DAN DIVERS ALERT NETWORK

Report on Decompression Illness, Diving Fatalities and Project Dive Exploration

DAN's Annual Review of Recreational Scuba Diving Injuries and Fatalities Based on 2002 Data

2004 Edition

Report on Decompression Illness, Diving Fatalities and Project Dive Exploration

The DAN Annual Review of Recreational Scuba Diving Injuries and Fatalities. Based on 2002 Data. 2004 Edition by Divers Alert Network.

Table of Contents

DAN Report on Decompression Illness, Diving Fatalities and Project Dive Exploration: 2004 Edition (Based on 2002 Data)© 2004 Divers Alert Network. ISBN 0-9673066-5-5.

Cover Dive Photo by William M. Mercadante

Acknowledgments

Data for the 2004 Report on Decompression Illness, Diving Fatalities and Project Dive Exploration have been collected and assembled by DAN employees and associated staff. DAN wishes to recognize the following people and departments for their important contributions:

Authors

Richard Vann, Ph.D.
Petar Denoble, M.D., D.Sc.
Joel Dovenbarger, B.S.N.
John Freiberger, M.D., MPH
Neal W. Pollock, Ph.D.
James Caruso, M.D.
Donna Uguccioni, M.S.

Contributors

DAN Medicine

Joel Dovenbarger, BSN
Daniel A. Nord, BFA, EMT-P, CHT
M. Celia Evesque, B.A., NREMT-I, DMT
Dan Kinkade, M.A., NREMT-P
Jon M. Rogers, Jr., EMT-1, CHT, DMT-A
Jane Foley, B.A.

DAN Research

Julie Ellis
Lan Li, B.S.
Jeanette Moore

DAN Communications

Renée Duncan, B.A.
Rick Melvin
Wesley Hyatt, B.A.

Reviewers

Peter B. Bennett, Ph.D., D.Sc.
Steve Barnett, B.A.
Frans Cronjé, M.D. BSc (Hons), CHT
Eric Douglas, B.A., EMT-B, DMT-B
Cindi Easterling, M.Ed.
David Lawler, EMT-B
Brian Merritt, M.Ed.
Jeff Myers, B.A.
Betty Orr, M.S.
Dan Orr, M.S.
Shaun Tucker, B.A.

DAN America wishes to thank all of the individuals involved in the worldwide diving safety network. This network includes many hyperbaric physicians, DAN on-call staff, nurses and technicians from the network of chambers who complete DAN reporting forms. DAN also wishes to thank the local sheriff, police, emergency medical personnel, U.S. Coast Guard, medical examiners and coroners who submitted information on scuba fatalities and injuries in U.S. and Canadian citizens.

DAN Senior Medical Staff & Reviewers

Guy de L. Dear, M.B., FRCA
Richard Moon, M.D.
Bryant Stolp, M.D., Ph.D.
Edward D. Thalmann, M.D.

DAN Emergency On-Call Staff and Volunteer Physicians

Joel Dovenbarger, BSN
Daniel A. Nord, BFA, EMT-P, CHT
M. Celia Evesque, B.A., NREMT-I
Jon M. Rogers, Jr., CHT, DMT-A, NREMT
Dan Kinkade, M.S., NREMT-P

Project Dive Exploration Dive Profile Collection for 2002 (collectors and number of dives)

DATA COLLECTION CENTERS

Nekton Rorqual (Caribbean)	5,004
Nekton Pilot	6,070

DAN INTERNS (Summer 2002)

Chris Kreigner	1,383
Scott Thompson	948
Beth Terpolilli	748
Jessica Thompson	688
Greg Yagoda	580
Jennifer Robison	253

RECREATIONAL DIVE PROFESSIONALS PROJECT COZUMEL, MEXICO

Mateo Guiterrez	279
Roberto Castillo	45

CAYMAN ISLANDS

Participating Dive Retailers

Cayman Diving Lodge
Dive Tech & Cobalt Coast
Don Foster
Eden Rock
Fisheye
Little Cayman Beach Resort/Reef Divers
Red Sails
Tortuga Divers

Dives collected by:

Cayman Diving Lodge	296
Don Foster	66
Little Cayman Beach Resort/Reef Divers	144
Tortuga Divers	42

Brazil

Atlantis Divers	219

INDEPENDENT FRCS

Total Dives Collected: 1,695

Andrew Monjan
Robert Eichholtz, Jr.
Brian Basura
Sergio Viegas
Mark Huck
Linda Finch
David Grenda
David Colvard
Jessica Thompson
Raymond Albers
Jurgen Galicia
Evelyn Joppa
Daniel Hartman
Robert Rydgig
Darrell Seale
Hank Ellis
Barry Hummel
Jeffrey Watkins
Albert Rosenberg
Robert Burke

DAN Regions and Regional Coordinators for Hyperbaric Treatment

DAN uses a network of approximately 500 hyperbaric chamber facilities in the United States and around the world, of which approximately 170 provide annual reports on decompression illness (DCI) injuries. The DAN U.S. network is divided into eight regions, each overseen by a Regional Coordinator.

International Headquarters and Southeast Region – Alabama, Georgia, North Carolina, South Carolina and Tennessee
Richard Moon, M.D.
Center for Hyperbaric Medicine and Environmental Physiology, Box 3823, Duke University Medical Center, Durham, NC 27710

Southwest Region – Arizona, California, Nevada and Utah
Lindell Weaver, M.D., FACP, FCCP, FCCM
Department of Hyperbaric Medicine, LDS Hospital, 8th Avenue and 'C' Street, Salt Lake City, UT 84143

Northeast Region – Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia and West Virginia
Cynthia Cotto-Cumba, M.D. and Robert Rosenthal, M.D.
Department of Hyperbaric Medicine, Maryland Institute for Emergency Medical Services Systems, University of Maryland, 22 S. Greene Street, Baltimore, MD 21201

Gulf Region – Arkansas, Colorado, Kansas, Louisiana, Mississippi, Missouri, New Mexico, Oklahoma and Texas
Keith Van Meter, M.D. and Randy Springer, CHT
St. Charles General Hospital, 3700 St. Charles Avenue, New Orleans, LA 70115

Midwest Region – Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin and Wyoming
Jeffrey Niezgoda, M.D. and Stephen Fabus
Department of Hyperbaric Medicine, St. Luke's Medical Center, 2900 W. Oklahoma Avenue, Milwaukee, WI 53215

Northwest Region – Alaska, Idaho, Montana, Oregon and Washington
Neil Hampson, M.D. and Richard Dunford, M.S.
Hyperbaric Department, Virginia Mason Research Center, 952 Seneca Street, Seattle, WA 98101

Pacific Region – Guam, Hawaii and U.S. Territories
Richard Smerz, D.O.
Hyperbaric Treatment Center, University of Hawaii, John A. Burns School of Medicine, 347 N. Kuakini Street, Honolulu, HI 96813

Florida and Caribbean Region – Florida and Caribbean Basin
Marc R. Kaiser and Ivan Montoya, M.D.
Diving Medical Center at Mercy Hospital, 3663 South Miami Avenue, Miami, FL 33133

International DAN Offices

DAN America
Michael D. Curley, Ph.D.
The Peter B. Bennett Center
6 West Colony Place • Durham, NC 27705 USA
Telephone +1-919-684-2948 • Fax +1-919-490-6630
dan@DiversAlertNetwork.org • www.DiversAlertNetwork.org
Dive emergencies: +1-919-684-8111 or +1-919-684-4DAN (4326) (collect)

DAN Latin America Emergency Hotline Network
Cuauhtémoc Sánchez, M.D., Executive Director
c/o Servicio de Medicina Hiperbarica, Hospital Angeles del Pedregal Camino a Santa Teresa 1055
Heroes de Padierna, 10700 • Mexico D.F. Mexico
Daytime Office Telephone +52-55-5568-8082 • Fax +52-55-5568-8083
danmex@hotmail.com
24-Hour Emergencies for All of Latin America
+1-919-684-9111 (collect; assistance in Spanish and Portuguese)

DAN Europe
Alessandro Marroni, M.D.
P.O. Box DAN • 64026 Roseto (Te) Italy
Telephone +39-085-893-0333 • Fax +39-085-893-0050
mail@daneurope.org • www.daneurope.org/main.htm
Dive emergencies: +39-039-605-7858

DAN Japan
Yosihiro Mano, M.D. and Shigeo Funaki
Japan Marine Recreation Association
Kowa-Ota-Machi Bldg, 2F, 47 Ota-machi 4-Chome Nakaku,
Yokohama City, Kagawa 231-0011 Japan
Telephone +81-45-228-3066 • Fax +81-45-228-3063
dan@danjapan.gr.jp • www.danjapan.gr.jp
Dive emergencies: +81-3-3812-4999

DAN South East Asia-Pacific
John Lippmann
P.O. Box 384, Ashburton, Victoria 3147 • Australia
Telephone +61-3-9886-9166 • Fax +61-3-9886-9155
info@danseap.org • www.danseap.org

Diving Emergency Services (DES)
DES Australia (within Australia) 1-800-088-200
DES Australia (from overseas) . . . . . .+61-8-8212-9242
DAN / DES New Zealand . . . . .0800-4DES111 (within New Zealand)
Singapore Naval Medicine
& Hyperbaric Center . . . . .6758-1733 (within Singapore)
DAN S.E.A.P.-Philippines . . . .+02-815-9911
DAN S.E.A.P.-Malaysia . . . .+05-930-4114

DAN Southern Africa
Frans Cronjé, M.D.
Private Bag X 197
Halfway House 1685 • Southern Africa
Telephone +27-11-254-1991 • Fax +27-11-254-1993
mail@dansa.org • www.dansa.org
Dive emergencies
(within South Africa) 0800-020-111
(outside South Africa) . . . .+27-11-254-1112
(hotline fax) . . . .+27-11-254-1110

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 dive safety organization associated with Duke University Health Systems in Durham, N.C., and is supported by the world's largest membership association of divers.

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, today DAN relies on membership, dive industry support, 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 in 2003

DAN is best known for its 24-Hour Diving Emergency Hotline, 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 as well as books and videos about scuba safety, training and health.

The 24-Hour Diving Emergency Hotline is DAN's premier service. DAN medics and physicians offer emergency consultation and referral services to injured divers worldwide. In 2003, DAN answered 2,787 calls for assistance on its Diving Emergency Hotline.

In the fall of 2001, the DAN Dive Safety and Medical Information Line extended its hours until 8 p.m. Eastern Time in order to be more convenient for DAN's West Coast members. DAN's Medical Information Line at +1-919-684-2948 (or 1-800-446-2671 toll-free in the United States and Canada) is now available weekdays from 9 a.m. to 8 p.m. Eastern Time. On the Medical Information Line, callers may make specific non-emergency medical inquiries.

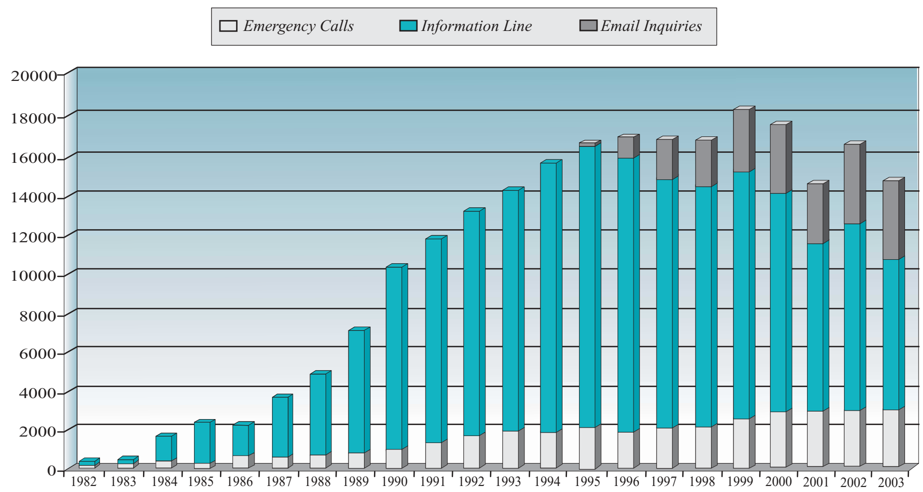
Also, divers can visit the medical pages of the DAN website — www.DiversAlertNetwork.org — where they can find answers to general questions on dive fitness and health.

In 2003, DAN answered more than 2,700 calls for emergency assistance from its members and divers on the Diving Emergency Hotline.

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 dive medical technician about non-emergency dive safety and health concerns. Respondents include DAN medics with the resources of DAN's senior medical staff, on-call physicians, diving researchers at Duke University Medical Center's (DUMC) Center for Hyperbaric Medicine and Environmental Physiology and other experts in dive medicine.

In some cases, DAN may refer callers to a dive medical specialist in their region for further evaluation. In 2003, DAN Medicine received 12,110 information inquiries (including 3,910 emails). Since its beginning in 1980, DAN has helped 203,948 callers through these services. Combined with calls to the 24-Hour Diving Emergency Hotline, the number climbs to 240,656.

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



DAN 24-Hour Diving Emergency Hotline with Immediate Insurance Verification

Dive and travel medical emergencies can happen at 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 Diver Health and Safety Research

DAN Research is dedicated to the study of diver health issues. Experimental research projects such as the U.S. Navy Flying After Diving study and development of the DAN Remote Emergency Medical Oxygen system are conducted in the hyperbaric chambers of the Center for Hyperbaric Medicine and Environmental Physiology at Duke University Health Systems (formerly F.G. Hall Laboratory).

Field research projects, such as Project Dive Exploration (PDE) and the Recreational Dive Professionals Study, are conducted at dive locations all over the world. DAN projects are privately funded through DAN membership, dive industry support and private grants.

For more information on any of the DAN Research Projects or to participate, please call DAN Research at 1-800-446-2671, +1-919-684-2948 ext. 260 or visit the DAN website at www.DiversAlertNetwork.org.

Injury and Fatality Data Collection

This annual diving report is based on data from injury, fatality and Project Dive Exploration (PDE) dive data. DAN Medicine and DAN Research have published the annual diving report since 1987. Initially, it was a report on injuries and fatalities only. It now includes the dive profiles from PDE, in which injuries are rare.

The report has shifted focus over the last few years to include comparisons between the three different populations of injury, fatality and PDE divers. A comparative analysis will investigate risk factors for diving injuries and fatalities. The original purpose of the report — describing the demographics of the cases and providing case summaries — will continue to be important. The report has also grown to include nitrox and mixed-gas diving injuries and deaths, because these gases have increased in use in the recreational population over the past few years.

Copies of current fatality, injury, and dive incident reports are available through DAN Research at 1-800-446-2671 or +1-919-684-2948 ext. 260. Reports may be downloaded from the DAN website at no cost to DAN Members.

Diabetes and Diving Project

DAN's project to determine the relative safety of divers with insulin-requiring diabetes was completed in 2001 and a scientific paper was accepted for publication to the Undersea Hyperbaric Medical Journal late in 2003. After its publication in the scientific literature, DAN will provide this information to its members. For information on when and where the results will appear, please visit the DAN website and check *Alert Diver* magazine.

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

Flying After Diving (FAD) Study

In 1999, DAN completed the first phase of a study of flying after scuba diving. This was part of an effort to investigate what surface intervals after diving were safe prior to flying aboard a commercial airliner. In May of 2002, DAN hosted an FAD workshop, which included representatives from the recreational diving industry and government diving agencies. The workshop reviewed all available data on flying after diving and agreed upon revised flying after diving guidelines for recreational diving that were first published in the November / December 2002 issue of *Alert Diver*. The full workshop proceedings will be published in 2004.

A second flying after diving study, funded by the U.S. Navy, began in May 2002. This study is investigating additional dive profiles and oxygen breathing in the surface intervals as a possible method for making the surface intervals shorter.

Project Dive Exploration (PDE) uses recording dive computers to collect information about the depth-time profiles of volunteer recreational divers.

Project Dive Exploration (PDE)

Project Dive Exploration (PDE) uses recording dive computers to collect information about the depth-time profiles of volunteer recreational divers. As of December 2003, PDE had collected more than 70,000 dive profiles since beginning data collection in 1995.

The goals of PDE include creating 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 and their risks of decompression illness (DCI).

Since its beginning, PDE has shared goals and methodology with Dive Safety Lab (DSL), a similar program developed and conducted by DAN Europe. DSL has collected more than 20,000 dives, many of them including post-dive follow-up with Doppler detection of venous gas emboli. With the encouragment of International DAN, both programs now share the same computer platform that allows data to be merged. Joining the efforts and data will accelerate the research and provide more power to our analysis.

Dive computer manufacturers Cochran, Suunto, Uwatec / Scubapro, DiveRite and dive recorder manufacturer ReefNet have strongly supported PDE. Cochran and DiveRite have dive log software that allows divers to email their PDE data directly to DAN. Suunto and ReefNet are working on this capability within their software.

Volunteer Field Research Coordinators (FRCs) and Data Collection Centers (DCCs) are responsible for gathering PDE data. (See Page 2 for a list of FRCs and DCCs from 2002.)

Since 1998, DAN and Nekton Diving Cruises have been working closely together on PDE. In 2001, DAN began working with the *Aggressor* Fleet liveaboard vessels to collect PDE dives, and in 2002, DAN embarked on PDE collection with Peter Hughes Diving.

Divers who wish to participate in PDE aboard the liveaboard vessels *Nekton Pilot, Nekton Rorqual, Cayman Aggressor, Turks and Caicos Aggressor* and *Kona Aggressor* should contact:
- Nekton Diving Cruises: call 1-800-899-6753 or visit www.nektoncruises.com
- Aggressor Fleet: call 1-800-348-2628 or visit www.aggressor.com
- Peter Hughes Diving: call 1-800-932-6237 or visit www.peterhughes.com

For more information about how to become involved in PDE, call DAN Research at 1-800-446-2671 or +1-919-684-2948 ext. 260 or visit the DAN website at www.DiversAlertNetwork.org

DAN Research Internship Program

The DAN Research Internship Program began in 1999 with three objectives:
- expand PDE data collection;
- provide experiences that might motivate young people towards careers in diving science or diving-related fields; and
- educate the diving public about DAN and PDE.

The Internship Program runs primarily from June through August, and interns are recruited largely from students at colleges, universities and medical schools. Student interns are often able to earn college credits for their summer work. Postgraduate students and periods other than summer may also be considered. Interns are trained at DAN and placed with dive retailers or dive operations that believe in the importance of research to improve dive safety and efficiency.

In 1999 the first DAN Research Intern collected more than 900 PDE dives at Discovery Diving in Beaufort, N.C. Since the inception of the program, DAN has trained a total of 24 interns who have collected PDE data on the U.S. east and west coasts plus the Gulf of Mexico, Caribbean and South Pacific.

Interns are trained at DAN and placed with dive shops or dive operations that believe in the importance of research to improve dive efficiency and safety.

In 2003, DAN trained eight interns from the United States and placed them in popular diving locations in the U.S. Caribbean and the South Pacific. These interns collected 5,300 dives in three months. For the 2004 summer program, DAN will place eight interns at various locations during the summer of 2004.

Many DAN Business Members have volunteered to be a Host Diving Facility for the summer Interns. A host facility allows the intern access to their divers, a space to work and helps DAN promote the PDE and internship program.

For application procedures or to learn more about being a host dive facility, contact the DAN Research Department at 1-800-446-2671 or +1-919-684-2948 ext. 260, or visit the DAN website at www.DiversAlertNetwork.org.

The Recreational Dive Professionals Study will collect and analyze the exposure and outcome data in dive professionals.

Recreational Dive Professionals Study

The Recreational Dive Professionals Study (RDP), a subset of PDE, began in 2003. It is designed to learn more about the diving style and dive profiles of dive professionals. For purposes of the study, a dive professional is defined as a recreational scuba diver who is currently working professionally in the diving industry as a dive instructor, divemaster, dive guide, videographer or photographer. The RDP Project was initiated because of data collected in 2001 by three dive guides in Cozumel who were serving as PDE Field Research Coordinators. These data suggested that the DCS incidence among dive guides was high compared to other dive groups (see Figure 2.8-2). The objective of the RDP is to determine if this preliminary observation was valid and, if so, what the cause might be.

The RDP will include dive professionals from Mexico (Yucatan including Cozumel, Playa del Carmen and Cancun), and the Cayman Islands. In Cozumel and Grand Cayman, some subjects have been loaned dive computers or interfaces from DAN Research to record all their dives. Some of the participants in Cayman and Cozumel are submitting dives to DAN Research. In the summer of 2004, DAN Research will send three interns to Cayman (two) and Cozumel (one) to assist in the collection of RDP data for two months.

For more information on this study, call DAN Research at 1-800-446-2671 or +1-919-684-2948 ext. 627, or email duguccioni@dan.duke.edu

Dive Computer Recognition Program

In 2000, DAN began a program to recognize manufacturers who make dive computers that were compatible with PDE. The program is open to all manufacturers that have implemented the DAN Dive Log-7 (DL7) standard in their dive log software. The DL7 standard was developed to support the collection of PDE data but is applicable in any other observational project.

The purpose of the Dive Computer Recognition program is to augment participation in PDE by increasing awareness of all dive computer users. To date, the four participating manufacturers (Cochran, DiveRite, Suunto and Uwatec / Scubapro) are distributing their products worldwide with an announcement that their dive computers are compatible with PDE. The Sensus depth-time data logger manufactured by ReefNet is also PDE-compatible.

DAN's Support to the Dive Medical Community

Through the DAN Recompression Chamber Assistance program, DAN provides training and financial support to recompression chambers throughout the Caribbean and other popular dive destinations to ensure that they remain in operation and are properly staffed. This program complements DAN's semiannual dive medical courses for physicians, nurses and other allied healthcare personnel to educate the international medical community on the proper care and treatment of injured divers.

In 1996, DAN broke ground in the field of dive injury treatment and insurance, by creating a Diving Preferred Provider Network (DPPN) of hyperbaric chambers to help manage the costs of recompression treatment and to make it easier for hyperbaric facilities to receive payment for services.

In 2002, DAN Services Inc. teamed with Med-Care Plus to offer DAN Members and their families access to a medical savings plan that offers up to 25 percent savings at physicians' locations, hospitals and medical facilities nationwide. The plan is neither insurance nor intended to replace insurance, but it provides assistance to more than 500,000 physician locations, 75,000 medical facilities and more than 70 percent of the hospitals in the United States.

The DAN Recompression Chamber Assistance Program provides training and financial support to recompression chambers throughout the Caribbean and other popular dive destinations.

DAN Training Programs

Oxygen First Aid for Scuba Diving Injuries

This course represents entry level training designed to educate the general diving (and qualified non-diving) public in recognizing possible dive-related injuries and providing emergency oxygen first aid. In addition, rescuers learn to activate the local emergency medical services (EMS) and / or arrange for evacuation to the nearest available medical facility.

In this report, nearly half of injured divers received emergency oxygen in the field but many of these did not receive oxygen concentrations approaching the recommended 100 percent. DAN and all major diving instructional agencies recommend that all divers be qualified to provide 100 percent oxygen in the field to injured divers.

For more than a decade, DAN has emphasized the benefits of providing oxygen to injured scuba divers.

Oxygen First Aid for Aquatic Emergencies

Every year more than 4,000 Americans die from drowning, and many more experience near-drowning events. For more than a decade, DAN has emphasized the benefits of providing oxygen to injured scuba divers. During that time more than 146,000 people worldwide have been trained in this first aid skill. In March of 1999, DAN Services, Inc., a wholly owned for-profit subsidiary of Divers Alert Network, launched the *Oxygen First Aid for Aquatic Emergencies (Aquatics)* program. Its goal is to extend the lifesaving skills of oxygen first aid to people who live near and play in and around water.

First Aid for Hazardous Marine Life Injuries

Although serious marine life injuries are rare, most divers experience minor discomfort from unintentional encounters with fire coral, jellyfish and other marine creatures at some point in their dive careers. Knowing how to minimize these injuries helps divers reduce their discomfort and pain.

The *First Aid for Hazardous Marine Life Injuries* program is designed to provide knowledge regarding specific types of marine creature injuries and the general first aid treatment for those injuries.

Automated External Defibrillators (AEDs) for Scuba Diving

Although a cardiac emergency should always prompt immediate call to the local emergency medical services, the *Automated External Defibrillators (AEDs) for Scuba Diving* Program educates the general diving (and qualified non-diving) public to provide first aid using Basic Life Support techniques and automated external defibrillators. This skill may prove to be lifesaving when you consider that diving is often conducted in remote locations, far removed from emergency medical help.

Advanced Oxygen First Aid for Scuba Diving Injuries

This advanced-level program provides additional training for those individuals who have successfully completed the DAN *Oxygen First Aid for Scuba Diving Injuries* course within the past 12 months. It is designed to train DAN Oxygen Providers to use the MTV-100 or a Bag Valve Mask (BVM) while providing care for a non-breathing injured diver and activating the local emergency medical services (EMS) and / or arranging for evacuation to the nearest available medical facility. This is not a stand-alone program. It is intended to train current DAN Oxygen Providers to provide oxygen using advanced-level skills.

Dive Emergency Management Provider (DEMP)

This program integrates the knowledge and skills from several DAN Training programs into a single eight-hour day (or a two-day course of four hours each). The *Diving Emergency Management Provider* course includes:

- *Oxygen First Aid for Scuba Diving Injuries;*
- *First Aid for Hazardous Marine Life Injuries;*
- *Automated External Defibrillators (AEDs) for Scuba Diving;* and
- *Advanced Oxygen First Aid for Scuba Diving Injuries* (knowledge and skills from DAN *Advanced Oxygen First Aid for Scuba Diving Injuries* are optional).

After reviewing the skills and knowledge development portions of the DEMP program, the students participate in an integrated scenario in which they can bring together all of the skills learned in each segment. To participate in this program, students must be current cardiopulmonary resuscitation (CPR) providers.

DAN Instructors and Instructor Trainers will now be able to offer a complete diving emergency program.

Remote Emergency Medical Oxygen (REMO$_2$)

The DAN *Remote Emergency Medical Oxygen (REMO$_2$)* system module supplements the DAN *Oxygen First Aid in Scuba Diving Injuries* course. Based on medical closed-circuit oxygen rebreather technology, the REMO$_2$ device provides injured divers with high concentrations of emergency oxygen for extended periods. This training course instructs the Oxygen Provider in the use of the new DAN REMO$_2$ system introduced in 2003.

Basic Life Support for Dive Professionals (BLSPRO)

The remote nature of dive accidents, whether a few hours from shore or days from civilization, frequently requires more advanced levels of care than are offered by traditional or entry-level CPR programs. DAN Instructors and Instructor Trainers will now be able to offer a healthcare provider-level basic life support program for their students and divers.

Basic Life Support for Dive Professionals (BLSPRO) is ideal for dive professionals and divers interested in understanding professional-level resuscitation techniques. This program is designed to be applicable to the diving market, including scenes and scenarios from dive situations, as well as the non-diving / healthcare market.

