinted with DAN's familiar logo and the Diving Emergency Hotline number. The tag's midsection allows space to imprint a diver's name and DAN member number.

DAN 24-Hour Diving Emergency Hotline with Immediate Insurance Verification

Dive and travel medical emergencies can happen any time. Callers to DAN's 24-Hour Diving Emergency Hotline can reach experienced medical professionals who are specially trained to handle dive and travel medical emergencies at any time, day or night.

With DAN's exclusive record-keeping system, DAN member emergency medical evacuation assistance and dive accident insurance policy records are kept in one central secure location at DAN. As a DAN member, if you (or your friend, spouse or physician) call DAN's Hotline with a diving emergency, DAN can verify membership benefits and insurance coverage right away and make arrangements for timely evacuation and / or recompression treatment.

DAN Membership Discounts

DAN members are eligible for special discounts on DAN products and other services. Check *Alert Diver* magazine for the most recent offers, or call DAN's Member Services Department at 1-800-446-2671.

DAN's 24-Hour Diving Emergency Hotline has medical professionals specially trained to handle dive and travel medical emergencies at any time, day or night.

1. INTRODUCTION

This report summarizes the activities of three diving populations:

- divers who dive safely;
- divers who sustain injuries; and
- divers who perish while diving.

Raw data are presented without analysis or interpretation.

The report has five sections with appendices. Section 1 summarizes data collection methods. Section 2 discusses the medical aspects of injuries and fatalities. Sections 3 and 4 compare the characteristics of the diver populations and their dives. Section 5 contrasts air diving with dives using nitrogen-oxygen (nitrox), helium-oxygen (heliox), or helium-nitrogen-oxygen (trimix) gas mixtures. The appendices present further details about injuries and fatalities.

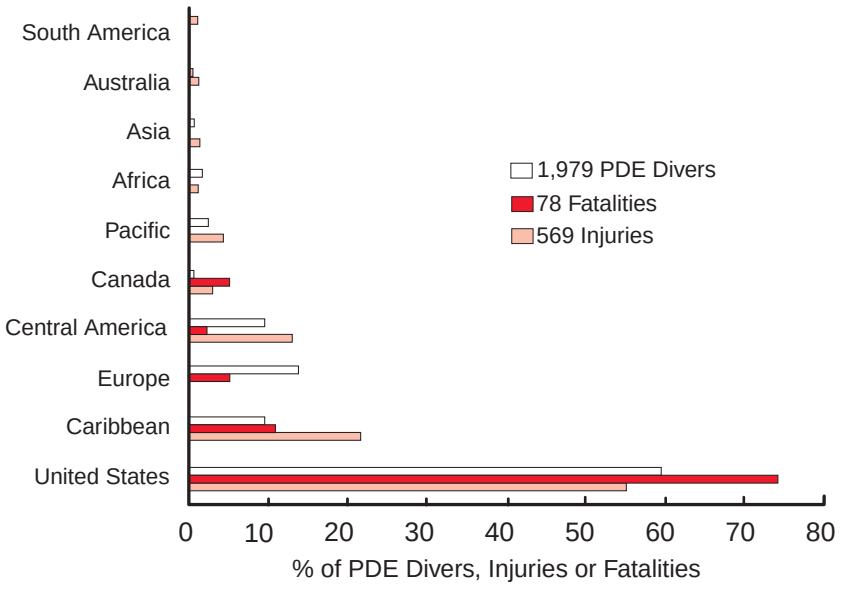
Reported data include:

- 18,512 dives collected from 2,520 divers during June 1997 to September 2000 in Project Dive Exploration (PDE) Five divers were recompressed;
- 591 diving injuries that were identified during calendar year 1999; and
- 78 fatalities that were identified in 1999.

The completeness of the data is indicated as the percent response of total cases. All data were treated as confidential medical information with no information that could identify the divers revealed.

Figure 1 shows the world regions in which the reported dives were conducted, and Figure 2 shows the nine U.S. states in which most of the data originated. (States were not available for PDE.) Appendix D contains complete distributions of U.S. injuries and fatalities.

Fig 1
World region of reported divers



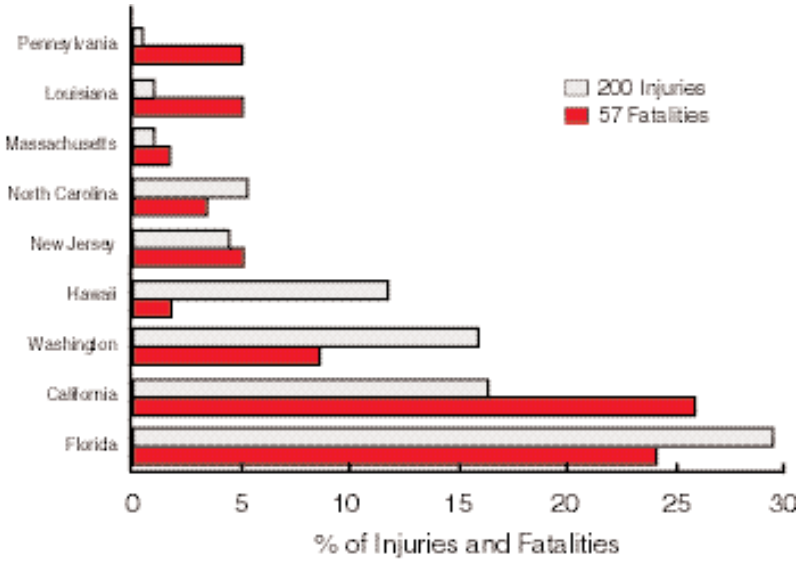


Fig 2
Sites of dive injuries and fatalities among U.S. states

1.1 Project Dive Exploration

Project Dive Exploration (PDE) is an observational study that uses dive computers to collect depth-time profiles from volunteer divers during their normal diving activities. PDE provides a control population of predominantly safe dives for comparison with injuries and fatalities.

Dive computer manufacturers Cochran, Suunto and Uwatec actively supported PDE with equipment donations, discounted purchases and software development.

Figure 3 shows data collection progress, beginning from PDE's inception in June 1997 to September 2000. Data came from 47 Field Research Coordinators (FRCs) working independently or from five Data Collection Centers (DCCs). FRCs solicited volunteers to provide information about themselves, their dives, and post-dive health effects.

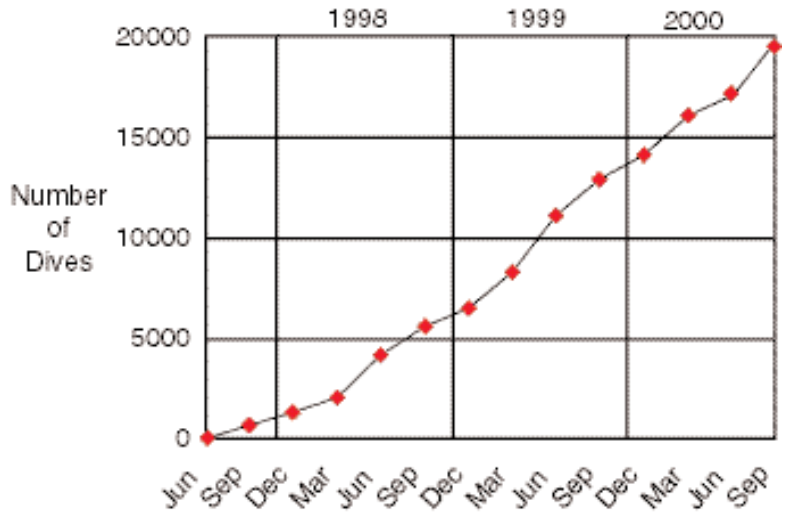


Fig 3
Project Dive Exploration data collection progress

1.2 Dive Injuries

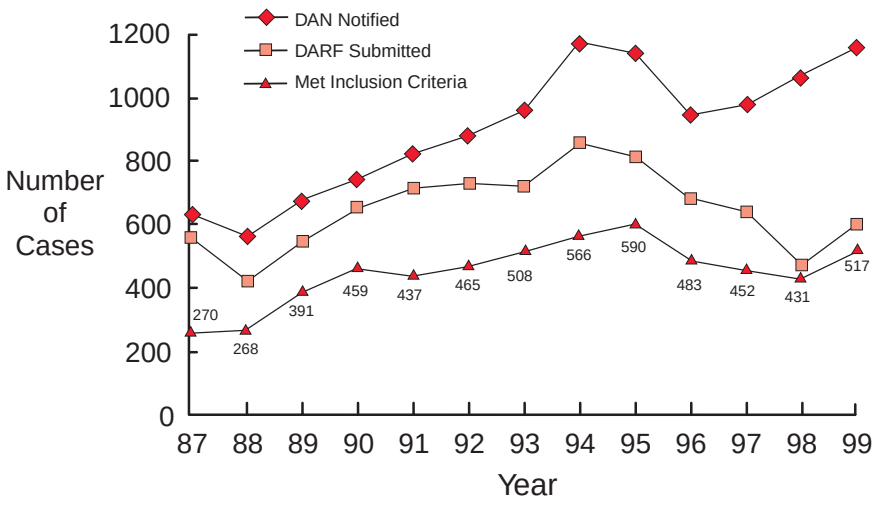
Figure 4 shows the annual record of dive injuries since 1987 when DAN began to gather information. The upper line represents all injuries about which participating chambers notified DAN. The middle line represents injuries for which written reports were submitted. The bottom line represents reports that were entered into a database. For entry into the database before 1998, divers were required to:

(a) have been recompressed for suspected decompression illness;
(b) be contacted by DAN after treatment for follow-up evaluation;
(c) have used open-circuit scuba with compressed air;
(d) be recreational divers, divemasters or instructors;
(e) have U.S. or Canadian residency; and
(f) be treated in a North American or Caribbean chamber.

Criteria (c) through (f) were dropped in 1998.

In 1999, DAN received 591 Diving Injury Report Forms (DIRF) of which 20 were submitted using a digital version of the DIRF (e-DIRF). Of these reports, 58.4% were DAN members, 35.9% were not DAN members, and 5.7% did not indicate membership status. DAN called injured divers and treating chambers to find missing information. A selection of dive injury cases is presented in Appendix A.

Fig 4 Annual record of dive injury cases



1.3 Dive Fatalities

Figure 5 shows the annual record of available recreational dive fatalities among U.S. residents through 1999. DAN receives reports of dive fatalities from investigative agencies, medical examiners, the Coast Guard, news reports and personal contacts. At present, DAN collects information provided by investigators on all reported fatalities except for commercial divers, free divers, military divers and non-U.S. residents. In 1999, there were 78 U.S. and Canadian residents involved in recreational dive fatalities. Of these, 19 were women and 59 were men. Of the 76 for whom information about DAN membership was available, 36% were DAN members. Individual summaries of these fatalities are presented in Appendix B.

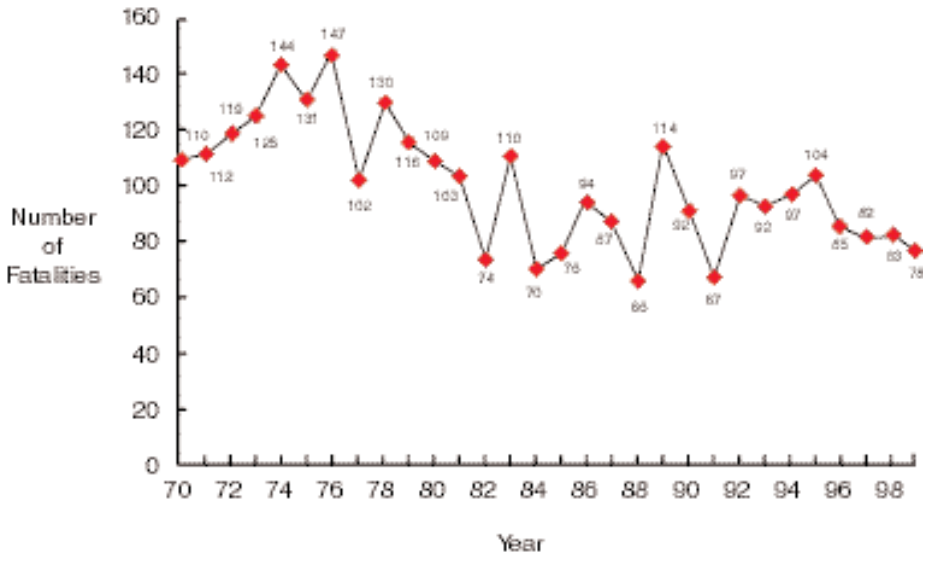


Fig 5
Annual record of dive fatalities

To report an injury, a fatality or a near-miss in diving, call DAN's Medical Department at +1-919-684-2948 or 800-446-2671.

DAN
Divers Alert Network
The Peter B. Bennett Center
6 West Colony Place
Durham, NC 27705

2. MEDICAL ASPECTS OF DIVE INJURIES AND FATALITIES IN 1999

2.1 Dive Injury Terminology

Arterial gas embolism (AGE) results from pulmonary barotrauma that allows gas bubbles to enter the arterial circulation. AGE symptoms are usually referable to the brain.

Bubbles that form in blood and tissue cause decompression sickness (DCS). Decompression sickness can affect practically any body system, with signs and symptoms ranging from trivial to fatal. Traditionally, DCS is categorized as "Type I" or "Type II."

Decompression sickness can affect practically any body system, with signs and symptoms ranging from trivial to fatal

Injury can be particularly severe if an AGE occurs during a dive when body tissues (particularly the brain) have absorbed significant nitrogen. This circumstance has been called "Type III DCS."

The diagnostic categories Type I DCS (DCS-I), Type II DCS (DCS-II), and AGE have definitions that are widely, although not universally, agreed upon:

- DCS-I includes only itching, rash, joint or muscle pain, swelling, or fatigue. No other symptoms may be present for a diagnosis of DCS-I.
- DCS-II includes neurological symptoms including muscle weakness, paresthesia (tingling or numbness), abnormal bladder or bowel function, sensory disorders (vision, hearing), memory problems and personality changes. DCS-II also includes cardiopulmonary signs / symptoms and death. A diagnosis of DCS-II may include DCS-I symptoms.
- AGE involves the rapid onset (<10 min) of cerebral symptoms. Diagnosis of AGE is supported by short dives, rapid ascent and rapid symptom onset. A diagnosis of AGE may include DCS-I and DCS-II symptoms.

Many DCS signs and symptoms can be indistinguishable from AGE or non-diving illnesses. Because there are no conclusive tests for AGE and DCS, diagnoses are usually presumptive and often ambiguous in mild cases. These difficulties led to introduction of the term "decompression illness" (DCI) to describe injuries caused either by AGE or DCS.

2.2 Dive Injuries and Fatalities in Project Dive Exploration

While the majority of Project Dive Exploration dives were conducted safely, there have been five recompressions and one fatality in 18,512 dives by 2,520 divers during the period of June 1997 to September 2000. Table 1 lists information about PDE divers who were recompressed.

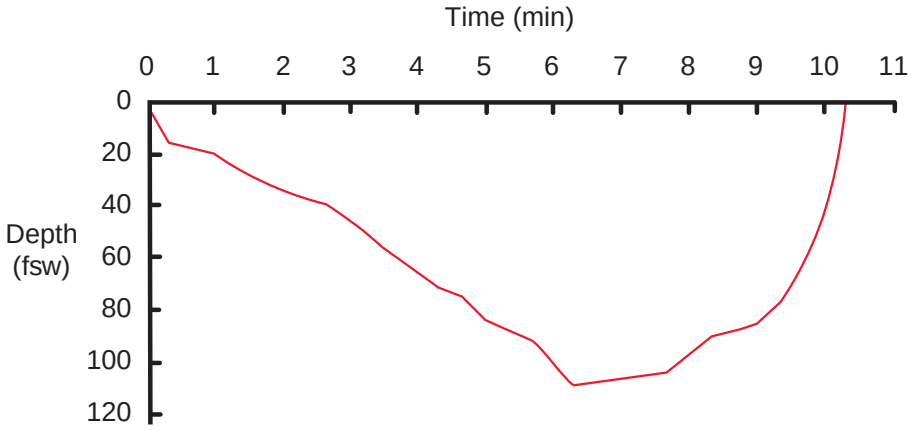
Table 1. PDE divers who were recompressed

Diver Characteristics		**Dive Characteristics**					Signs and Symptoms
Age (years)	Gender	Breathing Gas	# Days Diving	# of Dives	Maximum Depth (fsw)	FAD SI (hrs)*	
43	F	Air	5	11	140	26	tingling hand, shoulder pain
38	M	Air	6	13	121	NA	tingling forearms, skin changes
42	F	Air	6	20	112	NA	swelling & skin changes
30	F	Air	6	22	113	NA	shoulder & back pain
54	M	Trimix	6	6	232	NA	vertigo, nausea, incoordination

* FAD SI - surface interval after diving before flying

Figure 6 shows the depth-time profile for the PDE fatality that occurred in June of 2000. The victim was a 43-year-old male diver who was participating in an advanced class. Upon reaching the bottom at 106 fsw / 32.3 msw, the divers stood in a circle of other divers comparing gauges and signaling "OK" to each other. One student noted the victim seemed to have trouble breathing and motioned for the instructor to come over. The instructor checked the diver's pressure gauge, found air in his tank, and saw no apparent reason for the diver's difficulty. Noting the diver's eyes appeared larger than normal, the instructor motioned the divemaster to take him to the surface. The diver became unconscious as they swam to the anchor line at a depth of about 80 fsw / 24.3 msw. The divemaster inflated the injured diver's buoyancy compensation device at the anchor line, ascended rapidly and began cardiopulmonary resuscitation (CPR) on the boat. The divemaster did not develop symptoms after the rapid ascent. Further investigation of this case is in progress.

Fig 6
Depth-time profile for PDE diving fatality in 2000



2.3 Dive Injuries from the Diving Injury Report Form

Symptoms of diving injuries reported to DAN are summarized in Table 2. Neurological symptoms were most common, occurring in 728 of 1,484 reports of individual symptoms (49.2%). Of these, sensory symptoms including numbness, tingling, paresthesias, and abnormal sensations were far more common than more severe neurological symptoms such as muscle weakness, bladder dysfunction, or unconsciousness. Pain was the next most frequent complaint, occurring in 28.9% of symptom reports followed by constitutional symptoms at 13.5%. Cutaneous, cardiopulmonary, lymphatic, and other symptoms each occurred in less than 5% of reports.

Table 2. Summary of symptoms reported in dive injury cases.

Manifestation	Symptoms	# Divers Affected	# Symptom Reports	% of Symptoms
Neurological 527 Reports (47.3%) 728 Cases (49.2%)	Numbness/Tingling/Paresthesias	241	408	27.6%
	Dizziness/Vertigo	64	74	5.0%
	Muscle Weakness/Paresis/Paralysis	63	73	4.9%
	Higher function	32	37	2.5%
	Consciousness	15	15	1.0%
	Eye/Vision	17	21	1.4%
	Nystagmus	3	3	0.2%
	Hearing Loss	2	7	0.5%
	Speech Disturbance	11	11	0.7%
	Gait Disturbances	17	17	1.1%
	Rhomberg's Sign	2	2	0.1%
	Abnormal Sensation	22	22	1.5%
	Coordination Problem	24	24	1.6%
	Abnormal Reflexes	2	2	0.1%
	Bladder Dysfunction	12	12	0.8%
Pain 282 Reports (25.3%) 428 Cases (28.9%)	Limb	178	323	21.8%
	Trunk	62	63	4.3%
	Head	37	37	2.5%
	Location N/A or not reported	5	5	0.3%
	Girdle Pain	0	0	0.0%
Constitutional 200 Divers (17.9%) 200 Reports (13.5%)	Headache	64	64	4.3%
	Inappropriate Fatigue	69	69	4.7%
	Malaise	2	2	0.1%
	Light/Heavy Head	12	12	0.8%
	Nausea/Vomiting	51	51	3.4%
	Chills	2	2	0.1%
Cutaneous 34 Divers (3.0%) 34 Reports (2.3%)	Itching or Rash	33	33	2.2%
	Marbling	1	1	0.1%
Cardiopulmonary 17 Divers (1.5%) 17 Reports (1.1%)	Breathing Problems	7	7	0.5%
	Shortness of Breath, Dyspnea	7	7	0.5%
	Cough	2	2	0.1%
	Hemoptysis	1	1	0.1%
	Tachypnea	0	0	0.0%
	Palpitations	0	0	0.0%
Lymphatic 5 Divers (0.4%)	Swelling	5	7	0.5%
Other 50 Divers (4.5%) 66 Reports (4.5%)	Muscular Stiffness, Spasm, Cramps	23	38	2.6%
	Pressure	4	4	0.3%
	Other (not specified)	21	21	1.4%
	Barotrauma	2	3	0.2%
	Bleeding	0	0	0.0%
Total			1480	

Figure 7 shows the regional distribution of symptoms involving pain, paresthesia and muscle weakness. These symptoms were confined largely to the arms and legs. Over 60% of pain or paresthesia occurred in the arms. Pain was reported nearly four times more often in the arms than the legs. Muscle weakness, which was infrequent, was equally distributed between the arms and legs. Symptoms in the trunk (abdomen, chest, or back) were uncommon.

Fig 7 Regional distribution of pain, paresthesia, and muscle weakness

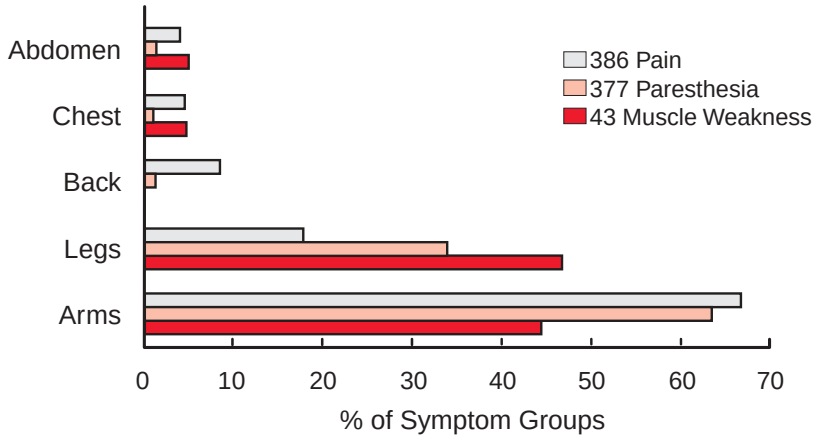


Figure 8 shows the distribution of pain, paresthesia and muscle weakness among the four limbs for each case report. Pain and paresthesia were most likely to occur in one arm, while muscle weakness was most common in both legs, although it could affect only one arm as well. The legs and multiple limbs were affected much less often than a single limb or the arms.

Fig 8 Limb distribution of pain, paresthesia, and muscle weakness

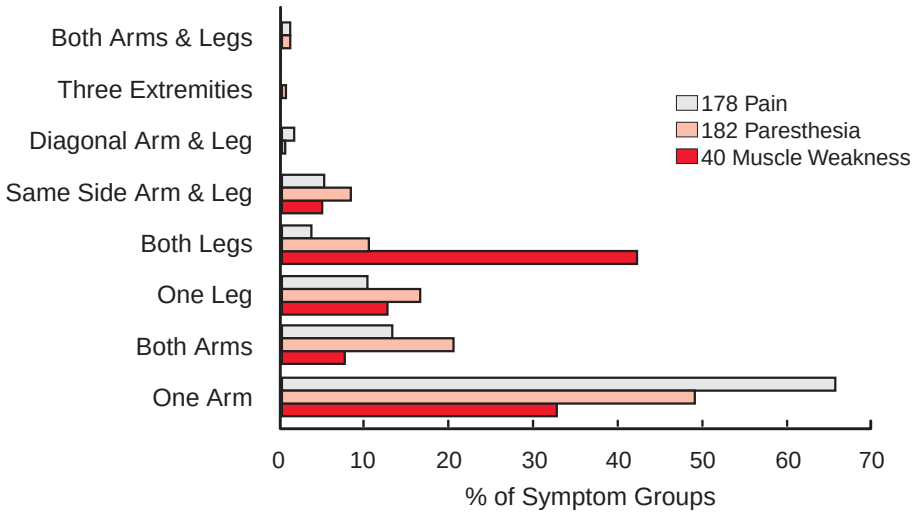


Figure 9 shows the 10 most common pairs of symptoms. Pain and paresthesia occurred together nearly three times more often than any other symptom pair, and either pain or paresthesia was present in each of the pairs shown. Muscle weakness (paired with paresthesia) appeared only once. Other symptoms that occurred in pairs were of a non-specific constitutional nature, including headache, fatigue, dizziness and nausea.

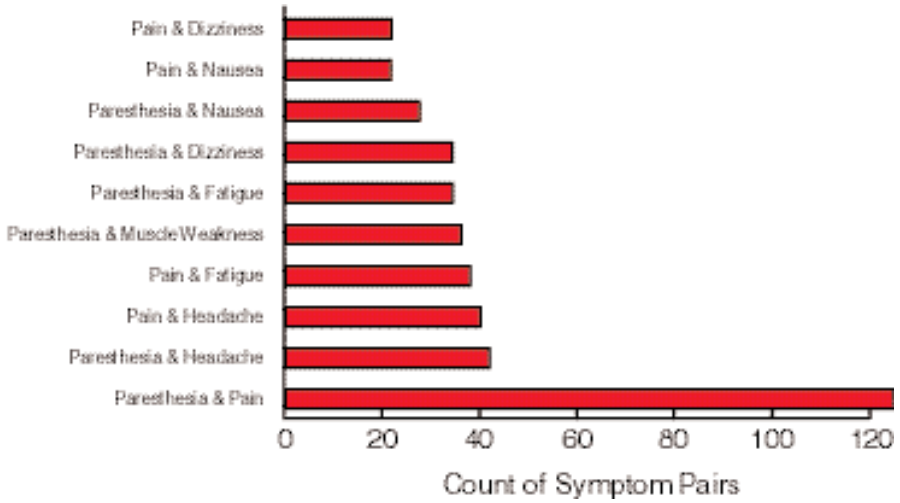


Fig 9
Most common pairs of symptoms

Figure 10 shows the most common symptom triplets that occurred in at least 10 cases. Paresthesia was present in each of nine triplets, and pain occurred in the top six. Muscle weakness was associated with pain and paresthesia. The other symptoms were non-specific constitutional including headache, dizziness, fatigue and nausea.