Coupled with DAN's existing Training programs, DAN Instructors and Instructor Trainers will now be able to offer a complete dive emergency program.

DAN Online — www.DiversAlertNetwork.org

DAN's website on the World Wide Web provides a wealth of information on scuba health and safety issues, as well as demonstrating the many benefits of DAN membership. This includes answers to frequently asked dive medical questions, oxygen course listings and the location of a DAN Business Member near you. Members can order DAN products, sign up and renew online.

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

This annual report, as well as the DAN *Annual Progress Report*, can be downloaded free of charge from the DAN website by DAN Members.

DAN *TravelAssist* provides up to $100,000 emergency medical evacuation assistance for any injury or illness incurred at least 50 miles from home.

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 award-winning *Alert Diver* magazine, the DAN *Dive and Travel Medical Guide* and dive and travel discounts.

DAN members are also eligible for dive accident insurance, DAN Term Life Insurance and the exclusive DAN Tag™, diving's medical emergency ID, and the DAN Dog Tag, modeled after the popular military dog tag. DAN Members are also eligible to apply for the DAN MasterCard® credit card from MBNA Bank America. For every new account that is opened and every purchase made with the card, MBNA contributes funds that help support the DAN Mission.

As of January 2004, more than 213,000 members belong to DAN in the United States, the Caribbean, Canada and Mexico, and the 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. *Alert Diver* is published bimonthly.

DAN *Dive and Travel Medical Guide*

New DAN Members receive a copy of the DAN *Dive and Travel Medical Guide*, a valuable reference on treating common diving and travel injuries and illnesses. The guide is also available through the DAN website or by calling DAN Membership Services.

DAN Dive Accident Insurance

DAN members are eligible for three different levels in dive accident coverage — the Preferred, Master and Standard Plans — in addition to DAN membership. DAN's Preferred Plan, in combination with membership benefits, provides unparalleled protection for divers and travelers.

DAN pioneered dive accident insurance in 1987, and in 1992 DAN launched medical evacuation assistance benefits. These moves gave DAN Members valuable additional benefits by helping fill a medical and financial need not being met by any other organization at the time. 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 evacuation charges associated with a dive injury. Although this issue still exists for some divers, DAN strives to help bridge this gap through education.

DAN Dive Safety and Health Products

DAN's product line includes a variety of books and videos about dive safety and health, and emergency oxygen equipment and diver first aid kits. DAN's Product Listing, displaying these and other DAN products, is available in every issue of *Alert Diver* magazine. DAN products are also available on the DAN website at www.DiversAlertNetwork.org

***Alert Diver* magazine is the only publication dedicated to diving safety and health.**

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 to support the DAN Mission. As of January 2004, more than 62,000 DAN Tags were in use.

DAN introduced the DAN Dog Tag in 1998. 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.

Business Members receive special quantity pricing on DAN training materials and safety equipment and selected DAN products for resale.

DAN Business Membership Program

DAN Business Membership is a unique membership class for dive businesses and professionals who want to show their support for dive safety and education while keeping their customers and students participating actively in the sport of scuba diving.

Business Members receive special quantity pricing on DAN training materials and safety equipment and selected DAN products for resale. Under the Rewards program, DAN Business Members also earn one point for enrolling a new DAN Member, and one point for every DAN insurance plan sold to new members. They can redeem points over a 24-month period to obtain DAN products.

Those who become DAN Business Members will receive *On Board*, the free quarterly official newsletter for DAN Industry Members as well as the online newsletter, *HighViz*. They also will get a DAN Business Member Certificate, a DAN Dive Flag, DAN Decals, two DAN Memberships, a subscription to *Alert Diver* magazine and several other bonuses, all for an annual fee of $125.

In 2002, the DAN Business Membership department program also assumed responsibility of the DAN Diver Identification System (formerly the Charter Boat Identification System) and the Partners in Dive Safety program.

DAN's Business Membership program provides its members with great benefits. Call 1-877-532-6776 or +1-919-684-2948 ext. 295 for more information on the program.

DAN Diver Identification System (DIDS)

With DAN's Diver Identification System (DIDS), divemasters will always know how many divers have returned safely from their dive and how many are still enjoying the dive.

The Diver Identification System, supported by DAN Donors and DAN Corporate Sponsors, evolved from DAN's popular Charter Boat Identification System. The revolutionary system now helps divemasters track their divers at all open-water sites and on charter boats.

The system consists of a DAN Tag™ Board and individually and sequentially numbered DAN Tags. It comes in three sizes: Small (6-Pack), Medium (12-Pack) and Large (24-Pack).

The system works like this: at the beginning of each dive trip, the divemaster assigns each diver an individually numbered DAN Tag, with the dive operation name and phone number. When the diver is on the boat, he or she places the DAN Tag on the DIDS board.

Before diving, the diver removes the tag and clips it to his or her buoyancy compensation device. The tag number will also correspond to the divemaster's roster number. When returning to the boat, the diver unclips the tag and returns it to the board for cross-checking by the divemaster. The system ensures that no diver will be left in the water.

The DIDS is free of charge. To start using the DAN Diver Identification System, call the Business Membership Team at 1-877-532-6776. To contribute to this program, call DAN Development at 1-800-446-2671 ext. 446.

DAN Partners in Dive Safety

The DAN Partners in Dive Safety™ program (PDS) recognizes dive operations that have reached a high level of emergency preparedness. Begun on Jan. 1, 1998, PDS applies to any dive center, resort, liveaboard or dive charter vessel that meets certain minimum requirements. The PDS program includes safety measures in three major areas of emergency preparedness: staff, diver, and emergency equipment.

- **STAFF EMERGENCY PREPAREDNESS** — All staff members must have current certification in four areas of emergency management, and they must provide current documentation of training in all aspects of emergency management from nationally or internationally recognized diver-training associations / agencies. These areas include:
  - First Aid (appropriate for location)
  - Water Rescue
  - CPR (Adult)
  - Oxygen First Aid Training

The DAN Partners in Dive Safety™ program (PDS) recognizes dive operations that have reached a high level of emergency preparedness.

With the DAN Student Membership program Dive Instructors can provide their students with essential dive insurance that all open-water students should have.

- **DIVER EMERGENCY PREPAREDNESS** — The dive operation ensures divers' preparedness by conducting:
  - Pre-dive activities that include dive briefings to review responsible diver activities and to remind divers of the safety stop
  - Post-dive activities that include two methods of accounting for their divers and dive debriefing.

- **EMERGENCY EQUIPMENT PREPAREDNESS** — A dive boat reflects a safety consciousness by having the following on board:
  - First Aid Kit (appropriate for the location)
  - Emergency Oxygen Unit capable of providing:
    - high concentrations of oxygen (100 percent is ideal)
    - oxygen for breathing and non-breathing injured divers
    - enough oxygen for simultaneous use by more than one diver

- **EMERGENCY ASSISTANCE PLAN** — All operations must have a functional emergency plan that links to local emergency medical services (ambulance services, rescue squads, etc.). A complete emergency assistance plan should be prominently displayed and should include:
  - Initial contact information
  - Emergency medical assistance contacts
  - Emergency first aid procedures
  - Diving medical consultation information
  - Recompression chamber information

For more details about the Partners in Dive Safety program, call DAN Business Membership at 1-877-532-6776 or +1-919-684-2948 ext. 295.

DAN Student Membership Program

Instructors now have two choices when enrolling their open-water students in the DAN Student Membership program. New rosters are available on the DAN website at www.DiversAlertNetwork.org — download the new roster and print it whenever you need it, or use the new online roster and email the student information directly to DAN. Either way, Instructors can provide their students with essential dive insurance that all open-water students should have.

When you enroll your students, be sure to give your students their Insurance Record and DAN membership application. Include your DAN number on the roster so you can earn valuable DAN points. Students will be enrolled when DAN receives the roster.

Instructors who do not have access to a computer can call the DAN Business Membership team at 1-877-532-6776 and request a free Student Membership Kit (product code 821-0300).

For every student who signs up as a regular DAN Member within six months of enrolling as a DAN Student Member, instructors or dive retailers receive a point they can use to purchase DAN safety products.

To order materials or learn more about the DAN Student Membership program, call 1-877-5DAN PRO (1-877-532-6776) or see the "Training & Education" section at the DAN website, www.DiversAlertNetwork.org. Use product code 821-0300 when ordering materials.

International DAN

International DAN (IDAN) is comprised of five independent DAN organizations based around the world to provide expert emergency medical and referral services to regional diving communities. International DAN offices include: DAN America, DAN Europe, DAN South East Asia-Pacific, DAN Southern Africa and DAN Japan. The President of DAN America represents DAN America to International DAN. The future goals of IDAN include standardization of services and member benefits, greater cooperation in areas of research, education and sharing of dive injury data.

The International Department at DAN America handles issues related to the DAN Mission and strategic goals in areas outside the U.S. but still within the DAN America region (North and South America). Its primary focus at this time is increasing DAN's presence in Latin America but that may expand to include Canada in the future.

To help reach the increasing diving community in Latin America, DAN through its International Department provides promotional, membership and training material in Spanish and Portuguese. Also, in 2001, DAN created a dedicated Spanish / Portuguese language emergency hotline (+1-919-684-9111) and a network of chambers and dive physicians to serve all of Central and South America.

For more information on the DAN International department, call 1-800-446-2671 or +1-919-684-2948 ext. 615 or 616.

The International Department at DAN America handles issues related to the DAN mission and strategic goals in areas outside the U.S. but still within the DAN America region.

DAN Development

Donors to DAN make a huge impact on all facets of the DAN Mission of dive safety. At DAN, we offer many giving opportunities that appeal to divers, dive enthusiasts and non-divers who are simply interested in the sport. Unrestricted gifts provide resources that support a variety of initiatives, which are directly related to dive safety. Of course, you may designate your gift for a specific program or initiative.

Financial support from DAN Donors — whether an annual gift, an endowment gift, or a planned gift — is essential to our maintaining the quality of the research, education and service we strive to provide for the benefit of divers.

If you would like more information or assistance, please contact us at 1-800-446-2671 or +1-919-684-2948 ext. 446. We can help you meet your philanthropic goals, while ensuring that divers continue to receive the best DAN can offer.

Donors to DAN make a huge impact on all facets of the DAN Mission of dive safety.

1. INTRODUCTION

Divers Alert Network (DAN) collected data during calendar year 2002 about divers who were injured, divers who died, and divers in Project Dive Exploration, for whom injury was rare. These populations are described below.

1.1 Project Dive Exploration (PDE)

Project Dive Exploration (PDE) is a prospective investigation of the medical history, depth-time exposure and medical outcome of a sample of the diving population. PDE seeks to estimate the incidence of decompression illness (DCI) within the components of this population and to investigate the relationship of decompression sickness (DCS) probability to the depth-time profile and diver characteristics. PDE also provides an injury-free control population for comparison with the injury and fatality populations.

PDE is funded by Divers Alert Network membership and donors. It was made possible by the development of downloadable dive computers and depth-time recorders. PDE became practical with the support of the manufacturers Cochran, DiveRite, Suunto, Scubapro / Uwatec and ReefNet, who made their dive computers and recorders PDE-compatible.

Figure 1.1-1 shows the number of dives collected between 1995 and 2002. To date, there have been more than 53,315 dives by 4,756 divers and 30 cases of DCS and two deaths.

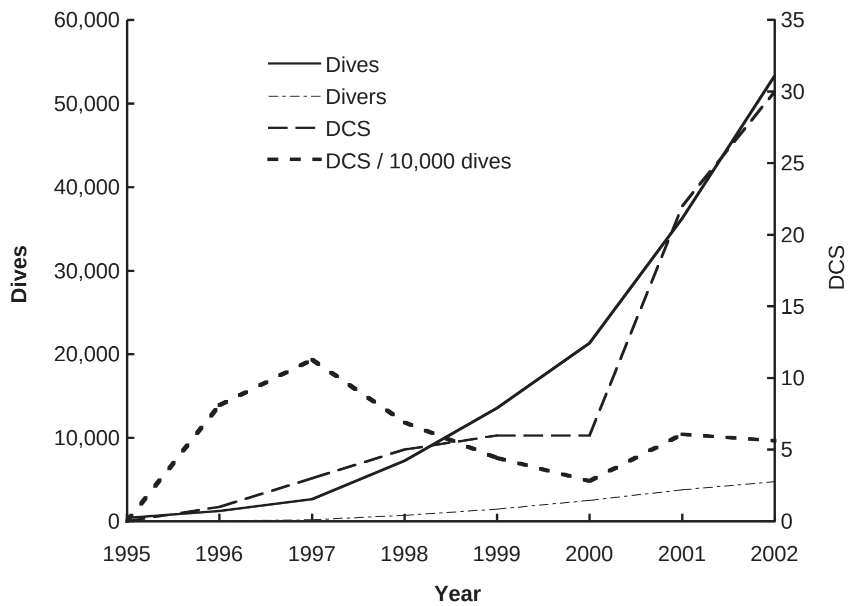


Figure 1.1-1 Project Dive Exploration progress.

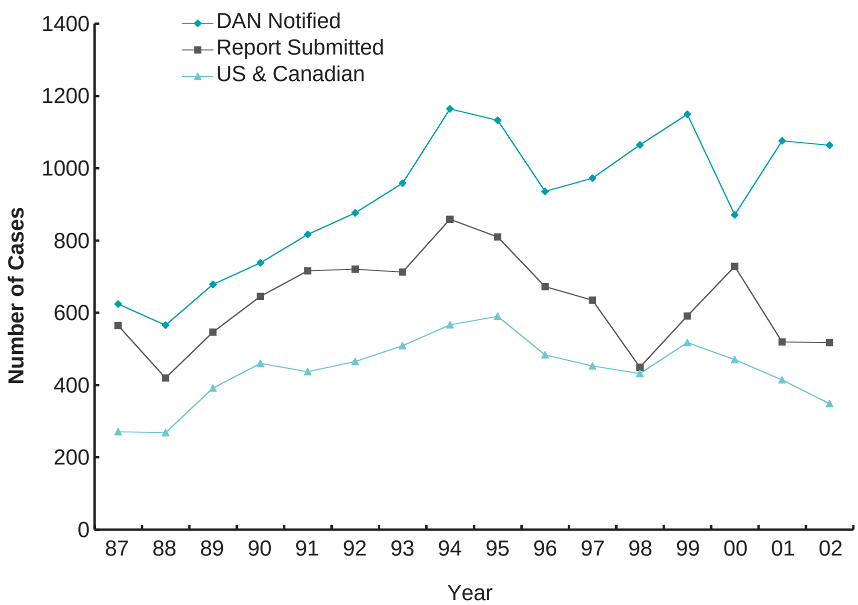
1.2 Diving Injuries

Figure 1.2-1 shows the annual record of diving injuries since DAN began collecting injury data in 1987. The upper line in Figure 1.2-1 represents the total count of dive injuries that participating chambers reported to DAN. The middle line in Figure 1.2-1 represents all injuries for which written reports were submitted to DAN. The bottom line represents recreational diving injuries among U.S. and Canadian residents, who are those included in this report.

In 2002, DAN America received 517 reports out of 1,063 treated cases. In 474 cases, reports pertained to recreational divers who resided in the U.S. or Canada. A total of 348 written reports contained sufficient information to be described in subsequent sections of this report.

Of 517 reports submitted in 2002, 60 percent were DAN America Members, 38 percent were not DAN Members, and membership status was unknown for two percent. DAN made follow-up calls to divers who did not have total resolution of signs and symptoms upon completion of all recompression therapy at three months, six months, nine months and 12 months, or until they reported full resolution. A selection of representative or interesting case reports is presented in Appendix A.

Figure 1 .2-1 Annual record of dive injury cases.



1.3 Diving Fatalities

John McAniff of the University of Rhode Island began collecting information about recreational dive fatalities in 1970. DAN joined the collection process in 1989 and worked with McAniff until his retirement in 1995.

Figure 1.3-1 shows the annual numbers of U.S. or Canadian residents who died during recreational diving and were reported to DAN. DAN gathers information about diving fatalities, but as DAN is not an investigating agency, information-gathering is restricted to interviews and record reviews. Thus, the collected information is unverified and frequently incomplete.

Fatalities who had resided in locations other than the U.S. and Canada could not be readily followed up and were not included in Figure 1.3-1. There were 83 U.S. and six Canadian diving fatalities for 89 reports in 2002. Case summaries for all of these are presented in Appendix B.

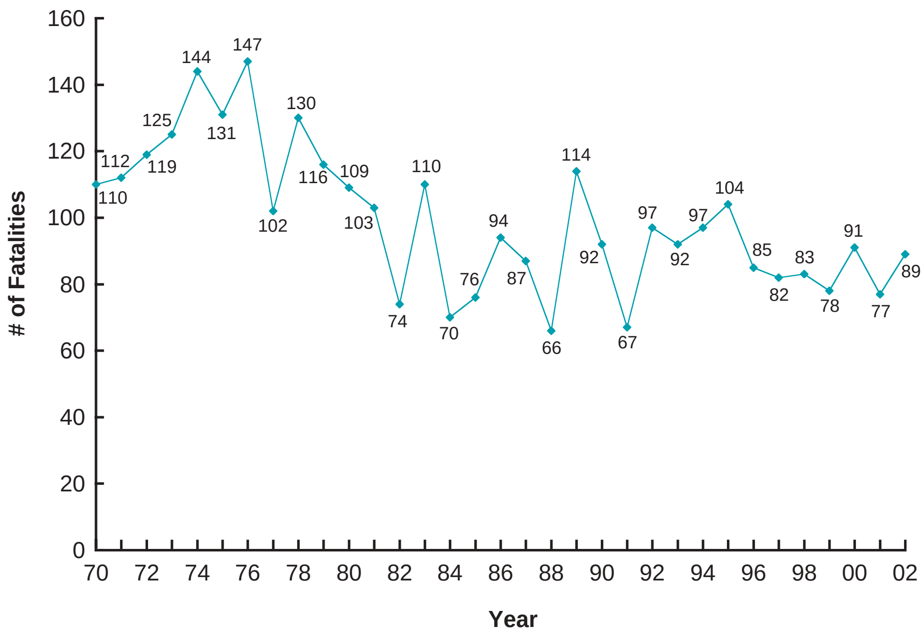


Figure 1.3-1 Annual record of U.S. and Canadian recreational diving fatalities.

2. Project Dive Exploration (PDE)

PDE is an observational research study that collects and analyzes electronic pressure-time exposures from recording dive computers worn by recreational divers.

2.1 Introduction

DAN Research is continuing to address the scientific need for a database of recreational dives through Project Dive Exploration (PDE). PDE is an observational research study that collects and analyzes electronic pressure-time exposures from data-logging dive computers worn by recreational divers. Currently, four dive computers and one data recorder are PDE-compatible: Cochran, DiveRite, Suunto, Uwatec and Reefnet Sensus. Other computer manufacturers will participate in the next year.

Since its inception in 1995, PDE has recorded more than 53,000 dives. Thirty cases of decompression sickness and two deaths have been associated with these exposures. The deaths were not felt to be DCI-related. In PDE, the diver's health status before the dive and at 48 hours after diving or flying is linked to the digitally recorded pressure-time exposure. PDE specifically captures:

1) the diver's demographic data;
2) the diver's pre-existing medical data;
3) the diver's digital dive pressure-time exposure data; and,
4) a 48-hour report on any medical outcome associated with the pressure exposure.

The project's goal is to provide accurate data for complex physiological modeling and hypothesis testing of diving-related conditions.

All participants in PDE must be certified recreational divers. If the diver is exposed to altitude during the 48-hour post-dive reporting period, this exposure becomes part of the recorded dive profile.

Participation is open to all divers 18 or older. Many divers participate under the guidance of a Field Research Coordinator (FRC), who coordinates the data collection and entry and submits the dive profiles to DAN. The FRC is a passive observer and is instructed not to interfere with the conduct of any dive. FRCs do not screen divers for symptoms of DCI, nor do they play any official medical role in the event of a dive accident. Divers are also encouraged to collect dive profiles on their own without the assistance of an FRC. Dive profiles downloaded from Cochran and DiveRite computers can be emailed directly to DAN. Further information is available at the DAN website at www.DiversAlertNetwork.org.

2.2 PDE 2002

The data described in this section summarize the characteristics of the divers and dives sampled by PDE. The captured data are not a representative sample of recreational diving, and using PDE to make general statements about all divers is inappropriate. However, as the size and scope of the PDE database increases, it will become easier to choose representative subsets of PDE participants to use as control groups for comparison studies (see the example of subsets in Table 2.2-1 on page 27). This case-control technique has recently been used with PDE data to study flying after diving ("The relative risk of decompression sickness during and after air travel following diving." JJ Freiberger, PJ Denoble, CF Pieper, DM Uguccioni, NW Pollock, and RD Vann. Aviat Space Environ Med 2002; 73:980-4).

Project Dive Exploration collected data on 17,060 dives in 2,214 dive series by 1,573 divers in 2002 (Figure 2.2-1). Seven divers were diagnosed with DCS and treated in hyperbaric chambers in 2002. The data collected on an annual basis continues to increase, bringing the total number of dives logged by PDE to 53,315 (Figure 2.2-2.)

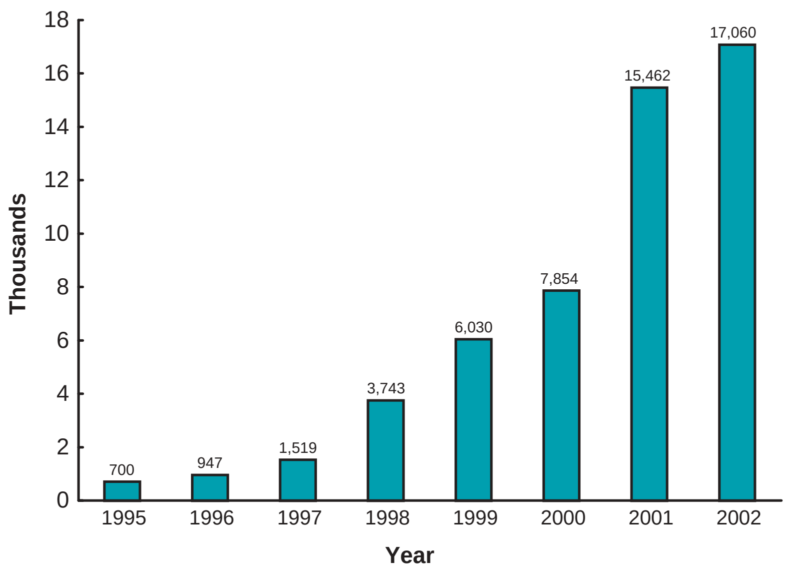
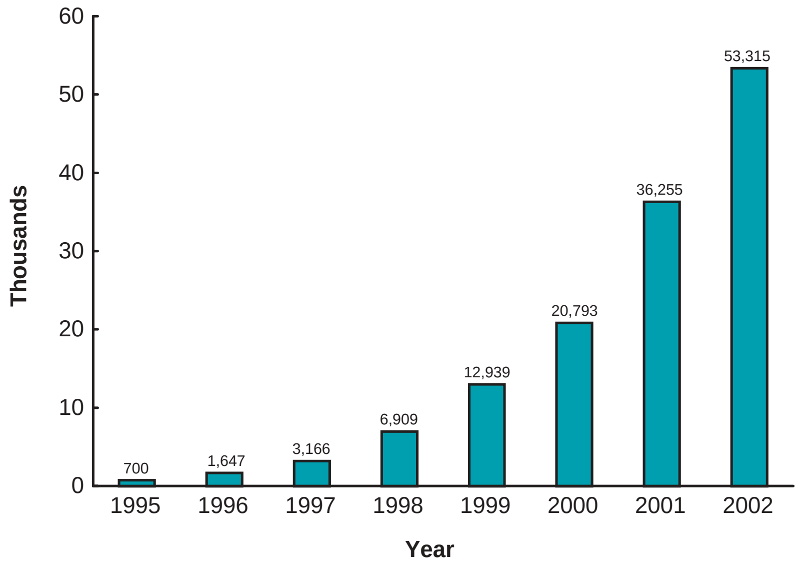


Figure 2.2-1 Annual data collection progress since 1995.

Figure 2.2-2 Cumulative number of PDE dives collected (1995-2002). (N=53,315)



Collection centers, FRCs, and summer interns all contributed to the large increase in data collection. In 2002, DAN also received data from individual divers using Cochran and Dive Rite downloadable dive computers that can submit profiles directly to DAN via the internet from their dive log application.

Table 2.2-1 shows an example of the breakdown and subgrouping of dives by methodology of data collection. PDE dives were collected from six main sources. It is easy to see why PDE divers do not necessarily represent the general diving population. Approximately 7.5 percent of all PDE dives collected in 2002 were from diving professionals in Cozumel, Mexico and 38 percent were from liveaboards. However, even though this sample may not be representative of the wider diving community, it does provide a large database from which matched cases can be selected later for comparison.

The categories in Table 2.2-1 are:

1) dive guides in Cozumel, Mexico;
2) divers on liveaboard dive boats;
3) 2002 DAN summer interns;
4) divers diving at Scapa Flow in Orkney, Scotland;
5) individual FRCs; and
6) individual divers who independently reported to DAN.

Groups 5 and 6 represent individual divers who used software written at DAN to individually collect and transmit the dive computer recorded profile information. We hope to encourage this form of reporting in the future. Because the methodology of PDE data storage is flexible, it is possible to construct other possible subgroups if the research need arises.

Source	# Divers	# Dives
Liveaboard collection centers	272	6,593
DAN interns	747	4,878
Scapa Flow, Scotland	254	2,795
Dive guides in Cozumel	23	1,283
Individual FRCs	242	1,063
Independent users of DL7 L-3 compatible dive computers	35	448
Total	**1,573**	**17,060**

Table 2.2-1 Sources of 2002 PDE data.

Data collection was relatively constant for most of the year, with a peak in the summer months (Figure 2.2-3). Those peak months correspond to the greatest activity for recreational diving and for DAN Interns. This has been a consistent finding over the five-year period 1998 to 2002.

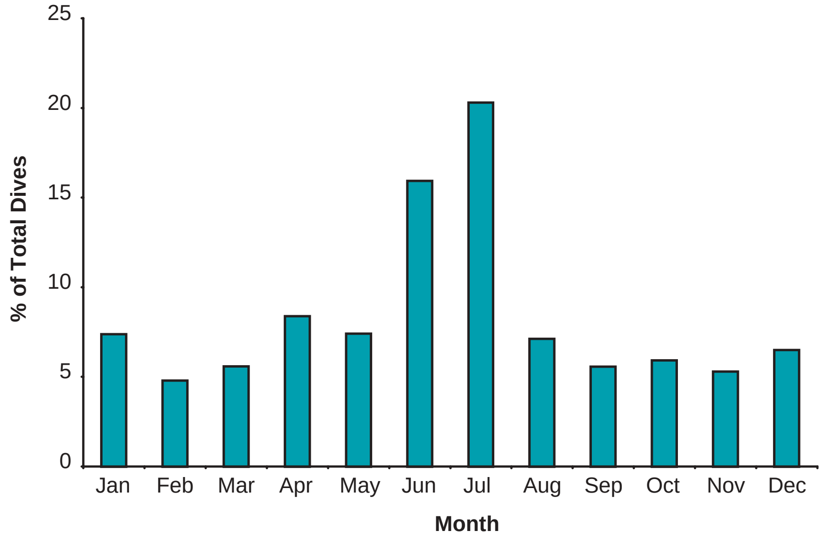


Figure 2.2-3 Percentage of total dives recorded by month (2002) (N=17,060).

2.3 Divers

The following information describes both the characteristics of the divers who participated in PDE in 2002 and the frequency of their diving exposure. During 2002, 1,573 divers participated in PDE. They made a total of 17,060 dives for which profiles were submitted to DAN. Most of the volunteers (84.4 percent) contributed only one series of dives. The median number of dives in each series was seven. The maximum number of dive series contributed by any one individual was 36. Only 54, or 2.8 percent of all divers, participated with more than four dive series. These were mainly individual FRCs who were using DL7 Level 3-compatible dive computers and sent in all their dives throughout the year. Including multiple dive series by a given diver, 1,573 divers contributed 2,214 series.

Tables 2.3-1 through 2.3-3 describe the diving frequency of PDE participants. Some divers contributed more than one dive series.

Table 2.3-1 Number of series per diver (2002).

# Series	Frequency	Percent
1	1,327	84.4
2 - 4	202	12.8
5 - 9	28	1.8
10 - 19	14	0.9
> 20	2	0.1
Total # Divers	1,573	100

Table 2.3-2 Number of dives per diver.

# Dives	Frequency	Percent
1	116	7.4
2 - 4	524	33.3
5 - 9	288	18.3
10 - 19	465	29.6
20 - 29	142	9.0
30 - 99	32	2.0
> 100	6	0.4
Total # Divers	1,573	100

Table 2.3-3 Basic statistics of divers' participation.

	Maximum	Mean	Median
# Series	36	1.5	1
# Days / Series	175	5.4	4
# Dives / Series	351	11.4	7
# Dives per day	6	2.1	2

The age and gender distribution for the 2002 PDE volunteers is shown in Figure 2.3-1. Most of the participants were between 30 and 50 years of age. However, consistent with U.S. demographics, older divers are a growing percentage of PDE participants. In 2002, divers over age 50 represented 20 percent of the sample, and divers under age 20 represented only 3 percent. Overall, women comprised 29 percent of all PDE divers, a number that has been stable over five years.

Figure 2.3-1 The age and gender of divers for each dive series in 2002 (N=2,214).

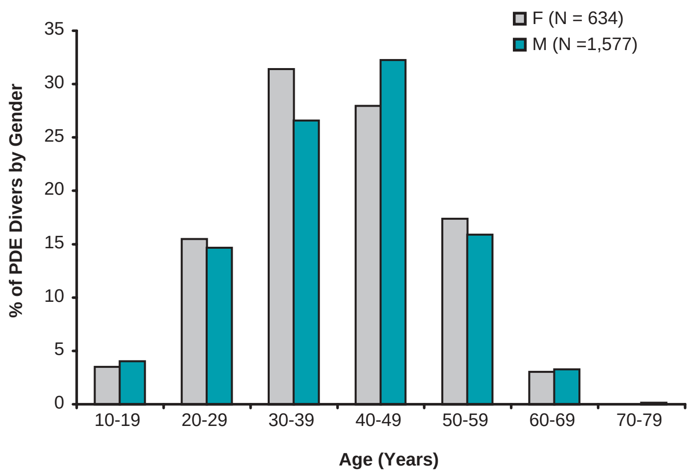


Figure 2.3-2 illustrates the certification level by gender of divers. Most divers had earned certification beyond basic "open-water" and only 2.2 percent were students.

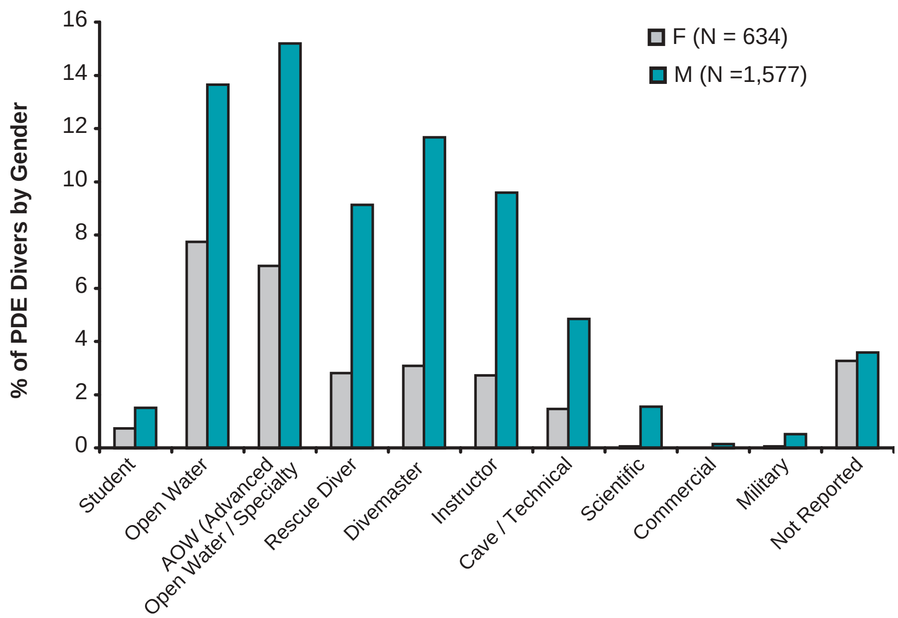


Figure 2.3-2 The percentage of 2002 PDE volunteers by certification of divers and by gender (N=2,214).

Forty-three percent of the sampled divers had five years or less since certification, and 28 percent had 10 years or more (Table 2.3-4). Many PDE divers are dedicated to their sport and appear to be life-time divers.

Table 2.3-4 The percentage of PDE volunteers by years for 1998 to 2002.

Years Diving	1998	1999	2000	2001	2002
1	19.3	16.4	17.9	15.5	15.6
2	4.8	7.1	9.8	6.4	6.4
3	7.8	7.9	7.1	10.9	7.1
4	6.0	7.9	6.3	6.0	6.6
5	4.4	3.5	5.4	3.8	5.1
6-10	25.3	23.7	21.0	19.4	18.4
>10	26.7	26.2	29.3	26.3	30.1
Not Reported	5.8	7.5	3.3	11.8	10.7
Total	100	100	100	100	100

When PDE divers were questioned about chronic health conditions, 48 percent of the participants reported some medical problem, 38 percent of participants denied any chronic health problem and the remainder (14 percent) did not report. Figure 2.3-3 shows the chronic health conditions reported by the divers providing PDE data in 2002. Some divers reported more than one condition.

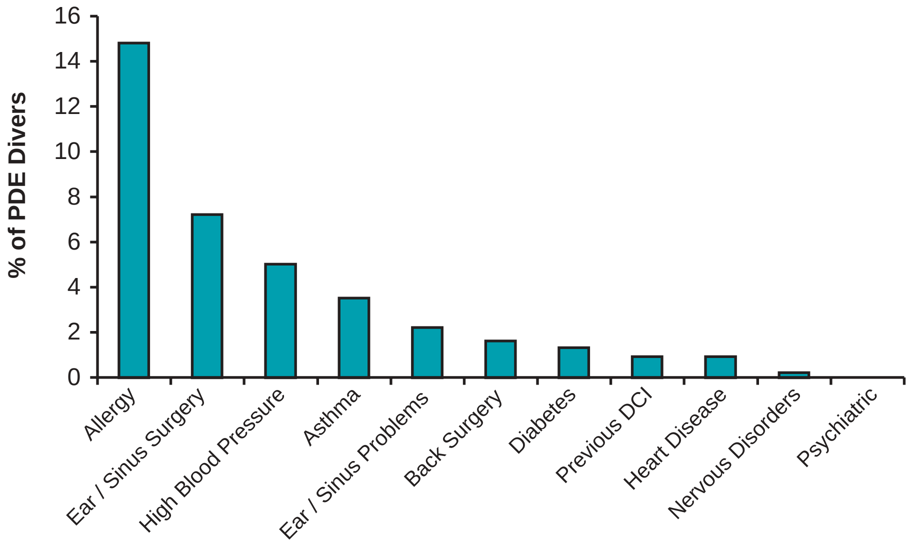


Figure 2.3-3 The percentage of PDE volunteers listing the following chronic health conditions in 2002 (N=2,214).

Seasonal allergy was the most frequently reported condition in our sample (15 percent). This was followed by chronic ear and sinus problems (7 percent). High blood pressure was reported in 5 percent of divers. As is consistent with the prevalence of asthma in the general population, 3.5 percent of divers reported having experienced asthma in the past. A total of 1.3 percent of the sampled divers reported having diabetes and 1 percent of participants reported having experienced previous incidences of DCS. The prevalence of diabetes is estimated to be between 4 and 6 percent of the world population.

PDE divers were also questioned about acute medical problems they experienced before diving. Most divers reported only minor complaints such as an upper respiratory infection (URI). Figure 2.3-4 shows some of the acute conditions recorded. The term "orthopedic" refers to any bone- or joint-related condition or injury. The use of birth control medication was reported by 23 percent of female divers.

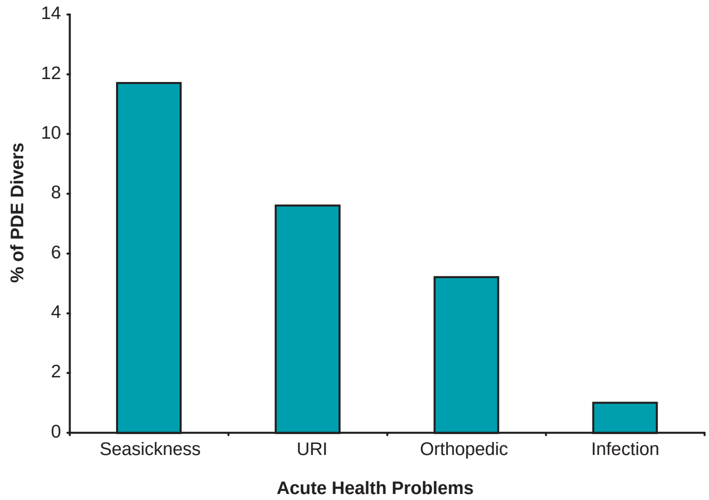


Figure 2.3-4 Percentage of PDE divers reporting the following acute health problems before a dive in 2002 (N=2,214).

2.4 Dives

Because evidence suggests that the type of diving environment may influence the risk of injury, stratification of the database by dive environment is necessary. Due to the nature of DAN's data collection methodology, most PDE data (95 percent) were collected during recreational diving in an ocean (saltwater) environment, 3.8 percent of PDE dive profiles came from freshwater diving and 1 percent of the dives were made in caves.

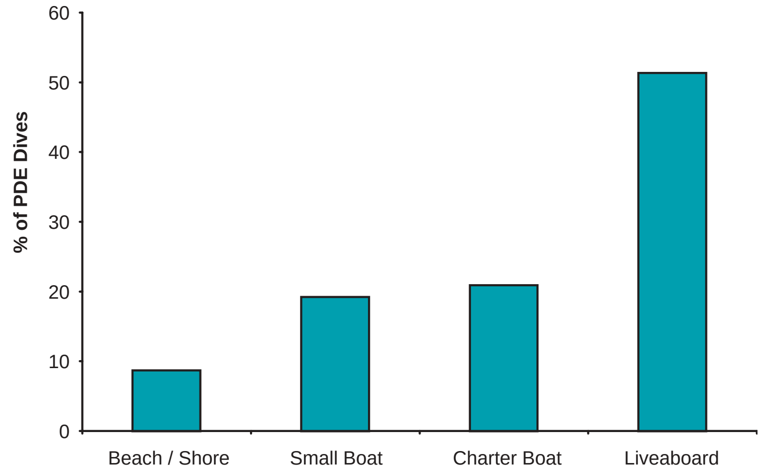
Because one of the goals for building the PDE database is to provide controls for case-control type comparisons with DAN's injury database, the characteristics of the overall five-year database are more meaningful to investigators. Table 2.4-1 summarizes the number of exposures available for use from each of the diving environments listed. The number of freshwater, cave and cold-water dive profiles are growing steadily.

Environment	# Dives	%
Ocean / Sea	39,788	94.6
Lake / Quarry	1,610	3.8
Cave / Cavern	489	1.2
Pool	30	0.0
Other	123	0.01
Total	42,040	100

Table 2.4-1 Percentage of the PDE sample by diving environment for the years 1998-2002.

Similar logic applies to the reason for cataloguing the platform (or venue) from which the dives were made. Figure 2.4-1 shows data collected over five years that describe the dive platform of PDE divers. The majority of PDE dive profiles were collected from live-aboards and represents a useful database of repetitive and multiday diving exposures.

Figure 2.4-1 Percentage of the PDE sample by dive platform for the years 1998-2002 (N=42,040).



Even though only 9 percent of the PDE dives were walk-in beach dives, this group represents a significant number of exposures that are available for comparison with other groups.

Figure 2.4-2a describes the breathing gas used by PDE volunteers in 2002. Air was used in majority of dives (70 percent). Nitrox was used in 28.5 percent and helium was part of the gas mix in 1 percent of the dives sampled. The use of nitrox was noted to be higher than in previous years, based on comparison of the 2002 to the five-year data (Figure 2.4-2b). The use of helium gas mixes increased to a lesser extent.

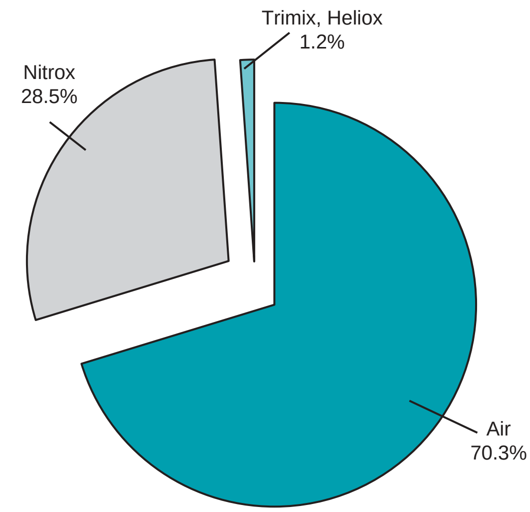


Figure 2.4-2a Percentage of the dives by breathing gas for 2002 (N=16,452).

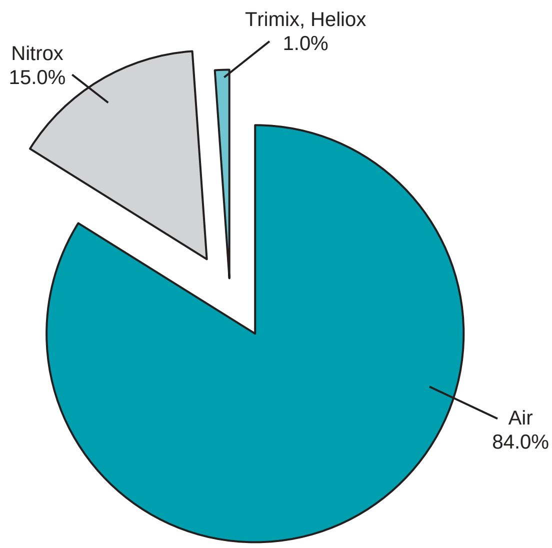


Figure 2.4-2b Percentage of the dives by breathing gas for the years 1998-2002 (N=42,040).

Almost all of the PDE divers (99 percent) used open-circuit scuba breathing apparatus. Rebreathers were used in 67 dives and surface-supplied gear in 46 dives in the five-year database.

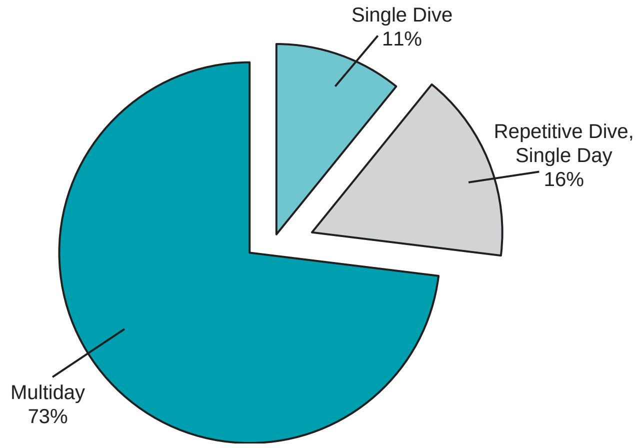
Thermal protection employed by divers in the sample depended on the geographic area where the dive was made. In Scapa Flow, nearly all divers (99 percent) wore drysuits. The percentage of drysuit use in the remainder of the sample was less than 1 percent.

The reported purpose of the dive in our sample was sightseeing in 83 percent of the cases, while teaching / learning, photography, proficiency, spearfishing, or non-professional work were declared in less than 1 percent each. Purpose was not explicitly declared in 15 percent of the sample, although the dives were in a typical recreational setting.

2.5 Dive Series

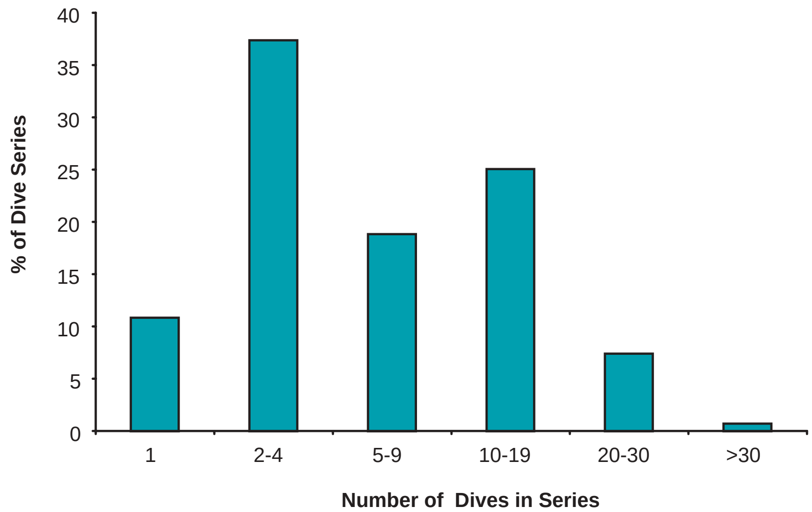
PDE has recorded 6,611 dive series from 1998 through 2002. Figure 2.5-1 breaks down those series by the number of days of diving. Dive series comprised multiday diving in 73 percent of cases, single-day repetitive diving in 16 percent of cases and single-dive days in 11 percent of cases. The 2002 data were not significantly different from the five-year data.

Figure 2.5-1 Percentage of the PDE sample by type of dive series for 1998-2002 (N=42,040).



Figures 2.5-2 and 2.5-3 indicate that the most frequent dive series pattern in our 2002 sample was two to four dives over one to two days. Series consisting of six to eight days of diving were common for liveaboard participants. Series with over six days diving were, for the most part, contributed by the Cozumel dive professionals who participated in PDE. The 2002 data were similar to that of the five-year averages, but the five-year sample had extremes of 50 days and 110 dives.

Figure 2.5-2 Percentage of the PDE sample with the indicated number of dives in the dive series for 2002 (N=2,214).



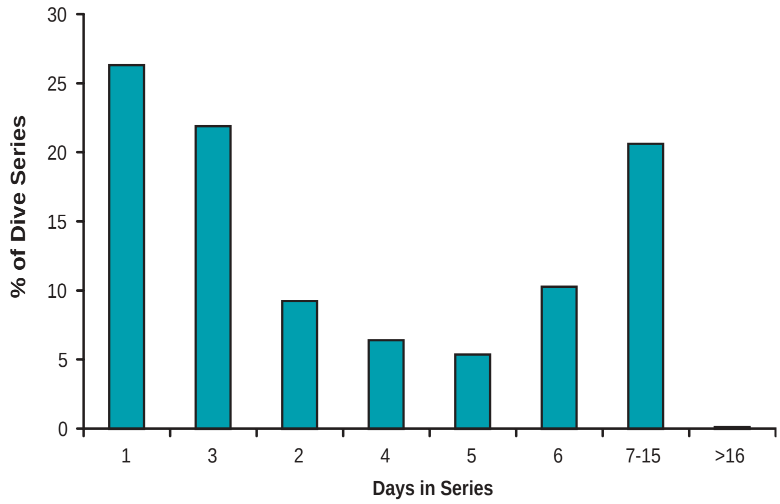


Figure 2.5-3 Percentage of the PDE sample with the indicated number of days in dive series for 2002 (N=2,214).

The maximum depth distribution for all dives sampled in 2002 by PDE is shown in Figure 2.5-4. In 75 percent of the sampled dives, the maximum depth was less than 90 fsw (feet of sea water / 27 msw, or meters of sea water). The maximum depth was greater than 120 fsw / 40 msw in less than 5 percent of dives. Divers who made a large numbers of dives in their series strongly influenced this distribution.

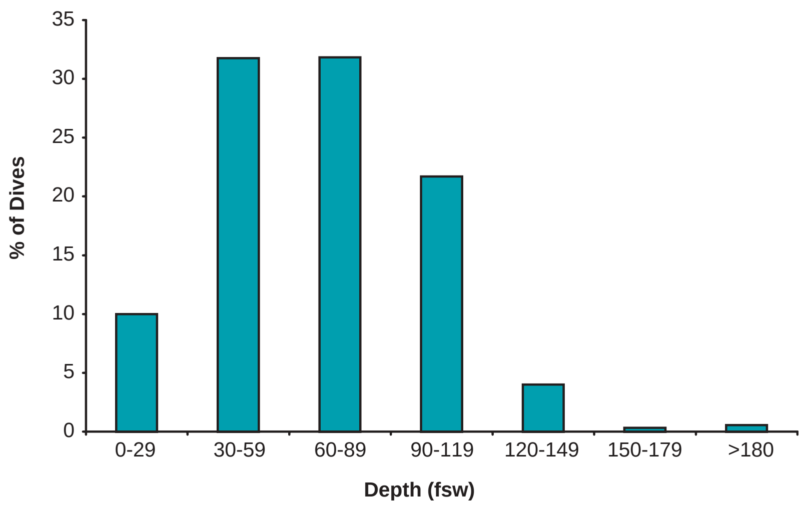


Figure 2.5-4 Percentage of the PDE dives that reached the indicated maximum depths for 2002 (N=17,060).

The maximum depth of the dive series (Figures 2.5-5, 2.5-6) more accurately represents how deep PDE divers descended. Over the five-year period reported, 58 percent of PDE divers made dives deeper than 90 fsw, and 22 percent dived deeper than 120 fsw at least once during their dive series.

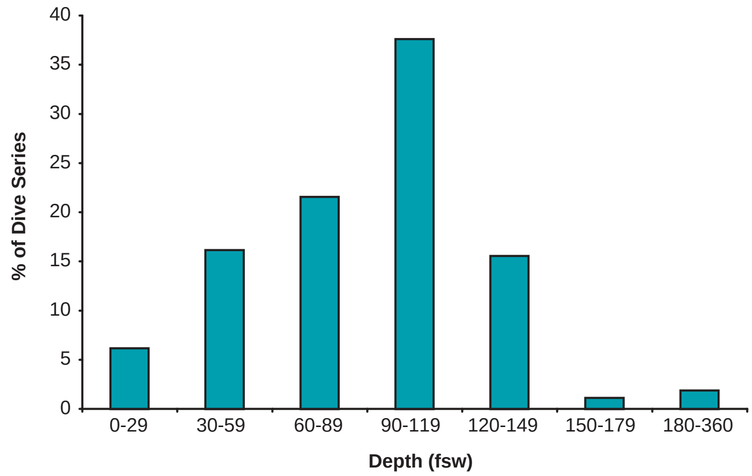


Figure 2.5-5 Percentage of the PDE dive series that reached the indicated maximum depth in 2002 (N=2,214).

Towards the end of the series, PDE divers dived to shallower depths. This is indicated by Figure 2.5-6, which compares the maximum depth of the dive series to the maximum depth on the last day of diving and of the last dive.

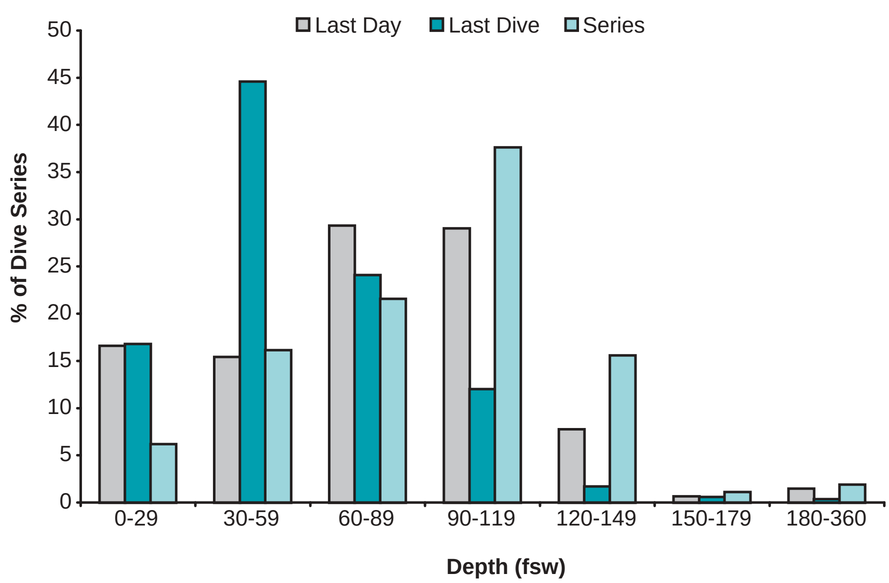
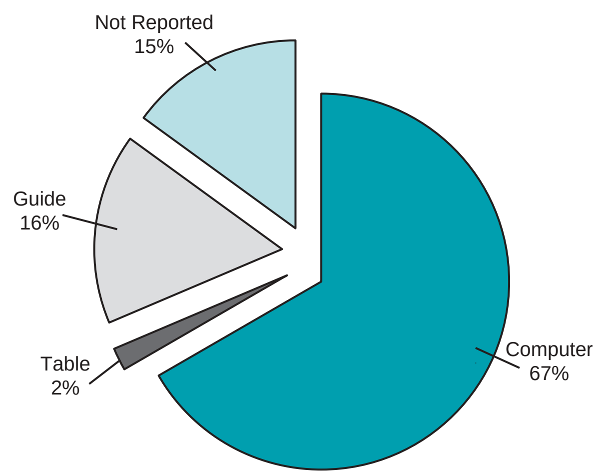


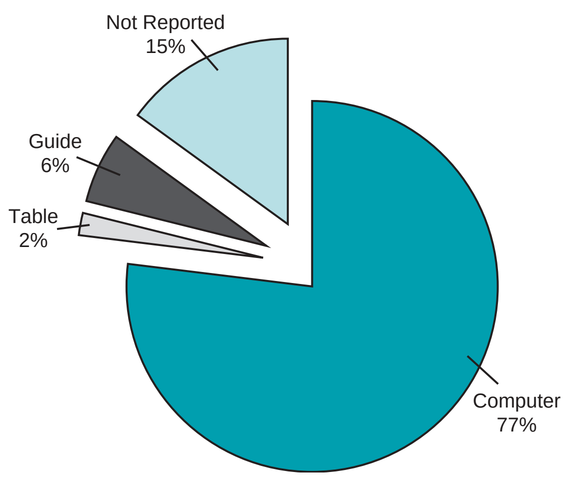
Figure 2.5-6 Percentage of the PDE sample for indicated maximum depths for the last dives from 2002 (N=2,214).