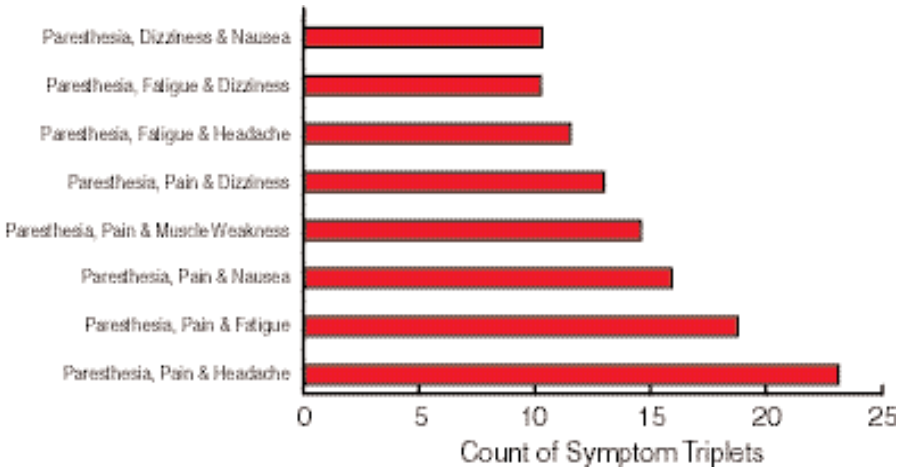


Fig 10
Most common symptom triplets

Figure 11 shows the distribution of the onset time of the first symptom. Ten percent of injured divers had symptoms before their last dive but continued to dive. Thirty percent had symptoms upon surfacing, and half of all initial symptoms had occurred within one hour. Less than 10% of symptoms occurred after 48 hours.

Fig 11 Distribution of onset time for the first symptom

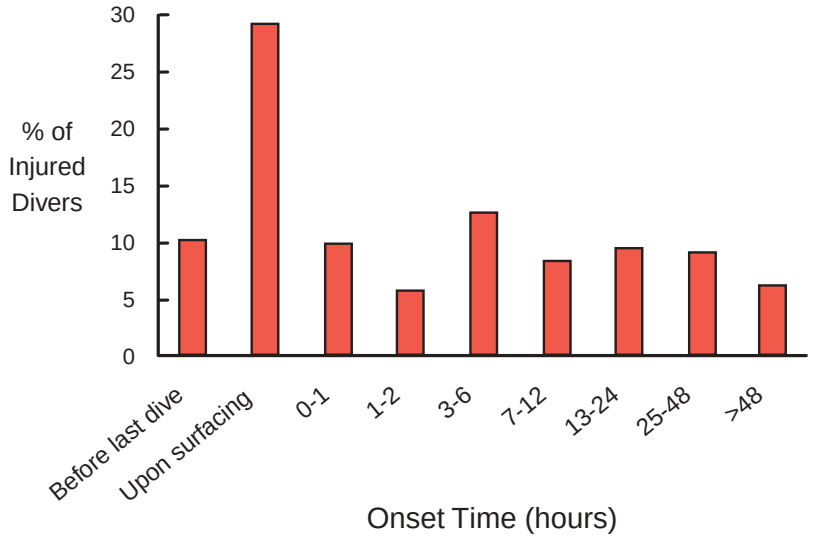


Figure 12 shows the distribution of onset time for the symptom categories of Table 2. About one-third of most symptom categories had their onset before the last dive or within the first hour after diving. In general, half of all symptoms had occurred within six hours; the exception was lymphatic symptoms, which, although few in number (five cases), were not reported until one to two days after diving was completed.

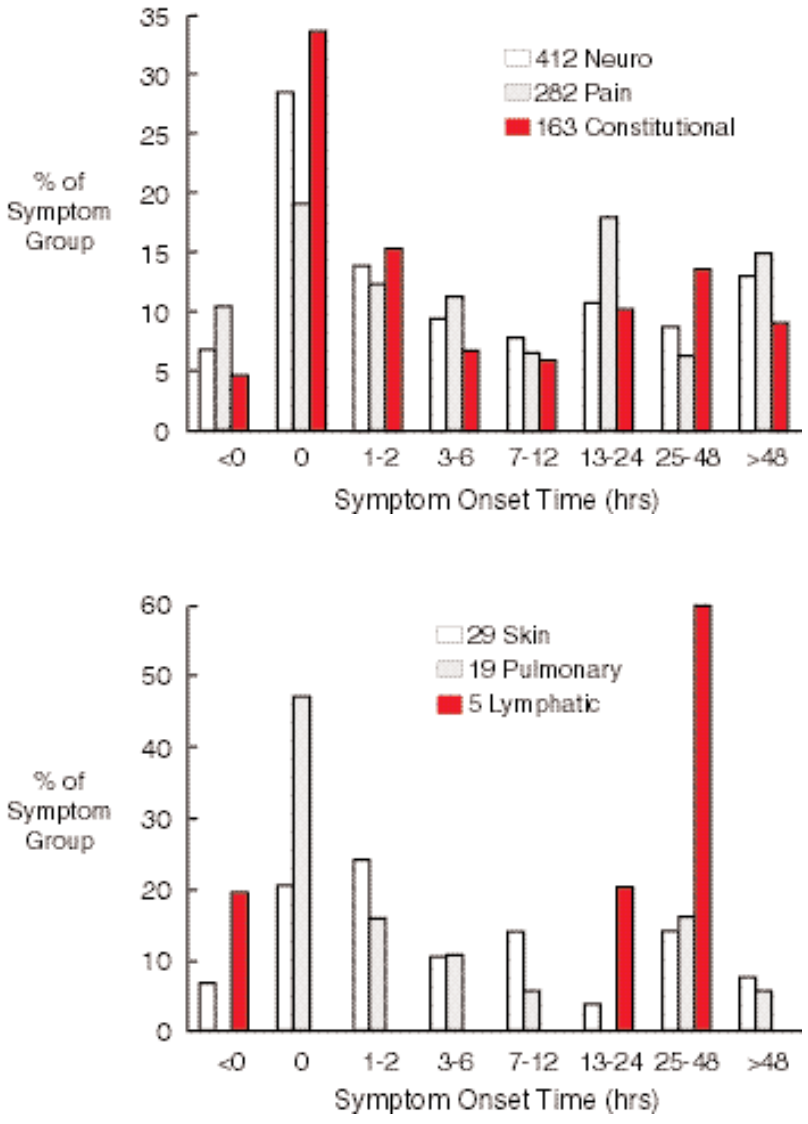


Fig 12 Distribution of onset time for symptom categories

Figure 13 shows the diagnoses assigned to injured divers by the treating physicians. Type II DCS was the most common diagnosis, assigned to 55% of all cases. Type I DCS was assigned half as often. Arterial gas embolism (AGE) was assigned to only 7% of cases, while decompression illness was the diagnosis of choice in 3%. Some physicians chose DCI as the diagnosis. "Other" included cases without assigned diagnosis that reported symptoms including joint and muscle pain, sensory, vertigo, otic barotrauma and problems of higher function. About 5% of the cases were judged to be unrelated to decompression after recompression therapy was completed.

Fig 13 Diagnoses assigned to injured divers

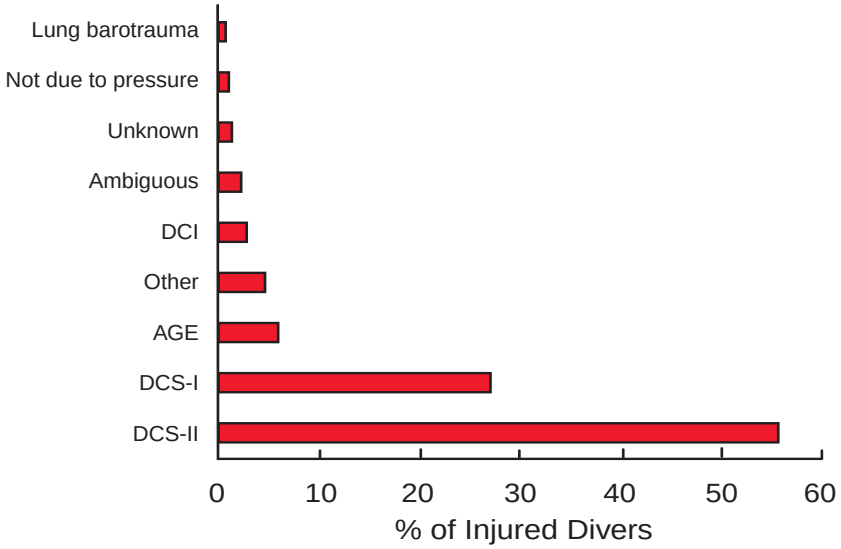


Figure 14 shows the assigned diagnosis and dive planning method. A diagnosis of AGE or barotrauma was two to three times more likely for divers who used dive tables and dive guides than for those who used dive computers.

Fig 14 Diagnosis and dive planning method

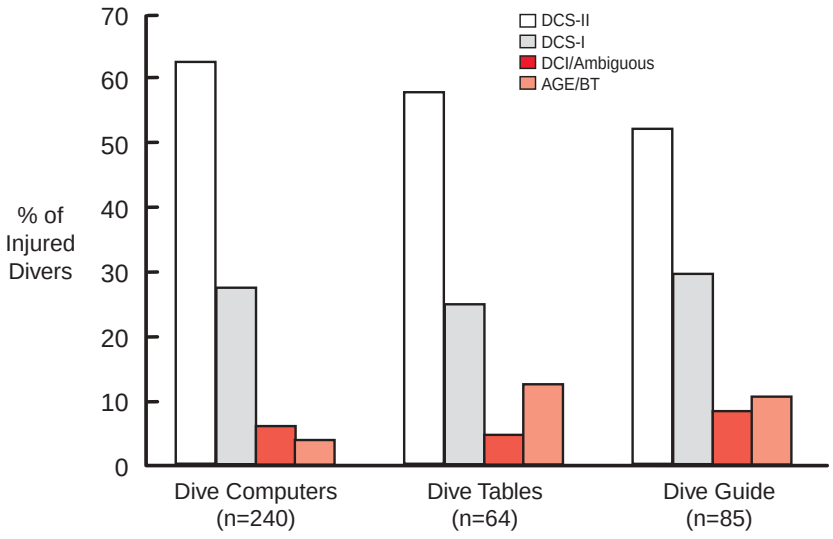


Figure 15 shows the time after symptom onset at which surface oxygen was provided. Data were available concerning the time from symptom onset to the use of surface oxygen for only 60 injured divers. Almost half of these received surface oxygen within four hours of symptom onset. Nearly 20% did not receive oxygen for more than 24 hours.

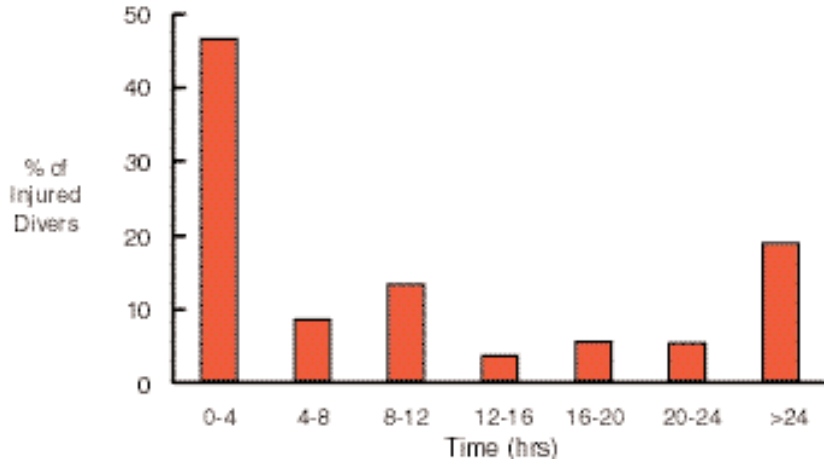


Fig 15
Time from symptom onset to surface oxygen

Figure 16 shows the method by which surface oxygen was provided to 103 injured divers. The non-rebreather mask was the most common delivery method with oxygen flow rates of 15 liters per minute (lpm) in 75% of the cases for which data were available.

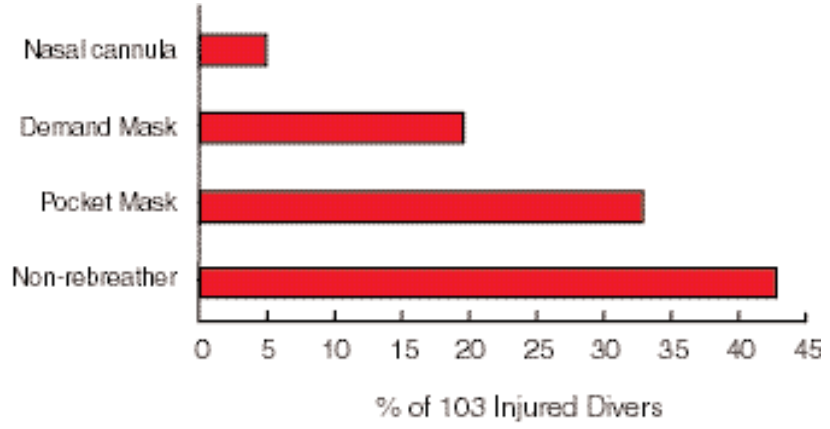


Fig 16
Method of providing surface oxygen to 103 injured divers

Figure 17 shows the duration of surface oxygen for 107 injured divers. Almost 70% of this group breathed oxygen for longer than one hour.

Fig 17 Duration of surface oxygen provided to 107 injured divers

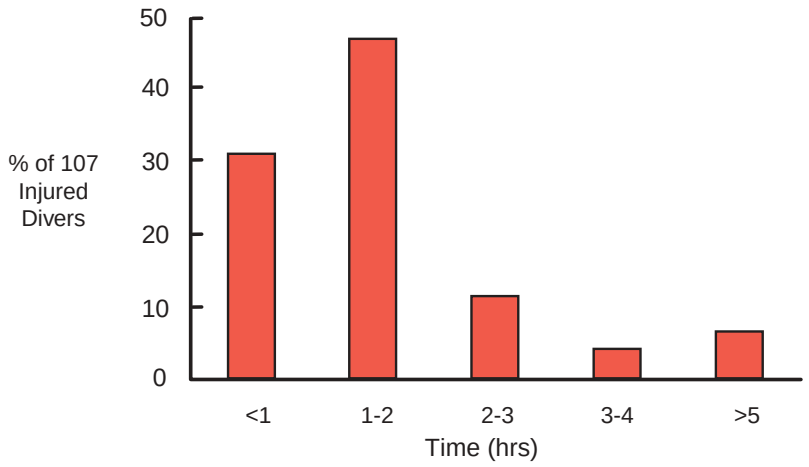


Figure 18 shows the delay to recompression after symptom onset for 280 injured divers. Half these divers were recompressed by 29 hours, and 80% by 95 hours after symptom onset.

Fig 18 Delay to recompression for 280 injured divers

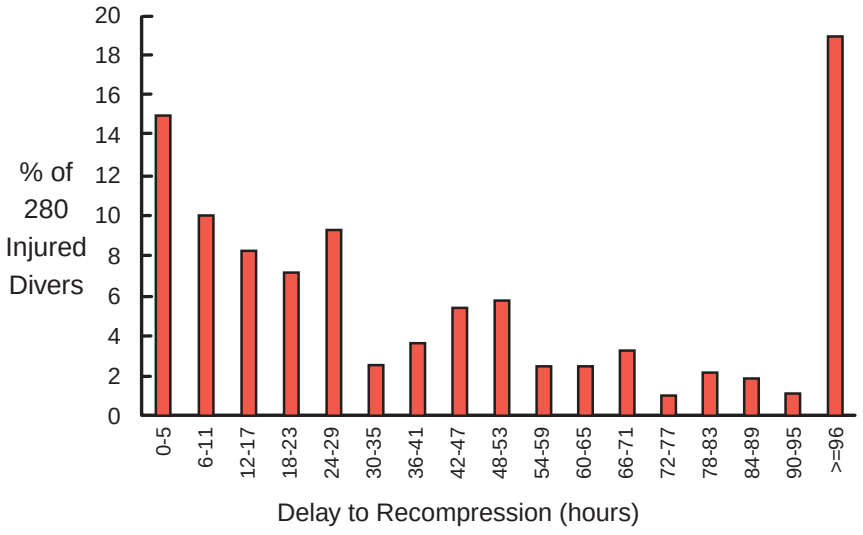


Figure 19 shows the most frequently used medications during therapy. Analgesics were most common. Oral and intravenous fluids and steroids were the only adjunctive medications used for DCI, but steroids were employed in only 4% of cases.

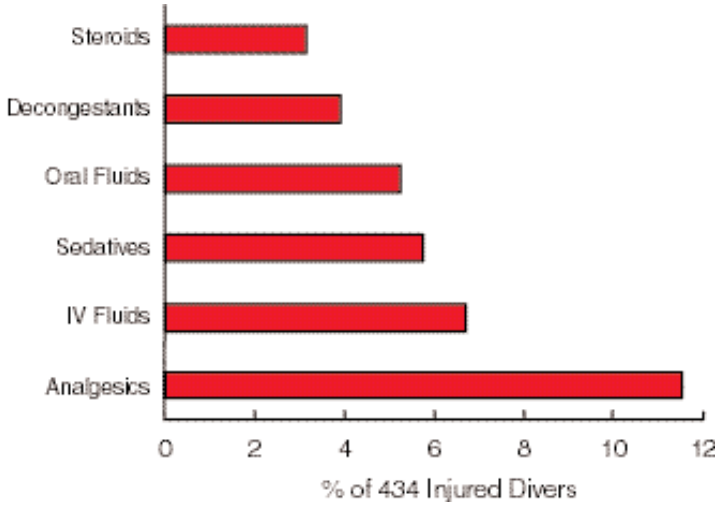


Fig 19
Most common medications used during therapy for 434 injured divers

Figure 20 shows the number of recompressions given for 434 cases. Sixty percent received only one recompression, few received more than four recompressions, and none more than 20.

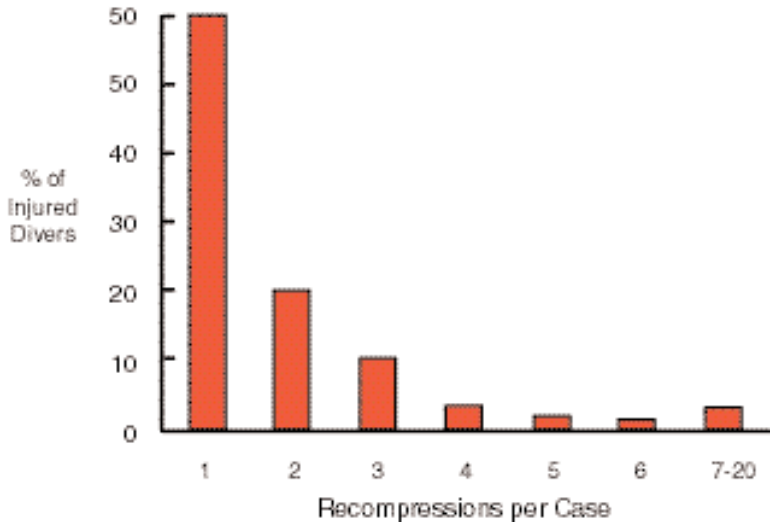


Fig 20
Number of recompressions per case for 434 injured divers

Figure 21 shows the recompression treatments used for first and repeat recompressions. Three-quarters of all first recompressions were with Table 6. Other represents Table 5A, the Catalina table, Table 4, and hyperbaric oxygen therapy at 30 fsw / 9 msw and 60 fsw / 18 msw.

Fig 21 Recompression tables for the first and repeat recompressions

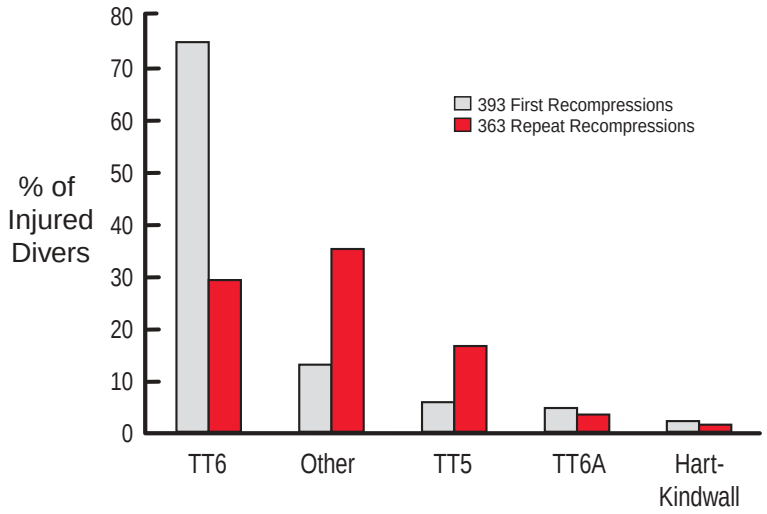


Figure 22 shows the effectiveness of recompression as a function of the number of recompressions. The fraction of divers with complete relief decreased from 65% with a single recompression to 36% with four or more recompressions. The fraction of divers having no improvement also decreased.

Fig 22 Symptom relief and the number of recompressions for 384 injured divers

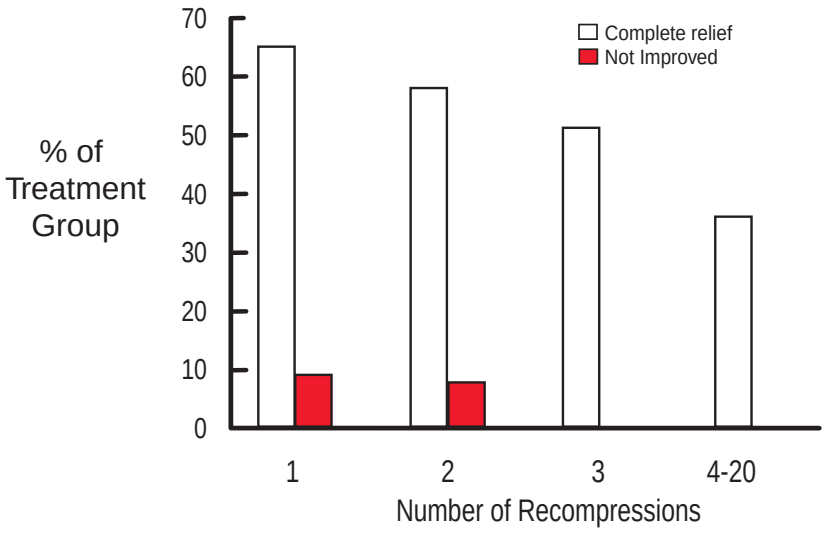


Figure 23 shows the extent of symptom relief across the diagnostic categories after all recompressions. The number of cases in each diagnostic category is shown in parentheses. Eighty percent of divers diagnosed with AGE had complete relief, while Type I DCS had 65% with complete relief and Type II DCS had less than 60% complete relief. About 4% of divers with Type II DCS were not improved by recompression.

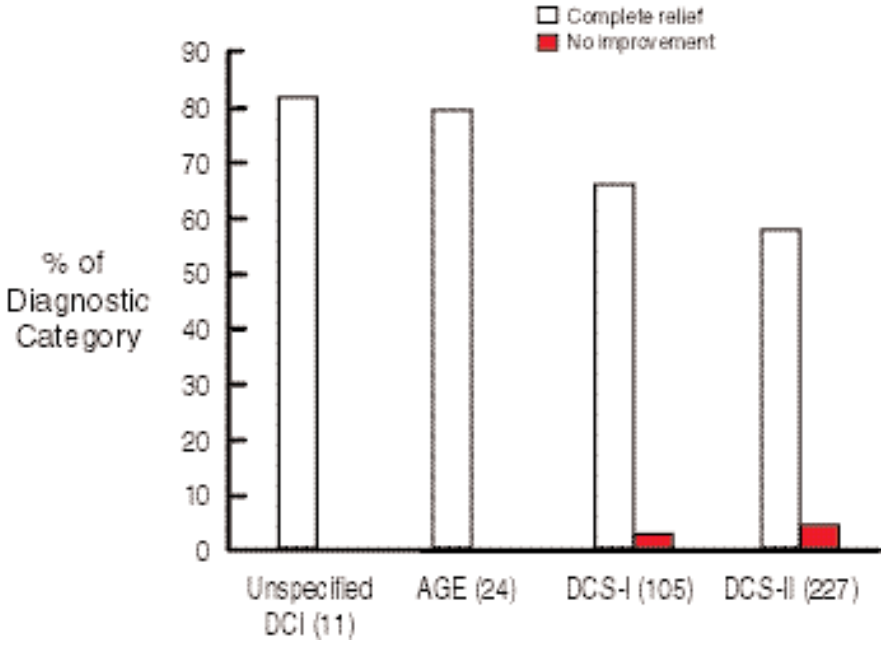
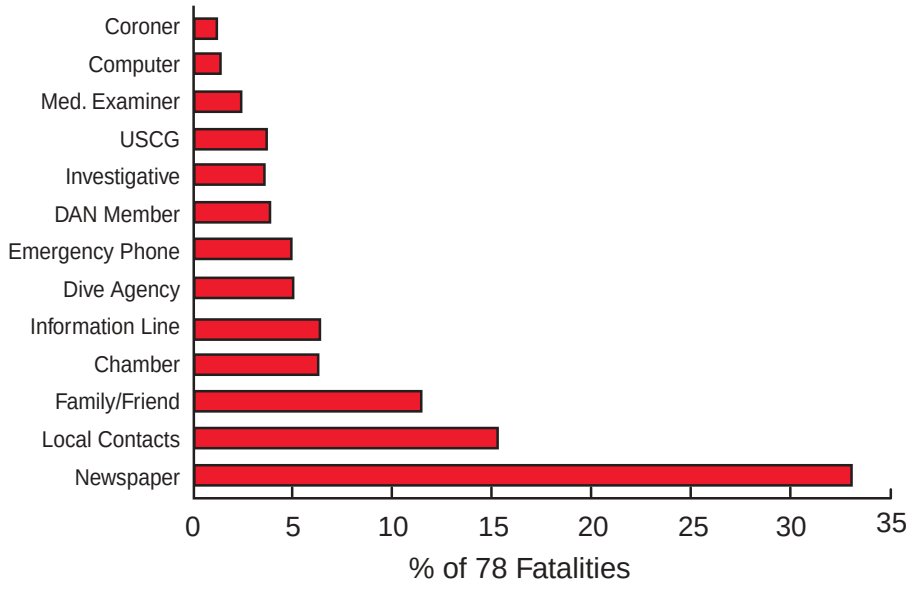


Fig 23
Symptom relief for each diagnostic category for 367 injured divers

2.4 Diving Fatalities

Relatively little is known about diving fatalities, compared with the information available about PDE divers or injured divers. Figure 24 shows that fatality data collection in 1999 often began with a telephone call or newspaper clipping that informed DAN of an event. DAN contacted witnesses or family members and official investigative agencies such as the Coast Guard, police departments, coroners, medical examiners, hyperbaric chambers and diving agencies. Occasionally, cases were sealed due to legal action.

Fig 24
Source of the first information about fatalities



The medical examiner assumed jurisdiction in most states and usually conducted an autopsy. Autopsy reports were available for review by DAN in 41 of the 78 cases and unavailable in 31 cases. Autopsies were not conducted in three cases, and the deceased was not found in another three cases. DAN recommends that the protocol in Appendix C be used when autopsies are conducted for diving fatalities and accidental drownings.