2.6 Dive Planning

Figures 2.6-1a and b illustrate the distribution of dive planning methods in 2002 and over five years. Most divers in our sample used dive computers to conduct and plan their dives. In the 2002 data, more divers stated they followed the dive guide (16 percent) than was indicated in the combined five-year sample. In the combined sample, 6 percent relied completely on others for their decompression planning by following a dive guide, and only 2 percent consulted dive tables without using a computer.



Figures 2.6-1a Percentage of the PDE sample in each reported type of dive planning for 2002 (N=2,214).



Figures 2.6-1b Percentage of the PDE sample in each reported type of dive planning for 1998 to 2002 (N=6,611).

Figures 2.6-2a and b show the percentage of divers in the 2002 and five-year samples who reported making decompression or safety stops. A safety stop was reported for 53 percent of all 2002 dives. This was an increase compared with the five-year sample. Most of the reported decompression dives were made at Scapa Flow, Scotland.

Figure 2.6-2a Percentage of the PDE sample making the indicated decompression stops in 2002 (N=16,452).

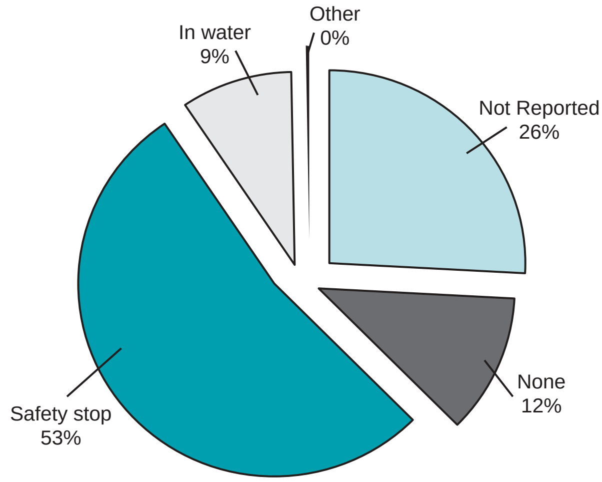
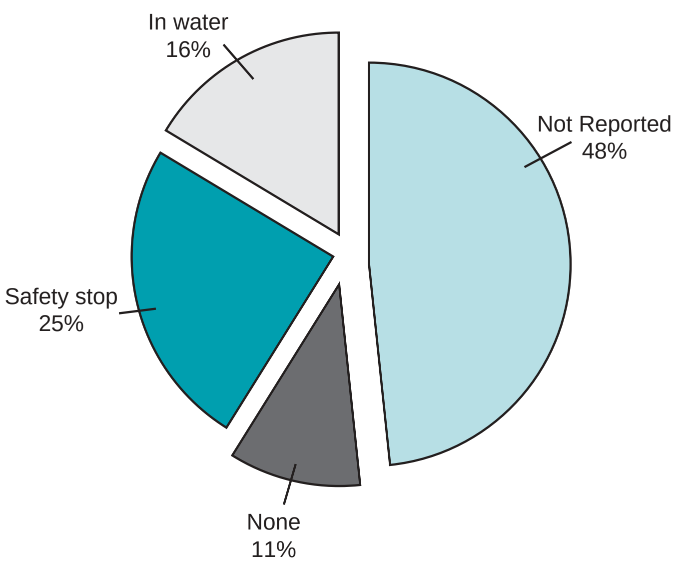


Figure 2.6-2b Percentage of the PDE sample making the indicated decompression stops for 1998 to 2002 (N=42,040).



The subjective work rate in the majority of dives was light. Only in 2 percent of all dives did the diver report a heavy work rate. There was little difference between the 2002 and the five-year average. (Figure 2.6-3).

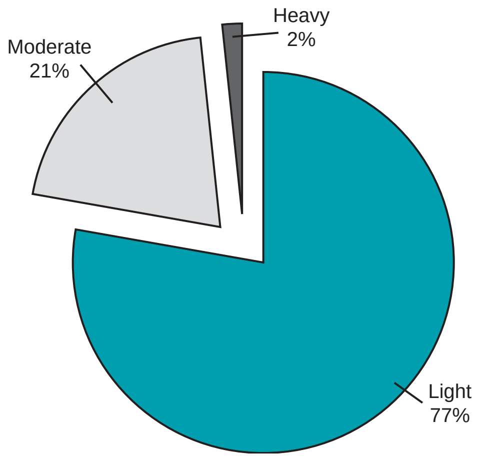


Figure 2.6-3 Percentage of the PDE sample reporting the indicated dive work rate in 2002 (N=13,092).

Figure 2.6-4 illustrates the reported thermal comfort of the divers in our sample. Most divers indicated they were comfortable. The subjective feeling of thermal comfort did not show any direct relationship to the minimum water temperature. The five-year data sample showed similar patterns.

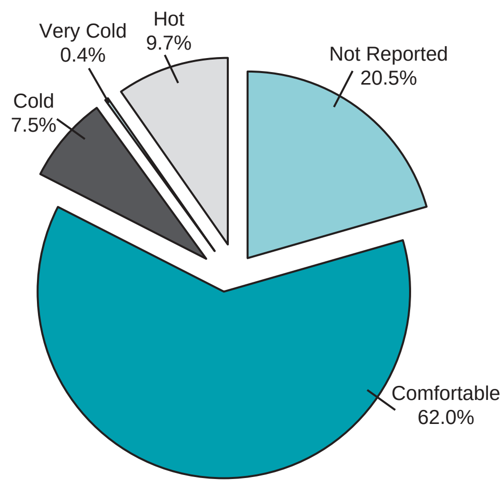


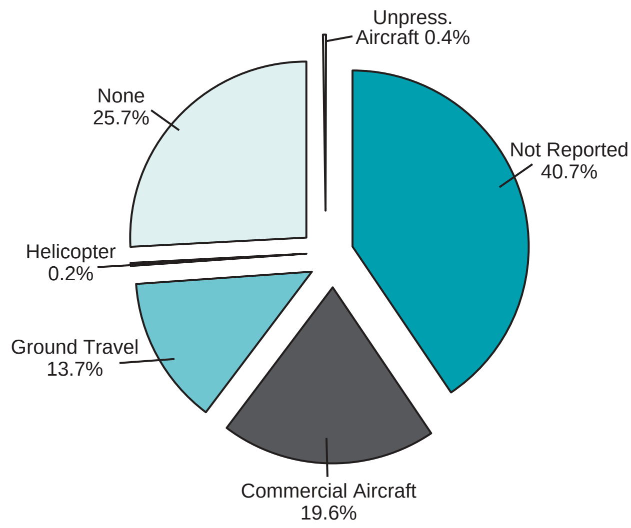
Figure 2.6-4 Percentage of the PDE sample reporting the indicated thermal comfort categories in 2002 (N=16,452).

2.7 Flying After Diving

If a diver was exposed to a secondary decompression stress due to altitude change within 48 hours of his last dive, the altitude exposure was considered as part of the PDE dive series. Because most altitude exposures occur with flying, this exposure is referred to as "flying after diving" (FAD) even though it also can be caused by mountain travel. Most altitude exposures in our sample occurred in commercial airliners that are required by law to maintain a cabin pressure equivalent to not more than 8,000 feet above sea level (approximately 77 percent of the atmospheric pressure at sea level). Flying in non-pressurized fixed-wing aircraft or helicopters after diving was uncommon.

Figure 2.7-1 shows that at least 19 percent of all reporting participants flew in commercial airliners within 48 hours of their last dive in 2002. Thirty-one percent of all PDE participants who reported altitude exposure flew commercially within 48 hours of diving. Most reporting PDE divers flew between 22 and 30 hours after their last dive. The five-year data were similar.

Figure 2.7-1 Percentage of the PDE sample reporting the following types of altitude exposure after dive series in 2002 (N=2,214).



2.8 Outcomes

PDE divers were asked to report symptoms and signs after diving before leaving the dive site. They were also asked to mail in a 48-Hour Report Form to confirm or deny the presence or absence of symptoms or signs at 48 hours after the last dive or flight. If a diver reported signs or symptoms in the 48-Hour Report Form, DAN followed up the report for details necessary to classify the outcome. Four possible medical outcomes were compiled: (a) uneventful (signs or symptoms denied); (b) an incident (a dive series that recorded a potentially dangerous event but with no injury); (c) an injury considered unrelated to DCI; and (d) DCI (DCS or AGE).

2.8.1 Incidents

Fig. 2.8-1 indicates that most PDE divers reported no difficulties. Problems were reported in approximately 5 percent of dives. Equalization was the most frequently reported difficulty (3.8 percent of total).

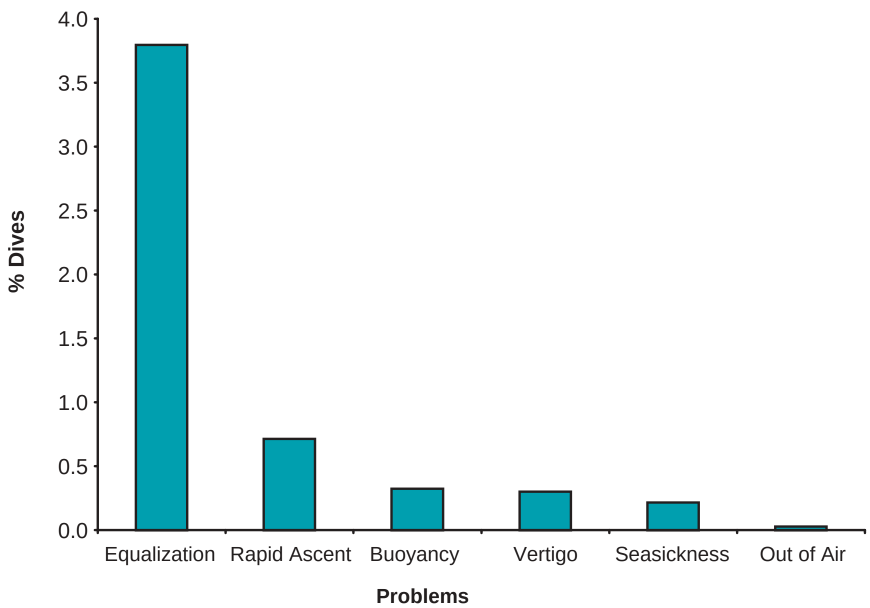


Figure 2.8-1 Percentage of the PDE sample reporting problems during dive in 2002 (N=16,452).

Equipment problems were reported in about 1 percent of our 2002 sample as listed in Table 2.8-1. Problems with the weight belt or fins were reported most frequently.

Table 2.8-1 Percentage of the PDE sample reporting the following equipment problems in 2002 (N=16,452).

Equipment Problems	Frequency	Percent
None	8,285	50.4
Weight Belt	44	0.3
Fins	43	0.3
BC	36	0.2
Thermal Protection	35	0.2
Regulator / Breathing Apparatus	26	0.2
Computer	21	0.1
Depth Gauge	9	0.1
Pressure Gauge	7	0.0
Mask	2	0.0
Missing	7,944	48.3
Total	16,452	100

2.8.2 DCS

As the electronic PDE database grows, analysts at DAN are able to further probe the characteristics of recreational diving depth-time exposures. Three of these efforts are described below: type of diving, repetitive diving and an analysis of dive profile patterns.

Table 2.8-2 summarizes the PDE data from 2002 concerning decompression sickness in four groups: (a) liveaboard trips; (b) shore or day boat dives; (c) cold-water wreck dives at Scapa Flow; and (d) recreational dive professionals. A total of seven divers underwent recompression therapy for DCS in 2002. (Note: No PDE diver has yet been diagnosed with AGE.) Symptoms developed within the two hours after surfacing in six cases, while one case presented 20 hours after surfacing. Four of five cold-water wreck divers were recompressed within six hours; one case developed after post-dive mountain travel and was treated within 24 hours. Cases in the other groups were recompressed within 24 hours of their last dive. All cases responded well to recompression.

Table 2.8-2 The incidence of DCS in the indicated groups of divers (2002).

Group	# DCS Cases	Denominator		Incidence	
		# Dives	# Divers	DCS Per 10,000 Dives	DCS Per Diver
Liveaboard	0	6,280	323	0.0	0.0
Shore / Day-Boat	2	6,596	749	3.0	0.3
Scapa Flow	5	2,795	254	10.7	1.2
Day-Boat Dive Professionals	0	216	4	0.0	0.0
Other	0	1,173	243	0.0	0.0
Total	7	17,060	1,573	2.9	0.3

Figure 2.8-2 summarizes the PDE data for five years. These data suggest there may be a significantly higher DCS incidence in cold-water wreck diving at Scapa Flow, Scotland, than in recreational diving in warm waters. The overall DCS incidence in PDE is now 5.5 cases in 10,000 dives, indicating that the overall incidence is not representative of the entire population.

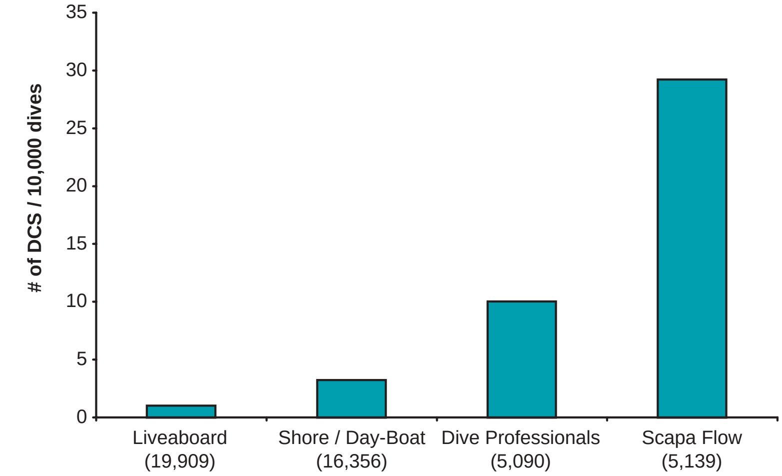


Figure 2.8-2 DCS incidence (cases/10,000 dives) by diving subgroup for 1998-2002.

Figure 2.8-3 shows the DCS incidence as the diving intensity increased from single dives to single-day repetitive dives and to multiday repetitive dives. Multiday cold-water wreck diving in Scapa Flow stands out as having the greatest morbidity rate, while multiday liveaboard diving had the lowest morbidity rate.

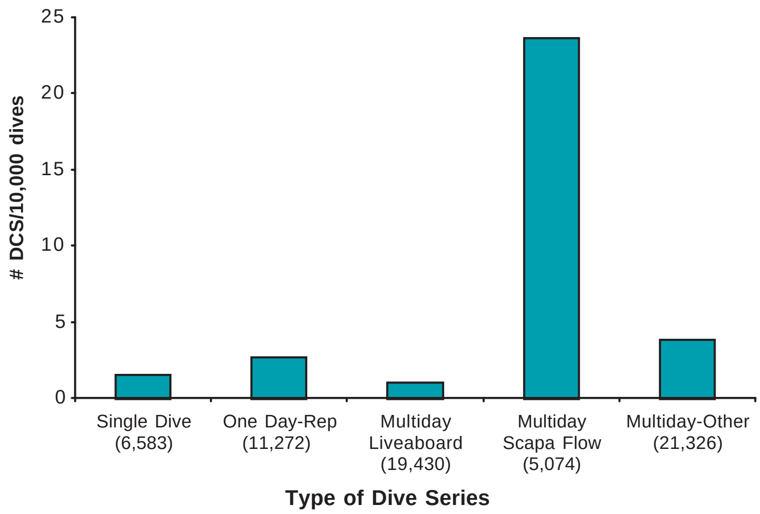


Figure 2.8-3 Diving intensity and DCS incidence for all PDE data 1998-2002.

Dive Profile Pattern Analysis

Dive profiles are often described as "square" or "multilevel." While true square dives are rare except in hyperbaric chambers, definitions of dive profiles that approximate square and multilevel dives can be useful to investigate potential sources of DCS risk. Dive computers, for example, are frequently used for multilevel diving to increase the total dive time.

We based our definitions of square and multilevel diving on four dive zones as illustrated in Figure 2.8-4: descent, bottom, multilevel, and shallow. The descent zone is from the surface to 85 percent of the maximum depth. The bottom zone begins at 85 percent of the maximum depth. The multilevel zone extends from 85 percent to 25 percent of the maximum depth. The shallow zone is from 25 percent of the maximum depth to the surface.

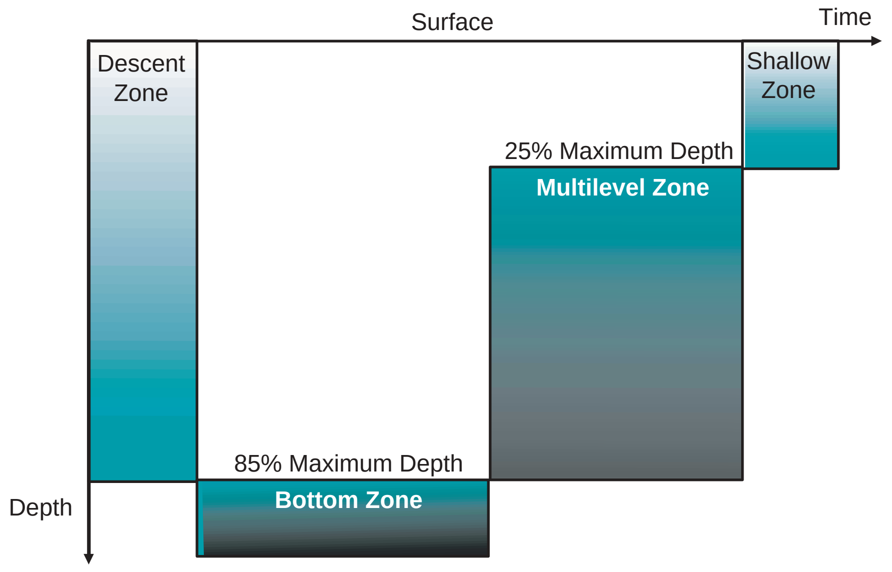


Figure 2.8-4 Depth and time zones dive profile pattern analysis.

For a square dive, the bottom zone must be at least 40 percent of the total dive time, and the sum of the descent and bottom times must exceed 70 percent of the total dive time. For a multilevel dive, the multilevel zone must be more than 40 percent of the total dive time. Dive profiles that do not meet these criteria were defined as intermediate. Safety or decompression stops in the shallow zone were defined by more than or equal to five minutes at 20 fsw or more than or equal to three minutes at 10 fsw.

Each PDE dive profile was characterized as square, multilevel, or intermediate. Twenty-five percent were square, 37 percent were multilevel, and 38 percent were intermediate. In 26 DCS cases, 12 resulted from dive series that had involved mainly square dives or were preceded by square dives, and 14 cases resulted from dive series that involved mainly multilevel dives.

An analysis of the maximum depth of square and multi-level dives (Figure 2.8-5) illustrates that multilevel dives are generally deeper than square dives.

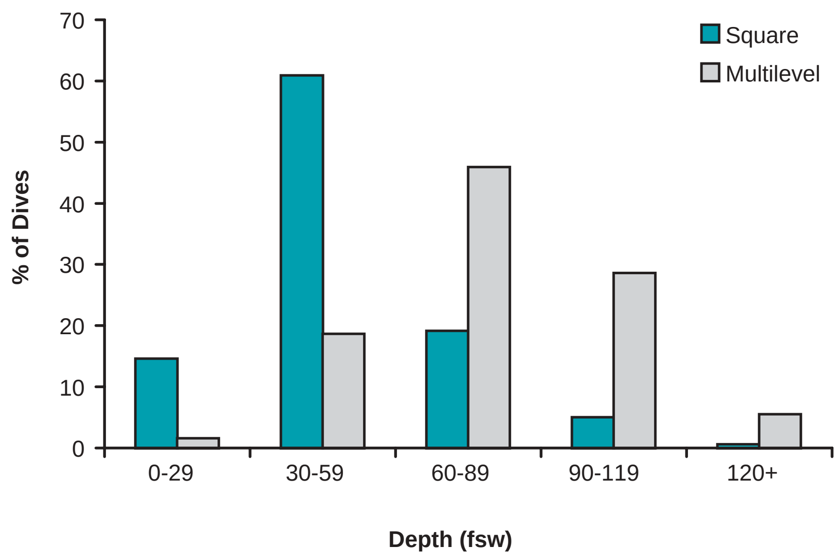


Figure 2.8-5 Percentage of the PDE sample reporting the indicated distributions of maximum depth by dive profile pattern in 2002 (N=16,452).

In summary, as PDE continues to grow, it is becoming an increasingly more useful database of recreational diving practices. It will allow analysis of the different subgroups of diving practices and depth-time exposures. When these data are combined with similar data from dives resulting in injuries, it will provide significant insight into how diving can be made even safer.

3. Dive Injuries

3.1 The Source of the Data

Consistent with DAN's medical mission to improve dive safety, DAN America collects information on recreational scuba diving injuries. DAN requested injury information from 280 hyperbaric chambers throughout all U.S. regions in 2002. A total of 167 chambers responded: 113 facilities indicated that they had treated a total of 1,063 dive injuries.

Eighty-three chambers submitted a total of 517 detailed Diving Injury Report Forms (DIRFs). As in previous editions of this report, cases were included for analysis if:

(a) diving was involved and the injury required recompression;
(b) the injury was not a re-treatment of a previous injury;
(c) the injured diver was a U.S or Canadian resident engaged in recreational diving; and
(d) the report was complete or the follow-up provided required information.

Four hundred and thirty-five cases met DAN's inclusion criteria. Also consistent with last year's report, the data were reviewed for cases that most likely did not represent decompression sickness (DCS) or arterial gas embolism (AGE): an additional 87 cases were removed on this basis. Except where otherwise appropriate, the injury section of this 2004 diving report is based on this sample of 348 reports from cases occurring in 2002.

The Source of the Reports

Figures 3.1-1 and 3.1-2 describe the sources of DAN's case reports in 2002.

U.S. Reports

In 2002, nearly half of all the diving injury reports received from U.S. chambers came from the southeastern United States (Figure 3.1-1). This is different from the previous year's reporting (2001), when the number of cases reported by the U.S. Northwest predominated. DAN sincerely appreciates the effort expended by the individual reporting chambers represented by these data.

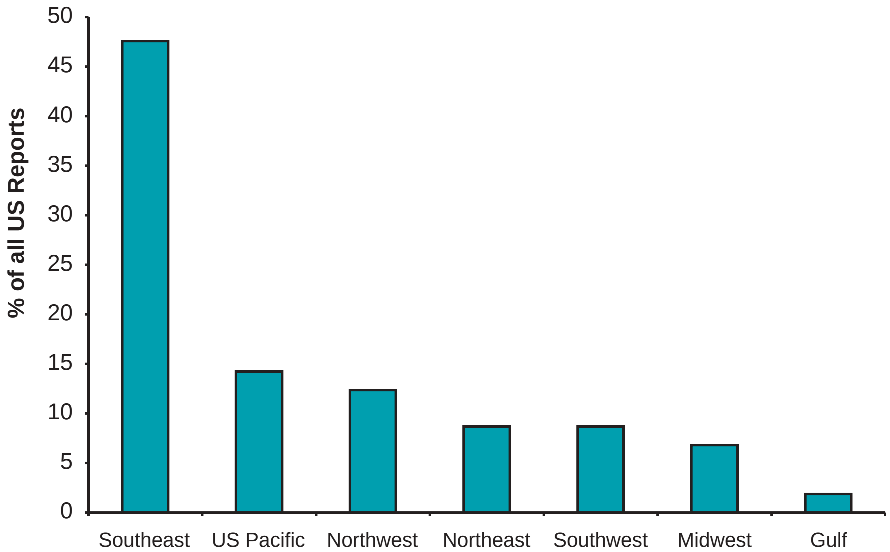


Figure 3.1-1 Regional source of injury reports (N=162).

International Reports

As shown in Figure 3.1-2, DAN received most of its international injury reports from the Caribbean. The Pacific islands accounted for 20 percent, Canada for 14 percent, South America for 8 percent and Bermuda for 1.7 percent. Five reports had no chamber location provided.

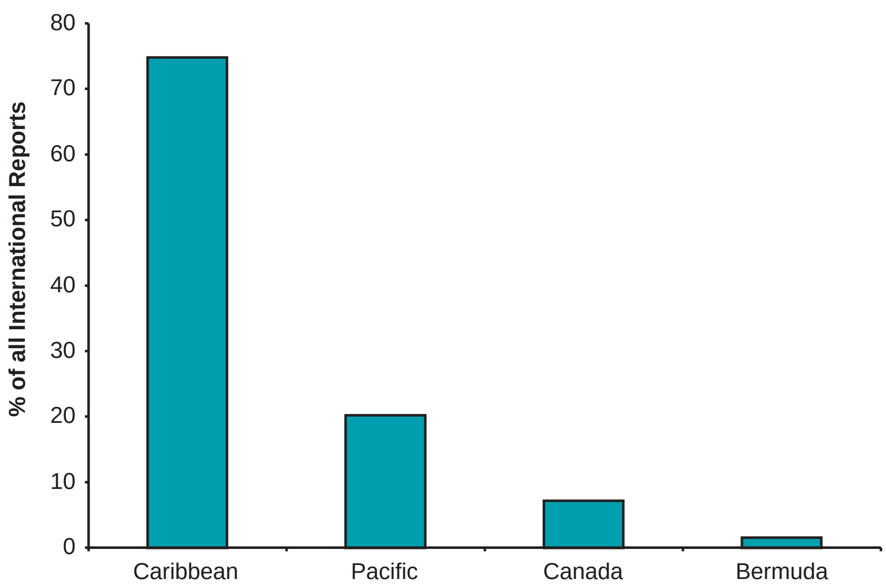


Figure 3.1-2 International source of injury reports (N=181).

The Perceived Severity Index (PSI) and the Case Reclassification Criteria

Perceived Severity Index (PSI)

A severity classification system was introduced in the 2002 Report (based on cases in 2000) and is continued in this year's report, which profiles cases from 2002. This classification system is called the Perceived Severity Index (PSI) and is an arbitrary system based on the perceived severity according to DAN physicians and researchers. The PSI categories listed in order of decreasing severity are:

(a) Serious Neurological;
(b) Cardiopulmonary;
(c) Mild Neurological;
(d) Pain;
(e) Lymphatic / Skin; and
(f) Constitutional / Non-Specific.

The definitions for the PSI categories can be seen in Table 3.1-1. The system is hierarchical. Each case is assigned to the category corresponding to its most severe symptom. For example, an injured diver with paresthesias (tingling or other abnormal sensation) of the feet (a mild neurological symptom) would be categorized as a serious neurological case if bladder impairment were also present. The PSI was also used as an aid for testing the consistency of reported diagnoses against the case descriptions.

Table 3.1-1 Perceived Severity Index (PSI).

Perceived Severity Index	Reported Signs or Symptoms
1. Serious Neurological	bladder or bowel dysfunction
	incoordination, difficulty walking, altered gait
	altered consciousness
	altered hearing, tinnitus, vertigo
	difficulty talking, altered mental status, memory, mood, orientation or personality
	altered reflexes
	weakness, partial weakness involving one side of the body, motor weakness, paraplegia, muscular weakness, decreased strength
	altered vision
2. Cardiopulmonary	cardiovascular irregularities, irregular heartbeats, palpitations
	pulmonary irregularities, cough, coughing up blood from lungs, shortness of breath, respiratory distress, voice change
3. Mild Neurological	paresthesia, numbness, numbness & tingling, tingling, sensation, twitching
4. Pain	pain, ache, cramps, discomfort, joint pain, pressure, sharp pain, spasm, stiffness
5. Lymphatic / Skin	lymphatic irregularities, swelling
	skin irregularities, burning of skin, itching, marbling, rash
6. Constitutional / Non-Specific	dizziness
	fatigue
	headache
	nausea and/or vomiting
	chills, perspiration, heaviness, heavy head, lightheadedness, malaise, restlessness

Distribution of Cases by PSI

The distribution of DCI cases in our sample as categorized by the PSI is shown in Figure 3.1-3. Most cases were classified as "Mild Neurological" (45 percent). "Serious Neurological" was second most common, with about one third (27 percent) of all cases, and "Pain" was third, with 20 percent.

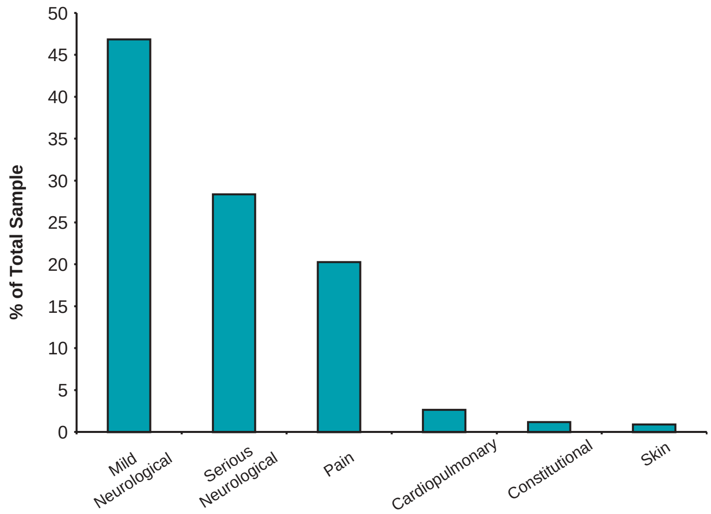


Figure 3.1-3 Distribution of cases by PSI (N=348).

Case (Diagnosis) Reclassification

In our sample, not all recompressed cases were determined to have been DCI. Out of 435 cases that met our inclusion criteria, all were treated by recompression. However, 87 of these cases were reclassified as "Not DCI" as a result of either:

(a) The treating physician's comments on the diagnosis (cases called "Other," "Unknown" or "Not Due to Pressure") or

(b) A DAN-initiated review and diagnostic reclassification based on the following guidelines.

Cases Reclassified as Not DCI

(a) Cases with single dives to shallower than 30 fsw / 9 msw and symptoms that could not be attributed to AGE;

(b) Cases with symptom onset times more than 48 hours after the last dive or altitude exposure;

(c) Cases with signs and symptoms likely due to a non-diving cause of injury after review of medical history;

(d) Cases with symptoms that resolved spontaneously without recompression in less than 20 minutes with surface oxygen or in less than 60 minutes without oxygen;

(e) Cases with no response to recompression were reviewed extensively before classification as "Not DCI."

Cases Reclassified as Ambiguous

(a) Cases with sufficient exposure but minimal or atypical symptoms;
(b) Cases in which symptoms resolved spontaneously after lasting less than 20 minutes with surface oxygen or less than 60 minutes without oxygen;
(c) Cases with confounding medical conditions that could explain the symptoms.

Decompression Sickness Cases

(a) Cases with a dive depth of at least 30 fsw / 9 msw;
(b) Headache, dizziness, anxiety, general weakness, fatigue, and subjective numbness and tingling of both hands and feet were not classified as DCS in the absence of other symptoms or without objective findings;
(c) Type I DCS (DCS I) included PSIs of Pain, Skin / Lymphatic, Constitutional / Non-Specific;
(d) Type II DCS (DCS II) included PSIs of Serious Neurological, Cardiopulmonary, Mild Neurological and simultaneous presence of Pain and Constitutional.

AGE Cases

(a) Cases with symptom onset in less than 15 minutes post-dive;
(b) Cases with cerebral neurological symptoms, signs or findings;
(c) Cases with symptom duration longer than 15 minutes;
(d) A rapid ascent, an out-of-air incident, or the presence of cardiopulmonary symptoms increased the confidence of an AGE diagnosis.

Lung Barotrauma Cases

(a) Mediastinal emphysema;
(b) Subcutaneous emphysema;
(c) Pneumothorax;
(d) The absence of any neurological signs or symptoms.

DCI Cases

(a) All cases listed as DCI were reclassified as either DCS or AGE if possible, based on the information available;
(b) Cases felt to be related to decompression but not possible to categorize definitively as DCS or AGE were called DCI;
(c) Cases that could include combination of DCS and AGE (Type III DCS).

Three hundred and forty-eight cases of the 435 cases remained after all criteria were applied. Table 3.1-2 shows the results of the reclassification review and their distribution by PSI.

Table 3.1-2 PSI by revised diagnosis (N=348).

Revised Diagnosis	# of Cases	Perceived Severity Index					
		Serious Neurological	Cardio-Pulmonary	Mild Neurological	Pain	Skin	Consti-tutional
DCS I	57				54	3	
AGE	23	18	2	3			
DCS II	198	74	2	113	7		
DCI	6		1	4	1		
Lung BT	6		5		1		
Ambiguous	58	7		41	7		3
Subtotal	**348**	**99**	**10**	**161**	**70**	**3**	**5**
Not DCI	87	12	5	23	26		12
Total	435	111	15	184	96	3	17

Figure 3.1-4 shows the percentage of these cases in each diagnostic classification category after review. As in previous years, DCS II cases predominated in our sample.

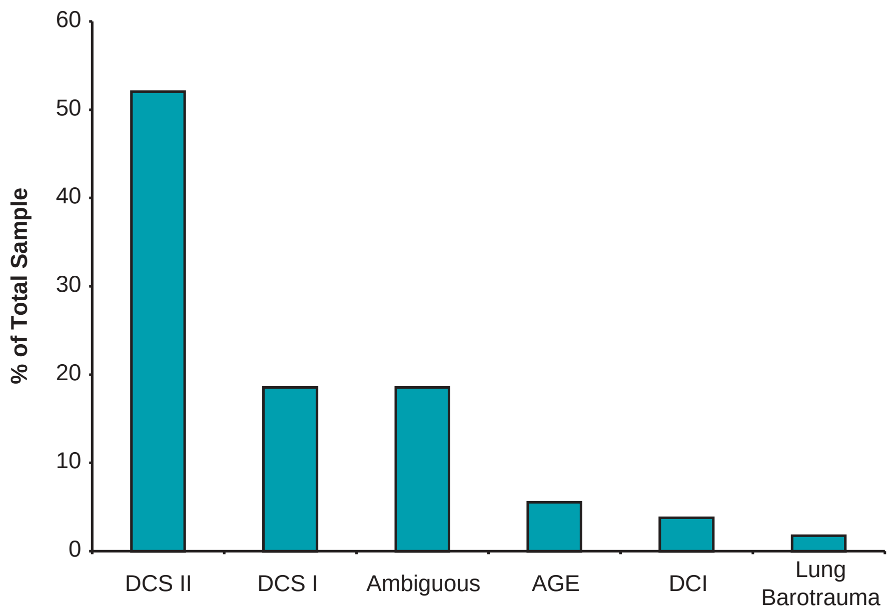


Figure 3.1-4 Distribution of cases according to reviewed diagnosis (N=348).

3.2 The Sample's Limitations

The Problem

Because DAN's injury data is based on voluntary notification and recording of diving injuries, the data shown here are not complete enough to be considered representative of any diving population other than this sample.

The Solution (the SERF)

DAN is addressing this issue of incomplete reporting and regional variation by preparing a new one-page Scuba Epidemiological Reporting Form (SERF). The SERF is designed to:

(a) Increase response rate in targeted diving regions so that the sample more accurately captures the type of injuries that occur;

(b) More accurately record time course, symptom severity and response to treatment;

(c) Address the issue of diagnostic ambiguity by surveying the treating physician's opinion regarding his or her confidence in the diagnosis; and

(d) Be compatible with DAN's Project Dive Exploration to facilitate capture of dive computer recorded depth time profiles from injured recreational scuba divers.

Until the SERF data are available, any conclusions drawn from the data discussed in this section apply to this sample only. The remainder of the injury section describes what we know about our sample of injured recreational scuba divers in detail.

3.3 The Diving Location and Purpose

The majority of the injury reports comes from recreational divers performing routine, non-technical dives in the ocean environment.

Location

Figure 3.3-1 shows the environment in which the diving injuries occurred in our sample. The majority (90 percent) took place in salt water, 9 percent in freshwater lakes and quarries, and fewer than 1 percent occurred under ice.

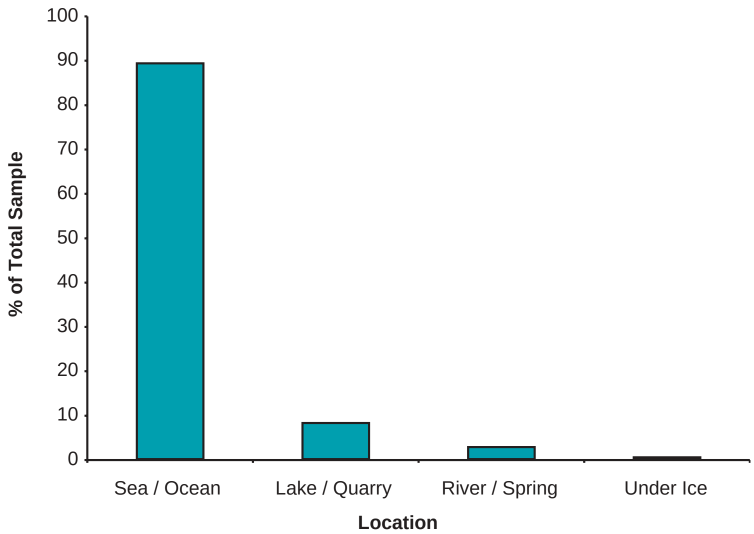


Figure 3.3-1 Environment in which diving injury occurred (N=348).

Purpose for Diving

Figure 3.3-2 shows the purpose for diving reported by injured divers. As expected, most dives were recreational, including such activities as sightseeing and underwater photography.

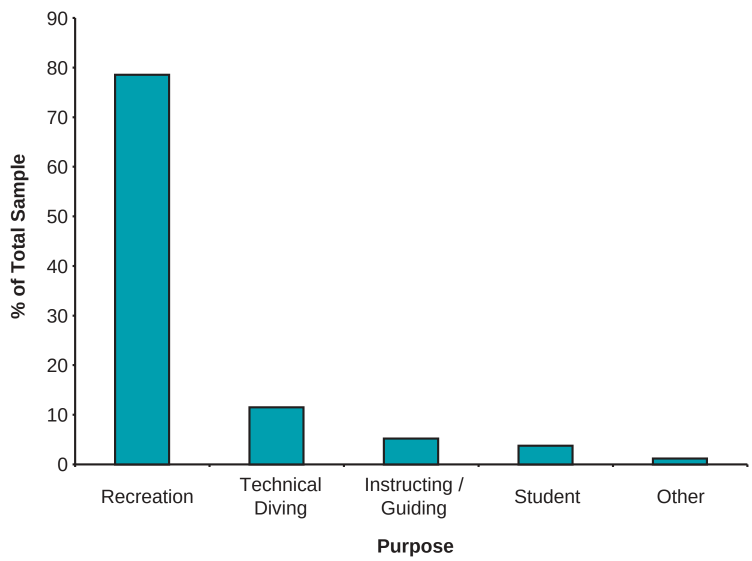


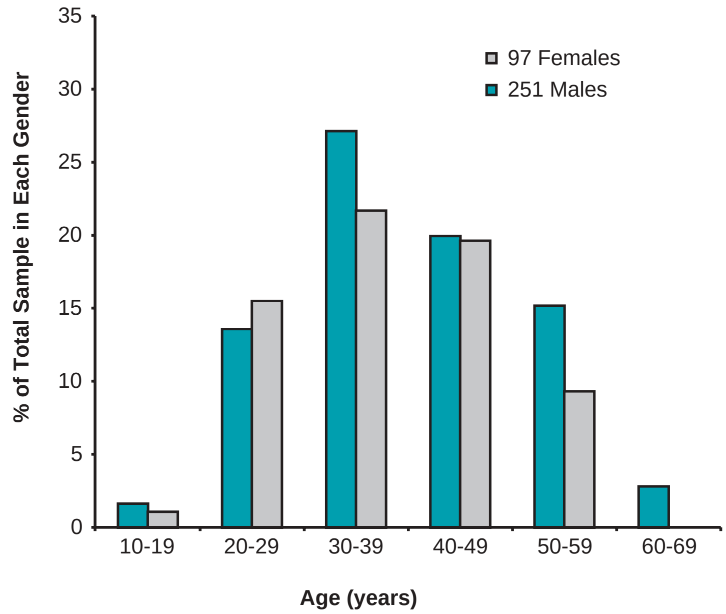
Figure 3.3-2 The purpose of dive as reported by injured divers (N=348).

3.4 Characteristics of Injured Divers

Age

People of all ages enjoy recreational diving. The age distribution of our sample reflects this finding. The age of injured divers varied between 13 and 69 years. The distribution of age by gender is shown in Figure 3.4-1. Males made up 72 percent of the injured population. This was consistent with the gender distribution of PDE as well as injuries logged in previous years. There were four divers who were 16 years of age or younger. The median age of injured females was the same as the males. Most divers were in the age 30-59 category.

Figure 3.4-1 Age of injured divers by gender (N=348).



Medical Conditions

Because diving injuries may be influenced by pre-dive physical conditions, DAN collected information on the medical condition of the injured divers in this sample. The frequencies of some selected pre-dive medical problems of injured divers are shown in Table 3.4-1. The most frequently reported acute health problem was an upper respiratory infection (URI). Fewer than 10 percent of the injured divers reported that they smoked, and less than 1 percent reported that they had diabetes or heart disease.

Health Problem	Frequency	%
Upper Respiratory Illness / Congestion	78	18.6
Musculoskeletal	53	12.7
Smoking	39	9.3
Previous DCI	36	8.7
Back Surgery	27	6.4
Asthma	27	6.4
High Blood Pressure	26	6.2
Ear Nose and Throat	21	5.0
Seasickness	19	4.5
Psychiatric	12	2.9
Gastrointestinal	9	2.2
Central Nervous System	5	1.2
Infections	5	1.2
Diabetes	4	1.0
Heart Disease	4	1.0

Table 3.4-1 Pre-dive health problems.

Experience

Figure 3.4-2 shows the highest level of certification of the injured divers in our sample. Open-water and advanced open-water were the most common types of certification. One percent of the divers in our injury sample were students. Divers with technical certification accounted for 3 percent of the sample, down from 5.3 percent reported in 2001.

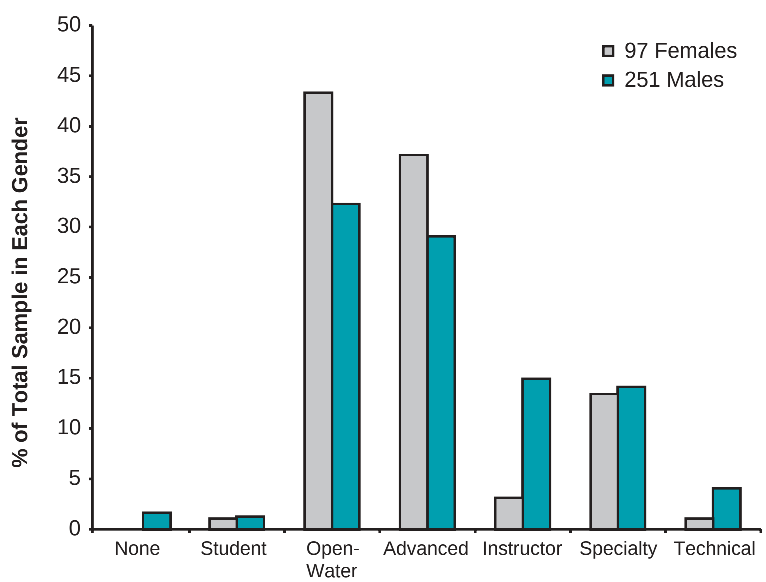


Figure 3.4-2 Certification of injured divers by gender (N=348).

AGE may be over-represented in the "inexperienced" category of the diving population. While AGE comprised only 5.4 percent of the injuries in our sample, 25 percent of the student and uncertified diver injuries were categorized as AGE. Similarly, among divers with AGE, students represented 5 percent of the cases, while they made up only 1.4 percent of all injured divers. This was similar to previous years and is consistent with the hypothesis that lack of experience may have contributed to pulmonary barotrauma and subsequent arterial gas embolism. Table 3.4-2 describes the diagnosis and certification of the injured divers in our sample.

Table 3.4-2 Diagnosis by certification of injured divers.

Diagnosis	#	Highest Certification Level (Percentage)						
		None	Student	Entry-Level	Advanced	Instructor	Specialty	Technical
DCS I	64	0	25	18	21.3	17.5	13	27.3
AGE	19	25	25	9	3.7	2.5	2.2	0
DCS II	180	50	25	44.3	51.9	65	58.7	63.6
DCI	13	0	0	4.1	4.6	2.5	4.3	0
Lung BT	6	0	25	2.5	0.9	0	2.2	0
Ambiguous	64	25	0	22.1	17.6	12.5	19.6	9.1

The average injured diver in our sample was not newly certified. Figure 3.4-3 shows the years since initial certification. Women had been diving for a mean of six years (median = three years) and men for a mean of 10 years (median = six years). The maximum number of years since certification was 39 for men and 25 for women. Forty-six percent of injured divers had five or fewer years since certification, 20 percent had five to 10 years, and 34 percent had more than 10 years since certification.

Figure 3.4-3 Years since initial certification by gender.

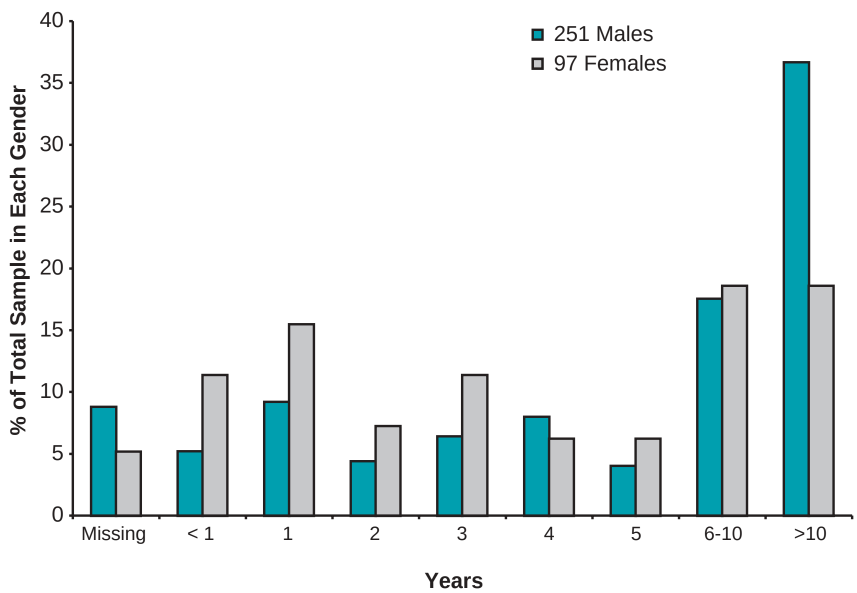


Figure 3.4-4 shows the number of dives in the 12 months preceding the injury. As in past years, 40 percent of injured men and 50 percent of women had made fewer than 20 dives in the previous 12 months.

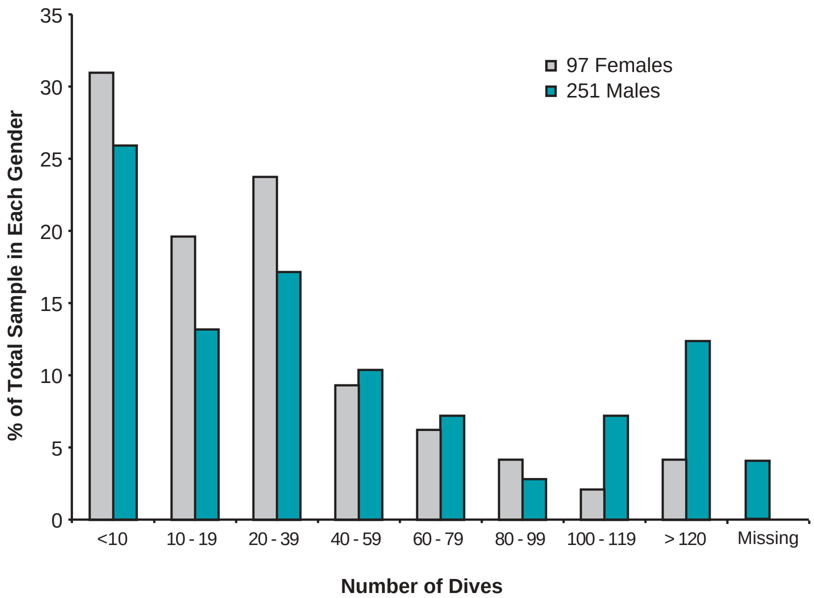


Figure 3.4-4 Number of dives in past 12 months by gender (N=348).

3.5 Characteristics of Dives by Injured Divers

Timing

Figure 3.5-1 shows the months in which diving injuries occurred in our sample for 2001 and 2002. As in the past, the maximum number of injuries in our database occurred in the summer months of the Northern Hemisphere, when more diving takes place.

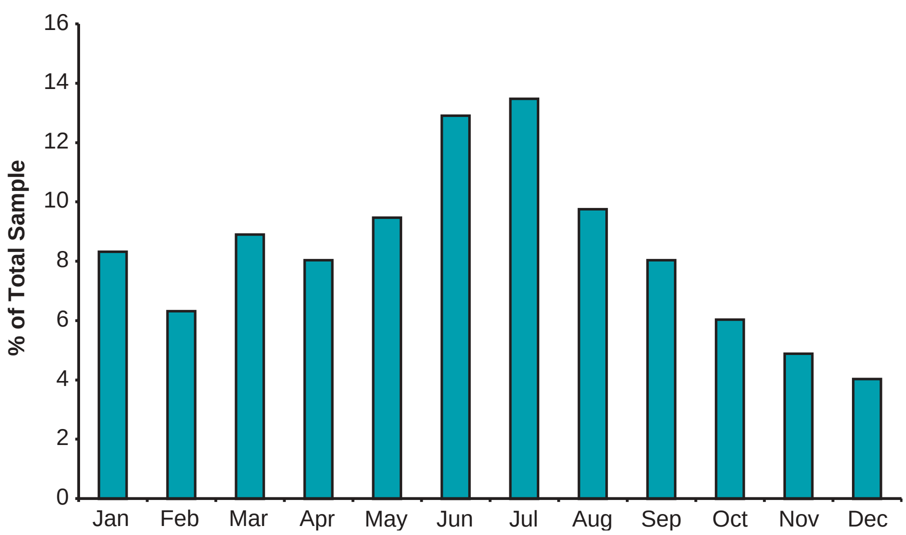
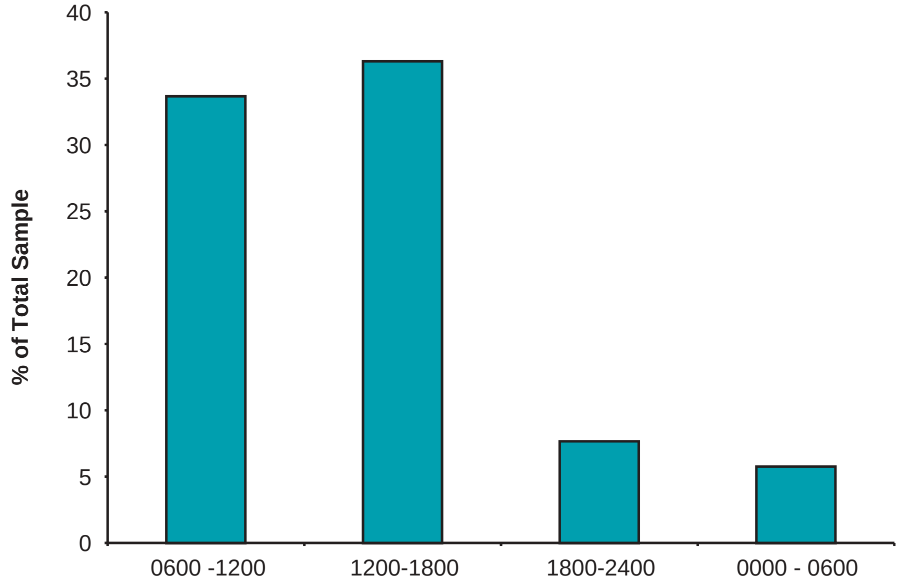


Figure 3.5-1 Month in which diving injury occurred for 2001 and 2002 (N=419).

Figure 3.5-2 shows the time of day of the last dive before the diving injury. Most dives (89 percent) occurred during daylight hours. The percentage of reported injuries during the evening and night (11 percent) was similar to past years.