Figure 25 shows the apparent cause of death. A case review by the DAN pathologist found that medical examiners cited drowning as the most common cause of death, although precipitating events were generally unknown. AGE was judged a factor in nearly 20%, and heart attack in six of the 78. Those who suffered from heart attack were men (56 +/- 8.5 years, mean +/- standard deviation; range 44-65 years). The category "Other" included asphyxia, anoxic encephalopathy, aspiration of vomitus, hypoxia, intracranial hemorrhage, lymphoma and subdural hematoma.

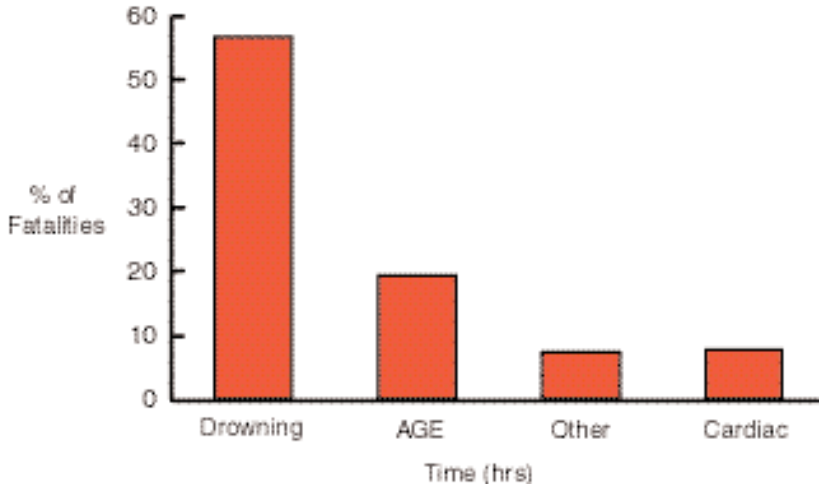


Fig 25
Cause of death in 78 diving fatalities

Figure 26 shows the phase of the dive in which the precipitating event was likely to occur for 60 fatalities. Problems became more likely as the dive progressed.

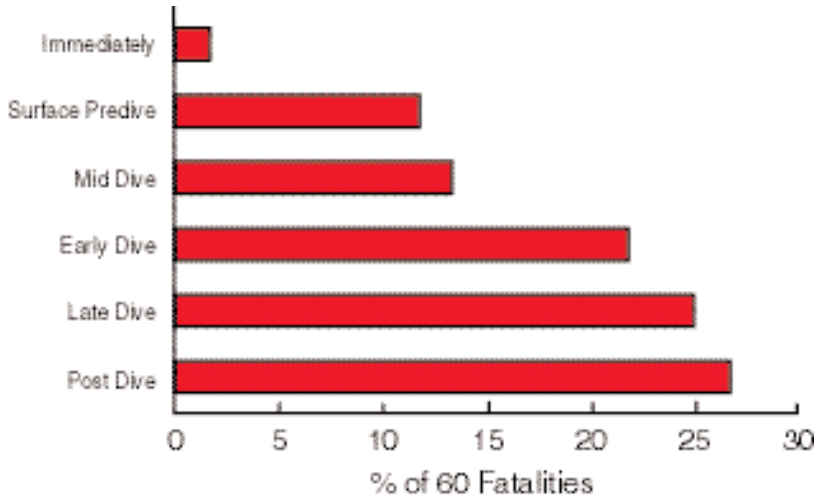
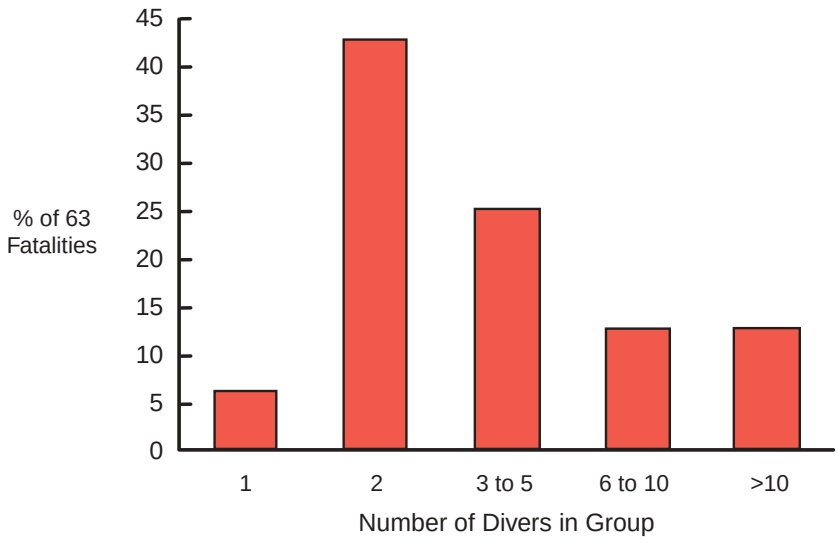


Fig 26
Dive phase in which the critical event occurred in 60 fatalities

Fig 27 Number of divers in the group

Figure 27 shows the number of divers in the immediate group with the victim. Only about 7% were diving alone.



3. DIVER CHARACTERISTICS

Figure 28 illustrates the distribution of age by gender across the three diver populations: PDE, injured and fatalities. The mean ages were 39 years for PDE, 33 years for injuries and 43 years for fatalities. These means are clearly reflected in the distributions, with fatalities having greater fractions of divers in age groups 50-59 and 60-69 than the other populations. This was despite an active effort to recruit older divers for the Aging Diver Project of Project Dive Exploration. The symbol "R" in Fig. 28 represents the five PDE divers who are listed in Table 1 and were recompressed.

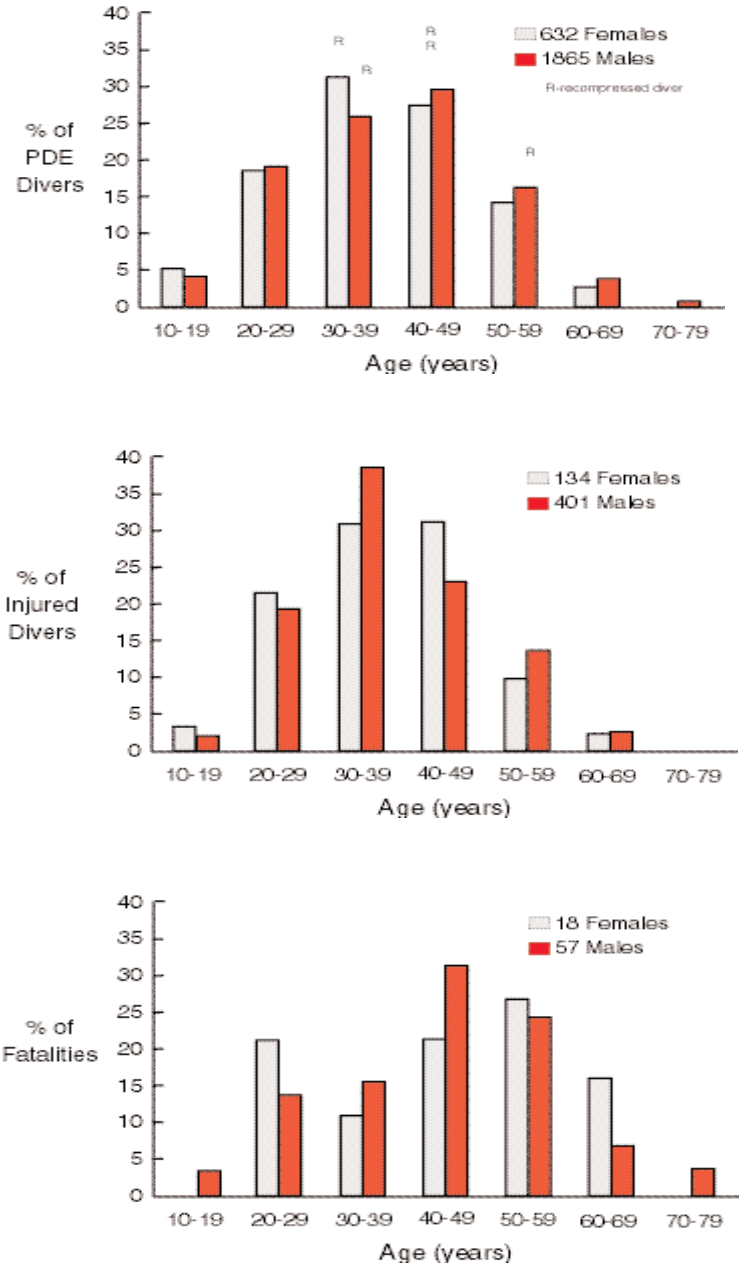


Fig 28
Age and gender for PDE divers (99.6% response), injured divers (100 % response), and diving fatalities (96% response)

Figure 29 shows the distribution of divers by certification. The category "Specialty" included military, scientific, commercial or law enforcement divers. For PDE, technical divers were included in the "Specialty" category. Over 30% of PDE divers were in the Specialty category, but "Specialty" divers were only 5-10% among injuries and fatalities. Advanced divers were the second largest groups in injuries and fatalities at about 30%; they were less common in PDE at 20%. Divers with Basic, Specialty or Advanced certification represented large categories in all populations. Two fatalities had no certification, and 25% of the female fatalities were students. There were few students in the PDE population and none among the injuries.

Fig 29 Certification of PDE divers (85% response), injured divers (83 % response), and dive fatalities (73% response)

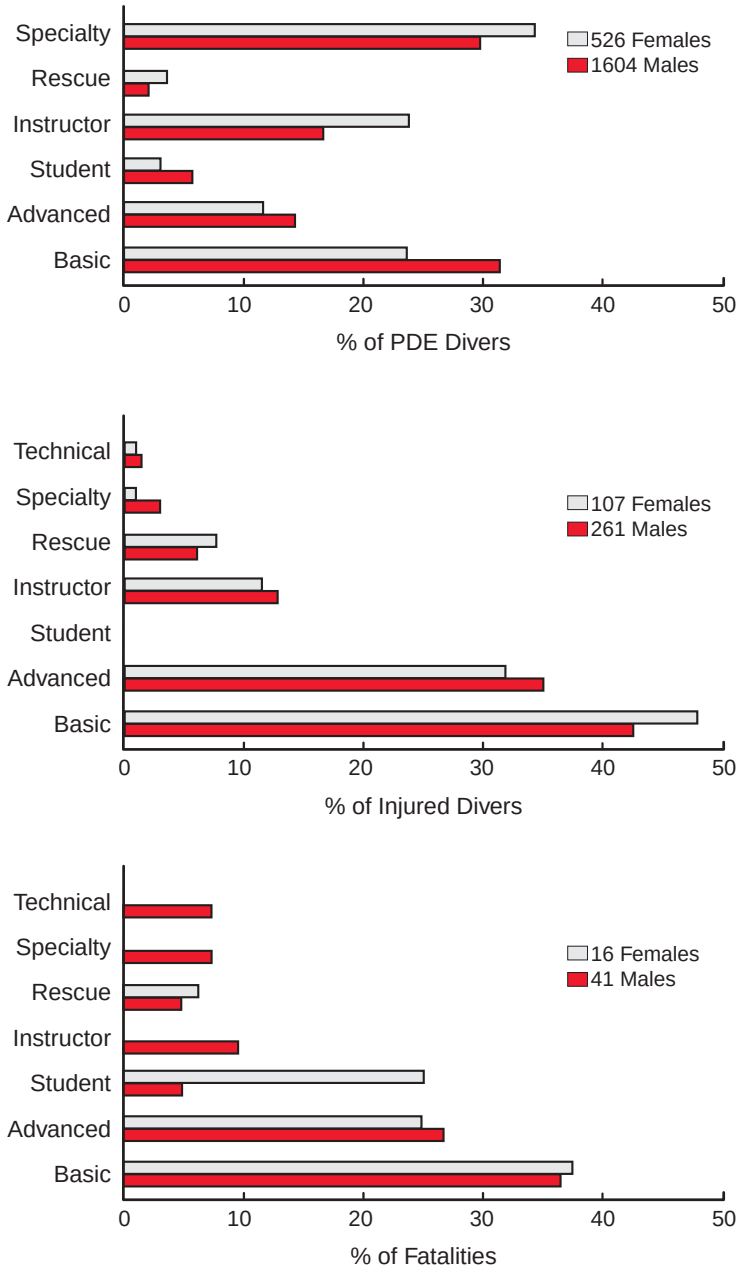


Figure 30 shows the health problems of the three populations. When the percentages of problems are compared among populations, the proportion of heart disease was three times greater in diving fatalities than in injuries or PDE divers. Similarly, the proportions of joint and muscle pain were three times greater for injured divers than for diving fatalities or PDE divers.

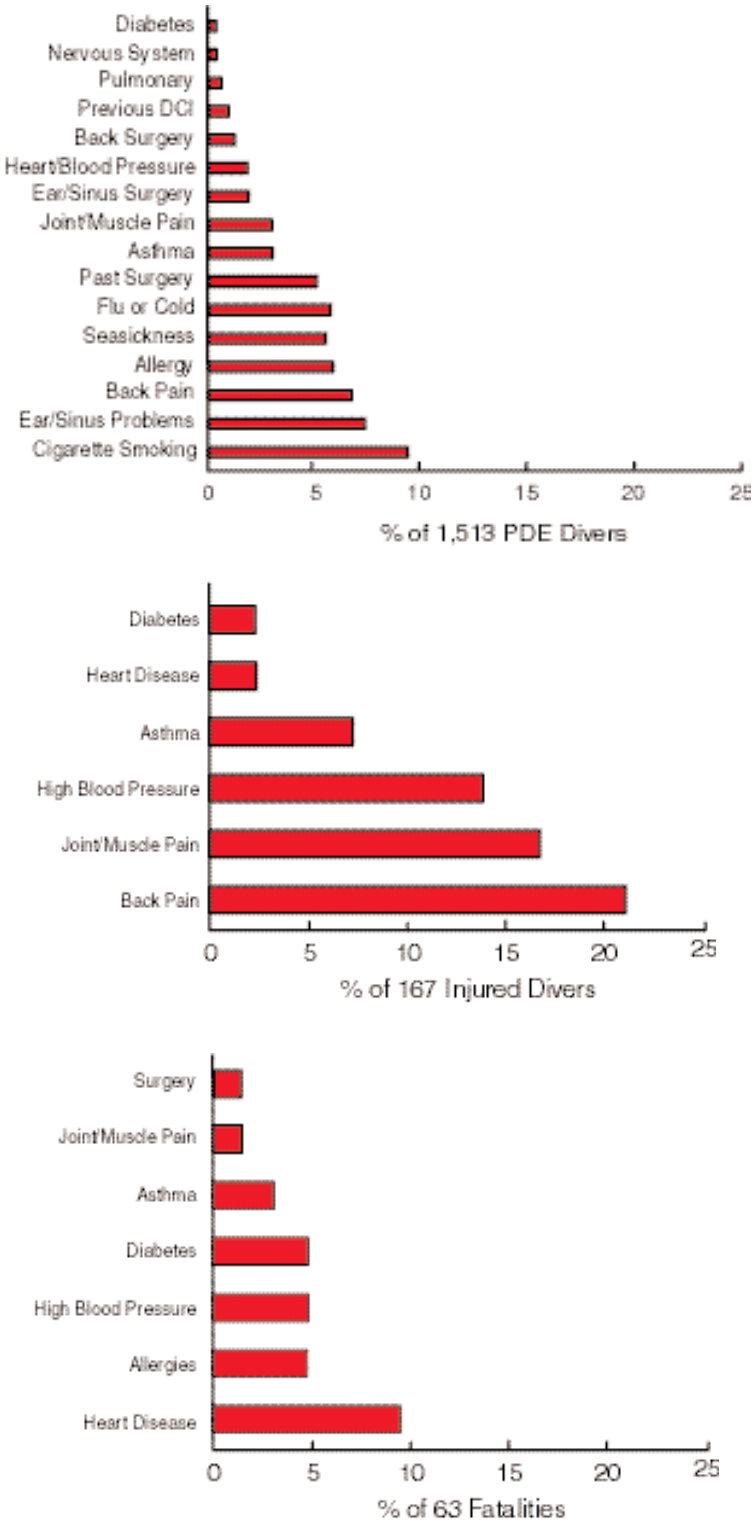
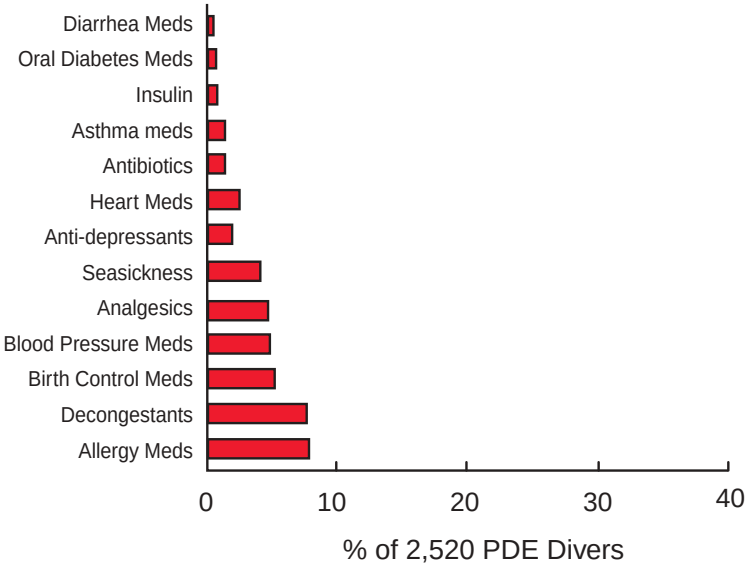
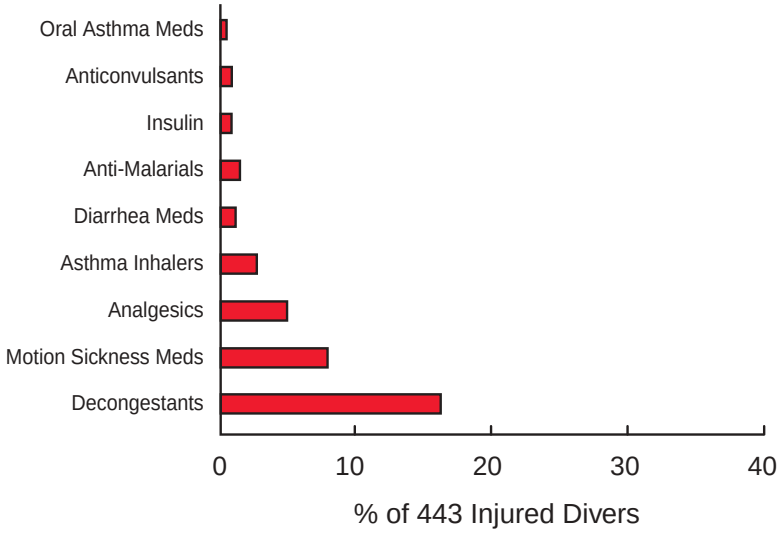


Fig 30
Health problems of PDE divers (68% response), injured divers (94 % response), and diving fatalities (81% response)

Fig 31
Medications used by PDE divers, injured divers, and diving fatalities

Figure 31 shows the medications used by the three diving populations. PDE divers who used insulin and diabetes medications were part of a DAN study of diabetes and diving. Little information was available about the medications used by diving fatalities.





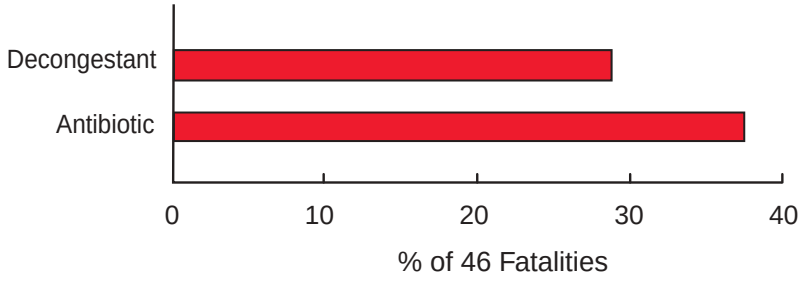


Figure 3.2 shows the years since initial training. The highest frequencies were apparent for new divers and for experienced divers in all three populations.

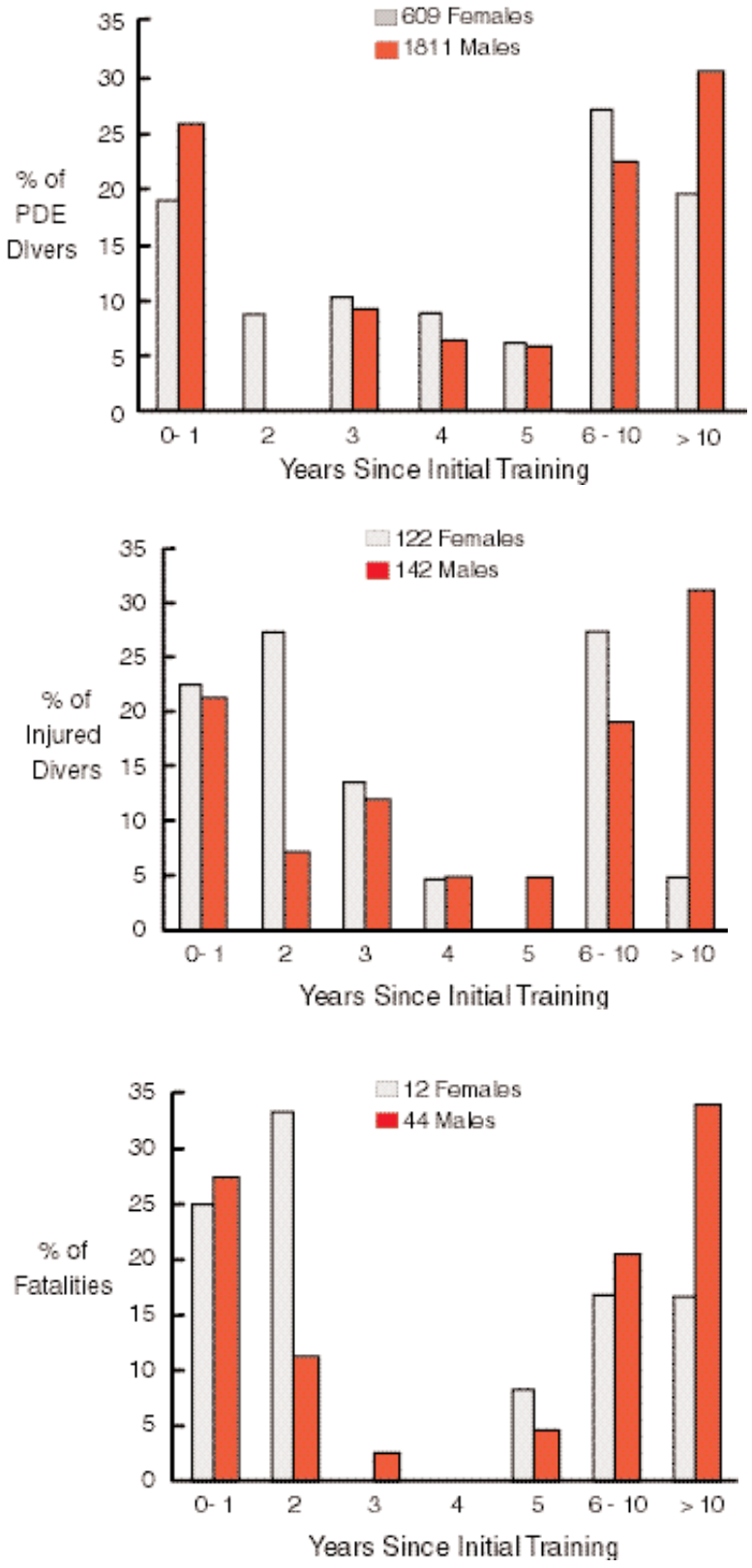
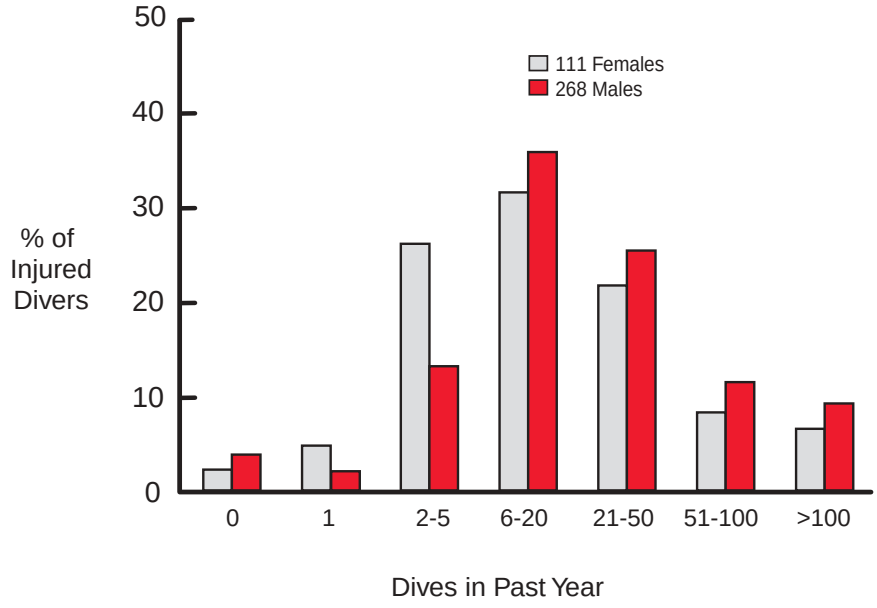
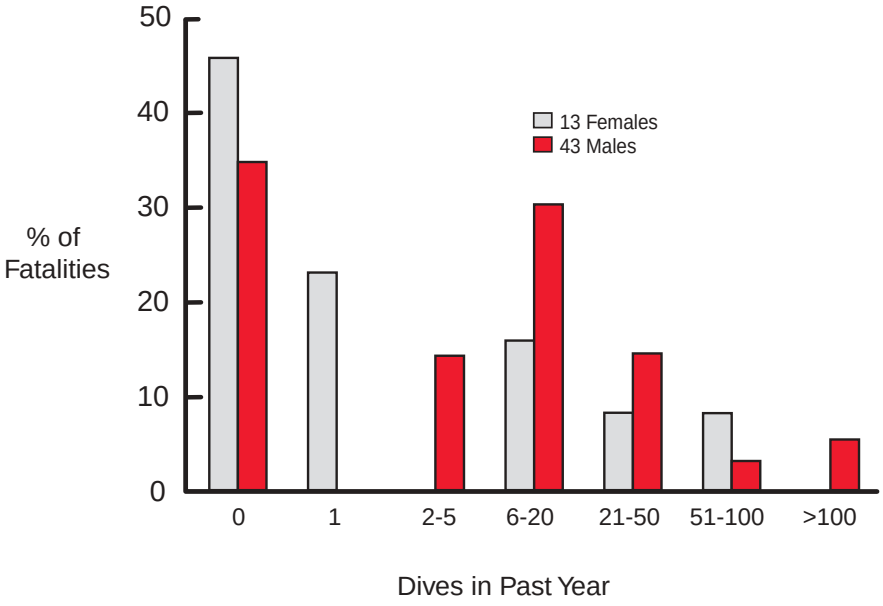


Fig 32
Years since initial training for PDE divers (96% response), injured divers (60 % response), and diving fatalities (72% response)

Figure 33 shows the distribution of the number of dives in the past year reported by and for injuries and fatalities. (These data were not available for PDE divers.) The most striking difference is that about 40% of diving fatalities had not been diving in the past year.

Fig 33
Number of dives in the past year for injured divers (74% response), and diving fatalities (72% response)





4. DIVE CHARACTERISTICS

Figure 34 shows the distribution of the dives across the months of the year for the three populations. PDE diving activity was greatest in June and July when the DAN Interns were collecting data. Injuries occurred in the peak diving period of May to August. July was the most common month for fatalities.

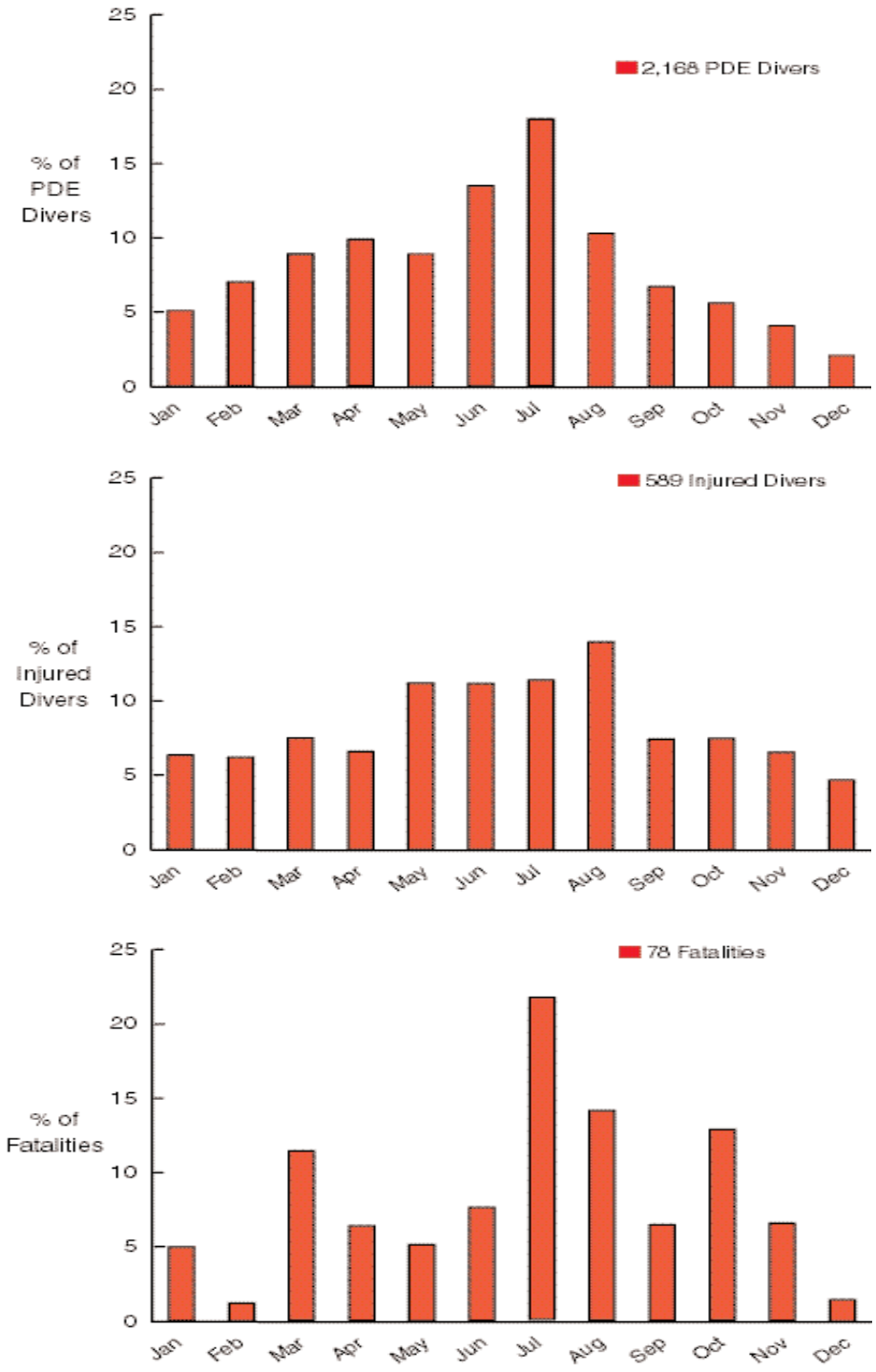


Figure 34
Month in which the PDE dives, injuries, and fatalities occurred (76% PDE response, 100% injury response, 100% fatality response)

Figure 35 shows the time of day (morning, afternoon, and evening) during which the dives occurred. PDE dives were most common in the morning while nearly 60% of fatalities occurred in the afternoon. PDE divers were three-times more active at night.

Figure 35
Time of day in which the PDE dives (93% response), injuries (98% response), and fatalities (53% response) occurred

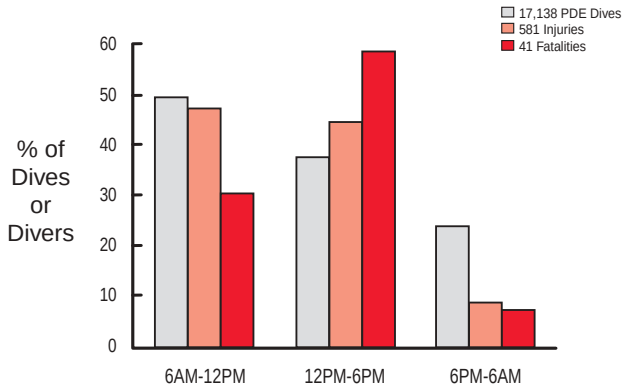


Figure 36 shows the reason for conducting the dives. Recreation predominated for both PDE and injured divers at 75-80% but only 47% of fatalities were recreational divers. The category "Other" included photographers, game collectors and commercial, scientific, military, and technical divers.

Figure 36
Reason for diving (77% response PDE, 82% response injuries, 96% response fatalities)

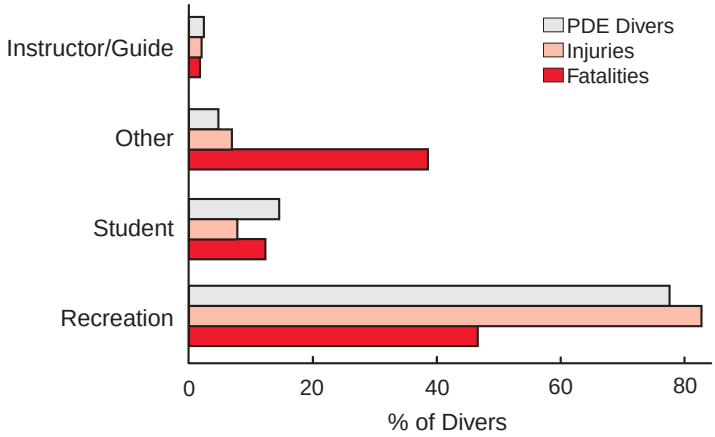


Figure 37 shows the dive site. The proportion of fatalities in fresh water was double that for PDE divers or injured divers in fresh water.

Figure 37
Dive Site (67% response PDE, 73% response injuries, 100% response fatalities)

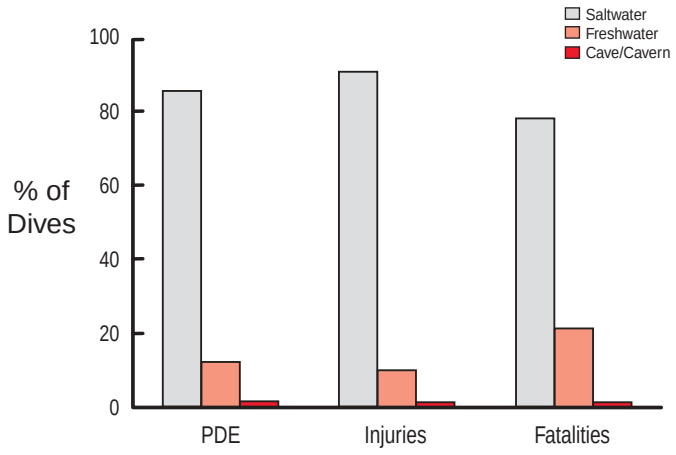


Figure 38 shows the dive platform for PDE divers and fatalities. (This information was not available for injured divers.) Half the PDE divers but none of the fatalities were from liveaboards. Fatalities were most common in divers who entered the water from the shore or from a charter boat.

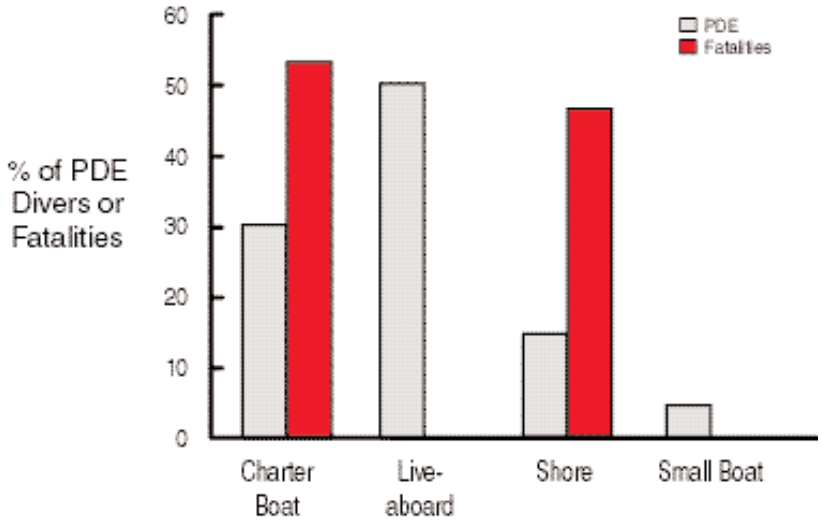


Fig 38
Dive platform (86% response PDE, 94% response fatalities)

Figure 39 shows the thermal protection worn by the three dive populations were generally similar.

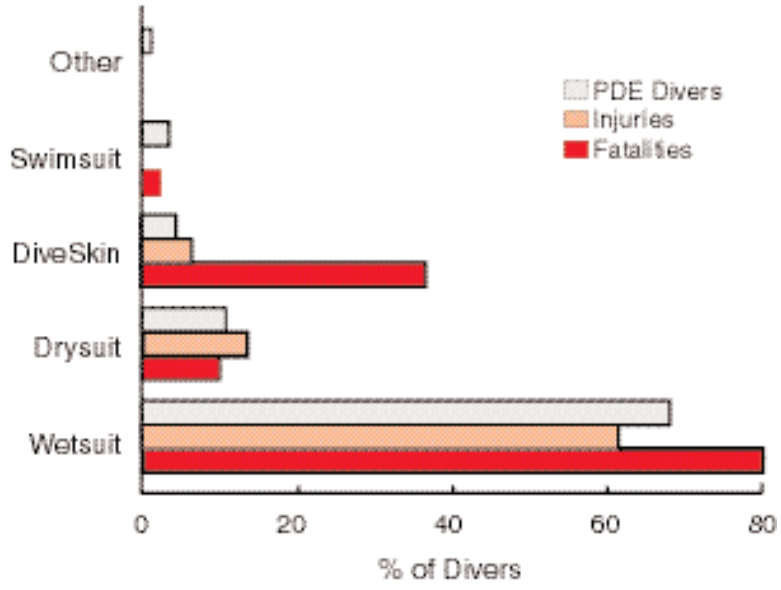


Figure 39
Thermal protection (57% response PDE, 88% response injuries, 77% response fatalities)

Figure 40 illustrates the breathing gases that were used. Air was the most common gas at about 90%. The proportion of divers who used nitrox was three times greater for PDE divers (12%) than for fatalities (4%). Trimix or heliox was used by 10% of diving fatalities, a larger proportion than in PDE divers or injured divers. Almost all divers in all populations used open-circuit scuba.

Figure 40 Breathing gas (64% response PDE, 73% response injuries, 95% response fatalities)

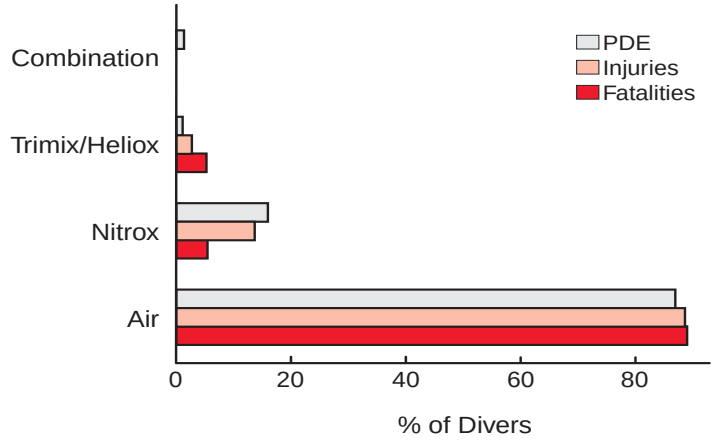
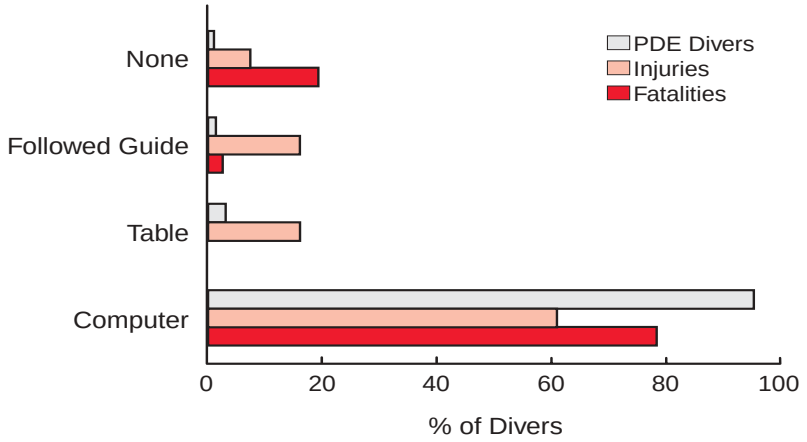


Figure 41 shows the dive planning methods used by the three populations. Nearly all (95%) of the PDE divers used computers while 61% of injured divers used computers, a proportion that has remained constant since rising to this level in 1997. Seventy-eight percent of the fatalities used dive computers, but 19% were reported to have used no dive planning. Only 7% of injured divers and 1% of PDE divers reported using no dive planning method.

Figure 41 Dive planning method (99% response PDE, 87% response injuries, 47% response fatalities)



For Project Dive Exploration, the depth-time profiles were recorded by dive computer and are accurately known. This is not so for the injuries and fatalities where the dive profiles can be characterized at best only by the number of days diving, the number of dives, and the maximum dive depth. These metrics are used below to compare the three diving populations.

Figure 42 shows the number of days of diving for PDE and injured divers. Fatality data were not available other than for the day of fatal injury. The first day was also the most common day for injuries while PDE divers dived safely for more than 15 days with over 20% of dives occurring during six or more days on liveaboards. The symbol "R" in Fig. 42 represents the five PDE divers who are listed in Table 1 and were recompressed for DCI.

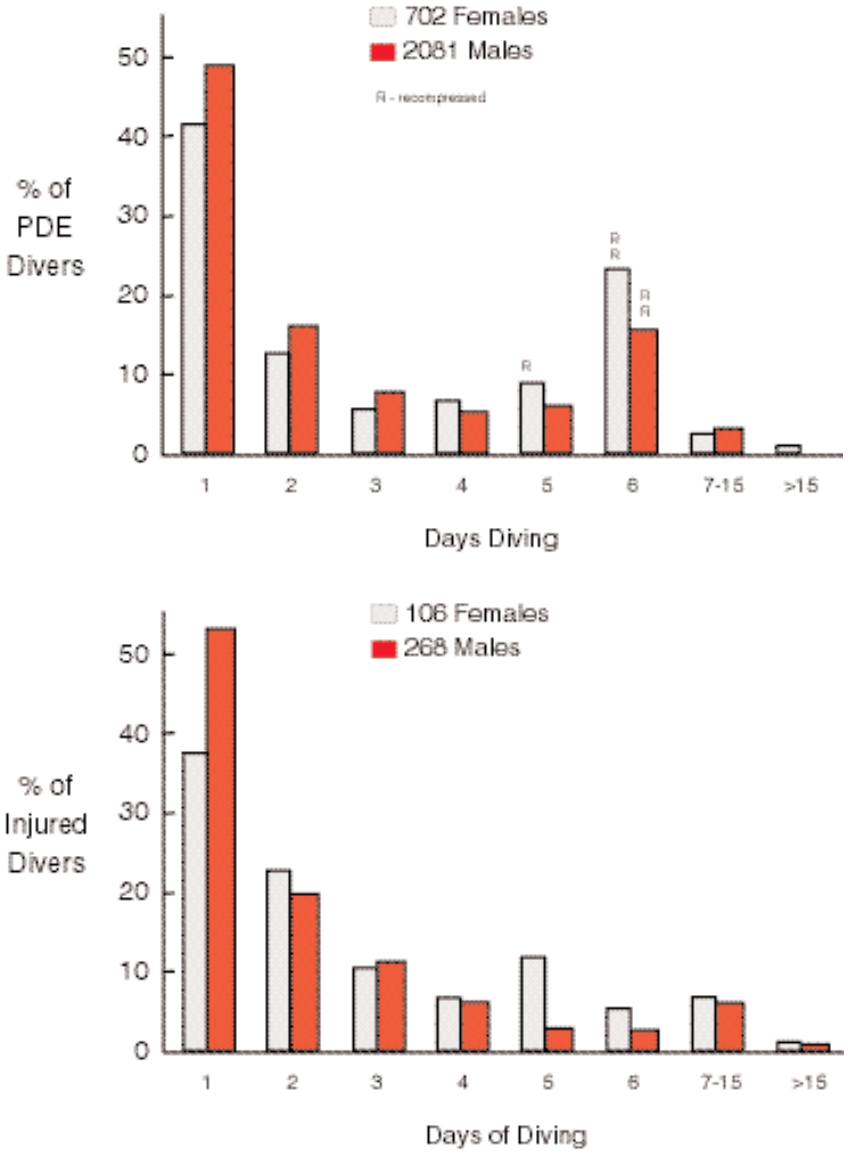


Figure 42
Number of days diving (94% response PDE, 84% response injuries)

Figure 43
Number of dives in the series (78% response PDE, 91% response injuries, 79% response fatalities)

Figure 43 shows the number of dives in the dive series. In PDE, there was a peak at two dives, but half the divers made six or more dives. The pattern was similar for divers with injuries. Eighty percent of fatalities, on the other hand, occurred during the first dive, and no fatalities appeared to make more than three dives, although DAN does not presently ask about more than three dives. The symbol "R" in Fig. 43 represents the five PDE divers who were recompressed for DCI and are listed in Table 1.

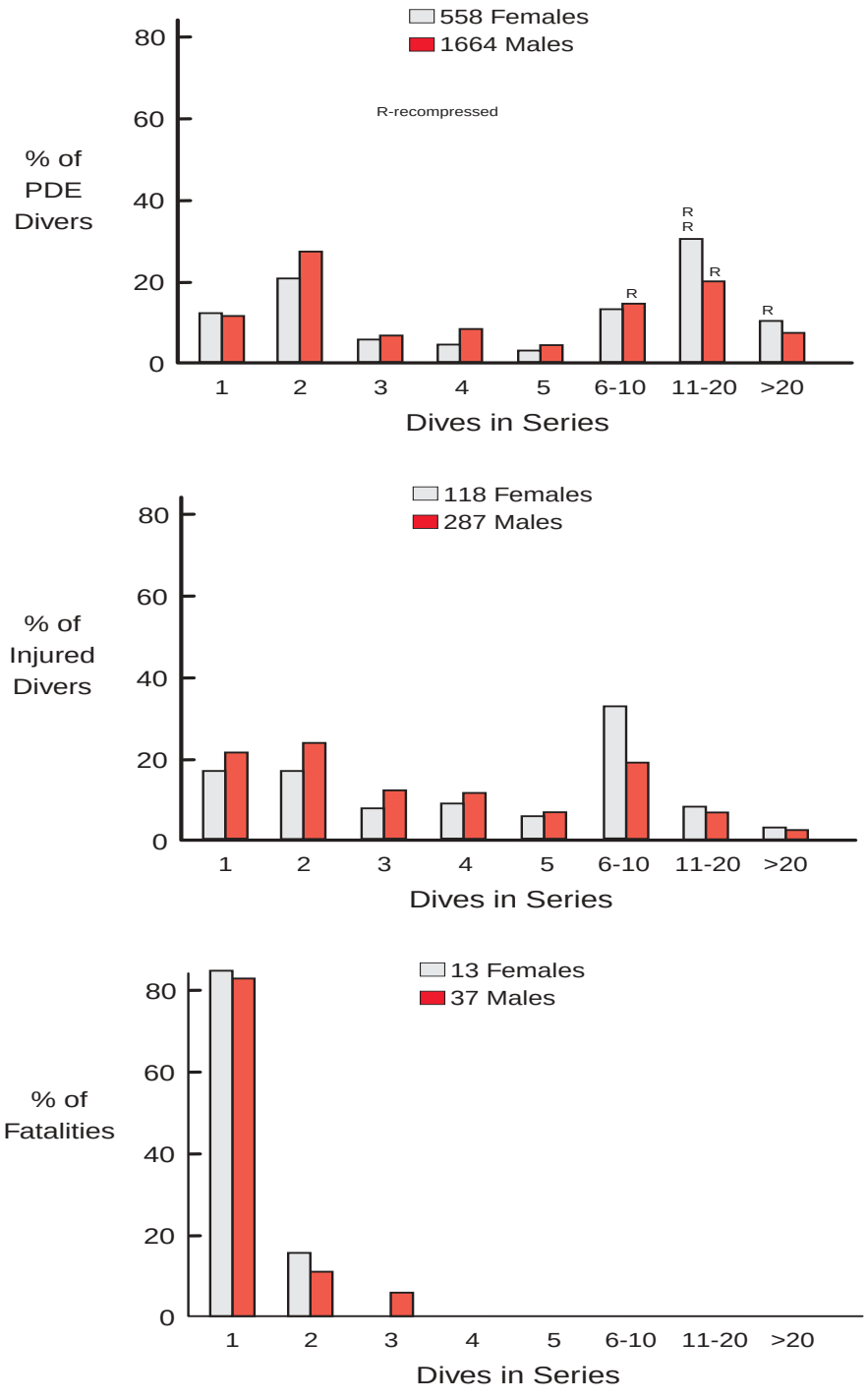


Figure 44 shows the distribution of maximum depths. Dive fatalities generally had the shallowest maximum depths, while injured divers had the greatest maximum depths. However, 12% of male diving fatalities dived deeper than 180 fsw. The symbol "R" in Fig. 44 represents the PDE divers listed in Table 1 who were recompressed for DCI and are listed in Table 1.

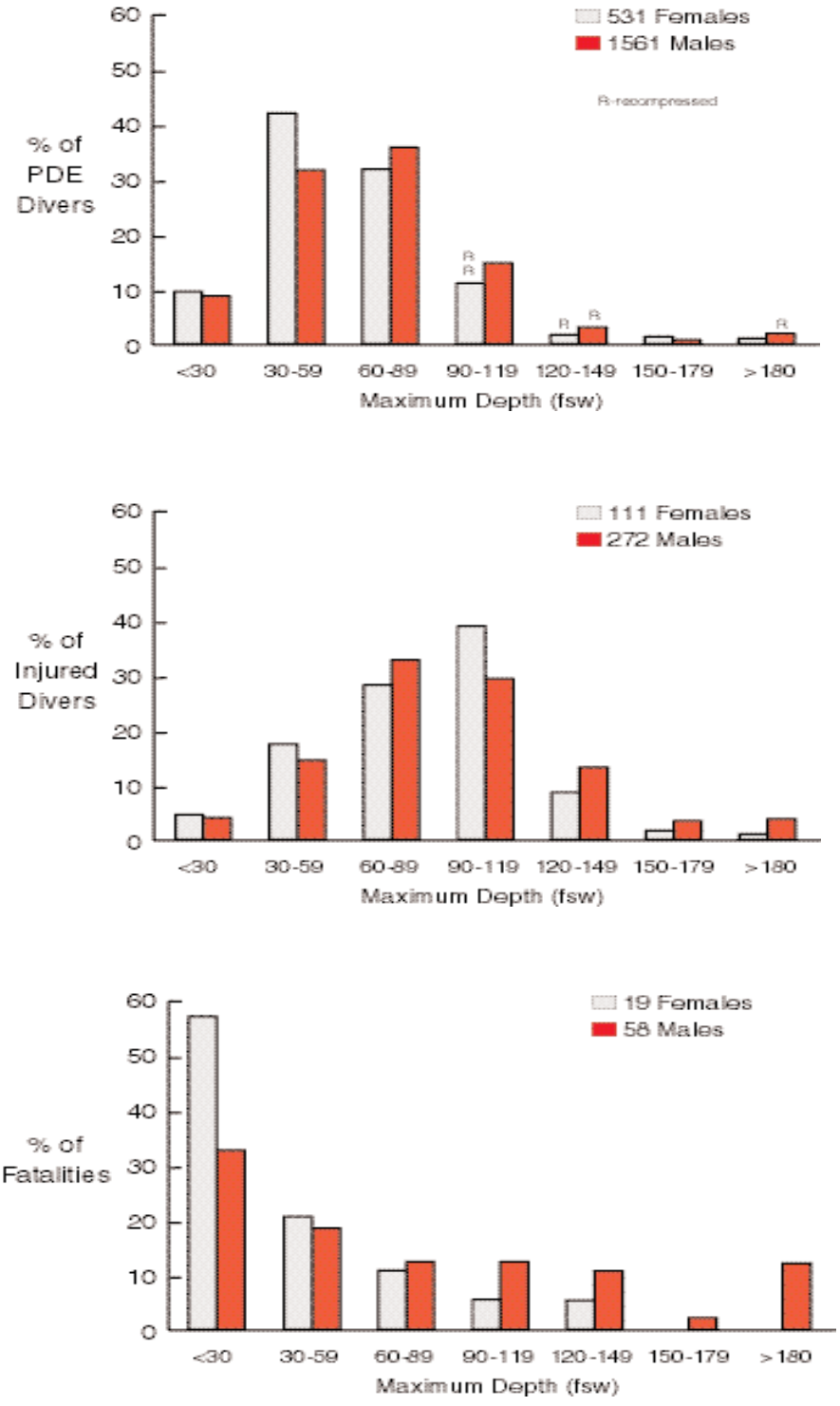
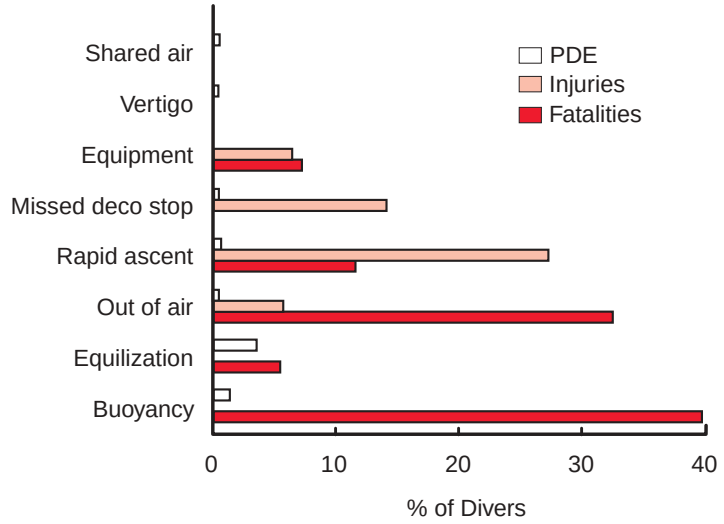


Figure 44
Maximum depth in the series (73% response PDE, 86% response injuries, 99% response fatalities)

Figure 45 shows the problems that occurred during diving. Problems were less common for PDE divers than for injuries or fatalities. Buoyancy and out-of-air were particularly frequent for fatalities while rapid ascent and missed decompression stops were most common for injuries.