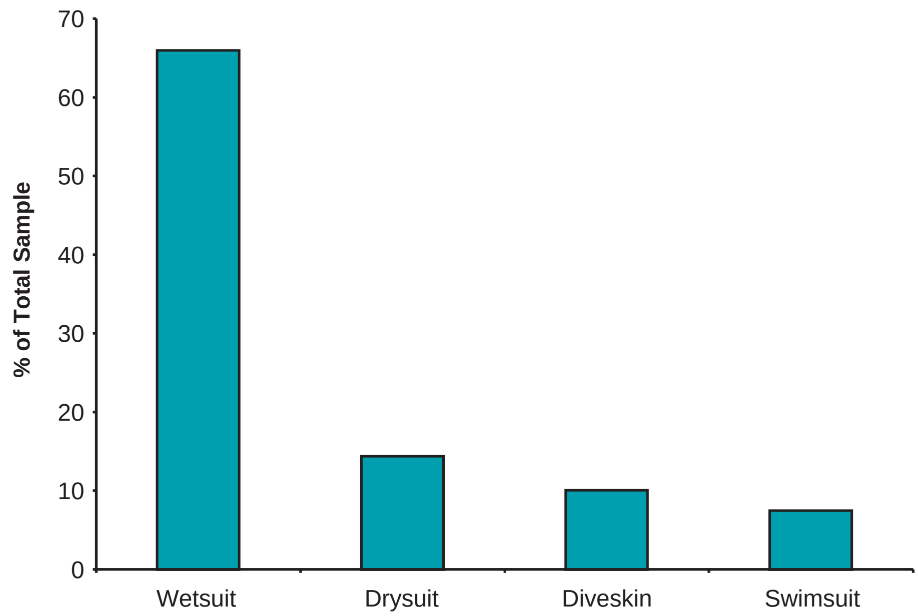
Figure 3.5-2 Time of day of the last dive (N=348).



Thermal Protection

Figure 3.5-3 shows the thermal protective dress worn by divers who reported injuries. The standard wetsuit was the most common thermal protection. Drysuit diving was observed in 15 percent, and diveskins and swimsuits were both used in less than 10 percent of the divers in our sample.

Figure 3.5-3 Type of thermal protective dress (N=348).



Gas and Breathing Apparatus

As in previous years, the largest percentage (96 percent) of our reports came from divers using open-circuit scuba. Less than 3 percent reported using a rebreathing apparatus, and only two divers used surface-supplied breathing equipment in our sample. Figure 3.5-4 shows the breathing gas used by the injured divers in our sample. Air was used by 85 percent, nitrox by 10 percent, and heliox or trimix by 5 percent. This was an increase in the percentage of heliox or trimix injuries compared to the 2001 data. All injured divers in our sample using heliox or trimix were male.

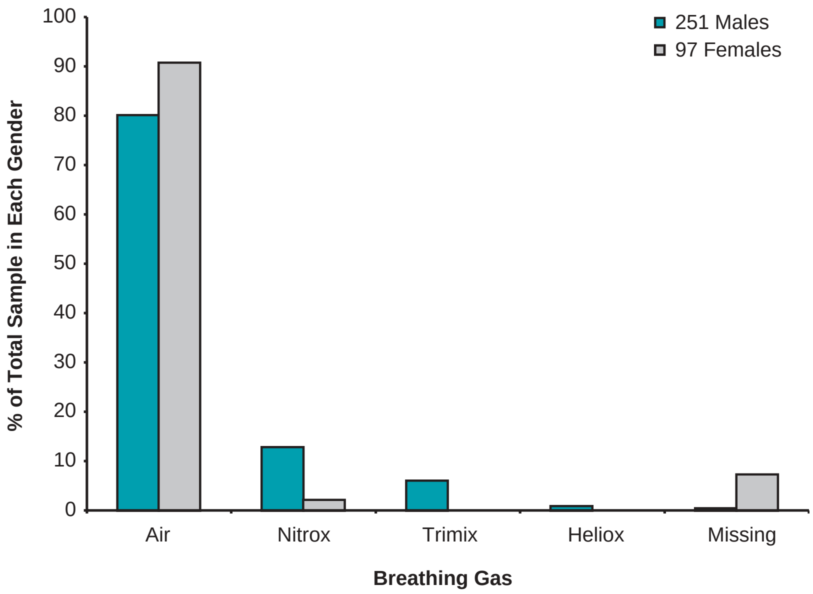


Figure 3.5-4 Breathing gas used in sample (N=348).

Figure 3.5-5 shows the dive planning methods used by the injured divers in our sample. Most of the injured divers used dive computers. Fifteen percent used tables, and 7 percent relied on their guides or buddies to plan their dives.

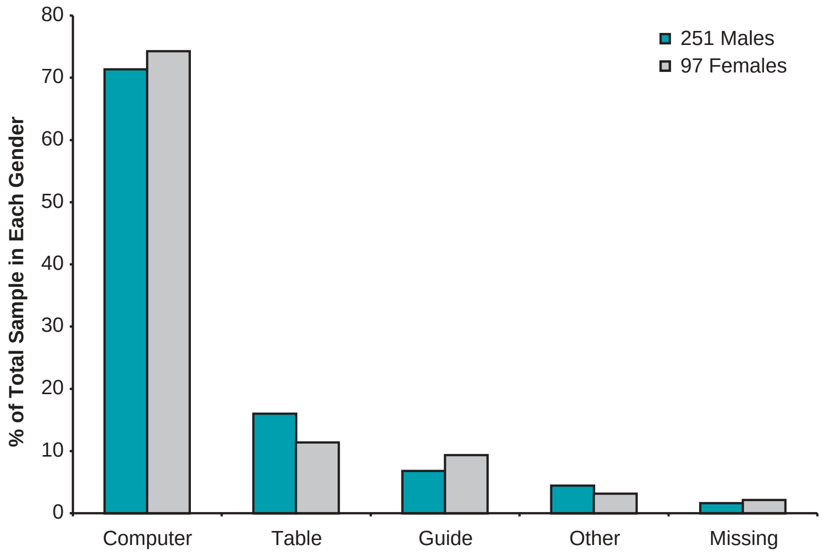


Figure 3.5-5 Dive planning methods used by injured divers by gender (N=348).

3.6 Estimate of Diving Exposure

The DAN diving report concentrates on injuries caused by decompression illness, which divers may experience when returning from depth to surface or when flying after diving. In recreational diving, which often includes repetitive and multiday diving, it is at times difficult to identify a single dive that was the cause of the decompression injury. To describe the exposure to decompression in the absence of the recorded depth (pressure) / time profile, we rely on factors that divers are likely to recall accurately:

(a) the number of consecutive days diving;
(b) the number of dives;
(c) reported maximum depth;
(d) procedural problems that may have affected decompression; and
(e) flying after diving.

Days in Dive Series

Figure 3.6-1 shows the number of consecutive days of diving preceding injury. A substantial number of DCS injuries in our sample occurred on the first day of diving — 44 percent of the DCS I reports and 35 percent of the DCS II reports. The percentage of injuries involving multiday diving appears to decrease as the number of days in the dive series increases, but this may be in part because divers who are injured do not continue to dive.

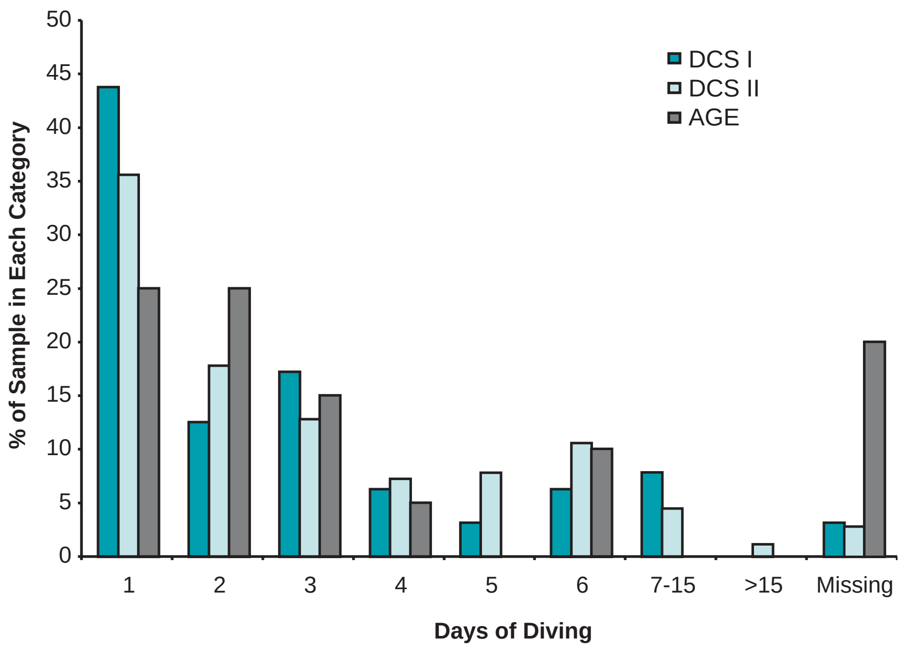


Figure 3.6-1 Consecutive days of diving preceding the injury (N=348).

Dives

Figure 3.6-2 shows the total number of dives preceding the injury when stratified by diagnosis. The median number of pre-injury dives was four, and the mean was 5.3. The median for men was three, one lower than for women. Women made more dives before they were injured than did men.

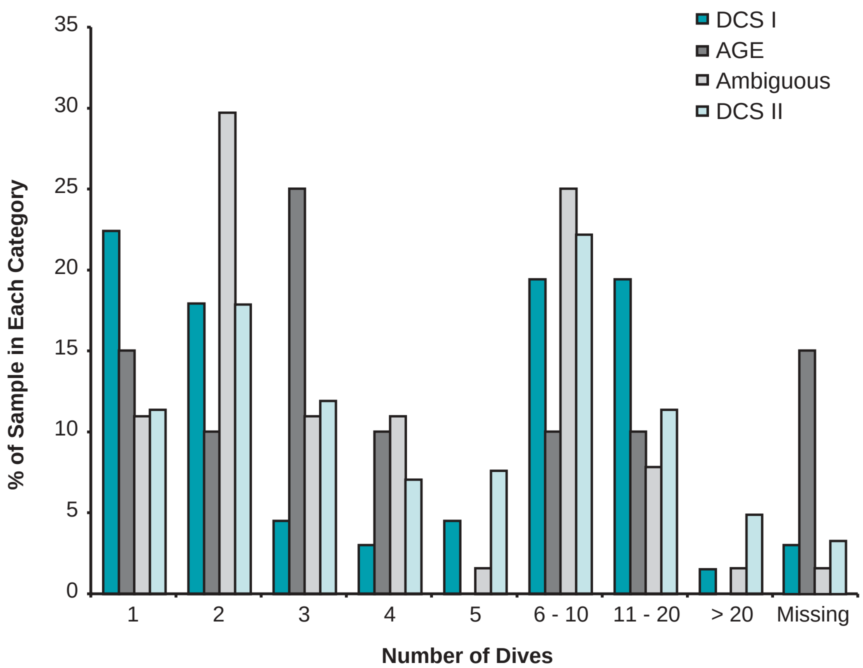


Figure 3.6-2 Total number of dives in series by diagnosis (N=348).

Depths

Figure 3.6-3 shows the maximum depth of the dive series when stratified by the type of injury as reported by the injured divers in our sample. This is not necessarily the last dive before the diver noted symptoms, nor is it necessarily the dive that caused the injury. However, it can be considered a measure of the diving exposure. The range of the maximum depths was from 20 fsw / 6 msw (air) to 477 fsw / 145.3 msw (trimix). The median depth was 90 fsw / 27.4 msw and the mean depth was 92 fsw / 28 msw. In our sample, the median depth for AGE (75 fsw / 22.8 msw) was shallower than the median depth for either DCS I (90 fsw) or DCS II (92 fsw).

Figure 3.6-3 Maximum depth of the dive series by diagnosis (N=348).

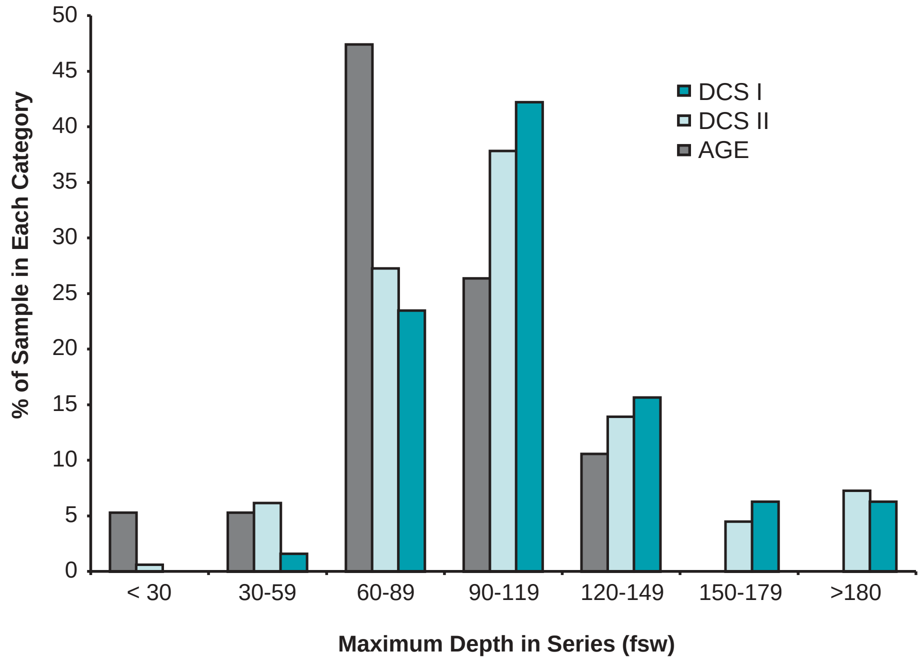


Figure 3.6-4 shows the maximum depth of the last dive in the dive series when stratified by diagnosis. The last dive may not necessarily have been the deepest dive of the series or the dive preceding the injury. Some divers apparently continued to dive after experiencing symptoms of DCS, because approximately 15 percent of the injured divers reported their first symptoms before making their last dive. In our sample, the range of depths for the series' last dive was from 18 fsw / 6 msw to 477 fsw / 145 msw. The median was 72 fsw / 22 msw, and the mean was 77 fsw / 23 msw. The maximum depth was the shallowest for divers injured by AGE, and there was no difference in maximum depth for DCS I and DCS II.

Figure 3.6-4 Depth of the last dive by diagnosis (N=348).

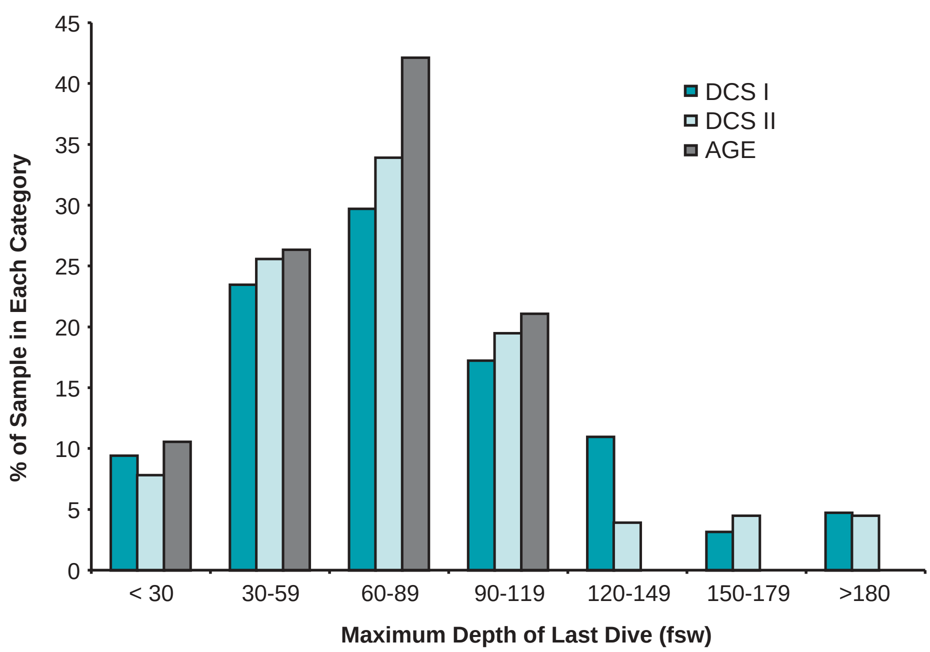


Figure 3.6-5 shows the maximum depth of the last dive by gender. In our sample there were no injured female divers who reported having dived deeper than 150 fsw / 45.7 msw.

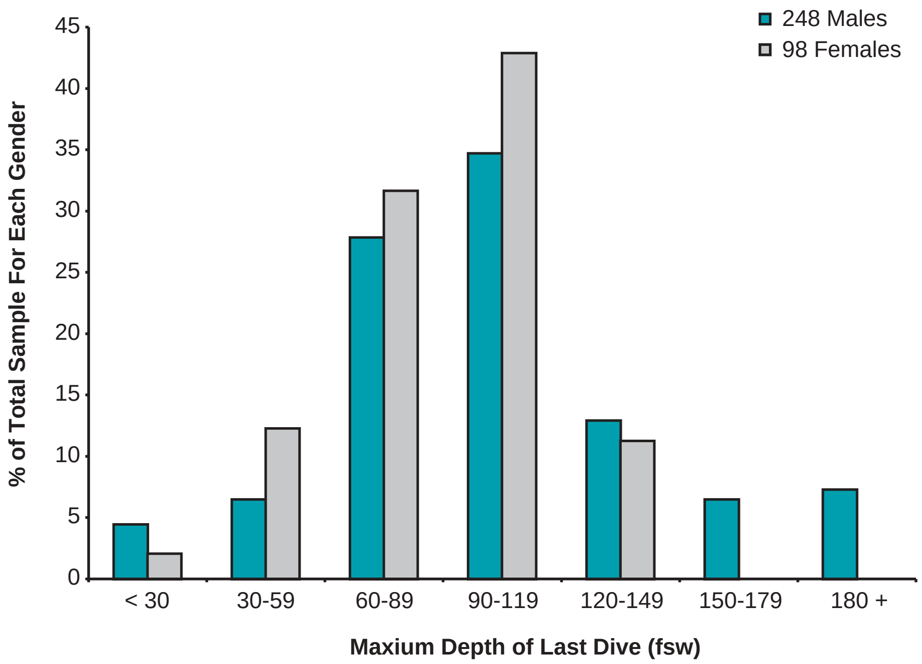


Figure 3.6-5 Maximum depth of last dive by gender (N=348).

Problems

Fifty-three percent of the cases in our sample reported having experienced some type of problem during the dive series. Figure 3.6-6 shows the distribution of these reported problems. The four most common problems were making a rapid ascent, overexertion, feeling cold and missed decompression stops.

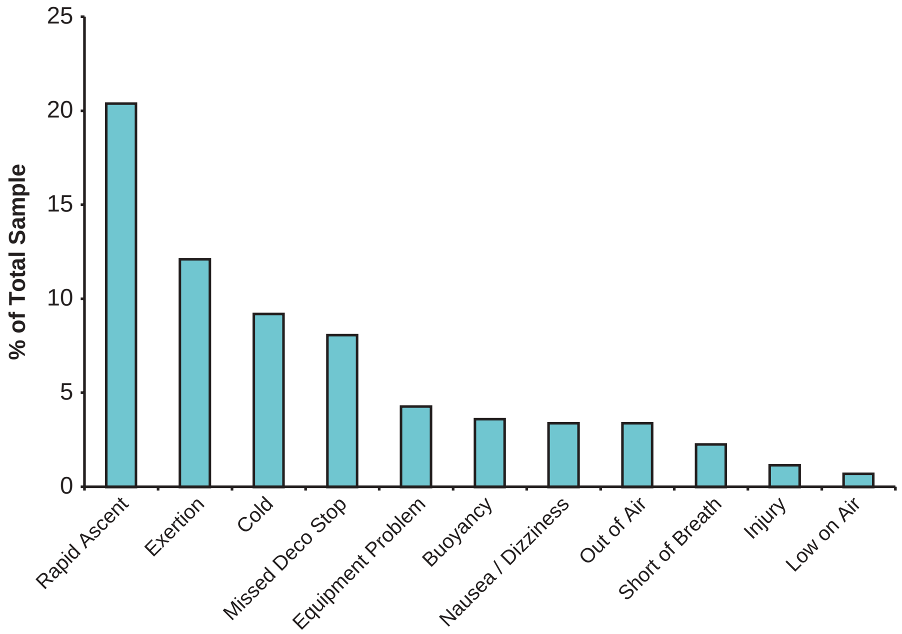
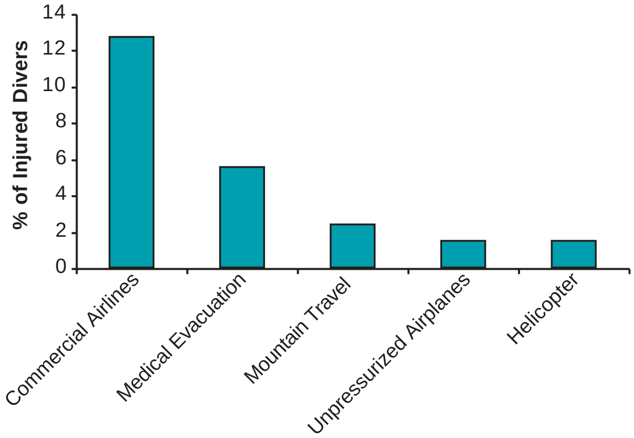


Figure 3.6-6 Frequency of reported problems during dive series (N=348).

Flying After Diving

Of the 348 injured divers in the 2002 data, 81 (23 percent) were exposed to altitude after diving (Figure 3.6-7). This included five during helicopter travel, five in unpressurized fixed-wing aircraft, eight during ground travel, 19 during organized medical evacuation and 44 (12.6 percent) in pressurized commercial aircraft.

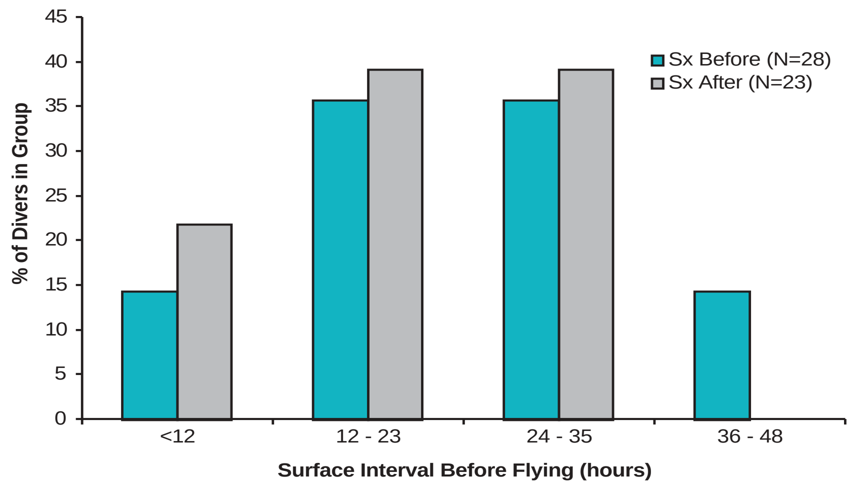
Figure 3.6-7 Altitude exposure after diving (N=81).



Of the 44 injured divers who flew by pressurized commercial aircraft, 55 percent had symptoms before flight but flew anyhow. It is not known if they flew to get to a chamber or because they did not recognize that they might have DCI. Thus, less than half the injured divers who flew after diving were true flying after diving cases in which symptoms developed during or after flight.

The mean preflight surface interval for divers who flew with symptoms was 22.7 hours (median 23 hours). For divers who did not have symptoms before flight, the mean preflight surface interval was 17.8 hours (median 22 hours). Figure 3.6-8 shows the distribution of time to flight for 28 divers who had symptoms before flying and for 23 divers who developed symptoms during or after flight. Forty percent of divers who did not have symptoms before flight waited 24 hours or longer before flying.

Figure 3.6-8 Surface interval before flying after diving and symptom onset.



3.7 Signs and Symptoms Reported by Injured Divers

Onset Times

Figure 3.7-1 shows the onset time for the first symptoms reported by injured divers in our sample. In half the cases, symptoms occurred within one hour of diving. Of interest is that in 14 percent of the cases, symptoms were reported before the last dive; this indicates that the diver either knowingly returned to the water with symptoms of DCS or did not recognize the symptoms prior to getting back in the water. In 6 percent of cases, symptoms occurred during the last dive while still underwater. As previously mentioned, in approximately 6 percent of the reports, the symptoms first occurred during or after a flight.

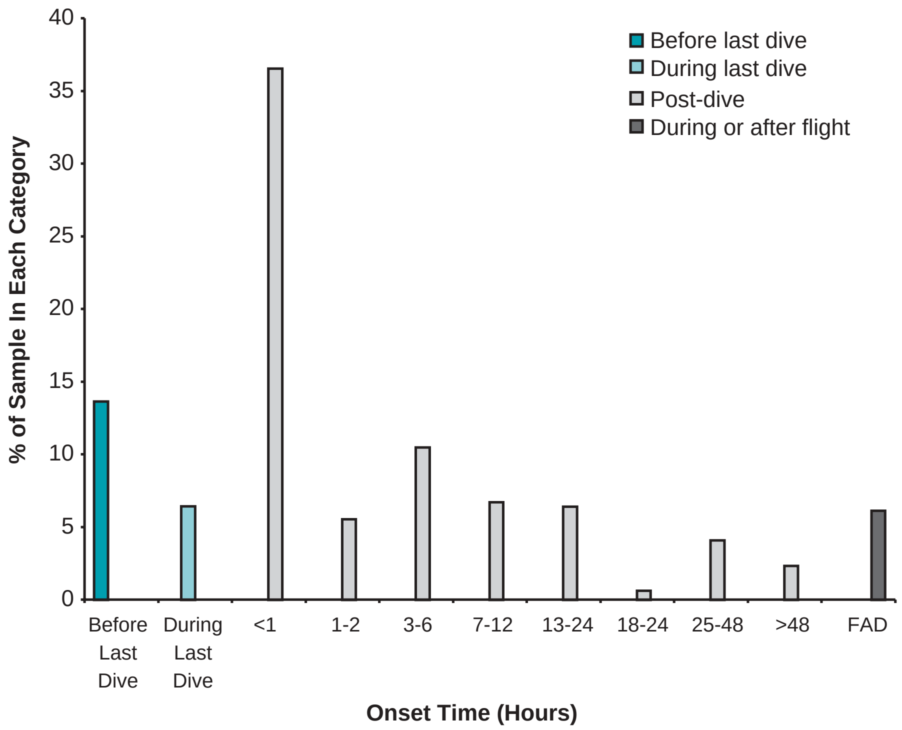


Figure 3.7-1 Symptom onset time (N=348).

Figure 3.7-2 shows the symptom onset time for the divers in our sample when stratified by diagnosis. Note that our criteria for AGE required that symptoms be manifested within 15 minutes of surfacing. Twelve divers developed their first symptoms during ascent while underwater. These included one case of AGE and four cases of DCS II. Cases with DCS symptoms appearing before the last dive included cases later classified as DCS II (25) and DCS I (13).