Figure 45 Problems during diving (57% response PDE, 79% response injuries, 87% response fatalities)



Exposure to altitude after diving imposes an additional risk of decompression illness. Figure 46 shows the type of altitude exposure for PDE and injured divers. Thirty percent of PDE divers and nearly 25% of injured divers indicated they had been exposed to reduced pressure.

Figure 46 Altitude exposure after diving (46% response PDE, 96% response injuries)

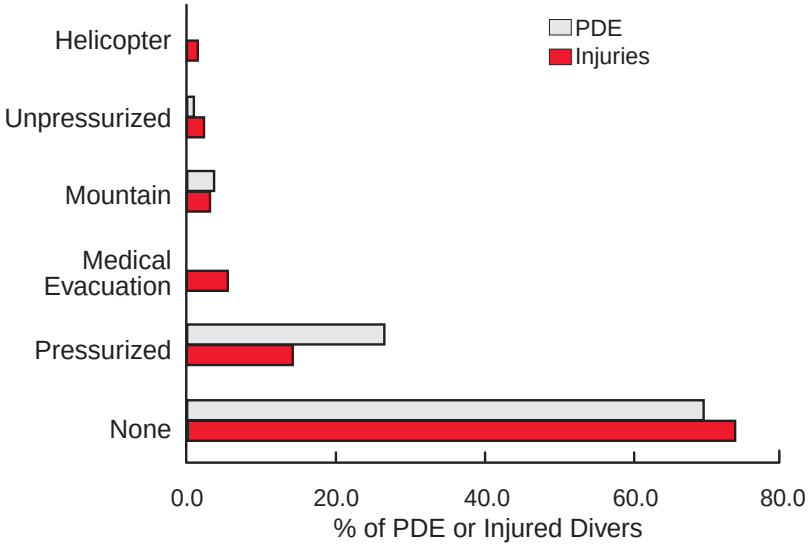


Figure 47 shows the distribution of surface intervals before flying for PDE and injured divers. Thirty-five percent of injured divers who flew waited less than 24 hours, while fewer than 15% of PDE divers waited less than 24 hrs. Many injured divers (65%) waited longer than 24 hrs before flying. The symbol "R" in Fig. 47 represents the PDE diver listed in Table 1 who had waited 26 hrs before flying after diving and was recompressed for DCI.

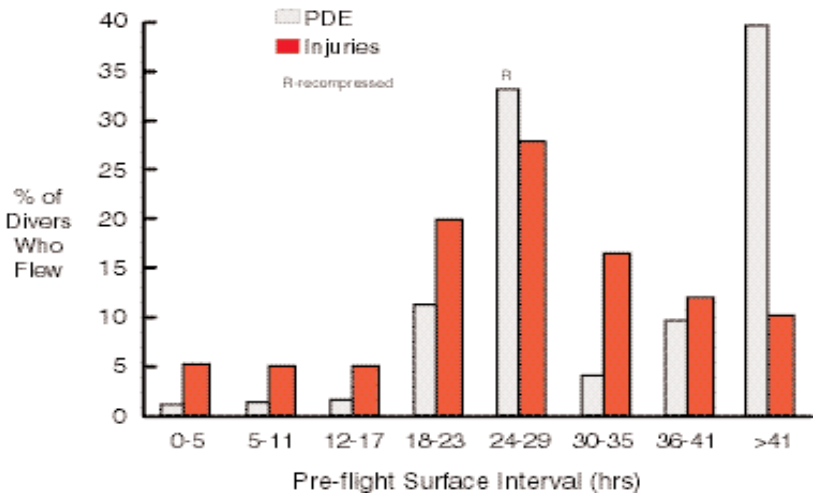


Figure 47
Pre-flight surface intervals for 312 PDE divers and injured divers (97% response for PDE, 54% response for injuries)

Figure 48 shows the distribution of surface intervals for: (a) injured divers who did not develop symptoms until during or after flight; and (b) injured divers who flew despite having symptoms suggestive of DCI. Forty-six percent of injured divers who flew had symptoms before flying, and 85% of these flew within 24 hrs of diving.

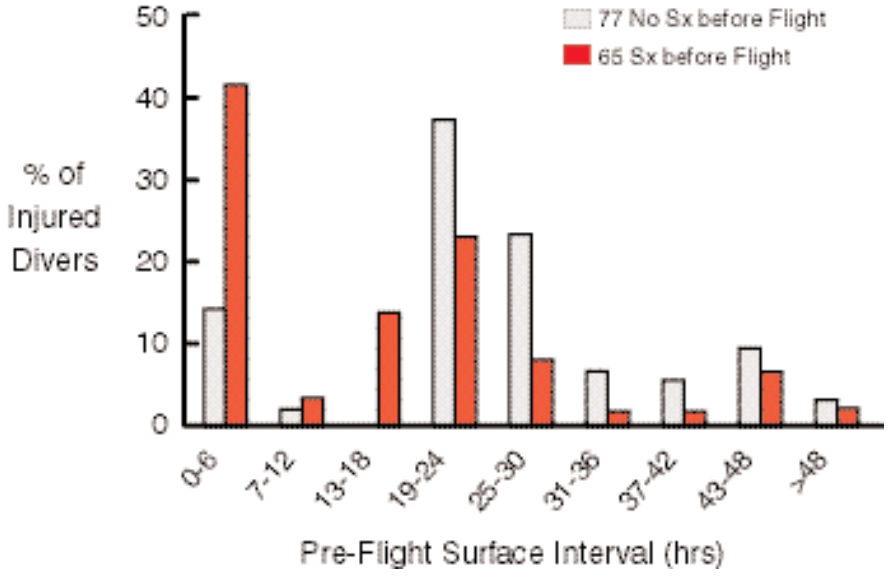


Figure 48
Pre-flight surface intervals for injured divers who flew with symptoms or who developed symptoms during or after flight (54% response)

5. NITROX AND HELIOX/TRIMIX DIVING

The use of mixed gases, rebreathers, and decompression is becoming more common, but experience with this methodology is not well documented. This section summarizes the information available to DAN.

The data reviewed are from:

- Project Dive Exploration for 1997-2000: 14,778 dives by 2,519 divers in which were three recompressions. This is a subset of the PDE data discussed earlier.
- Diving injury data from 1995-2000: 11,781 dives by 2,480 divers.
- Diving fatalities from 1990-1999: 845 divers.

The three populations are subdivided by the breathing mixtures they used: air; nitrogen-oxygen (nitrox); and helium-oxygen (heliox) or trimix (helium-nitrogen-oxygen).

Figure 49 shows nitrox diving activity in DAN data from 1990 to 2000 as a fraction of all diving including air. In PDE, annual nitrox diving fluctuated between 10% and 20% since 1997. Nitrox injuries as a fraction of all annual injuries increased steadily from 2% in 1995 to 12% in 2000. The nitrox fatality fraction varied between zero and 5% of total annual fatalities.

Figure 49
Nitrox diving activity

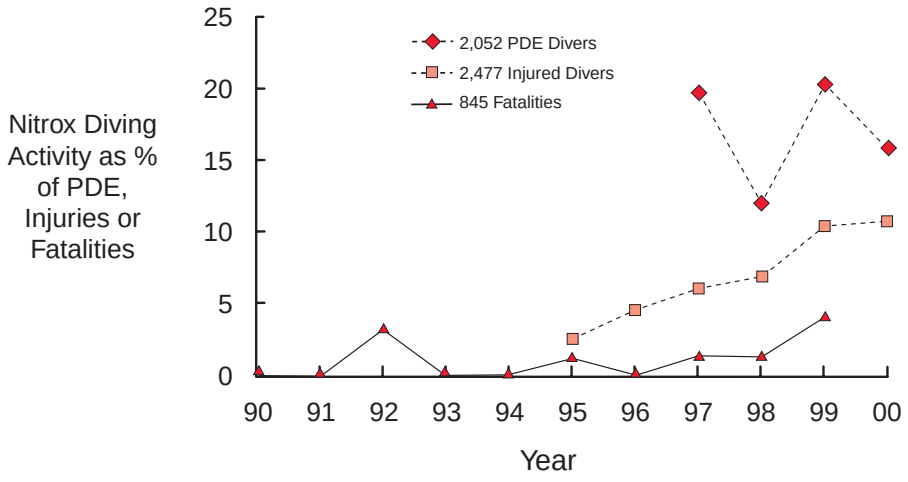


Figure 50 shows the annual heliox/trimix activity. During the first two years of PDE data collection, a number of the FRCs were active technical divers, and 15-25% of collected dives were heliox/trimix. In 1999 and 2000, heliox/trimix diving had fallen to 1% of the total PDE dives. The large changes in PDE heliox/trimix activity has no intrinsic meaning and only reflects the early phase of the project. Heliox/trimix diving injuries first appeared in 1997 and are presently at 1-2% of the total annual injuries. Heliox/trimix fatalities fluctuated from zero to 13% of the total annual injuries.

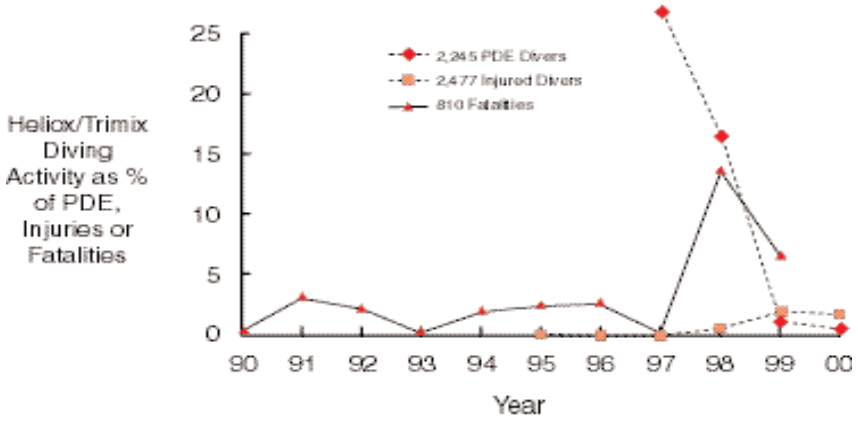


Figure 50
Heliox/trimix diving activity

Table 3 is a summary of PDE divers, injured divers, and diving fatalities over all years from 1990-2000 by gas mixture. Table 4 shows the same information expressed as percentages of the total PDE divers, injured divers, or diving fatalities. The greatest fraction of nitrox diving was by PDE divers while the lowest fraction was among fatalities. Heliox/trimix diving was greatest among PDE divers and lowest among injured divers.

	PDE	Injuries	Fatalities
Air	1,741	2,319	810
Nitrox	472	147	9
Heliox/Trimix	306	14	26

Table 3
Number of PDE divers, injured divers and diving fatalities by gas mixture

	PDE	Injuries	Fatalities
Air	79%	95%	96%
Nitrox	14%	5%	1%
Heliox/Trimix	7%	0%	3%

Table 4
Percentages of air, nitrox and heliox or trimix divers in the three populations

Table 5 shows the percentage of female divers among the three populations. There was approximately the same fraction of female nitrox divers (11-13%) in each population, but for heliox/trimix diving, PDE divers had the greatest fraction of females (28%) while the smallest fraction of females was among fatalities (4%).

Table 5 Percentage of female divers

	PDE	Injuries	Fatalities
Air	27%	28%	18%
Nitrox	13%	14%	11%
Heliox/Trimix	30%	7%	4%

Table 6 shows the mean diver ages for the three populations and three gas mixes. In general, fatalities were the oldest population, although PDE nitrox divers were older as well. These differences are reflected in the age distributions of Fig. 51.

Table 6 Mean diver age (years)

	PDE	Injuries	Fatalities
Air	38	36	40
Nitrox	45	37	44
Heliox/Trimix	36	39	41

Figure 51 shows the distributions of diver age. Over half the PDE heliox/trimix divers were in the 30-39 age group, while PDE nitrox divers were disproportionately represented in the 60-69 age group. Injuries and fatalities were distributed more or less normally, although injured divers and diving fatalities were older than the corresponding air divers.

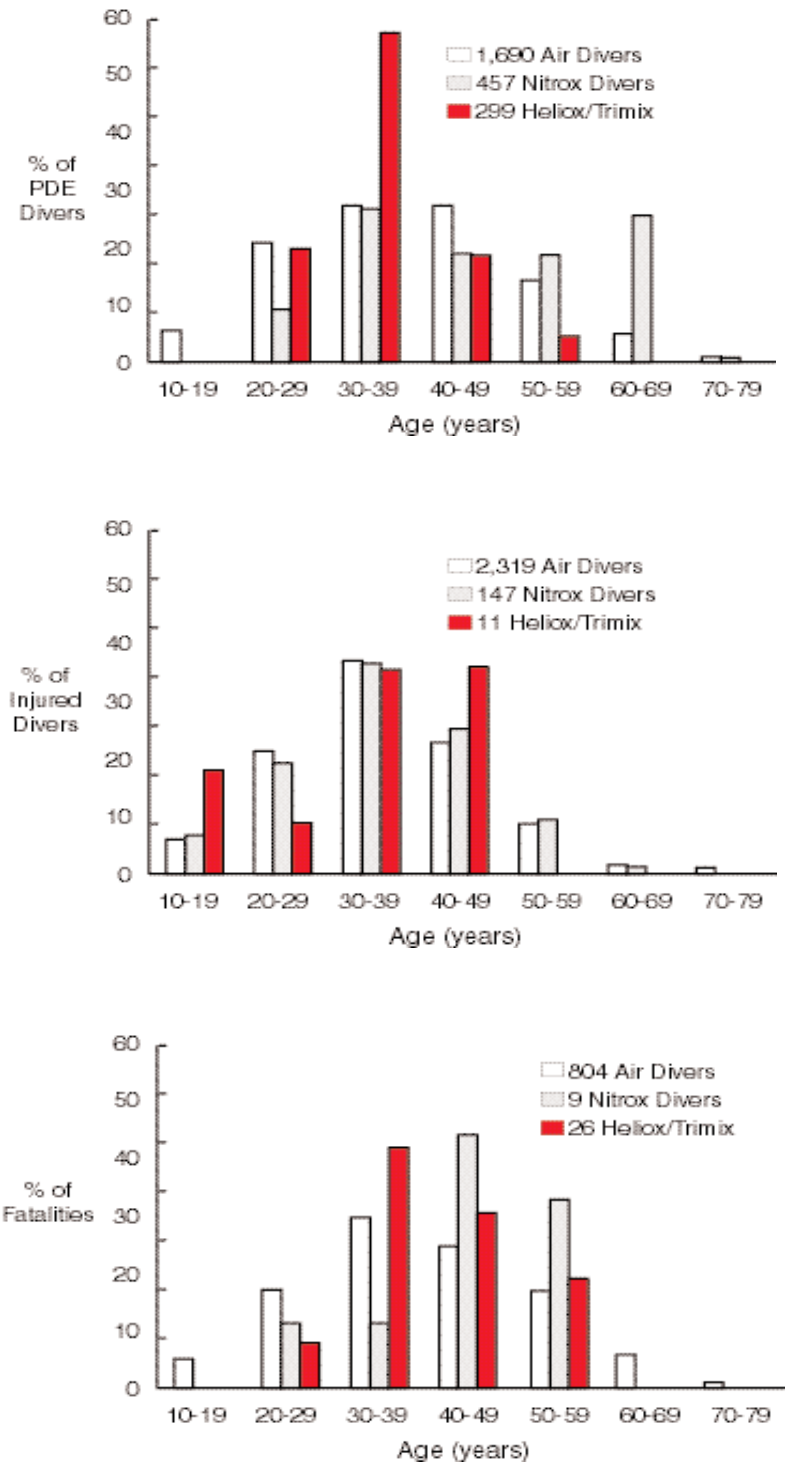


Figure 51 Distribution of diver age for PDE, injuries and fatalities

Figure 52 shows the distributions of certification for the three populations and the three gas mixes. For PDE, the highest proportions of divers held a "Specialty" certification that included technical divers. Air divers who were injured were more likely to have basic certification, and injured heliox/trimix divers were most often instructors. Air and nitrox fatalities most often had basic certification, while heliox/trimix fatalities were commonly instructors or held technical certification.

Figure 52 Diver certification

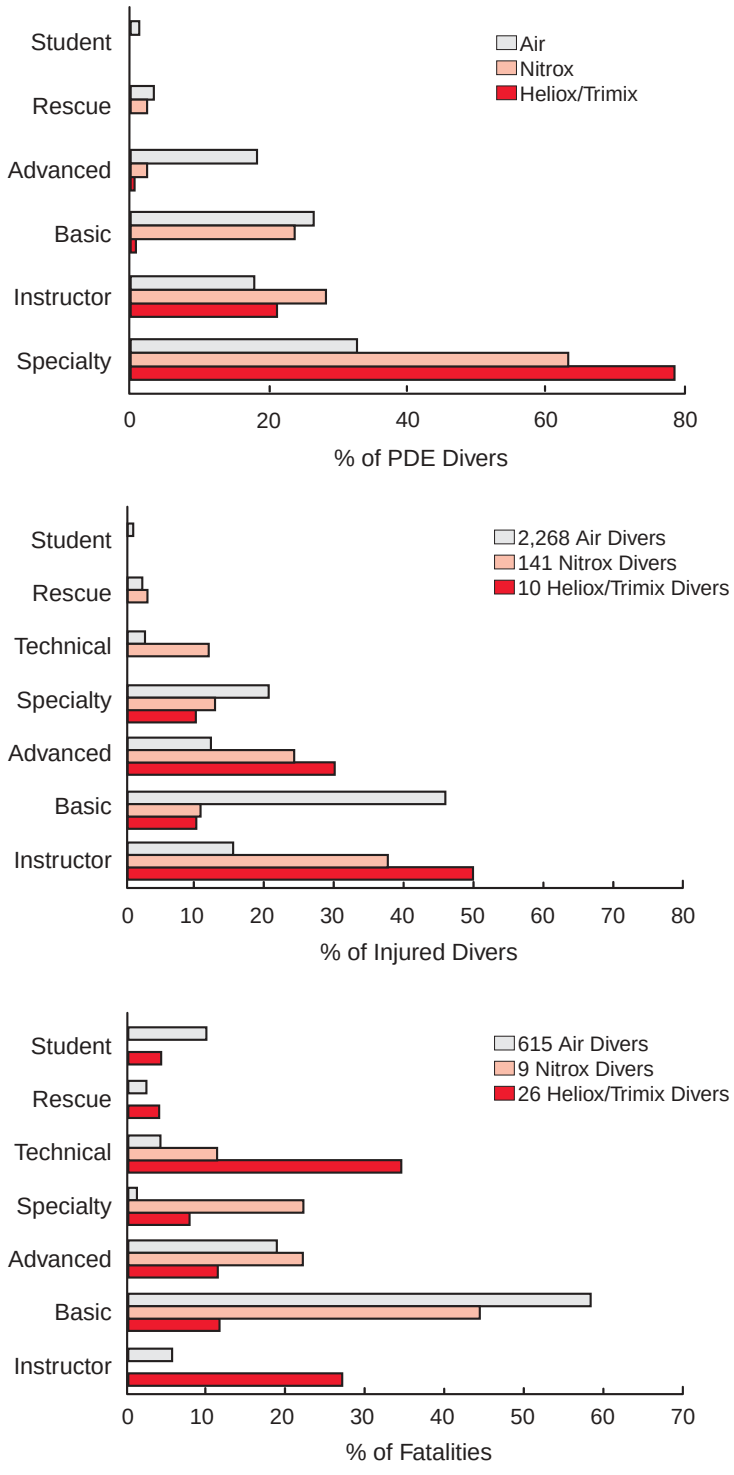


Table 7 shows the mean years since initial diver certification. Those divers who were most recently certified were the PDE divers who used heliox or trimix and the diving fatalities who used air or nitrox.

	PDE	Injuries	Fatalities
Air	9	9	7
Nitrox	11	10	7
Heliox/Trimix	7	11	11

Table 7
Mean years since certification

Figure 53 shows the dive platform used by PDE divers and diving fatalities. (Dive platform information was not available for injuries.) For PDE, half the air diving was from liveaboards, half the nitrox diving was from charter boats, and half the heliox/trimix diving was from small boats. Shore dives were the most common starting point for air and nitrox fatalities, while small boats were most common for heliox/trimix fatalities.

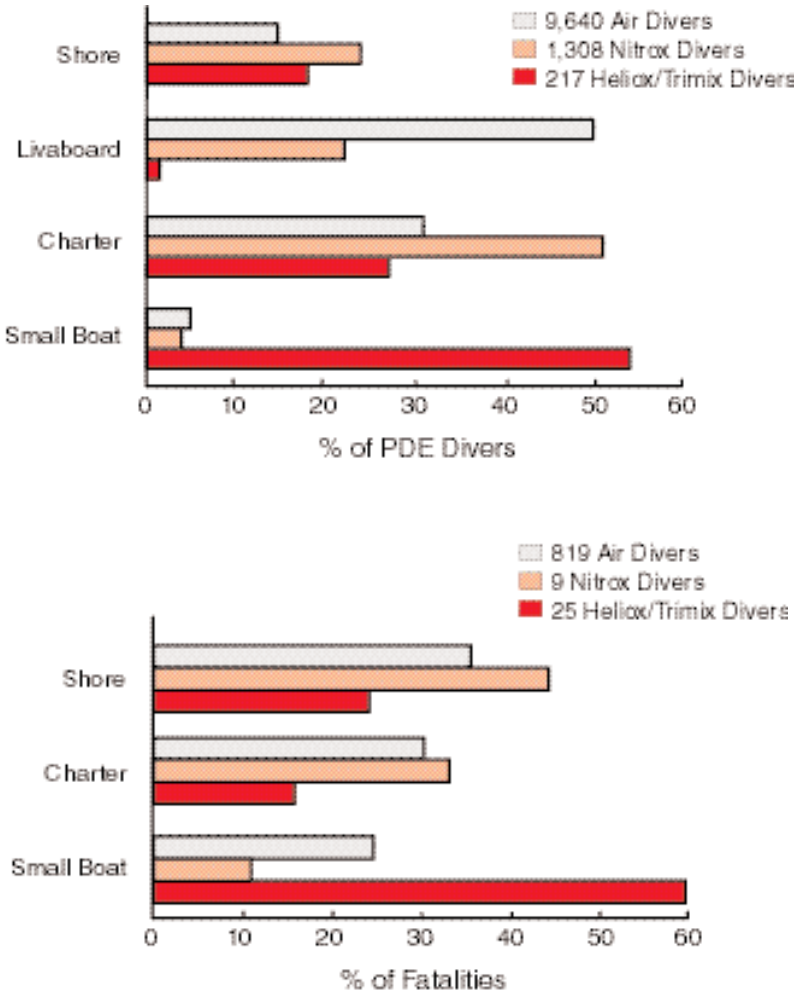


Figure 53
Dive platform

Table 8 shows the mean days of diving and Table 9 shows the mean number of dives for the three populations. For fatalities, information is available only for the day of the event. Dive trips were longer for PDE divers than for injured divers. For PDE, air divers had the shortest trips while heliox/trimix divers had the longest trips (Table 8), but air divers made more dives during their trips than did heliox/trimix divers (Table 9). PDE nitrox divers also dived less frequently than air divers (Tables 8 and 9). For fatalities, the first dive was likely to be critical for all gases.

Table 8 Mean days of diving

	PDE	Injuries
Air	3	2
Nitrox	8	2
Heliox/Trimix7	10	2

Table 9 Mean number of dives

	PDE	Injuries	Fatalities
Air	7	5	1.3
Nitrox	5	4	1.2
Heliox/Trimix	3	3	1.1

Table 10 shows the mean maximum dive depth for the three populations. Injured divers had the greatest maximum depths, while fatalities had the shallowest depths. The maximum depths for nitrox dives were greater than for air dives for all populations, while heliox/trimix dives were uniformly deeper than air or nitrox dives.

Table 10 Mean maximum dive depth

	PDE	Injuries	Fatalities
Air	75	91	35
Nitrox	95	100	40
Heliox/Trimix	157	181	81

Figure 54 shows the distributions of maximum dive depth for the three populations. The majority of maximum depths was deeper than 180 fsw for all populations who used heliox/trimix. PDE nitrox divers rarely exceeded 120 fsw, while deeper nitrox dives were more common for injured divers. Air fatalities were more common during shallow diving.

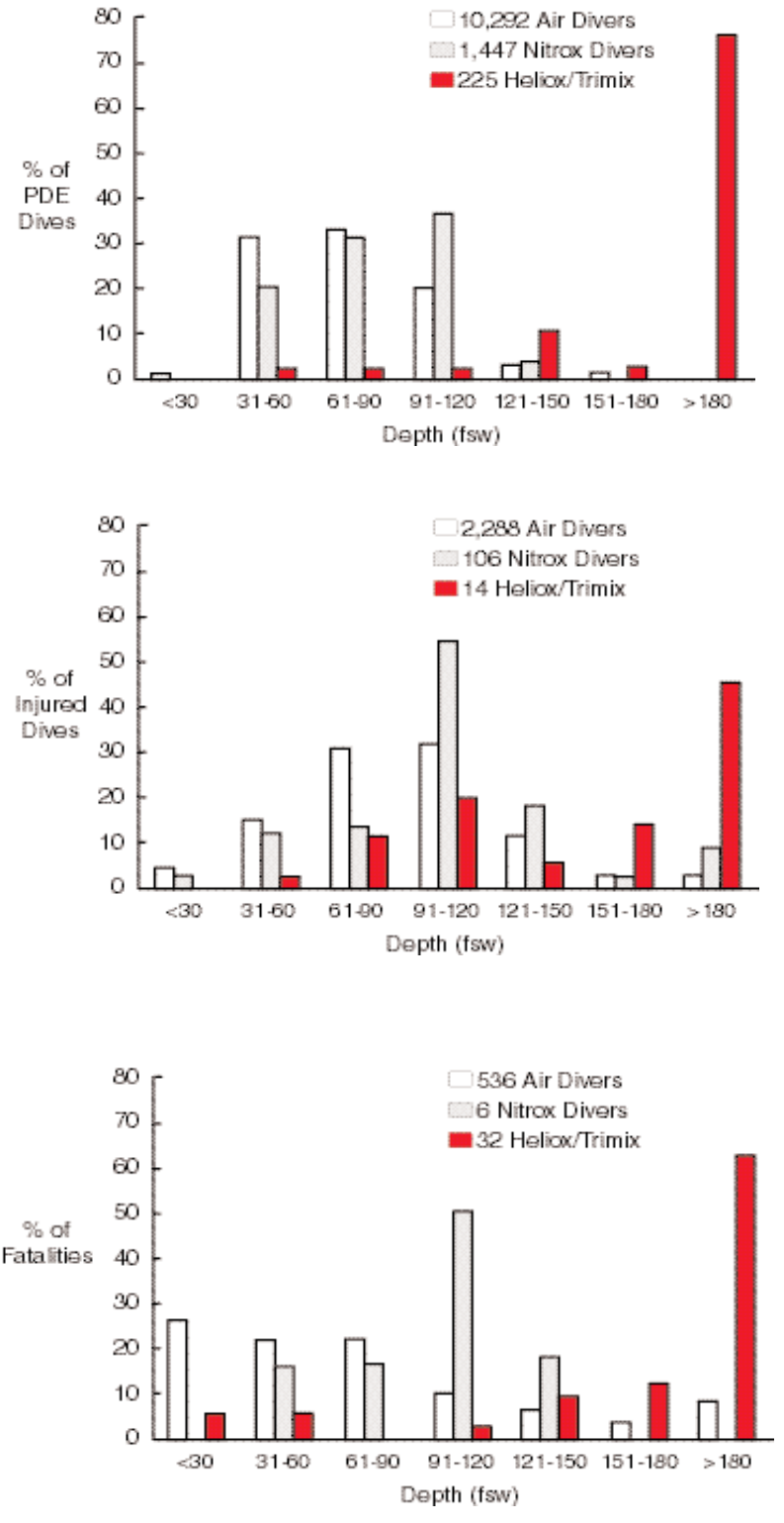


Figure 54 Distributions of maximum dive depths

Table 11 shows dive computer use. For PDE, 90% of all divers used computers. All PDE divers wore a computer to record their depth-time profiles even if they did not dive according to the computer. For injuries, half the air divers but only a quarter of the heliox/trimix divers used computers. Computer use was most common for nitrox and heliox/trimix fatalities.

Table 11 Dive computer use

	PDE	Injuries	Fatalities
Air	93%	53%	42%
Nitrox	92%	42%	89%
Heliox/Trimix	91%	27%	100%

Tables 12 and 13 show the proportions of the three populations and gas mixes that reported making a rapid ascent or running out of gas. Both events were uncommon for PDE. Running out of gas was common for both fatalities and injuries.

Table 12 Rapid ascent

	PDE	Injuries	Fatalities
Air	0.6%	23%	24%
Nitrox	0.7%	12%	22%
Heliox/Trimix	0%	18%	8%

Table 13 Out of gas

	PDE	Injuries	Fatalities
Air	0.2%	3.4%	44%
Nitrox	0.2%	4.8%	33%
Heliox/Trimix	0%	0%	35%

Figure 55 shows the estimated maximum inspired oxygen partial pressure in 74 nitrox diving injuries. About 5% of these exposures had a maximum oxygen partial pressure of 1.71-1.8 atm, but the most common partial pressures (45%) were 1.21-1.4 atm.

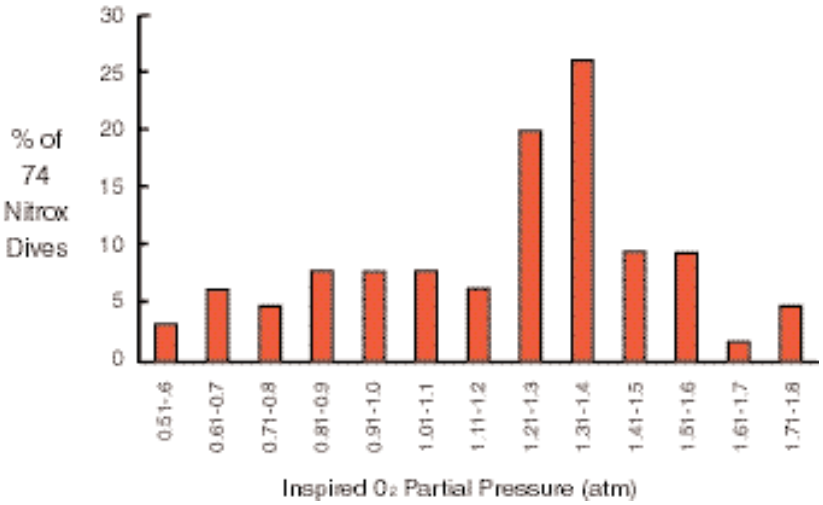


Figure 55
Maximum oxygen partial pressure and nitrox diving injuries

Data were available for only nine nitrox fatalities, and of these, only five had sufficient information for a minimal description of the dive profile. Table 14 summarizes information from for three of the cases. The maximum oxygen partial pressure did not exceed 1.35 atm, and there was no indication of oxygen toxicity in these cases. The critical events appeared to be rapid ascent or running out of gas.

Table 14
Nitrox fatalities

Depth (fsw)	Time (min)	% Oxygen	PIO2 (atm)	Comment
40	30	32	0.71	Rapid ascent
91	15	36	1.35	Rapid ascent
115	38	30	1.35	Out of Air

Two nitrox fatalities did have indications that oxygen convulsions may have occurred. In one case, an experienced diver was found unconscious at 135 fsw after about 45 minutes of breathing 38% oxygen in nitrogen with an inspired oxygen partial pressure of 1.93 atm. A seizure was not observed. The diver was not formally trained in nitrox diving but knew that the oxygen partial pressure was higher than recommended. He believed he could handle the mix and accepted the risk.

The second case involved an experienced cave diver who was observed to convulse during a cave dive. His dive profile involved 15 minutes on air at 80-104 fsw (0.87 atm maximum oxygen partial pressure) followed by 45 minutes on 40% oxygen in nitrogen at the maximum depth of 84 fsw (maximum 1.42 atm oxygen partial pressure).

Appendix A. Injury Case Reports

Introduction

In 1999, 1,149 cases of decompression illness were treated by chambers in the DAN network of referral hyperbaric centers, the highest number of cases reported since 1995, when 1,164 cases were reported.

The following case reports illustrate the range of clinical scenarios. Several issues still complicate the evaluation treatment and outcome process. These include the divers' lack of familiarity with symptoms of decompression illness, denial of symptoms, and the vague and subjective nature of many of their complaints.

Case 1. Neurological DCI After Repetitive Diving Complete Resolution with Treatment

The diver was a 38-year-old male in good health. He had been diving for two years and had completed about 15 dives per year. After a check-out dive on the first dive day, the diver performed repetitive diving on the following two days without incident. On the fourth day of diving, the diver performed two dives: 95 feet/29m for 35 minutes with a safety stop, a one-hour surface interval, and then a dive to 50 feet/15m for 44 minutes, also with a 20-foot/6-m safety stop. All of his dives were within acceptable decompression limits according to his dive computer. During the previous evening he had performed one dive, after which he consumed six beers.

Approximately one hour after the last dive of the day, he began to notice the sensation of weakness in his left hand. Over the course of the next hour he experienced tingling in his left hand, which extended from his fingertips to his forearm. A generalized feeling of weakness and fatigue followed this, as though he had just done a great deal of heavy exertion.

The diver's symptoms persisted for another hour, and he decided to contact a local physician for evaluation. He was placed in a chamber and recompressed according to U.S. Navy Table 6, with partial relief of his left wrist weakness and tingling after the treatment. His generalized sense of weakness had resolved. He was treated the following day with U.S. Navy Treatment Table 5 with complete relief of his remaining symptoms.

Dehydration after beer consumption could have played a role in this event. The onset of symptoms within two hours after surfacing is fairly typical. Early treatment after symptom onset probably contributed to his complete recovery.

Case 2. Flying After Diving with Delayed Symptom Onset and Hyperbaric Treatment

The diver, a 30-year-old male advanced open water diver with seven years of diving experience, had performed eight dives in the last 12 months and 150 since certification. He was in good medical health but had a history of three fractured vertebrae in his lower back during high school and a traumatic pneumothorax from a blunt trauma several years prior to his scuba injury.

While vacationing in Hawaii he performed two days of diving with his wife. He performed a total of four dives on the first day, which include one evening and one night dive. There were no problems with these dives, and the surface interval before his next dive the following morning was approximately 12 hours. He performed an 80-foot/24m dive for 25-minutes; after a surface interval of one hour and 30 minutes he dived again to 60 feet/18m for 35 minutes. He felt fine the remainder of the day, had no more than two alcoholic drinks that evening and took a commercial flight the next morning, approximately 30 hours after his last dive.

The following morning the diver awoke with general soreness and aches and pain in his shoulders

and elbows. He was somewhat fatigued but felt that his symptoms were primarily due to the long flight and carrying his luggage in the airport. He caught his next flight that morning and returned home, at an altitude of 5,000/1,524m feet above sea level. The diver went to work for the next four days. He attributed his persistent symptoms to tiredness and fatigue from his trip or a viral illness. He finally sought evaluation by a doctor five days after returning home and six days after the onset of symptoms.

During his evaluation he complained of shoulder, elbow and wrist pain, fatigue and dull pain in the muscles of his back and in his upper chest, with tingling and numbness in the right hand and forearm. He was found to have some difficulty concentrating, and his short-term memory was impaired. He received a short hyperbaric treatment, which resolved all his symptoms, with the exception of some remaining mild fatigue and muscle soreness. He received a second hyperbaric treatment the following day with complete resolution.

This case illustrates the point that mild symptoms of decompression illness can easily be confused with other injuries and illnesses. DCI symptoms do not commonly begin more than 24 hours after surfacing from a recreational scuba dive unless there has been an altitude exposure. While flying 18-24 hours after a dive is usually safe, occasionally symptoms can be precipitated by flying after a longer interval.

Case 3. Symptoms Mimicking Other Conditions

The diver was a 69-year-old, 5-foot-8, 170-pound male in reasonable health, although taking "stomach medication" and two medications for elevated blood pressure. He also reported a history of arthritis in his neck and lower back, but with no pain or symptoms at the time of the accident. He was an open water diver with 30 years of diving experience, having performed over 400 dives in the previous five years and 80 dives in the last 12 months.

On the first day of diving he performed three multilevel dives to 120-130 feet/36.5-40m. Dive times ranged from 30-40 minutes. The following day he dived to 110 feet/33.5m for 40 minutes. After a surface interval of one hour and 20 minutes, he dived to 96 feet/29m for 40 minutes. After a surface interval of four and a half hours, he performed a 113-foot/34m multilevel dive for 45 minutes. All dives were within acceptable limits according to his dive computer.

Within 30 minutes following exiting the water after his last dive, he developed a sharp left shoulder pain and tenderness in the back of his neck. Since he was used to experiencing occasional pain associated with his arthritis, he treated himself with a nonsteroidal anti-inflammatory medication that he commonly used. Over the next two days his neck pain gradually resolved, but his shoulder pain persisted. He also noticed that the painful area in his left shoulder appeared swollen, and that his left arm was weaker than his right. He had no other symptoms suggestive of decompression illness, such as numbness, tingling or extreme fatigue.

On the third day the diver was evaluated by his physician, who, despite unremitting shoulder pain, found no evidence of weakness or swelling of the left shoulder. The diver was compressed using U.S. Navy Treatment Table 6 approximately 72 hours after his symptoms first began, and he experienced complete resolution of all symptoms.

Symptoms that mimic other conditions, particularly if they are similar to pre-existing diseases, may not be recognized as decompression illness.

Case 4. Pain-Only DCI with Delayed Treatment

The diver was a 27-year-old, 5-foot-2, 120-pound, healthy female advanced open water diver who had been certified for six months and had made a total of 18 dives. Her first day of scheduled diving consisted of three dives to 35 feet/10.6m for 45 minutes each. Surface intervals were 45 and 25 minutes, respectively. On her second day of diving, she performed a 52-foot/15.8-m dive for 25 minutes; after a surface interval of two hours, she made a second dive to 60 feet/18m for 45 minutes. These dives were uneventful inland quarry dives. The following day she was scheduled to make two ocean dives, but due to being extremely seasick, she did

not participate in the first one. She eventually made a multilevel dive to 75 feet/22.8m for 45 minutes. She had no problem during ascent or descent.

The following day, approximately 24 hours after her last dive, the diver noticed a slight ache in her right elbow, wrist and ankle, which appeared to increase in intensity over the next 12 hours. After waiting three more days, she called a dive physician, but declined evaluation, preferring to wait and see if symptoms would resolve. On the fifth day, the diver sought medical evaluation. She denied carrying heavy equipment or any history of previous arm or wrist injury or symptoms similar to her present complaints. She was treated with a U.S. Navy Treatment Table 6, with complete resolution of her symptoms.

Although the onset of symptoms of decompression illness is usually less within the first few hours after surfacing from a scuba dive, it can be longer.

Case 5. Flying After Diving with Symptoms

The diver was a 47-year-old, 5-foot-2, 180-pound female who was physically active, with a history of hypertension, a sleeping disorder and a lower back injury for which she had surgery. She was an advanced diver with eight years of experience, having made one dive trip per year, 75 dives in the last five years and 20 in the past 12 months.

Prior to the accident, the diver had performed 14 dives during the course of six days. Each dive, which was usually multilevel, was within the limits prescribed by her dive computer and included a 3-minute safety stop. During each of her last two days of diving, she made a 94-foot/28.6-m dive followed by a dive to 50 feet/15m. Following her second dive on the last day of diving, she noticed that the muscles in her arms and legs were aching.

That evening she noticed that the joints in her legs and arms felt as if "they were cramping," and that she felt an urge to stand and stretch. The following morning, the diver flew home to the United States approximately 20 hours after her last dive. During the flight home, the diver noticed that the aching in both elbows and knees progressed to moderate pain. She also developed right shoulder pain and pain in both calves. Her right elbow pain was the worst, and she reported it as severe.

The diver waited two days before contacting a physician. Three days after her flight home she was treated with a U.S. Navy Treatment Table 6 and had gradual improvement of all of her symptoms. At the end of her treatment only her right elbow and right knee still had any degree of pain, and it was very mild. This pain resolved over the next 10 days.

Flying with symptoms can worsen existing symptoms.

Case 6. Flying After Diving with the Onset of Symptoms During the Flight

The diver, a 57-year-old. 5-foot-10, 153-pound male in good health, had been diving for two and a half years and had an advanced open water certification. He had performed a total of 54 dives during that time, with 44 dives within the last 12 months.

The diver performed 26 dives during the course of 12 consecutive diving days. On most days the first of two dives was to a depth between 60 and 100 feet/18 and 30m, and the second to less than 60 feet. He dived with a computer, following very conservative guidelines. His final day of diving started with a morning dive to 97 feet/29.5m, followed by an afternoon dive two hours later to 50 feet/15m. Other than normal fatigue, the diver felt fine. He drank two alcoholic beverages that evening, awoke the following morning feeling fine and boarded an aircraft 28 hours after his final dive. He had three commercial aircraft connections before he reached his home.

The first flight was a short hop at low altitude to a larger airport. The second flight was in a pressurized aircraft to the mainland of the United States. Shortly after reaching altitude, the diver began to experience a prickly sensation, primarily from his waist down, but also over his chest, back and arms. This was followed by the onset of mild joint pain in his legs, arms and hands. Symptoms lessened after landing, but increased again soon after reaching

altitude during his final flight home. The day following his arrival, the prickly skin sensation persisted in his legs, with pain in hands, left knee, and right elbow and forearm. The following day he contacted DAN for referral to a dive medicine physician. On examination no objective neurological deficits could be found, but the examining physician recommended recompression therapy for probable decompression illness. The diver declined to be treated and preferred to wait and see if his symptoms would resolve.

The following day the diver reported to a different hyperbaric facility for a second opinion. He received the same advice, and this time accepted treatment, which consisted of a U.S. Navy Treatment Table 6. Symptoms gradually improved during the treatment and had completely resolved by the end of recompression. The following day during the drive home he experienced a return of mild joint ache and prickly sensations in his legs. Over the next four days he treated himself with nonsteroidal anti-inflammatory drugs but his symptoms remained. He then returned to the hyperbaric facility, where he received a hyperbaric treatment every day for the next three days, for a total of four treatments. He was symptom free upon exiting the chamber and for the following five days.

At that time he was treated with non-steroidal anti-inflammatory drugs (NSAIDS) for mild recurrent symptoms, which eventually resolved completely, three months after his last hyperbaric treatment.

Case 7. Spinal Cord Decompression Illness with Paralysis

The diver was a male experienced scuba diver (he had made several trips to tropical dive sites) with a history of myocardial infarction 15 years previously, who was taking medication for high blood pressure. On his first day of diving he performed two dives: 53 feet/16m for 40 minutes followed by a surface interval of two hours and 14 minutes, then a 60-foot/28-m dive for 47 minutes (all within the limits of his dive computer). Approximately a half hour after his second dive, he began feeling a “pins and needles” sensation in his right arm and in both legs. He was evaluated and released at the local hospital because he did not have objective signs of decompression illness.

Approximately two hours, later he returned to the hospital because of worsening symptoms. His evaluation revealed loss of sensitivity and weakness in both legs. He had to be catheterized for inability to urinate. Recompression treatment was recommended, and shortly thereafter he was placed in a hyperbaric chamber for treatment. He was treated with an extended U.S. Navy Treatment Table 6 with minimal improvement. He had a second treatment several hours later, and over the next week and a half received two treatments per day. The diver experienced gradual improvement each day and was able to stand and walk by the end of therapy. He was able to urinate on his own but did have difficulty controlling bowel function. He continued to have numbness in the calves and soles of his feet and occasional pain from muscle cramping.

Following treatment, the diver waited three days without change in his symptoms before flying home to the United States. He experienced no worsening of his symptoms during the flight. Because of intermittent difficulty urinating and unsteadiness of his gait, he sought evaluation by a diving physician, who administered several additional hyperbaric treatments. At the point at which there was no incremental improvement during a hyperbaric session, treatments were stopped. Bowel and bladder functioning was close to normal, gait was significantly improved, but he continued to have numbness in his calves and the bottoms of his feet and some residual leg weakness.

Incomplete resolution of symptoms is less likely with longer time to treatment and older age. This case also illustrates the point that symptoms of decompression illness may not be accompanied by abnormal neurological signs on physical exam, particularly shortly after onset.

Case 8. Spinal Cord Decompression Illness with Paralysis and Multiple Treatments

The diver was a 34-year-old, 5-foot-10, 145-pound male who had been diving for three months, having made a total of 10 open water dives. He had a history of migraine headaches and intermittent abdominal pain.

During the first day of diving, he performed a 75-foot/22.8m dive for 29 minutes, which included a three-minute safety stop at 15 feet/4.5m. After returning to the boat, he noticed his left arm and shoulder tingling with some sensation of numbness. Although he could walk, he felt that his left leg was dragging a little. These symptoms lasted approximately an hour and did not alarm the diver. Two hours after surfacing, he made a dive to 49 feet/15m for 36 minutes, performing a safety stop during ascent. The patient had no symptoms during the dive or during the one and a half hour surface interval before his third dive, which was to a depth of 40 feet/12m for 48 minutes, with a safety stop. His ascent was at an appropriate rate, and his depth-time exposures were all within the limits of his dive computer. He experienced no further symptoms that day or evening.

The following day the diver felt fine and made a dive to a maximum depth of 91 feet/27.7m. After only two minutes at the deepest depth, he ascended to 60 feet/18m for approximately 12 minutes, then ascended to 30 feet/9m, where he stopped for approximately four minutes before ascending to 10 feet/3m, where he made another two-minute stop. The diver and his buddy surfaced well away from the dive boat, and while waiting for the boat to return to pick them up, the diver again began to feel numbness in his arm and shoulder. As the buddy was assisting the diver on the surface, the diver became unresponsive and lost consciousness. He remained unconscious until the boat crew picked him up and brought him on board. He was given 100 percent oxygen and gradually became more alert.

He was then transported to the hyperbaric chamber, where he felt much better and only complained of numbness on his left side and in both thighs. He was able to walk and move about with some assistance. During his treatment in the chamber, he began experiencing numbness from the midchest region down, and his leg weakness worsened. The treatment was extended up to 12 hours. After a 20-hour surface interval he received a second treatment, with an extended U.S. Navy Treatment Table 6. He was then transferred to a hospital-based facility.

At this point the diver was unable to sit up unassisted and required a urinary catheter. He received an additional Table 6 and began a series of shorter two-hour treatments, 14 treatments in all. After making slow progress during these treatments, he was able to walk short distances unassisted, although he lacked coordination, balance and muscle strength in his lower extremities, and strength was significantly reduced. Bowel and bladder function returned to normal. He continued to have small patchy areas of numbness in his left leg.

This diver experienced severe neurological decompression illness after what appeared to be extremely safe dives. The symptoms exhibited on the first day of diving should have been a warning to the diver, but unfortunately they were ignored.

Appendix B. 1999 Dive Fatality Reports

Introduction

In 1999, 109 scuba diving fatalities were reported to DAN by numerous sources, including investigative agencies, medical examiners, U.S. Coast Guard and personal contacts. Of these 109 cases, DAN collected additional information on 78 cases. DAN does not currently follow up on cases involving commercial divers, military divers, free divers, or non-U.S. citizens. The number of cases included in this year's report is slightly lower than the average for the past 10 years, which is 88 diving fatalities.

The following case reports represent all 78 diving fatalities that DAN followed up on in 1999. DAN is not an investigative agency, but collects data for research purposes only. In this regard, we do not always have access to the complete medical record of an individual, nor can we obtain all of the investigative reports concerning a specific event. We rely on investigative agencies, the U.S. Coast Guard and medical examiners to share information with us. We also rely on personal contact with witnesses, friends and family of the diver, and individuals involved with the dive and subsequent rescue attempts. Without the cooperation of numerous individuals as well as federal, state and local agencies, this report would not be possible.

The reason DAN collects dive fatality data and passes it along to the dive industry is that most of the fatal diving accidents in this report are avoidable. The vast majority of dive fatalities involve a significant error in judgment by the diver or a violation of generally accepted safe diving practices. DAN hopes that these case reports illustrate the mistakes that were made and that everyone is able to learn from them. The primary mission of DAN is diver education and dive safety.

As has been the case in previous years, common factors associated with fatal diving accidents included running out of air, rapid ascents, diver inexperience and coronary artery disease. While the terminal event is frequently drowning, that is simply a final common pathway, and the events that resulted in the drowning are more significant in terms of preventing similar mishaps in the future. Appropriate medical screening and conservative diving habits — as well as having divers not venture beyond their level of training and experience — would decrease the number of fatal diving accidents that occur each year

99-01 - Spearfishing to Deep Depth with Rapid Ascent

A 25-year-old male received his initial open-water diving certification just three months earlier and had minimal diving experience. He was spearfishing on an oil rig and descended to 220 fsw / 67 msw to shoot a large fish. The diver appeared to struggle on the bottom and made a witnessed rapid ascent. Witnesses stated that he initially seemed fine on the surface, then vomited through his regulator and lost consciousness. The diver was transported to a local medical facility where he was pronounced dead on arrival.

99-02 Non-Certified Diver on a Resort Course Dive

A 37-year-old female was making her first ever dive as part of a non-certification resort course. She descended to 20 fsw / 6 msw with her boyfriend as a dive buddy and immediately became uncomfortable in the water. The decedent spit her regulator out of her mouth. Her buddy attempted to assist her, but she knocked his regulator out of his mouth as well. The decedent lost consciousness and was assisted to the surface. She was transferred to a recompression chamber, where a U.S. Navy TT6A was initiated, but she was eventually pronounced dead. The autopsy report was not made available, but the death was signed out as a drowning.

99-03 Entanglement in Kelp with Rapid Ascent

A 53-year-old male divemaster was teaching students when his buddy became entangled in kelp. The divemaster also became entangled while rendering aid. The incident occurred in 40 fsw / 12 msw during descent. The divemaster made a witnessed rapid ascent, after which he lost consciousness and was taken to the recompression chamber. He was pronounced dead prior to the initiation of therapy.

99-04 Experienced Diver in Poor Physical Condition

A 60-year-old female had two years of dive experience and divemaster certification. She made a shore entry dive to 75 feet / 22.6 msw for 40 minutes and surfaced. During the surface swim back to the beach, the decedent complained of extreme fatigue and required assistance. She eventually lost consciousness. She was taken to a local hospital, where she died that evening. The decedent had complained of some fatigue prior to the dive and was in a poor state of physical conditioning. An autopsy report is unavailable; clinically an air embolism was suspected. The history and witness accounts do not corroborate an air embolism, and a cardiac event, among other possible contributing factors, cannot be excluded.

99-05 Experienced Diver Who Lost Consciousness on Ascent

A 54-year-old experienced male diver made a wreck dive to 120 fsw / 36.5 msw for 20 minutes. He signaled to his buddy that he wanted to ascend, but they became separated when the decedent lost consciousness at 40 fsw / 12 msw while going up the anchor line. The decedent's body was recovered six hours later. The decedent was out of air, had not dropped his weight belt, and had broken a strap on a fin. An air embolism is less likely the cause of death if loss of consciousness truly occurred at 40 fsw. An autopsy was performed, and the findings were consistent with drowning.

99-06 Experienced Instructor Challenging Deep Air Record – Made a Rapid Ascent

A 30-year-old dive instructor who was a very experienced diver was challenging the open-water air depth record. He planned a dive to 400 fsw / 121.9 msw; he would be accompanied by a buddy down to 200 fsw / 60.9 msw, continuing on his own beyond that depth. This dive was made in cold water, and the decedent wore a drysuit. The decedent had a history of Type I DCS two years earlier. For unknown reasons, the decedent made a rapid, uncontrolled, ascent from 385 fsw / 117 msw and shot past decompression stops and safety swimmers. He died during the transport to a medical treatment facility.