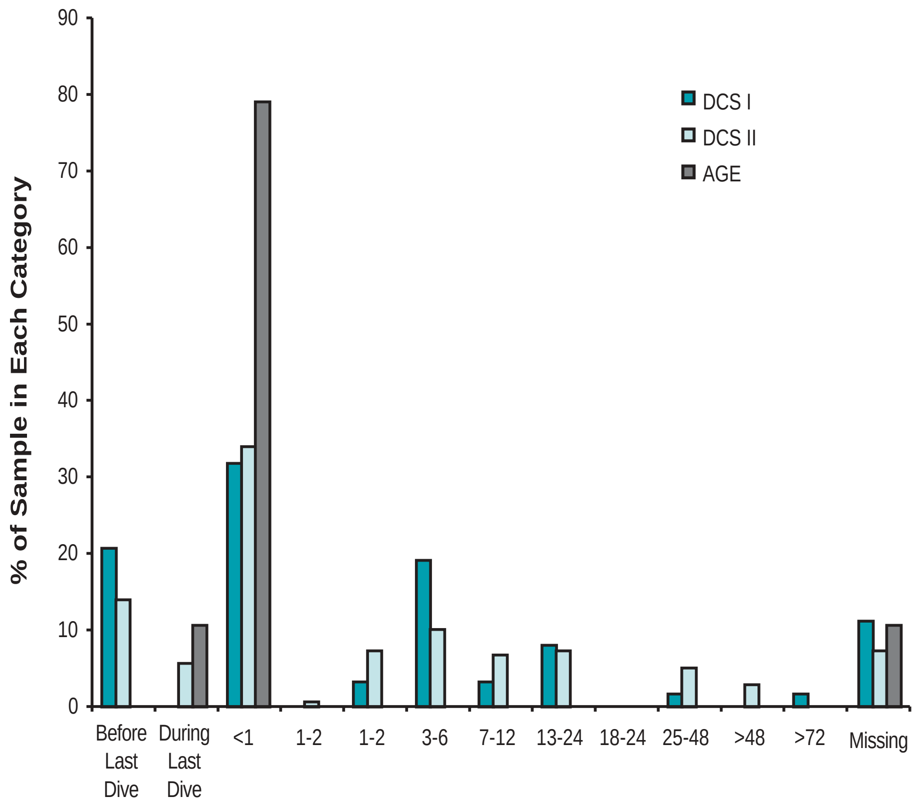


Figure 3.7-2 Symptom onset time by diagnosis (N=348).

Symptom Types

Figure 3.7-3 shows the distribution of symptom types reported on arrival at the recompression chamber. Thirty-seven percent of all divers reported pain as their first symptom. The next most frequently reported first symptom was numbness and tingling, at 26 percent of all divers. Muscular weakness was eventually reported in 21 percent of cases and was more frequently noted by medical personnel than by the divers themselves. Divers may seek treatment primarily in response to the pain of their injury. Mild neurological findings may be noticed later once the diagnosis is suspected.

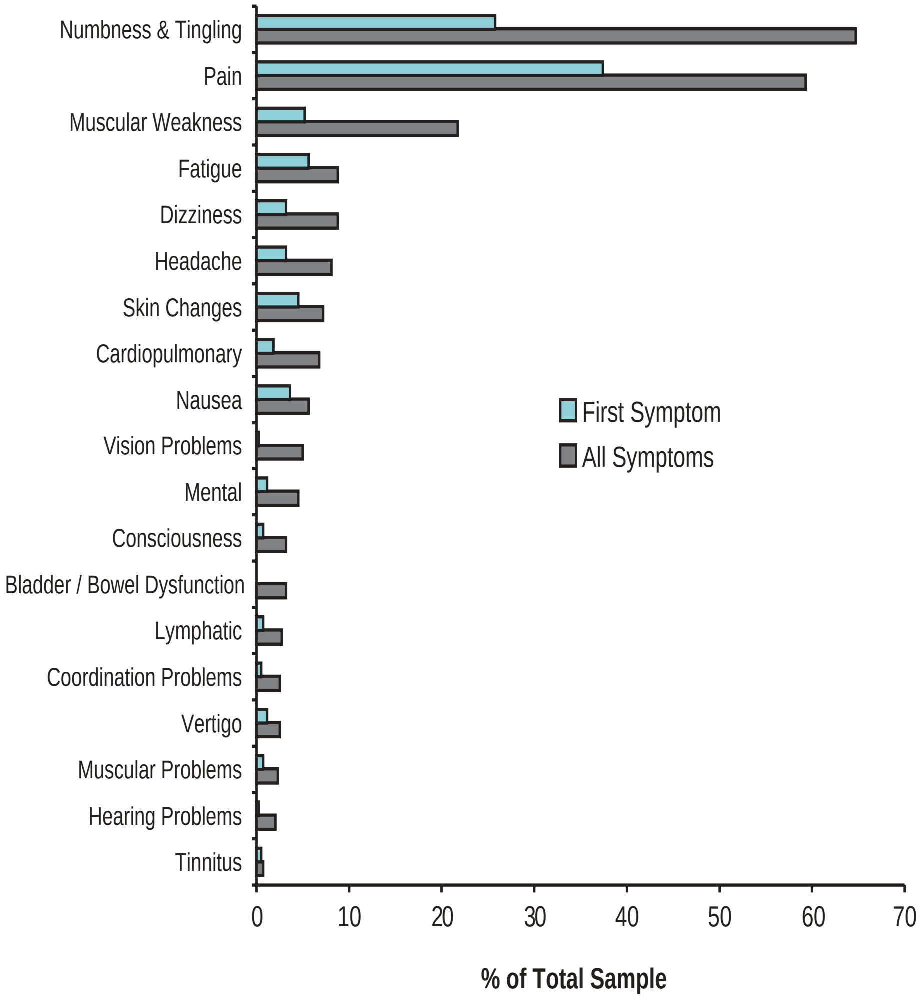


Figure 3.7-3 Reported symptoms (N=348).

Depending on the symptom reported, between 2 and 5 percent of the injured divers in this sample reported serious neurological problems: these included vertigo, bladder dysfunction, visual disturbances, unconsciousness and coordination problems. Muscular weakness was noted in 21 percent of the divers in our sample, and partial paralysis of the legs (paraparesis) was the most common form of muscular weakness (6 percent). Paralysis was reported as paraplegia (paralysis of the lower half of the body) in 0.5 percent of injured divers and as hemiplegia (paralysis of one side of the body) in 0.2 percent. This breakdown is shown in Figure 3.7-4.

Figure 3.7-4 Distribution of muscular weakness.

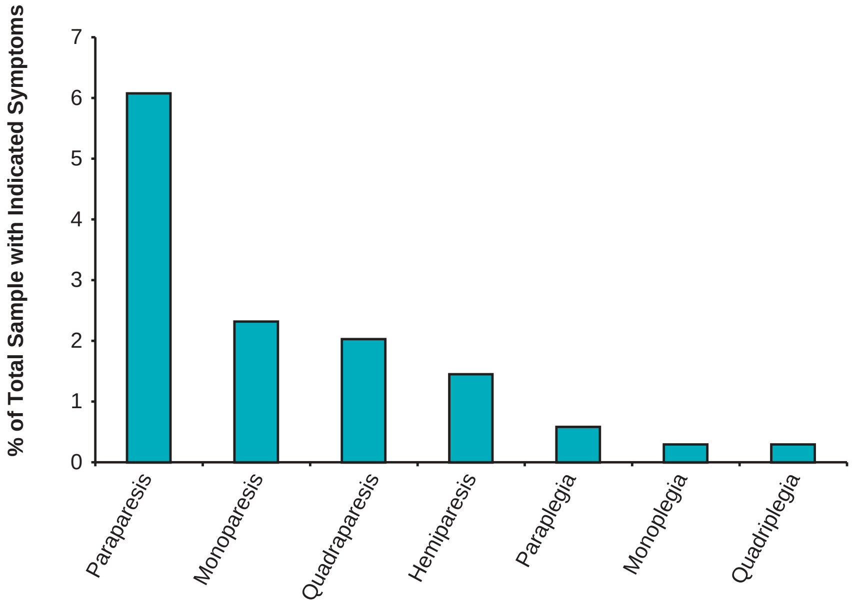
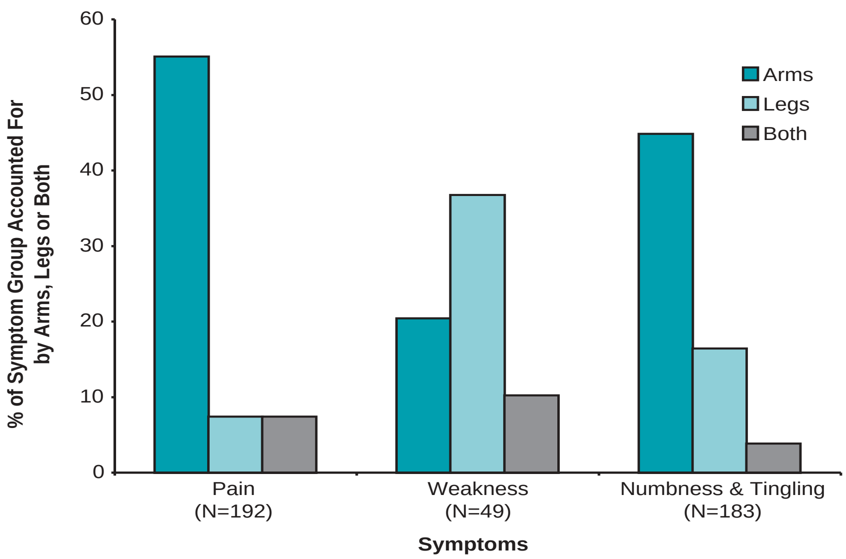


Figure 3.7-5 shows the distribution of pain, paresthesia (numbness, tingling and / or sensory deficit) and decreased muscular strength. Pain and paresthesia affected the arms most often, and weakness affected the legs more frequently. Arms and legs were rarely affected at the same time.

Figure 3.7-5 Distribution of pain, numbness and tingling, and muscular weakness by limb.



3.8 Therapies Given

Injured divers sought help in the form of surface oxygen first aid as well as more sophisticated recompression therapy in hyperbaric chambers. The following section describes the therapy received by our sample of injured divers.

Oxygen Therapy

Forty-eight percent of all of the divers in our sample received oxygen therapy prior to recompression. There were 167 reports of surface oxygen use in our sample of 348. This is an increase from previous years (43 percent in 2001 and 20 percent in 2000). Figure 3.8-1 indicates the method used for delivering surface oxygen in these divers. The most common method employed was non-rebreather masks.

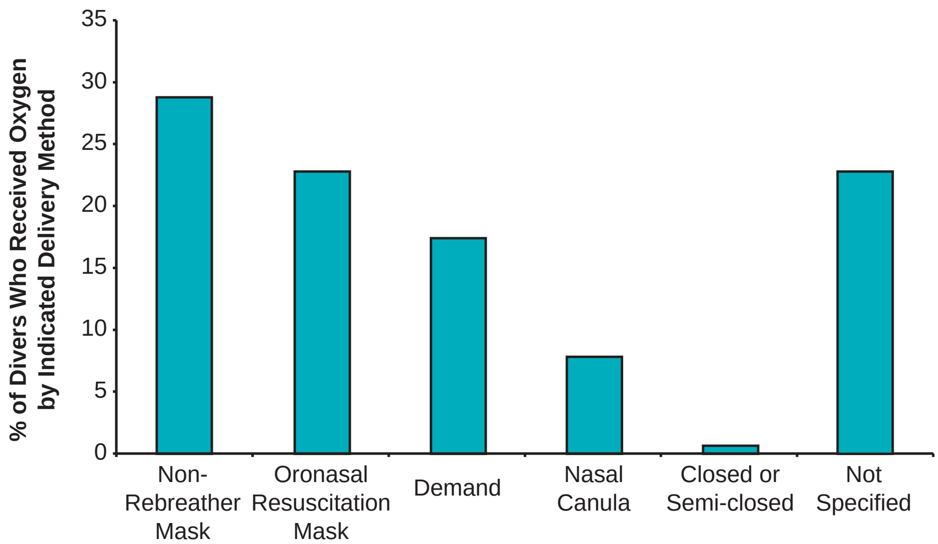
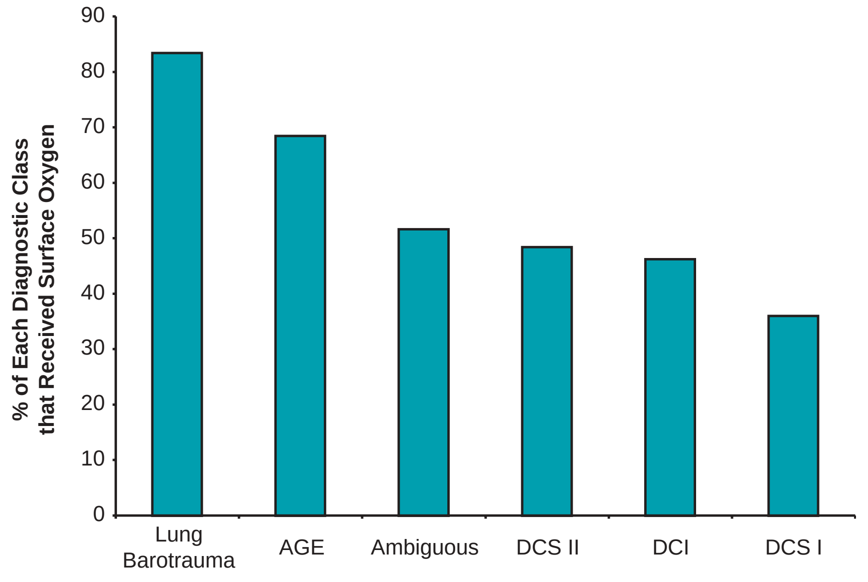


Figure 3.8-1 Method for delivering surface oxygen before recompression in injured divers (N=167).

Figure 3.8-2 shows the percentage of each diagnostic class of patients that received surface oxygen. Individuals diagnosed with lung barotrauma and arterial gas embolism were the most likely to receive surface oxygen. It is also interesting to note that a high percentage of divers who may not have had DCS or AGE (ambiguous) were given oxygen. This indicates that oxygen is administered freely and for a variety of indications.

Figure 3.8-2 Administration of first aid oxygen by diagnosis (N=167).



Recompression Therapy

Figure 3.8-3 shows the type of recompression chamber used to treat the divers in our sample. As in previous years, most were treated in multiplace chambers (69 percent). Some reports had missing information on chamber type.

Figure 3.8-3 Type of chamber in which injured divers were treated (N=348).

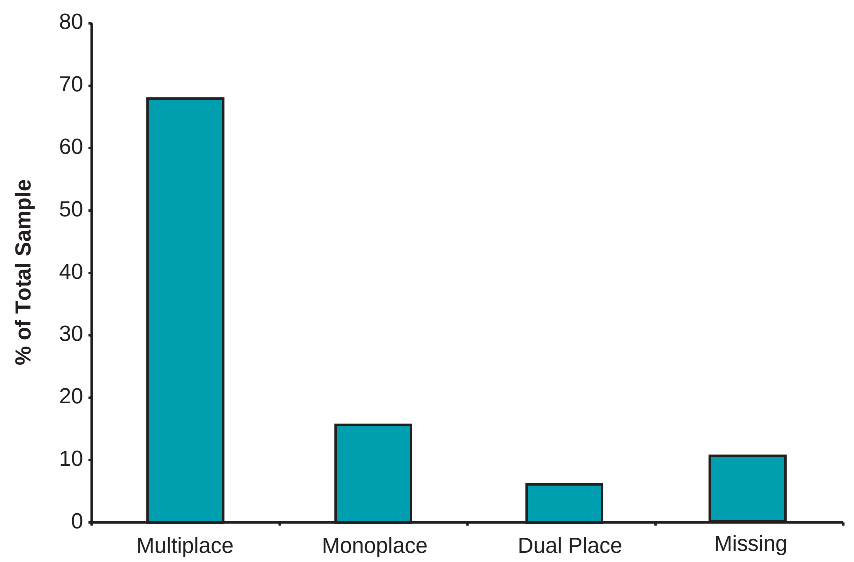


Figure 3.8-4 shows the initial treatment table used. U.S. Navy Treatment Table 6 (TT6) was used in 76 percent of initial treatments compared to 61 percent in 2001. U.S. Navy Treatment Table 5 (TT5) and Table 6A (TT6A), with 4.1 percent and 2.2 percent, respectively, were used less frequently than in 2001 (5.6 and 4.8 percent, respectively).

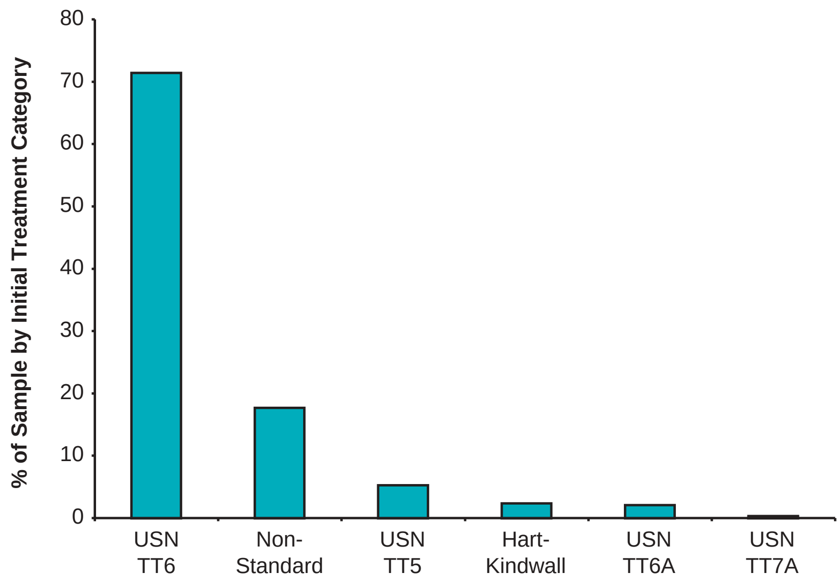


Figure 3.8-4 Initial treatment table used to recompress injured divers (N=342).

Figure 3.8-5 shows the total number of recompressions given for each case. Nearly 80 percent of all injured divers in our sample had completed their course of treatment after three recompressions. The median number of treatments was two, and the highest number was 25. Five percent of injured divers received more than five treatments.

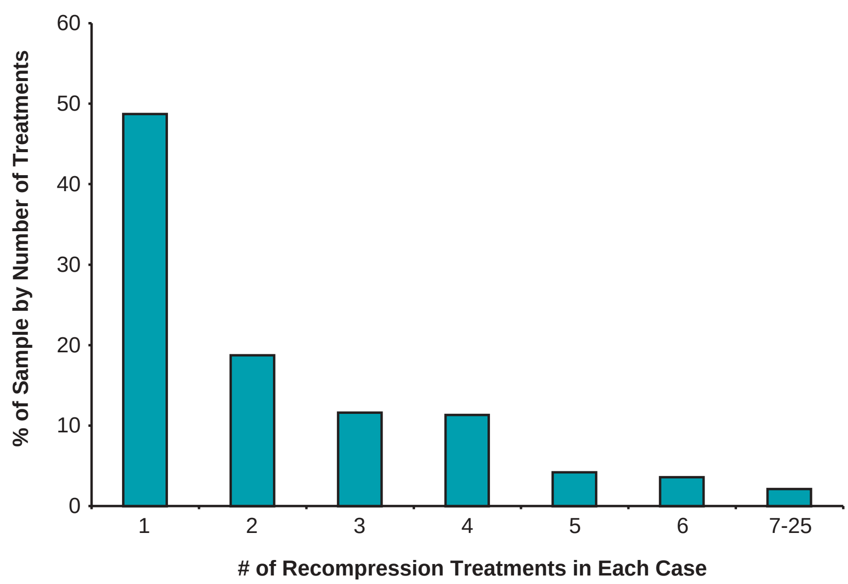


Figure 3.8-5 Total number of recompressions for injured divers (N=337).

Table 3.8-1 shows the number of recompressions both by diagnosis and Perceived Severity Index (PSI). Cases classified as "DCI" received the most treatments. Some cases in the "Not DCI" category received as many as 10 treatments. Among PSI categories, symptoms categorized as cardiopulmonary, pain, constitutional and mild neurological received the fewest treatments, while skin and serious neurological received the most treatments.

Table 3.8-1 Mean number of recompressions by diagnosis and PSI.

Category		Recompressions			
Diagnosis	N cases	Median	Maximum	Mean	Standard Deviation
DCS II	198	2	13	2.7	2.1
Not DCI	87	1	10	1.8	1.8
DCS I	56	1	5	1.7	1.1
Ambiguous	58	1	6	1.6	1.1
AGE	23	3	25	4.5	5.3
DCI	6	2	6	1.5	4.7
Lung Barotrauma	6	1	3	1.6	0.8
Perceived Severity Index (N=346)					
Mild Neurological	161	1	7	2.2	1.6
Serious Neurological	99	3	25	3.7	3.5
Pain	69	1	5	1.6	1.0
Constitutional	10	1	4	1.6	0.8
Cardiopulmonary	5	1	2	1.6	0.9
Skin	3	2	4	2.7	1.2

3.9 Therapeutic Outcomes

Effect of Surface Oxygen

In 348 cases classified as decompression illness, none resolved before admission without oxygen first aid. Figure 3.9-1 shows the response of the 69 injured divers for whom we have data about receiving surface oxygen prior to recompression. Improvement was reported after surface oxygen in 25 cases, and complete relief of symptoms before admission to the treating facility was reported in 34 cases. Ten cases were unchanged.

Curiously, 11 of the cases that reported complete relief after oxygen first aid were still recompressed multiple times. This could represent recurrence of symptoms or inaccurate reporting, because six of the cases that had reported complete resolution after oxygen first aid were listed as having residual symptoms at discharge. Among cases classified as "Not DCI," five responded with complete relief to surface oxygen. In the "Not DCI" group, two cases completely resolved before admission but that was without oxygen. There did not seem to be any effect of pre-recompression surface oxygen on outcome after recompression when measured by the presence of residual symptoms at discharge.

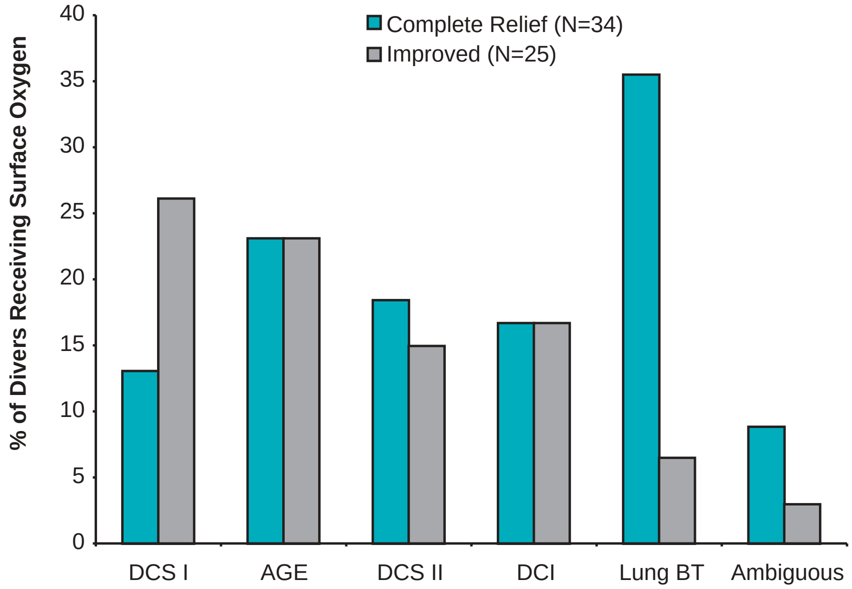


Figure 3.9-1 Effects of first aid oxygen on resolution before recompression (N=69).

Effect of Recompression

Figure 3.9-2 shows the percentage of divers who continued to have symptoms (residual) at six separate time points during the course of their treatment: after the first recompression treatment, at discharge, and at three-, six-, nine- and 12-month follow-ups. Seventy-one percent of the cases in our sample reported complete resolution of all symptoms at the time of discharge. Out of 101 cases with residual symptoms at discharge, a complete follow-up was available for 45 cases at the time this report was written. At a three-month follow-up, 81 percent of the 45 injured divers with follow-up had a complete resolution. At 12 months, that increased to 98 percent.

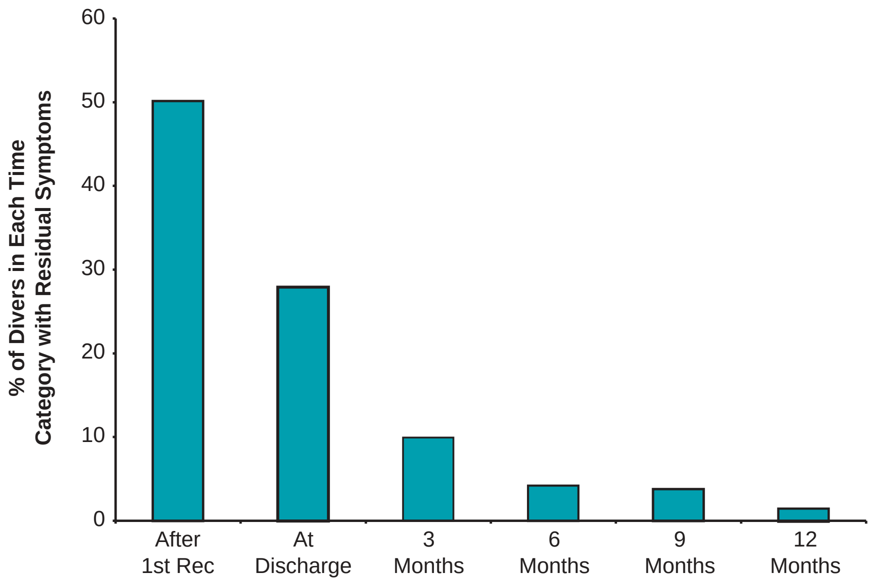


Figure 3.9-2 Treatment outcomes (N=348 at discharge, N=45 for follow-up).

Figure 3.9-3 shows that cases classified in the diagnostic category of "Not DCI" reported the highest percentage of incomplete resolution after all recompressions. This suggests that recompression therapy did not treat symptoms not due to DCS or AGE.

Figure 3.9-3 The outcomes at discharge by diagnostic category (N=336).