99-07 Open-Water Diver with Significant Past Medical History, AGE

Little information is available on the death of this 64-year-old female who possessed open-water diving certification. Her past medical history included high blood pressure and an elevated serum cholesterol. The decedent and her buddy made a dive to 40 fsw / 12 msw for 15 minutes, but they became separated when the dive buddy had a mask problem. The decedent was found on the surface, unconscious, with her buoyancy compensation device fully inflated. An autopsy was performed; the cause of death was released, but the full autopsy report was not available.

99-08 Experienced Instructor Spearfishing on Oil Rig – AGE with Head Trauma

A 44-year-old male, an extremely experienced dive instructor, was spearfishing on an oil rig with another diver. The decedent speared an extremely large grouper at 190 fsw / 57.9 msw while his dive buddy waited up at 130 fsw / 39.6 msw. He then ascended to meet up with his buddy and signaled that he planned on bringing the fish to the surface. The two divers separated again, and the decedent went to the surface, apparently striking his head on part of the rig during the ascent. A third diver who was waiting back in the boat saw the victim surface, call for help, then lose consciousness. The decedent's body submerged before he could be brought into the boat; recovery occurred 30 minutes later. He was pronounced dead at a local hospital. The decedent's tank was empty, and his regulator showed signs of poor maintenance. He had

not dropped his weights and still had the fish and his spear gun in tow while he struggled on the surface. The autopsy and subsequent investigation all point to an air embolism as the cause of death, with head trauma as a contributing factor.

99-09 Experienced Advanced Diver with Significant Past Medical History

A 47-year-old male had advanced open-water diving certification and extensive experience. He had a history of insulin-requiring diabetes mellitis: his past surgeries included coronary artery bypass grafting, a kidney transplant and multiple toe amputations. The decedent was taking antibiotics for an unknown reason and had recently experienced hypoglycemic events. He and a dive buddy made a 30-minute dive to 40 fsw / 12 msw from a boat. The two divers became separated during ascent and the decedent did not return with his buddy. Other divers found the decedent on the bottom, unconscious, 20 minutes later. Resuscitation efforts were unsuccessful. The decedent's tank was empty. A cardiac event or hypoglycemic episode cannot be completely excluded.

99-10 Panicked Diver

There are few details available on the death of this female diver, including her age and certification level. She was with a group of divers when she indicated that she was nauseated; she then panicked at depth. The autopsy and associated reports were not made available.

99-11 Advanced Open-Water Student Using Drysuit for First Time

A 21-year-old male certified diver had fewer than five lifetime dives and was a student in an advanced open-water certification course. He was using a drysuit for the first time and complained prior to the dive that the suit was leaking. The decedent struggled during the surface swim and never descended. He lost consciousness on the surface and was not able to be resuscitated. An autopsy was performed, but the report is not available.

99-12 Advanced Certified Diver Who Failed to Turn Air on During Second Dive

A 56-year-old male diver had advanced open-water certification and 50 lifetime dives. He was obese and in a poor state of physical conditioning. The decedent made a shore entry dive into a quarry, without a buddy, and stayed at 29 feet / 8.8 msw for 15 minutes. He apparently exited the water to cool off and re-entered the quarry without turning his air back on. The decedent was found unconscious on the bottom 15 minutes after last being seen on shore. The autopsy findings were consistent with drowning.

99-13 Solo Diver Who Had an Out-of-Air Emergency, Panic Attack and Rapid Ascent

A 32-year-old male diver with advanced open-water certification and an unknown level of experience made a wreck dive to 100 fsw / 30.4 msw in a large group. Several divers reported seeing the decedent on the bottom, alone, taking pictures. The decedent was later seen making a panic ascent to 60 fsw / 19 msw and buddy breathing off another diver's pony bottle. He lost consciousness at depth and was brought to the surface. He died during transport to the local hospital. The local medical examiner ruled the death a "heart attack," which would be extremely unlikely and is not corroborated by the history. The diver lost a fin while on the bottom and had an out-of-air emergency. While an air embolism is certainly possible in this case, the history of loss of consciousness while still at 60 fsw is more consistent with drowning. An autopsy was performed by the local medical examiner, but the report was not released.

99-14 Diver Surfaced Alone After a 90 FSW-Dive, Found on Bottom Unconscious

A 39-year-old male had advanced open-water certification and had completed 25 lifetime dives. He made a dive on a wreck with a large group of divers, but he did not have a designated dive buddy. After 20 minutes into an uneventful dive to 90 fsw / 27.4 msw, the divemaster noticed that the decedent had only 800 psi of air left and sent him to the surface. The decedent apparently completed a safety stop and was seen on the surface holding onto a float as other divers completed the final stages of the their dive. When a head count was performed

on the boat, the decedent was noted as missing. A search found him at 111 fsw / 33.8 msw, unconscious and with the regulator out of his mouth.

99-15 Undisclosed Problem on Ascent from 150 FSW

DAN does not have a report of the investigation or autopsy related to the death of this 28-year-old male who had open-water diving certification. He made a wreck dive to 150 fsw / 45.7 msw with a large group of divers and experienced an undisclosed problem during ascent.

99-16 Newly Certified Diver Making First Dive Since Check-out Dives – Out of Air

A 37-year-old male received his initial open-water diving certification one week earlier. This was his first dive since his check-out dives. The decedent made a shore entry dive to 45 fsw / 13.7 msw for 35 minutes with a buddy, but the two divers became separated during their return to shore. The decedent ran out of air and may have been over-weighted. He ditched his gear in an attempt to get to the surface but was found unconscious on the bottom 15 minutes later. The autopsy findings were consistent with drowning.

99-17 Diver Conducting Personal Task

A 47-year-old male was cleaning the hull of a boat with a dive buddy and using scuba equipment. His dive certification level and experience are not known. During the surface swim back to shore, the diver apparently drowned. A cardiac event or air embolism cannot be excluded on the minimal history provided. The autopsy and investigative reports were not made available.

99-18 Inexperienced Diver Making First Night Dive, Panicked During Ascent

A 27-year-old female had open-water certification but had completed fewer than 20 lifetime dives. She was making her first night dive in a small group and, for some unknown reason, panicked during ascent. The decedent knocked her dive buddy's regulator out of his mouth and, as he concentrated on getting his alternate air source out, the two divers became separated. A safety diver pulled the decedent up to the boat. She was transferred eventually to a nearby medical facility. Resuscitation efforts were unsuccessful. The autopsy report was not made available for review.

99-19 Open-Water Certification Student – Loss of Consciousness During Post-Dive Surface Swim

A 48-year-old male was a student in an initial open-water certification course. He completed an uneventful dive to 20 fsw / 6 msw for 15 minutes but complained of fatigue on the surface. The decedent lost consciousness during the post-dive surface swim and could not be resuscitated. An air embolism cannot be excluded, but the dive history and the decedent's past medical history and lack of physical conditioning make a cardiac event more likely. The autopsy report was not made available.

99-20 Newly Certified Diver: Made a Deep Dive, Ran out of Air and Made a Rapid Ascent from 170 FSW / 51.8 MSW

A 19-year-old male received his initial open-water certification two weeks earlier. He made a dive to 227 fsw / 69 msw with two dive buddies. The three divers ascended to 190 fsw / 57.8 msw after a bounce to their maximum depth. The decedent ran out of air and began to buddy breathe with the second diver. The third diver then ran out of air, and the decedent essentially made a free ascent to the surface from 170 fsw. The decedent was taken to a local hospital, where he was pronounced dead. The second diver was treated numerous times for severe decompression sickness and still has residual symptoms. The third diver never developed symptoms of decompression sickness. The two surviving divers went back into the water to perform some unspecified "in-water recompression" on air after the emergency ascent. An autopsy report on the decedent was not made available.

99-21 Significant Past Medical History – Loss of Consciousness on Surface

A 51-year-old morbidly obese male had significant diving experience, but numerous health problems. He made a dive to 30 fsw / 9 msw with a buddy, but the divers became separated when the decedent surfaced because of a problem with his regulator. Witnesses say the decedent began a surface swim then rapidly lost consciousness. Resuscitation

efforts were unsuccessful. The autopsy findings were consistent with drowning; a cardiac event or other contributing natural disease factor cannot be entirely excluded.

99-22 Diving Without A Specified Buddy

The experience level of this 20-year-old male certified diver is unknown. He made a dive to 110 fsw / 33.5 msw for 50 minutes in a large group. It is uncertain if the original dive plan called for a decompression dive or if the diver became lost in the wreck he was diving on. It is also uncertain if the diver had a designated dive buddy. After the decedent did not return with the rest of the group, the divemaster went back down and found him near the anchor line. The decedent was unconscious when brought from depth, but he had not run out of air. No details regarding the autopsy or subsequent investigation were made available.

99-23 Student in Open-water Course – Loss of Consciousness on Ascent

A 56-year-old female was a student in an initial open-water dive certification course. A group of six divers and an instructor were performing checkout dives in a quarry to a depth of 20 fsw / 6 msw using a shore entry. During the second dive of the day, the decedent lost consciousness on ascent and was assisted to the surface. She was transported to a nearby hospital where she died 20 hours later. The autopsy disclosed focal infarcts in the medulla and global ischemic damage in the brain.

99-24 Non-Certified Diver Who Ran Out of Air While Spearfishing

A 52-year-old male had no formal dive certification and very limited diving experience. He was morbidly obese and was taking numerous prescription medications. The decedent made two dives to 28 fsw / 8.5 msw with a buddy in order to spearfish. He ran out of air during the second dive, and the two divers buddy breathed to the surface. The decedent was initially breathing on the surface but became short of breath and then stopped breathing. Resuscitation efforts were unsuccessful. The autopsy disclosed evidence of significant natural disease processes in addition to findings consistent with an air embolism.

99-25 Newly Certified Diver with Fewer Than 20 Lifetime Dives

Little information was made available about the death of this 22-year-old female; she had just completed initial open-water certification and had fewer than 20 lifetime dives. The history provided is consistent with the diver suffering an air embolism. She was taken for recompression therapy, which was unsuccessful.

99-26 Solo Diver Collecting Lobster – Entangled in Dive Flag Rope

This 65-year-old male certified diver had extensive diving experience and frequently made dives without a buddy or another person on the boat. He also had a habit of diving until his tank was down to approximately 200 psi remaining. He often used a dive flag attached by a rope to his buoyancy compensation device. The decedent made a dive to collect lobster and was not reported missing for several hours. His body was found floating on the surface two days later by a group of fishermen. The decedent was entangled in his dive flag rope, and his tank was empty. He was dressed in long pants and a shirt for thermal protection. Post-mortem toxicology on body cavity fluid was positive for alcohol, but the level was not high enough to exclude decomposition as the source.

99-27 Student with Significant Past Medical History Diving in an Advanced Course

A 69-year-old female had open-water certification and was a student in an advanced open-water course. She had been diving for 10 years. The decedent's medical history was notable for coronary artery bypass surgery one year earlier. She made a deep dive to 131 fsw / 39.6 msw for 14 minutes, had an uneventful ascent to 35 fsw / 10.6 msw, but became separated from her instructor and the other divers prior to reaching the surface. There is little information available on the events that occurred in the water, and an autopsy report was not available. The pathologist's interpretation of the cause of death was provided. An air embolism cannot be excluded based on the dive history.

99-28 Student in an Advanced Course with Significant Cardiac Medical History

A 65-year-old male had basic open-water certification but fewer than 20 lifetime dives. He was enrolled as a student in an advanced open-water course and made a shore entry dive for a planned 80 fsw / 24.3 msw for a 50-minute dive. Shortly after entering the water and swimming away from the pier, the decedent lost consciousness and sank beneath the surface. Resuscitation efforts at the scene and at the local hospital were unsuccessful. An autopsy was not performed, but the decedent had a past medical history that, along with the input of witnesses, is consistent with the medical examiner's presumed cardiac cause of death.

99-29 Uncertified Diver Who Panicked During Descent

A 28-year-old uncertified female was apparently making a dive under the instruction of her father, who was not a certified instructor. She panicked during descent and was also possibly over-weighted. After losing consciousness in the water, the decedent was brought to the surface. She was eventually transferred to a recompression chamber, where she failed to respond to treatment. The autopsy report was unavailable, but the cause of death was listed as drowning.

99-30 Experienced Diver Who Went Spearfishing Alone

A 45-year-old male had open-water certification and significant diving experience. He was spearfishing with a large group of divers but separated from the group without a dive buddy. He was known to dive alone frequently. The decedent did not return to the boat with the other divers. His body was recovered three days later, and his tank was empty. The decedent may have suffered an air embolism, but that cannot be proven without witnesses to the event and with minimal autopsy findings after a long post-mortem interval.

99-31 Certified Diver Making Two Dives in Rough Seas and Strong Currents

A 35-year-old male was a certified open-water diver, but he had only completed seven lifetime dives. He made two dives in rough seas in a strong current. The first dive consisted of a bounce to 50 fsw / 15.2 msw and was quickly aborted for unknown reasons. During the second dive to the same depth, the decedent soon became separated from his dive buddy and was found floating unconscious near the boat. The autopsy disclosed findings consistent with drowning, along with evidence of head trauma, including an acute subdural hematoma.

99-32 Student Who Had Not Completed His Check-Out Dives Became Separated from Buddies, Made a Rapid Ascent

An 18-year-old male had not yet completed his initial open-water certification class and, in fact, had not gone beyond the pool phase of training. He performed an open-water dive with two dive buddies and was noted to be anxious and having difficulty controlling his buoyancy. The divers spent less than 10 minutes at 27 fsw/ 8.2 msw, and then the decedent became separated from the others on the bottom. He made a witnessed rapid ascent and was later found floating on the surface unconscious. The autopsy disclosed a right pneumothorax and subcutaneous emphysema in addition to changes consistent with drowning.

99-33 Experienced Diver Collapsed in Surf Zone After Dive

A 56-year-old female had advanced open-water certification and extensive dive experience. She had experienced an episode of near-drowning two years earlier. The decedent made three dives on a coral wall in order to photograph fish. She became separated from her buddy at the end of the third dive. The decedent collapsed in the surf zone while walking back to shore. The forensic pathologist concluded that the death was due to natural causes, perhaps exacerbated by diving. The autopsy findings are consistent with that scenario.

99-34 Diver Making Shore Dive Alone in Rough Surf – Found on Surface with Head Trauma

The certification and training level of this 55-year-old male are unknown. He made a shore entry in rough surf with another diver, but the buddy

quickly returned to shore with an equipment problem. The decedent was later found on the surface, unresponsive, with significant evidence of blunt head injury. The medical examiner initially signed out the death as cardiac-related, but after reviewing the decedent's recent history of significant physical activity without symptoms of ischemic heart disease, he concluded that the head trauma was sufficient to cause unconsciousness and result in drowning. Of note is the fact that the decedent suffered a significant closed head injury in the past that had required surgery.

99-35 Experienced Diver Using a Rebreather Entered the Water Without Buddy and Without Finishing Pre-Dive Equipment Check

A 72-year-old male with extensive dive experience was qualified on a rebreather diving apparatus, which several research divers were using to explore a cave system in a freshwater spring. The decedent was preparing for one last dive to take a few pictures before departing the dive site. He had forgotten his fins back in his room and returned to retrieve them while his dive buddy went off to get his own personal dive gear. The decedent returned to the entry point and submerged before his dive buddy was present. He was found a short time later, unconscious and on the bottom. A thorough investigation revealed that the decedent's rebreather was switched to accept an external gas source when it should have been configured to employ the gas flasks contained within the rig itself. The decedent would have noticed this, but he failed to complete the extensive pre-dive checklist that is required before diving that particular rebreather. An autopsy disclosed a large amount of blood in the stomach, which may have contributed to the decedent's lack of attention to detail that day or may have occurred at the same time he lost consciousness. The decedent had skipped portions of his pre-dive checklist for this apparatus in the past.

99-36 Infrequent Diver Making First Ocean Dive, Ran Out of Air and Made a Rapid Ascent

A 43-year-old male was a certified but inexperienced and infrequent diver. He was making his first lifetime ocean dive, having previously only made dives in lakes and quarries. The decedent ran out of air after a 15-minute dive to 50 fsw/15 msw, and after making a rapid ascent, he could not get up the ladder on his own. He lost consciousness and could not be resuscitated. The autopsy showed, in addition to evidence of natural disease processes, some possible changes consistent with pulmonary barotrauma.

99-37 Student in Open-Water Course Making First Dive

A 53-year-old female was a student in an initial open-water diving certification class making her first ever lifetime dive. The decedent had an uneventful dive except for communicating a feeling of fatigue to the instructor. Shortly after surfacing she lost consciousness and was transferred to a recompression facility. After no response to recompression therapy, a thorough evaluation revealed the underlying cause for loss of consciousness. An autopsy was not performed, and it is unlikely that the dive had anything to do with this woman's death. The cause of death was a ruptured berry aneurysm along with an acute myocardial infarction.

99-38 Student in an Advanced Course Had Difficulty Breathing and Panicked

A 45-year-old male had open-water certification and moderate diving experience. He was under instruction for advanced open-water certification. The decedent experienced difficulty breathing and panicked prior to descending. The autopsy disclosed a previously undiagnosed malignancy.

99-39 Inexperienced Diver Diving with Equipment Problems Panicked on Descent and Refused to Take Regulator from Buddy

A 23-year-old female had open-water certification but limited diving experience. She made two dives to 10 fsw/3 msw using a shore entry with a buddy. The decedent did not have her buoyancy power inflator connected because the couplings did not match; she also carried weights in the pockets of the BC. The decedent had significant problems with buoyancy during the first dive and panicked during the descent for her second dive. She refused to take both her own second stage as well as the

second stage from her buddy's octopus. Resuscitation efforts on the beach and at a nearby hospital were unsuccessful.

99-40 Inexperienced Diver Who Panicked After Equipment Difficulties and Submerging with Snorkel Instead of Regulator

A 34-year-old male had received initial open-water certification just a few months earlier and had less than five lifetime dives. He and his dive buddy made a shore entry dive in a pond to a depth of 25 fsw/106 msw for 30 minutes. The decedent experienced significant difficulty with his gear while on the bottom, and this was compounded by extensive silt they stirred up. He went to the surface with his buddy to reorient his gear and in the process descended with the snorkel in his mouth instead of his regulator. The decedent then panicked on descent and struggled to get to the surface, losing a fin in the process. After submerging again, the decedent was pulled from the water, unconscious, by another diver. An investigation revealed the decedent had his snorkel on the right side instead of the left and his buoyancy compensation device was on incorrectly. In addition to the toxicology results noted above, a nasal swab showed traces of cocaine indicating fairly recent use.

99-41 Experienced Diver Complaining of Significant Fatigue

A 44-year-old male had advanced open-water certification and significant diving experience. He made a shore entry dive and a surface swim, but before descending he complained of significant fatigue and dropped his weight belt. The decedent lost consciousness, was brought to shore, and then transferred to a local hospital. He was pronounced dead upon arrival.

99-42 Experienced Cave Diver Entangled in the Guideline

This is one diver involved in a double fatality that occurred during a cave exploration dive. A 46-year-old male was a certified cave diver and very experienced. He and his dive buddy penetrated the cave and descended to 78 feet/23.7 msw. The divers had a guideline break, and they became entangled in the line, as visibility became nearly zero. The bodies of the divers were recovered the next day when someone realized that they were missing. Both divers were out of air; this diver had removed his tanks, presumably in an effort to exit through tight spaces.

99-43 Infrequent Diver Dived to 90 FSW Alone While Low on Air to Free the Anchor

The information on this diving fatality, which involved a 47-year-old female, is incomplete. She was known to be an infrequent diver, but her experience level is not known. The decedent made two uneventful dives, and she complained of fatigue on the surface after the second dive. Despite having only 500 psi/34 bar of air remaining in her tank, the decedent went down alone to 90fsw/27.4msw to free the anchor from the bottom. When she did not return and the anchor came loose, her husband, who was also acting as her dive buddy, solicited assistance. The decedent's body was not found until the next day. The autopsy report is not available.

99-44 Experienced Diver Became Separated from Buddies – Probable Cardiac Problem

A 59-year-old male had advanced open-water diving certification and extensive diving experience. He made a wreck dive in freshwater to 125fsw/38msw and became separated from his buddy and the other divers. A thorough search found the decedent's body one hour later, on the bottom and adjacent to wreck. The decedent apparently complained of fatigue prior to the dive, and an equipment check showed that his tank was nearly out of air. The medical examiner concluded that the cause of death was cardiac related, and nothing found in the rest of the investigation refutes that theory.

99-45 Technical Diver with Coronary Artery Disease Diving Trimix for Wreck Dive

A 52-year-old male was making a deep trimix dive to penetrate a wreck. He was a certified technical diver and very experienced. The decedent descended with two other divers, but for an unknown reason, he decided to abort the dive after a 10-minute

bottom time. When the other divers surfaced, the decedent could not be located, and rescue divers found him on the bottom near the wreck. The equipment evaluation revealed no significant problems. A cardiac event cannot be excluded, and coronary artery disease was determined to be a contributing factor by the medical examiner.

99-46 Experienced Diver Spearfishing Solo Became Trapped In Rocks

A 40-year-old experienced, certified diver made a shore entry dive in freshwater to go spearfishing. He did not dive with a buddy. The decedent became entrapped in rocks on the bottom, and his body was not recovered until the next day when he was reported missing. The diver's tank was empty.

99-47 Altitude Dive in a Drysuit Experiencing Significant Buoyancy Problem

A 64-year-old male had advanced open-water certification but fewer than 20 lifetime dives. He made a shore entry dive in a lake located at greater than 5,000 feet/1,524m above sea level employing a drysuit. The diver complained of fatigue prior to the dive. He was heavily weighted and experienced significant buoyancy problems during the dive, which went to 18 feet/5.4m maximum depth. Shortly after beginning the dive, the decedent ascended on his own. His dive buddy surfaced a few minutes later and found him unconscious on the surface. The decedent was pronounced dead at a local medical treatment facility.

99-48 Technical Diver With Health Problems Making Deep, Wreck Dives On Trimix

A 44-year-old male had only two years' dive experience but was a certified technical diver. He was morbidly obese and had numerous health problems. The decedent was making a series of deep, wreck penetration dives using trimix. He had an uneventful first dive of the day, though witnesses stated that he had difficulty swimming from the boat to the anchor line prior to descent. Prior to initiating his descent for the second dive, the decedent lost consciousness on the surface and resuscitation efforts were unsuccessful. The autopsy disclosed significant evidence of natural disease processes.

99-49 Experienced Diver Having Breathing Difficulty At Depth

A 43-year-old female diver with advanced open-water certification and significant diving experience made a dive to 40fsw/12msw for 30 minutes. The decedent had an unknown problem at depth, appeared to have some difficulty breathing, and spit her regulator out shortly after reaching the surface. She lost consciousness shortly thereafter. The body was embalmed prior to an autopsy, and the autopsy report was not made available for review. The possibility of a cardiac event certainly exists.

99-50 Infrequent Diver Separated from Buddy Became Entangled in Kelp

A 41-year-old male had advanced open-water certification and moderate experience but was an infrequent diver. He made a shore entry dive but had difficulty equalizing his ears, and all of the other divers, including his buddy, went ahead of him. The decedent did not return with the other divers, and his body was not recovered until 24 hours later. He had attempted to drop his weight belt, but the belt became entangled in his BC strap. The decedent's regulator was entangled in kelp. The autopsy findings were consistent with drowning.

99-51 Diver Involved in Introduction to Diving Course

A 42-year-old female was not a certified diver and was using scuba gear from a cruise ship as part of an introduction to diving experience. She spent five minutes at 8fsw/2.4msw before being found unconscious without her regulator in her mouth. The autopsy findings were consistent with drowning; other factors, such as heart disease, may have contributed to this death.

99-52 Diver Making Shore Dive in Rough Surf Became Separated From Buddy

A 47-year-old male certified diver made a shore entry dive to 21fsw/6.4msw. The sea state was rough, and the decedent was likely tossed about in the surf zone along the rocks. The decedent and his dive buddy became separated, and the dive buddy later found the decedent on the bottom, unconscious, with his regulator out of his mouth. The stricken

diver was taken to a local hospital where he was pronounced dead. The autopsy lists an accidental cause of death, but a major contribution by cardiovascular disease cannot be excluded.

99-53 Diver Entering Water Without Buddy

A 25-year-old male had open-water certification and two years of diving experience. He made a freshwater dive to 30fsw/9msw and entered the water without a dive buddy as part of a search pattern drill. The decedent was supposed to set up the search line, but the bag containing the line came to the surface shortly after the decedent descended. The dive site was remarkable for excessive debris, a thick silt bottom, and extremely poor visibility. Other divers entered the water to recover the decedent. Resuscitation efforts were unsuccessful, and the diver was pronounced dead on arrival at the local hospital.

99-54 Diver Experienced Equipment Problems and Became Separated From Buddy

A 57-year-old female had open-water certification and moderate experience in the two years since she became a certified diver. She made a shore entry into a quarry with her husband as a dive buddy. The couple made two dives to 40-50fsw/12-15msw, with the first dive lasting 35 minutes. During the second dive, the decedent had regulator and buoyancy problems. The two divers became separated, and the husband found the decedent unconscious on the bottom with her regulator out of her mouth. The stricken diver was brought to the surface and transported to a local hospital, where she died two days later.

99-55 Experienced Diver Made a Rapid Ascent and Became Unconscious at Surface

A 76-year-old male was a very experienced, advanced open-water diver who was spearfishing with another diver. They had spent 25 minutes at 78fsw/23.7msw when the decedent was assisting his buddy in removing a fish off his spear. The two men had significant difficulty removing the fish, and the decedent made a witnessed rapid ascent. Upon reaching the surface, the decedent cried out for help before rapidly losing consciousness. Resuscitation efforts were unsuccessful. The autopsy discussed changes consistent with air embolism, along with evidence of significant natural disease processes.

99-56 Diver With Equipment Problems Was Spearfishing And Became Separated From Buddy

A 27-year-old male certified diver was spearfishing around an oil rig in a large group. The dive included excursions down to 140fsw/42.6msw. The decedent was noted to be having problems with leaks from his buoyancy compensation device and pony bottle and was also having some trouble controlling his buoyancy at depth. He became separated from his buddy at approximately 60fsw/18msw while attempting to fix his BC. An immediate but unsuccessful search was performed by multiple divers down to a depth of 200fsw/61msw. A body was never recovered.

99-57 Experienced Cave Diver Entangled in Guideline

A 52-year-old male divemaster with cave diving training and experience made a cave entry dive to 78 feet/23.7m for 135 minutes on nitrox. The decedent and his dive buddy both became entrapped when their guidelines broke and the dive buddy became entangled in the lines. Both divers died in the cave, and no one realized that they had not surfaced until the next morning.

99-58 Experienced Diver without Formal Cave Training Entered a Cave, Had Equipment Problems, Panicked and Became Separated From Buddy

A 32-year-male advanced diver with over 5,000 lifetime dives made a shore entry dive into a cave to a maximum depth of 215 feet/65.5m. He was a novice at cave diving and was under instruction for trimix diving. This was their second dive of the day; visibility was poor. The decedent had some difficulty with his tank and regulator configuration and the buddy attempted to assist him. The decedent panicked and struggled with his buddy, and the two became separated. The decedent's body was recovered the next day.

99-59 Solo Diver with Numerous Equipment Difficulities

A 38-year-old male diver had advanced open-water and rescue diver certifications. He had had two previous out of air emergency ascents and was known not to pay much attention to detail. The decedent entered the water without a buddy to make a wreck dive to 60fsw/18msw using nitrox. When the decedent did not return after an hour, other divers entered the water to search for him. The decedent's body was recovered four hours later. An equipment evaluation revealed that none of the three tanks the victim had with him were turned on, and his BC inflator hose was also not attached. The decedent also had made obvious attempts to remove his weight belt, but the belt was tied under the BC and could not be removed. The autopsy findings were consistent with drowning.

99-60 Diver Had Buoyancy Problems and Became Separated From Buddy

A 21-year-old male had been certified as an open-water diver at age 13 but had less than 20 lifetime dives. He and another diver went spearfishing and made a dive to 60fsw/18/msw. Approximately eight minutes into the dive, the decedent was having significant problems with his weight belt and buoyancy. The dive buddy attempted to assist the decedent, but they became separated. The dive buddy ran out of air searching for the decedent, and a body was never recovered.

99-61 Diver with Past Heart Surgery Had Problems Breathing at Depth

There is very little information available about this diving fatality, including the age and certification level of the victim. A male diver who had undergone coronary angioplasty one year earlier had some difficulty breathing while at depth. He was pronounced dead at a local hospital. An autopsy was performed, but the findings were not made available.

99-62 Over-Weighted Inexperienced Diver Struggled Briefly at the Surface

A 38-year-old male diver had initial open-water certification but less than five lifetime dives and none in the previous 12 months. He made a shore entry dive to 30fsw/9msw and was over-weighted. The decedent reportedly began the dive with 2,000 psi of air in his tank. He reportedly surfaced, appeared to struggle briefly on the surface, and then lost consciousness. Resuscitation efforts were unsuccessful. The autopsy findings corroborate the dive history, which is classic for an air embolism.

99-63 Student Making Check-Out Dive Lost Consciousness on Descent

A 52-year-old male was enrolled in an initial open-water dive certification class and was making a check-out dive. The decedent lost consciousness during the descent at a depth of approximately 40 fsw/12msw. He sank to the bottom and was brought to the surface by the instructor. The decedent was so morbidly obese that his equipment needed to be removed prior to pulling him into the boat. Resuscitation efforts were unsuccessful.

99-64 Experienced Diver Ran Out of Air at Safety Stop Suffered Spinal Cord DCI

A 49-year-old male with open-water certification and significant diving experience made a wreck penetration dive to 85fsw/26msw and ran out of air at the safety stop. He buddy breathed to the surface with the divemaster, but complained of fatigue and rapidly lost consciousness. The decedent was transferred to a recompression chamber where he was resuscitated and treated numerous times over several weeks with hyperbaric oxygen. The diver's initial presentation included signs of spinal cord decompression illness along with the loss of consciousness. At approximately the same time the diver was being prepared for transfer to another medical treatment facility for physical rehabilitation, he suffered an acute, fatal pulmonary embolism. Of significant note is the fact that the decedent suffered a traumatic pneumothorax three years before his diving accident.

99-65 Experienced Diver Became Separated From Buddy on Bottom

A 46-year-old female was a very experienced certified diver. She and her buddy made a 85fsw/26msw dive for 42 minutes before they became separated on the bottom. The dive buddy surfaced, and when the decedent did not follow behind, another diver went in to search for her. The decedent was found unconscious on the bottom with the regulator out of her mouth and her mask strap broken. Resuscitation efforts were unsuccessful. The autopsy report was not made available for review, but the medical examiner reported the findings as consistent with drowning.

99-66 Advanced Diver Making Cold, Deep Wreck Dives Had a Rapid Ascent

A 51-year-old male had advanced open-water certification with 43 lifetime dives, but few made in cold water or to deep depths. He made several deep wreck dives in a cold lake over the course of two days. The decedent and his dive buddy were at 125 fsw/38msw when he signaled that he wanted to ascend. The dive buddy was not sure why the decedent wished to abort the rest of the dive, but he followed him up through the water column. The plan had been to use an anchor rope on ascents, but the decedent chose to make a free ascent, as he had during previous dives on this trip. The dive buddy witnessed the decedent make a rapid ascent, then sink back down toward the bottom, where he lay unconscious and without a regulator in his mouth. He was brought to the surface, where resuscitation efforts were unsuccessful. During the previous day of diving, the decedent had also made rapid ascents and had to employ a pony bottle once because of insufficient air.

99-67 Technical Diver Making Deep Dives on a Wreck Suffered at Seizure at Depth

A 33-year-old experienced technical diver with a poor level of physical conditioning made repetitive dives to 186 fsw on a wreck. During the second dive, the decedent's buddy stated that the victim appeared to have a seizure while on the bottom, approximately seven minutes into the dive. The decedent lost consciousness, and his regulator was out of his mouth. The dive buddy inflated the decedent's buoyancy compensation device and sent him to the surface. He was pronounced dead at the local hospital. An investigation did not reveal the cause of the seizure, though one might suspect the decedent accidentally used a decompression mixture at depth. An autopsy was performed but the report was not made available.

99-68 Certified Diver Diving Alone Found Unconscious on the Bottom

This 50-year-old male certified diver was making his fourth dive of the day in a freshwater pond. He and his dive buddy took turns surfacing in order to keep an eye out for alligators. At one point the decedent did not rejoin his dive buddy as expected, and he was found unconscious on the bottom. Resuscitation efforts were unsuccessful.

99-69 Diver with Significant Past Medical History was Separated From Buddy and Began Having Problems on Surface

A 54-year-old female had been certified as an open-water diver for five years and had made approximately 30 lifetime dives. She had multiple medical problems, including a past history of breast cancer, arthritis, pulmonary and cardiac problems, and she had not made a dive within the past year. The decedent and her husband descended to 20fsw/6msw down the anchor line but stopped and returned to the surface. The decedent was having difficulty clearing, and they made another attempt to descend. This time the husband continued down the anchor line, but the decedent stopped again at 20 fsw and returned to the surface. On the surface she called for assistance and stated that she was having trouble breathing. She appeared to be disoriented and quickly lost consciousness. Resuscitation efforts, including transport to a nearby recompression chamber, were unsuccessful. The autopsy findings were consistent with an air embolism but also revealed evidence of natural disease processes.

99-70 A Non-Certified Solo Diver Making a Salvage Dive in a Cold Lake

A 23-year-old male had no documented formal dive training and made a shore entry dive into a lake in an attempt to salvage a snowmobile. The water temperature was extremely cold, and the victim brought a line down with him, which was attached to shore for the salvage procedure. The decedent tied a car crankshaft to his leg to use as a weight for descent. The autopsy report and additional information from the investigation were not made available.

99-71 Experienced Diver With A Leaky BC Lost Consciousness On The Tag Line

A 44-year-old male with open-water certification and significant dive experience made a dive to 100 fsw/30msw for 17 minutes. He was part of a large group of divers on the boat. The rough sea state and strong current made hanging on the tag line difficult after ascending from the dive. The decedent lost consciousness while hanging on the line and was transferred to the local emergency room where resuscitation efforts were unsuccessful. The autopsy findings were consistent with drowning. Two leaks of uncertain significance were found in the buoyancy compensation device during the equipment inspection.

99-72 Newly Certified Diver Diving with Equally Inexperienced Buddy Does Not Surface After Buddy Signals to Ascend

A 49-year-old male had just completed initial open-water certification and was making his first dive outside of a training situation. His dive buddy was his son, who was equally inexperienced. The two divers entered the water from a boat and planned a dive in an area where the bottom was at 125fsw/38msw. The decedent initially had some trouble with his hoses, but the two divers eventually descended. At 50fsw/15.2msw, the decedent's son had some trouble with his weight belt and motioned for both of them to ascend. The decedent did not surface with his son and, after waiting several minutes for his father to come up, the decedent's son went back down to look for his father. The decedent was found unconscious at 125 fsw, and his son brought him to the surface. Resuscitation efforts were unsuccessful. The decedent's son was treated for symptoms of decompression sickness at a local hyperbaric chamber. A cardiac event or other factor contributing to the drowning cannot be excluded.

99-73 Advanced Course Student Became Separated From Instructor and Lost Consciousness on the Surface

A 53-year-old male was under instruction in an advanced open-water certification class using mixed gas scuba. He had initial open-water certification but only seven lifetime dives. The decedent made a shore entry and shortly thereafter became separated from his instructor. He was witnessed to surface, signaled that he was ok, then quickly lost consciousness. The decedent was resuscitated and brought to the hospital where he spent 14 hours on a ventilator before being pronounced dead.

99-74 Certified Cave Diver Became Separated From Buddies in No Visibility Conditions

A 33-year-old male was a certified cave diver who entered a cave along with two other equally trained dive buddies. Visibility became zero after a severe silting, and the divers decided to abort the dive after reaching a maximum depth of 90 feet/27.4m. The divers became separated, and only two of the three in the group found their way out of the cave. The decedent's body was recovered approximately eight hours later.

99-75 Diver with Significant Cardiac Medical History Became Separated From Buddy

A 66-year-old male diver with open-water certification had a history of heart disease for which he took nitrates on a regular basis. He was also in a poor state of physical conditioning. The decedent made a 100fsw/30msw dive from a boat and became low on air during the ascent. He became separated from his dive buddy and did not return with the group of divers he had entered the water with. The body was never recovered.

99-76 Newly Certified Diver Became Separated From Buddies And Was Found On Bottom Entangled In Fishing Line

A 41-year-old male had been certified for one month and was making his fifth lifetime dive. He made a shore entry lake dive to 100 feet/30m with two other divers, but they became separated. One dive buddy found the decedent unconscious, with his regulator out, on the bottom at 141 feet/43m, but he could not bring the stricken diver to the surface. The decedent's body was recovered three days later with fishing line around some of his equipment.

99-77 Head Trauma In The Surf Zone That May Have Caused Unconsciousness

A 39-year-old female had open-water certification and 25 lifetime dives. She also had a possible asthma history. The decedent made a shore entry but never submerged. She suffered closed head trauma in the surf zone and became separated from her buddy. The trauma was apparently sufficient to render the decedent unconscious.

99-78 Newly Certified Diver Separated From Buddy And Found Stuck In Pipe

A 53-year-old inexperienced diver received his initial open-water certification five months earlier. He and a dive buddy made a 50-minute dive to 45 feet/13.7m; they became separated late in the dive. The decedent's body was found four hours later, stuck in the intake pipe for the cooling water of a power plant. The boat was anchored near a sign that clearly pointed out the dangerous pipe and stated that diving was prohibited in that area.

Appendix C. Autopsy Protocol for Recreational Scuba Diving Fatalities

The 1992 *Report on Diving Accidents and Fatalities* included an autopsy protocol written by Drs. Eric Kindwall and Jorge Pellegrini[1]. Several aspects of that protocol have been incorporated in the following section on performing and interpreting a post-mortem examination on a diving fatality victim.

Since most pathologists and autopsy technicians rarely perform an autopsy on someone who died while scuba diving, few medical examiners' offices will have significant experience in performing appropriate post-mortem examinations in that setting. The following is a guideline that can be followed with the understanding that some of the recommended procedures will be impractical and may only take place in a facility with significant laboratory resources available.

The medical examiner must put together all of the available information, including the autopsy findings, prior to determining the cause of death in a diving fatality. If the pathologist performing the autopsy is unfamiliar with diving physiology, consultation should be obtained to assist in the interpretation of the findings.

History

This is absolutely the most important part of the evaluation of a recreational diving fatality. Ideally, one should obtain significant past medical history with a focus especially on cardiovascular disease, seizure disorder, diabetes, asthma and chronic obstructive pulmonary disease. Medications taken on a regular basis as well as on the day of the dive should be recorded, and information regarding how the diver felt prior to the dive should be obtained. Any history of drug or alcohol use must also be noted. The dive history is extremely important. If possible, the investigator should find out the diver's experience and certification level.

The most important part of the history will be the specific events related to the dive itself. The dive profile (depth, bottom time) is an essential piece of information, and if the diver was not diving alone (not recommended), eyewitness accounts will be invaluable.

Questions to be asked include:

- When did the diver begin to have a problem: pre-dive, descent, bottom, ascent, post-dive?
- Did the diver ascend rapidly (a factor in air embolism and pulmonary barotrauma)?
- Was there a history of entrapment, entanglement, or physical trauma?
- If resuscitation was attempted, what was done and how did the diver respond?

External Examination and Preparation

A thorough external examination includes the following activities:

- A search for signs of trauma, animal bites, or envenomation should be carried out. Palpate the area between the clavicles and the angles of the jaw for evidence of subcutaneous emphysema.
- X-rays of the head, neck, thorax and abdomen should be taken to look for free air.
- Modify the initial incision over the chest to make a "tent" out of the soft tissue (an I-shaped incision) and fill this area with water. A large-bore needle can be inserted into the second intercostal spaces bilaterally; if desired, any escaping air can be captured in an inverted, water-filled, graduated cylinder for measurement and analysis. As the breastplate is removed, note any gas escaping from vessels. Excellent diagrams exist in one of the standard forensic pathology texts[2].
- The carotid arteries should be tied off immediately upon opening the chest.

- Open the pericardial sac under water and note if pneumopericardium is present. After filling the pericardial sac with water, repeat the needle insertion maneuver, this time into the right and left ventricles, with capture of any escaping gas if practical. After the mediastinum, heart and great vessels have been examined under water for the presence of air; the water may be evacuated and a standard autopsy may be performed.
- Carefully examine the lungs for bullae, emphysematous blebs and hemorrhage.
- Note any interatrial or interventricular septal defects. Carefully check for evidence of cardiovascular disease and any changes that would compromise cardiac function.
- Toxicology — obtain blood, urine, vitreous, bile, liver and stomach contents. Not all specimens need to be analyzed, but at least look for drugs of abuse. If an electrolyte abnormality is suspected or if the decedent is a person with diabetes, the vitreous may prove useful.
- Prior to opening the skull, tie off all of the vessels in the neck to prevent artifactual air from entering the intracranial vessels. Tie the vessels at the base of the brain once the skull is opened. Disregard bubbles in the superficial veins or venous sinuses. Examine the meningeal vessels and the superficial cortical arteries for the presence of gas. Carefully examine the circle of Willis and middle cerebral arteries for bubbles. Alternatively, the brain may be removed prior to opening the chest, if desired.
- Have an expert evaluate the dive gear. Are the tanks empty? If not, the gas should be analyzed for purity (e.g., is carbon monoxide present?). All gear should be in good working order with accurate, functioning gauges.

Possible Findings

The following anatomic findings may be seen with the clinical entities listed. Not all of the anatomic changes will be seen in each case, and the lists are certainly not exhaustive.

- Air embolism: intra-arterial and intra-arteriolar air bubbles in the brain and meningeal vessels, petechial hemorrhages in gray and white matter, evidence of COPD (chronic obstructive pulmonary disorder) or pulmonary barotrauma (pneumothorax, pneumomediastinum, subcutaneous emphysema), signs of acute right heart failure, pneumopericardium, air in coronary and retinal arteries.
- Decompression sickness: lesions in the white matter in the middle third of the spinal cord including stasis infarction; if there is a patent foramen ovale (or other potential right-to-left heart shunt) a paradoxical air embolism can occur due to significant venous bubbles entering the arterial circulation.
- Venomous stings or bites: a bite or sting on any part of the body, unexplained edema on any part of the body, evidence of anaphylaxis or other severe allergic reaction (beware of post-mortem changes caused by marine life).

Interpretation

- The presence of gas in any organ or vessel after a scuba diving death is not conclusive evidence of decompression sickness or air embolism. During a long dive, inert gas dissolves in the tissues, and the gas will come out of solution when the body returns to surface atmospheric pressure. This, combined with post-mortem gas production, will produce bubbles in tissue and vessels. This has caused many experienced pathologists to erroneously conclude that a death occurred due to decompression sickness or air embolism.
- Intravascular bubbles, especially if present predominantly in arteries, found during an autopsy performed soon after the death occurred is highly suspicious for air embolism. The dive history will help support or refute this theory.
- Gas present only in the left ventricle or, if analysis shows the gas in the left ventricle has a higher oxygen content than that present on the right side, would lead the pathologist to correctly conclude that an air embolism probably occurred.

- Intravascular gas from decomposition or off-gassing from the dive would have little oxygen and be made up of mostly nitrogen and carbon dioxide.
- Deeper, longer dives can cause decompression sickness and significant intravascular (mostly venous) gas. Rapid ascents and pulmonary barotrauma are associated with air embolism.

Divers Alert Network has medical personnel who are available to provide guidance in the performance and interpretation of autopsies on dive accident victims.

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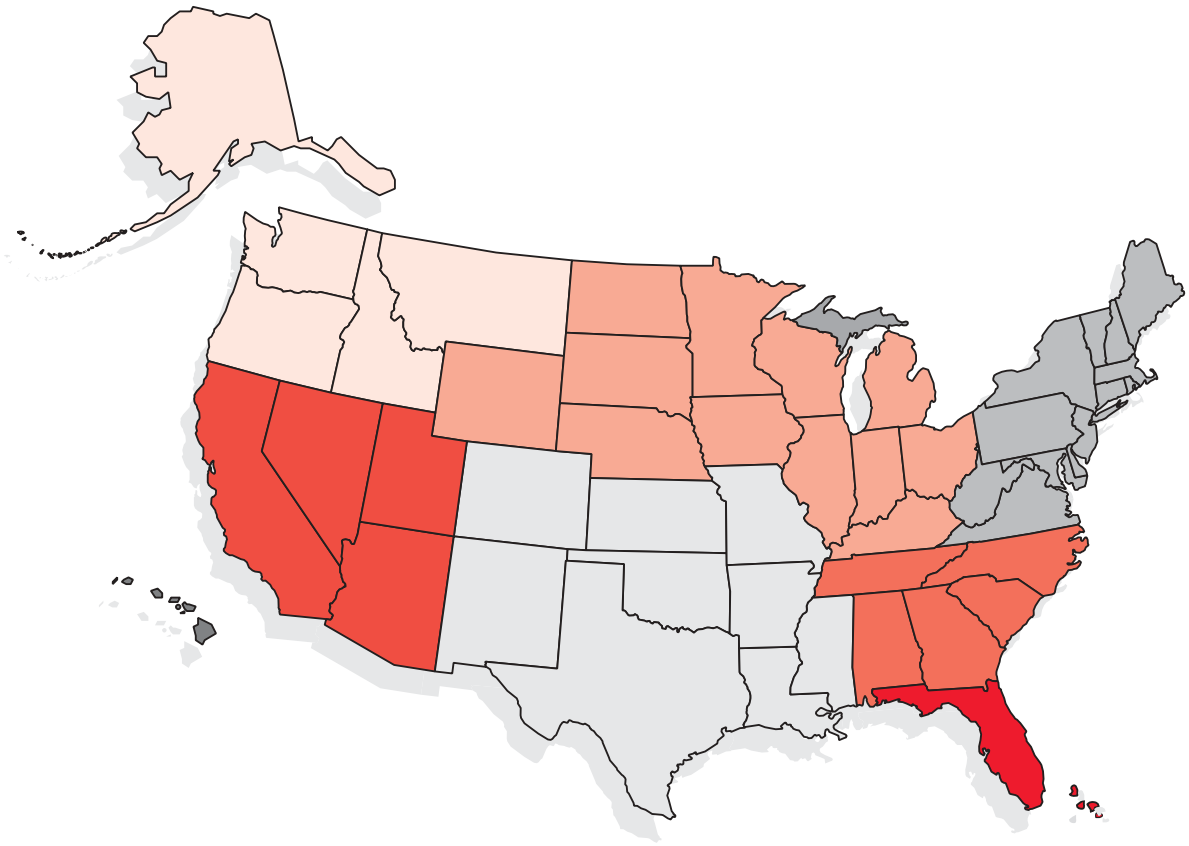
2. Spitz, WV (editor). Medicolegal Investigation of Death. pp 776-778. Charles C. Thomas: Springfield, IL, 1993.

INJURIES & FATALITIES BY REGION & STATE 1999

(Total number used in report analysis)



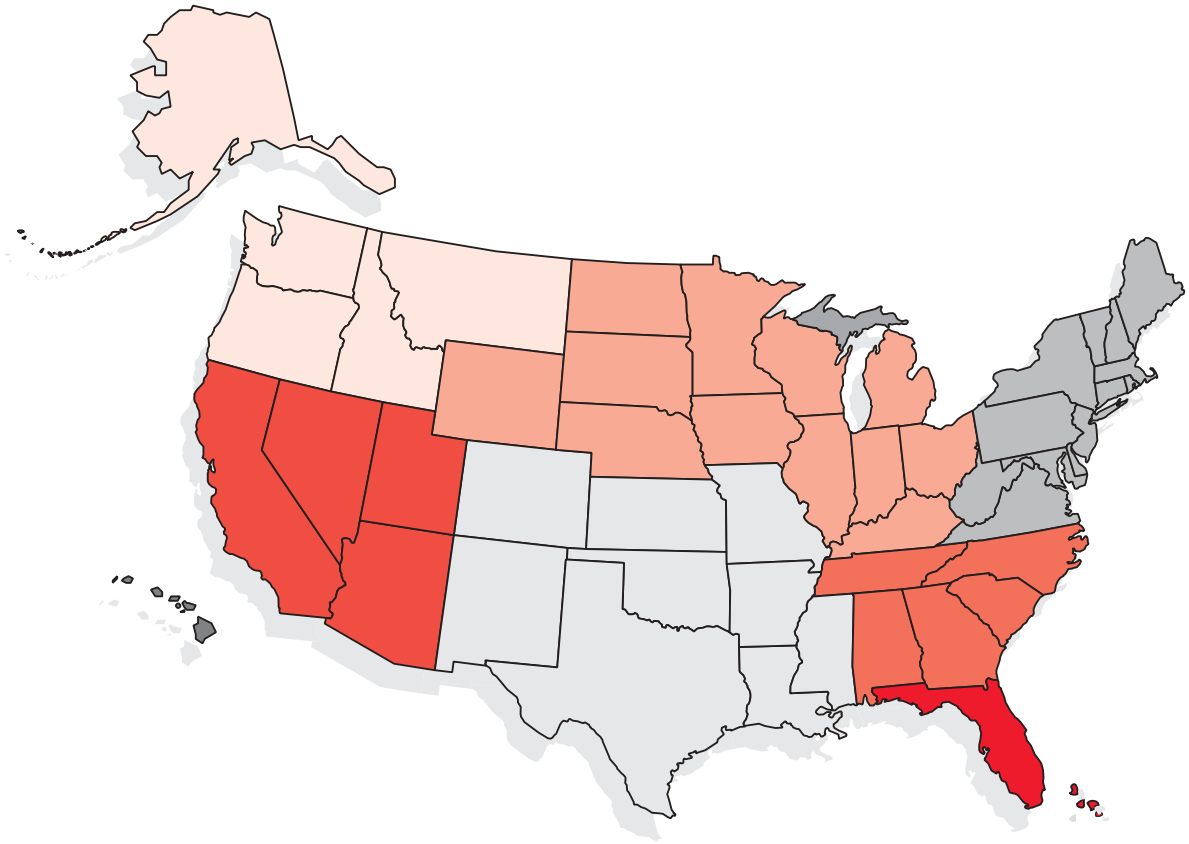
	Fatality	Injury
Southeast Region	**3**	**14**
Alabama	0	0
Georgia	0	1
North Carolina	2	11
South Carolina	1	2
Tennessee	0	0
Southwest Region	**16**	**48**
Arizona	0	0
California	15	43
Nevada	0	5
Utah	1	0
Northeast Region	**10**	**25**
Connecticut	0	0
Delaware	0	2
Maine	1	0
Maryland	0	1
Massachusetts	1	3
New Hampshire	0	0
New Jersey	3	12
New York	2	5
Pennsylvania	3	1
Rhode Island	0	0
Vermont	0	1
Virginia	0	0
West Virginia	0	0

	Fatality	Injury
Gulf Region	**5**	**8**
Arkansas	0	0
Colorado	0	0
Kansas	0	0
Louisiana	3	4
Mississippi	0	0
Missouri	1	0
New Mexico	0	1
Oklahoma	0	0
Texas	1	3
Midwest Region	**3**	**15**
Illinois	0	2
Indiana	0	0
Iowa	0	0
Kentucky	0	0
Michigan	2	10
Minnesota	0	0
Nebraska	0	0
North Dakota	0	0
Ohio	1	5
South Dakota	0	0
Wisconsin	0	6
Wyoming	0	0

	Fatality	Injury
Northwest Region	**5**	**41**
Alaska	0	0
Idaho	0	1
Montana	0	1
Oregon	0	2
Washington	5	37
Pacific Region	**3**	**33**
Hawaii	1	27
U.S. Territories	1	4
Caribbean Region	**23**	**210**
Florida	14	86
Mexico/Central America Region	5	73
Other (Canada, Europe)	**5**	**34**
Total State	57	264
Total Region	78	391

INJURIES & FATALITIES BY REGION & STATE 1998

(Total number reported to DAN)



	Fatality	Injury
Southeast Region	**4**	**46**
Alabama	0	0
Georgia	1	5
North Carolina	2	28
South Carolina	1	7
Tennessee	0	6
Southwest Region	**18**	**139**
Arizona	0	7
California	17	126
Nevada	0	5
Utah	1	1
Northeast Region	**13**	**121**
Connecticut	0	0
Delaware	0	0
Maine	1	0
Maryland	0	9
Massachusetts	3	33
New Hampshire	0	0
New Jersey	3	21
New York	2	27
Pennsylvania	3	10
Rhode Island	1	1
Vermont	0	0
Virginia	0	20
West Virginia	0	0
Washington, DC	0	0

	Fatality	Injury
Gulf Region	**6**	**76**
Arkansas	0	0
Colorado	0	0
Kansas	0	2
Louisiana	3	9
Mississippi	0	2
Missouri	1	10
New Mexico	0	5
Oklahoma	0	2
Texas	2	46
Midwest Region	**4**	**65**
Illinois	0	12
Indiana	0	1
Iowa	0	0
Kentucky	0	0
Michigan	2	14
Minnesota	0	11
Nebraska	0	0
North Dakota	0	0
Ohio	1	24
South Dakota	0	0
Wisconsin	1	3
Wyoming	0	0

	Fatality	Injury
Northwest Region	**6**	**103**
Alaska	0	27
Idaho	0	0
Montana	0	0
Oregon	1	16
Washington	5	60
Pacific Region	**6**	**36**
Hawaii	3	36
U.S. Territories	1	0
Caribbean Region	**30**	**368**
Florida	19	216
Mexico/Central America Region		
	8	49
Other (Canada, Europe)	**14.4**	**85**
Total State	78	802
Total Region	109	1088

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