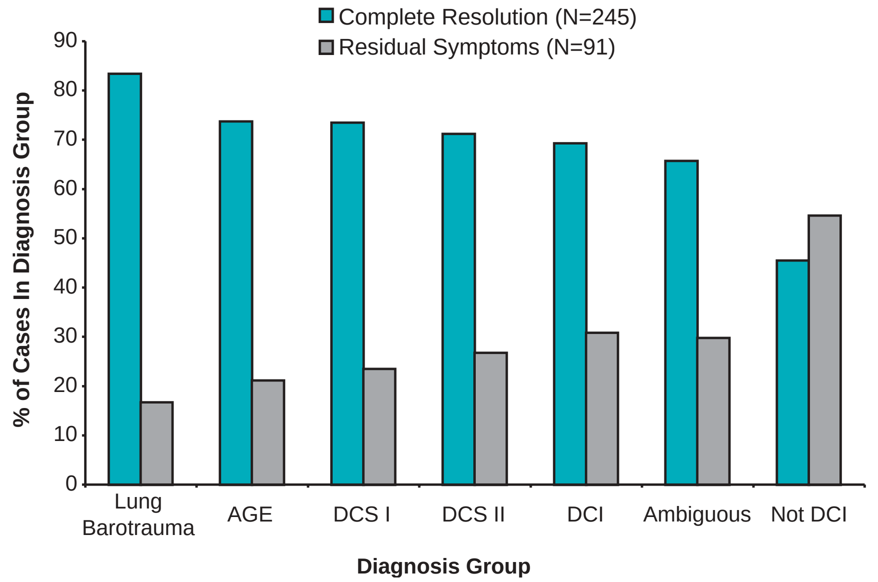
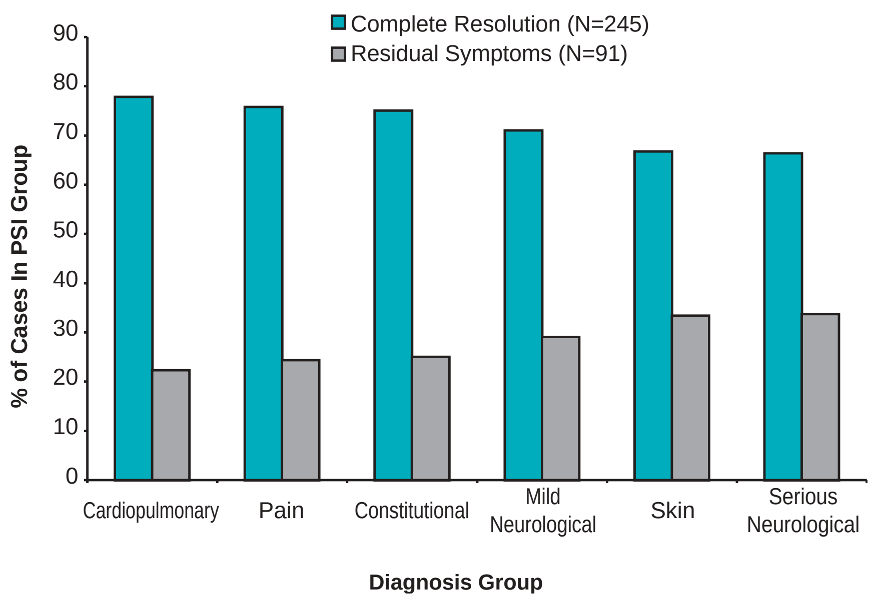


Figure 3.9-4 indicates that there was little difference in outcome at discharge between the PSI categories of the cases in our sample. The proportion of residual symptoms range from 22 percent (cardiopulmonary) to 30 percent (serious neurological).

Figure 3.9-4 The outcomes at discharge by Perceived Severity Index (N=336).



Delay to recompression after symptom onset did not seem to affect outcome in our sample. Figure 3.9-5 indicates the percent of cases with complete relief at discharge when categorized by time to recompression.

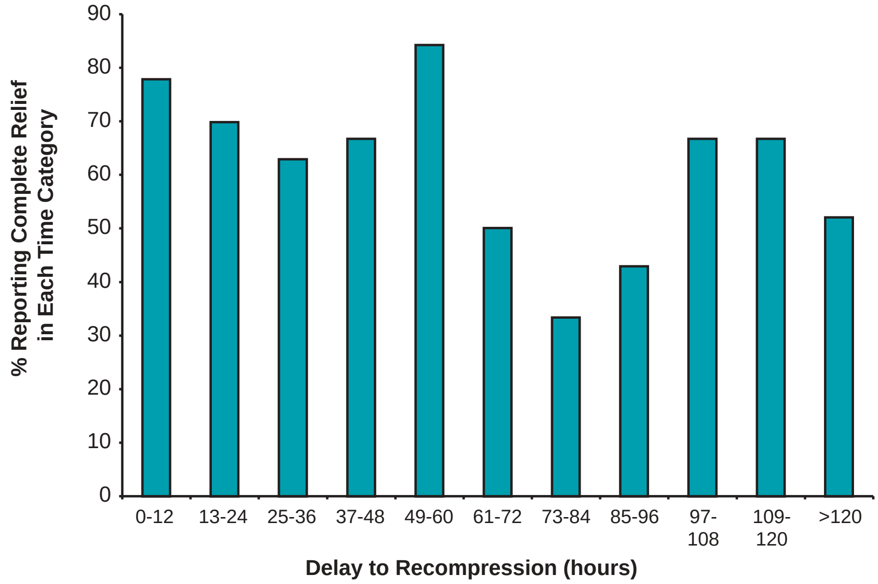


Figure 3.9-5 Percent of cases with complete relief at discharge (N=348).

Effect of Delay to Recompression

Figure 3.9-6 shows the delay to recompression for injured divers from time of first symptom onset. The median delay to treatment was 19 hours (mean 37 hours), with a range from less than one hour to 10 days. Forty-two percent were recompressed within 12 hours, and more than half of the cases were recompressed within 24 hours.

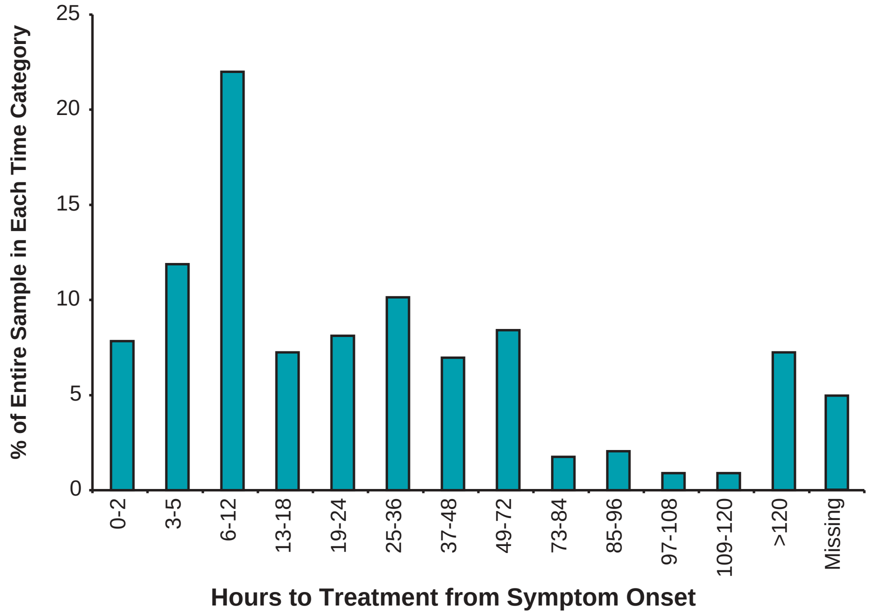


Figure 3.9-6 Delay to recompression from the time of first symptom onset (N=348).

Table 3.9-1 shows the delay to recompression by diagnosis. Barotrauma cases were treated earliest. Those classified as Not DCI had the longest delay to treatment.

Table 3.9-1 Delay to recompression by diagnosis.

Diagnosis	#	Median (hr)	Range (hr)	Mean (hr)	Standard Deviation
Lung Barotrauma	6	6	2-33	12	13
DCI	6	9	1-110	37	50
DCS II	198	15	1-591	39	70
DCS I	57	22	1-192	32	54
AGE	23	24	2-90	20	30
Ambiguous	58	34	2-592	52	95
Not DCI	83	35	1-703	68.2	90

Table 3.9-2 shows the delay to recompression by PSI classification. More than half of the serious neurological cases (54 percent) and cardiopulmonary cases (56 percent) were recompressed within 12 hours, while only 37 percent of mild neurological and 32 percent of pain cases were recompressed within the same time frame. Serious neurological and cardiopulmonary cases had significantly shorter delays than mild neurological or pain cases.

Table 3.9-2 Delay to recompression by PSI (N=348).

Diagnosis	#	Median (hr)	Range (hr)	Mean (hr)	Standard Deviation
Skin Changes	3	5	1-5	4	2
Cardiopulmonary	10	7	2-52	16	17
Constitutional	5	10	2-152	32	67
Serious Neurological	99	15	1-591	34	74
Mild Neurological	161	26	1-592	44	76
Pain	70	30	1-302	37	55

4. Dive Fatalities

Divers Alert Network is not a primary investigative agency for scuba fatalities, but DAN is notified of diving deaths through sources such as newspapers, government agencies, family members, and the internet. Fatality information is often less complete than the information provided on diving injuries or data from Project Dive Exploration, and fatalities that occur outside the United States can be particularly difficult to follow up. A forensic pathologist who is trained in dive medicine reviews cases included in this report.

DAN pursues all fatality reports that appear to involve recreational diving. Data collection often begins with a telephone call or a newspaper clipping that informs DAN of an event. This starts a process in which DAN contacts witnesses or family members and official investigative agencies such as the Coast Guard, police departments, coroners, medical examiners, hyperbaric chambers or diving agencies. DAN does not claim that this is a comprehensive list of dive fatalities: these data are based on reports received.

DAN collects dive injury and fatality information in compliance with the federal Health Insurance Portability and Accountability Act (HIPAA), legislation designed to protect the interests of affected individuals and their families. The Protected Health Information (PHI) is used solely to research the nature and treatment of the events and for no other purpose. DAN does not disclose PHI to any party other than employees, representatives and agents of DAN who have a need to know.

There were 89 diving fatalities in 2002, involving 77 men and 12 women. Autopsy reports were available for 51 cases, not available in 22 cases and unknown or not done in 14 cases. A body was not recovered in two cases.

4.1 Characteristics of Divers Who Died

The age distribution for diving fatalities is shown in Figure 4.1-1. For the first time in several years, no adolescent or teenage fatalities were reported. The youngest diver fatality was 24 years of age and the oldest 73. The largest proportion of male fatalities (68 percent) were between the ages of 40 and 59, and the largest proportion of female fatalities were between 20 and 39 (58 percent). The age range for females was from 24-69 years, with an average of 40.8 years. The range for males was 24-73 years, with an average of 48.6 years.

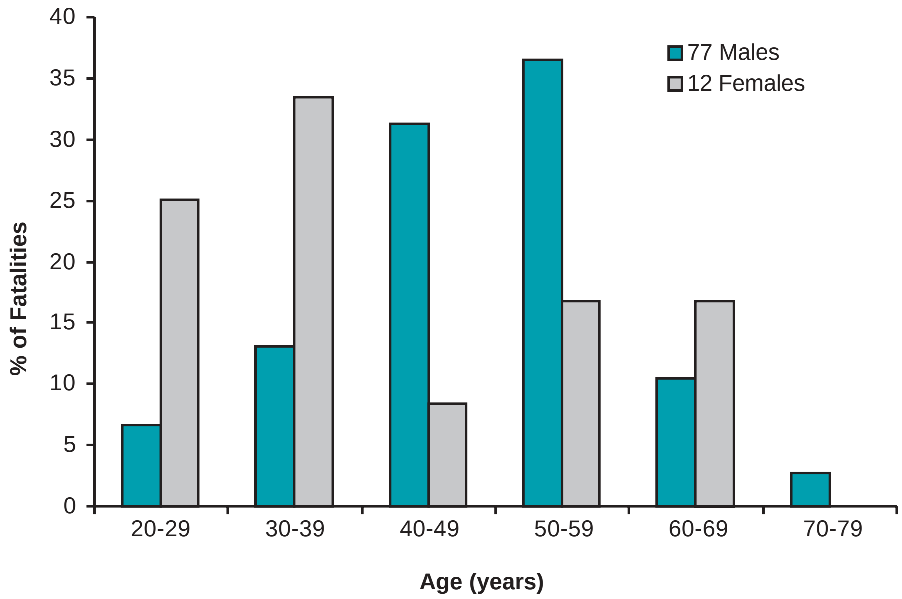


Figure 4.1-1 Distribution of fatalities by age and gender for divers who died in 2002 (N=89).

Figure 4.1-2 shows the chronic health conditions reported for divers who died. High blood pressure and heart disease (HBP / HD) remain the most frequently reported chronic health conditions. The percentage of HBP / HD has remained approximately the same over the last several years, while the percentage of cigarette smoking decreased slightly. The percentages of diabetes and asthma were unchanged. Reported allergies in 2002 increased to 9 percent from 1 percent in 2001. Some divers had more than one chronic health condition, but the presence of a chronic illness was not necessarily related to the cause of death.

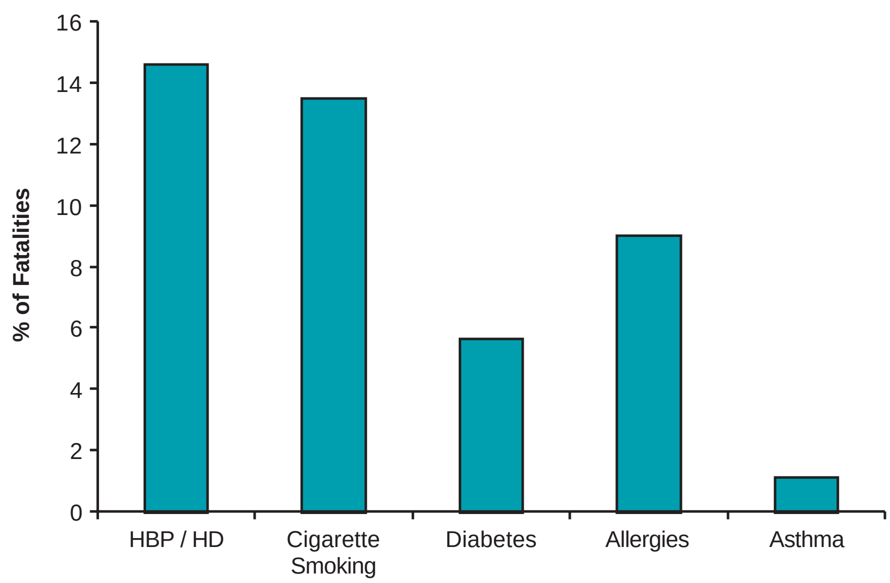


Figure 4.1-2 Chronic health conditions in diving fatalities for 2002 (N=89).

Figure 4.1-3 shows the categories of obesity in the fatality population as defined by the 1998 U.S. National Heart, Lung, and Blood Institute based on body mass index (BMI, an individual's weight in kilograms divided by height in meters squared). Generally speaking, increasing BMI indicates increasing obesity (except in individuals with unusually large muscle mass). Only 12 percent of divers who died were underweight or of normal BMI. Thirty-three percent were overweight, and 55 percent were obese. Obesity is associated with poor health, heart disease and poor exercise tolerance. The lack of physical stamina and poor cardiac health can limit a diver's ability to cope with adverse circumstances during diving and may contribute to the risk of a fatal event.

Individuals are classified as:

- "underweight" = BMI of less than 18.5 kg / m^2;
- "normal" = BMIs of 18.5 to <25.0 kg / m^2;
- "overweight" = BMIs of 25.0 to <30.0 kg / m^2; and
- "grade 1 obesity" = BMIs of 30.0 to <35.0 kg / m^2.
- "grade 2 obesity" = BMIs of 35.0 to <40.0 kg / m^2.
- "morbid obesity" = BMIs of ≥40.0 kg / m^2.

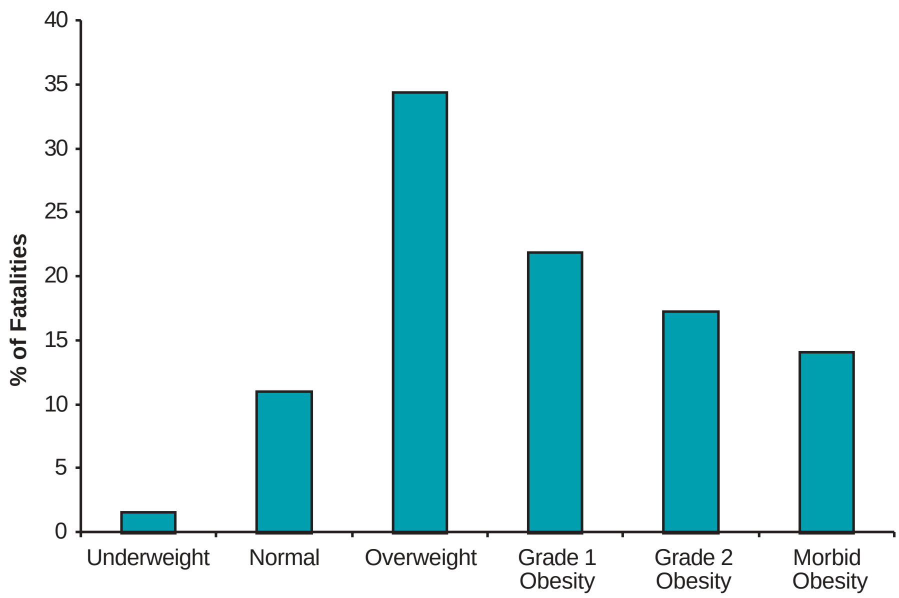


Figure 4.1-3 Body fatness estimated from BMI for diving fatality victims (N=89).

Figure 4.1-4 shows the distribution of certification levels by gender for the divers who died in 2002. Males represented 87 percent of all fatalities. The largest proportion of divers had open-water or advanced certification. The certification status of 16 males and two females was unknown. Five student fatalities occurred during open-water or basic scuba training and one happened during search-and-rescue training.

Figure 4.1-4 Certification status of divers who died in 2002 (N=89).

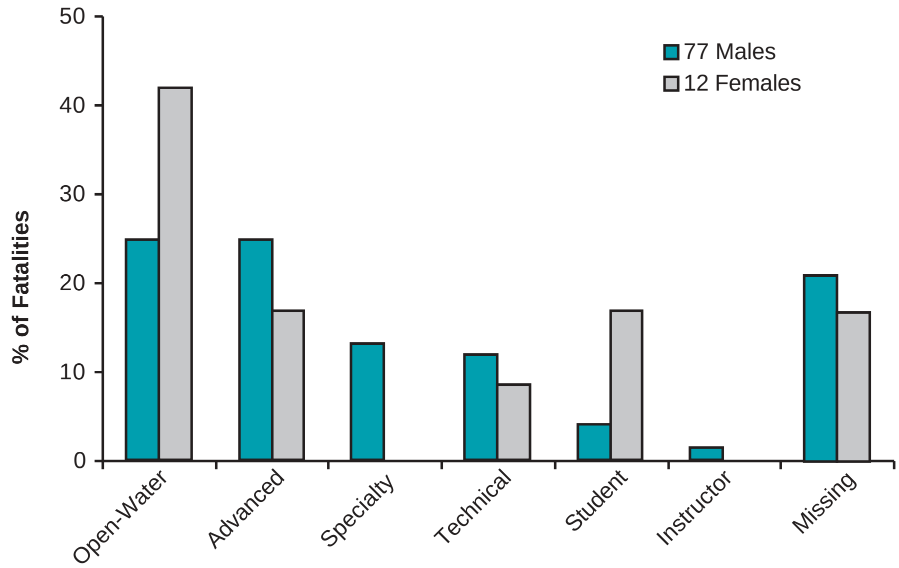


Figure 4.1-5 shows the number of years since initial certification for divers who died. Women who had been certified for one year or less accounted for the largest proportion of female deaths, and men who had been certified for six years or more accounted for the largest proportion of male deaths. Of 19 divers with one-year certification or less, 11 were open-water certified, five were open-water students, one was a technical diver, one had a specialty certification, and the certification status of one diver was unknown. Seven of the first-year divers had made four dives or fewer, and five had made 20 or more dives.

Figure 4.1-5 Number of years since initial certification of divers who died in 2002 (N=89).

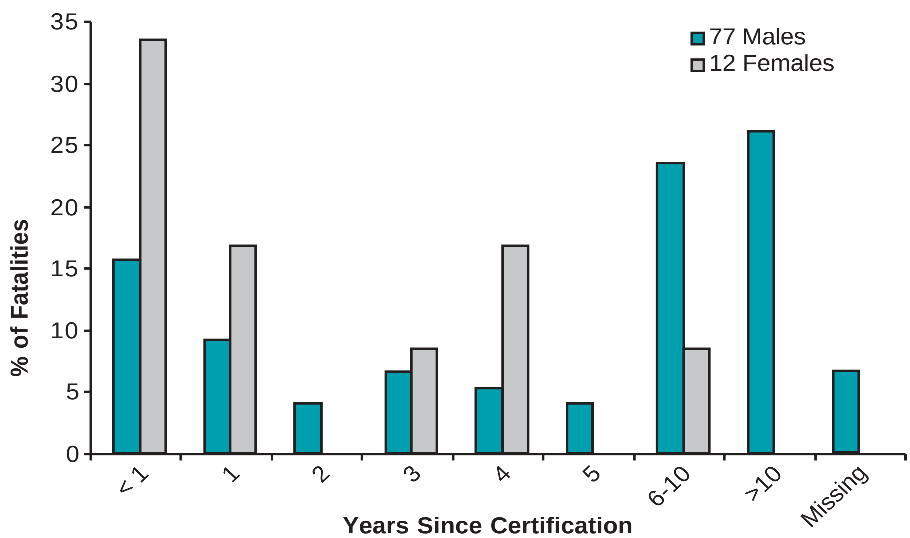


Figure 4.1-6 shows the number of dives performed in the previous 12 months by divers who died. This information was available for 31 males and eight females. Female divers who died made an average of 42 dives with a range of one to 300. Male fatalities had an average of 13.3 dives with a range of one to 75 dives. As in previous years, death was most common for divers who made fewer than 20 dives.

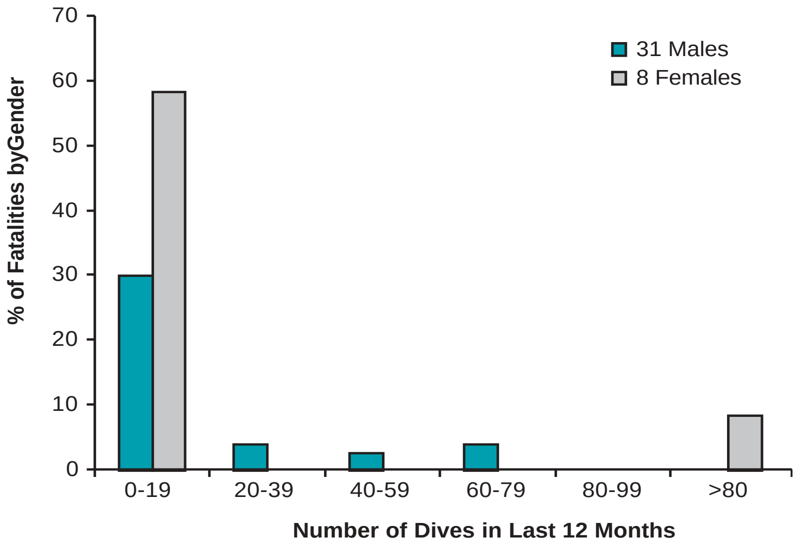


Figure 4.1-6 Number of dives that were performed by diving fatalities for 2002 in the 12 months prior to death (N=39).

4.2 Characteristics of Dives by Divers Who Died

Figure 4.2-1 shows the distribution of scuba fatalities in the United States over the months of 2002. As in 2001, August was the peak month for scuba fatalities.

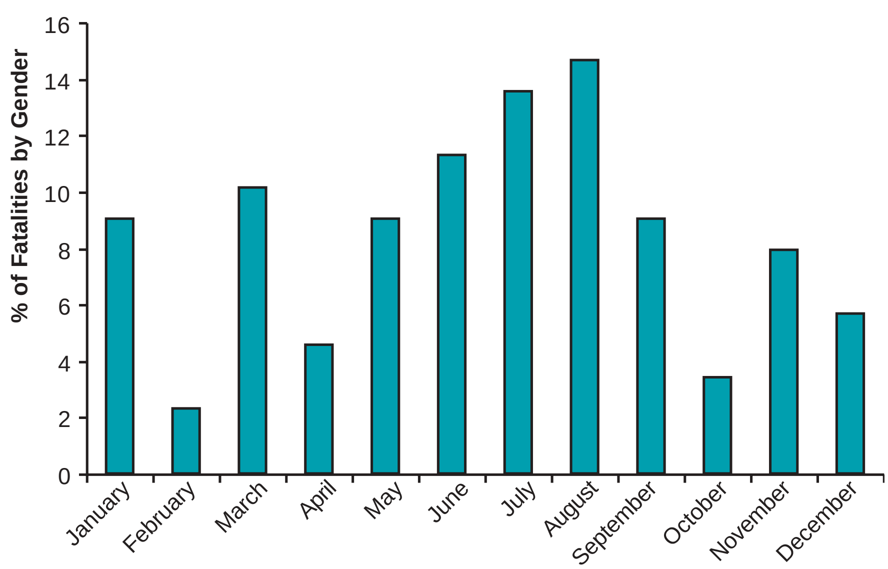


Figure 4.2-1 Month in which divers died in 2002 (N=60).

Figure 4.2-2 shows that fatalities in 2002 were most common in the afternoon. This is different from 2001, when fatalities were most common in the morning.

Figure 4.2-2 Time of day that death occurred in 2002 (N=57).

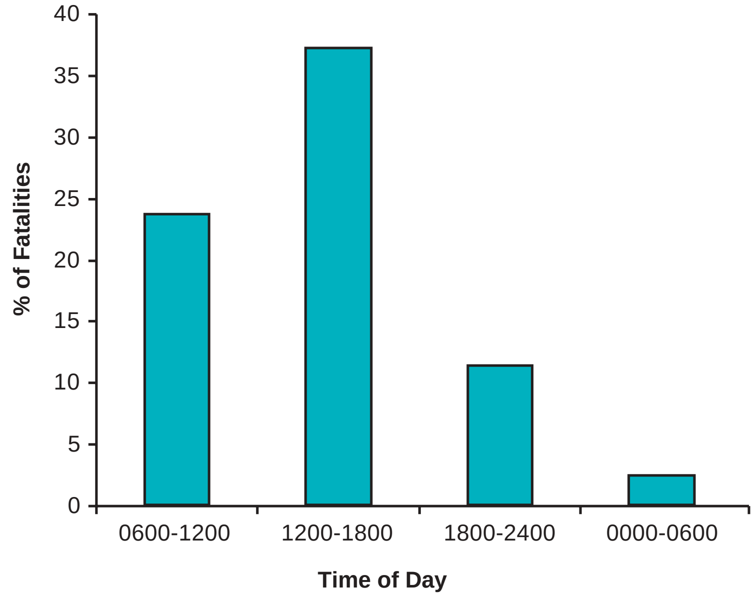
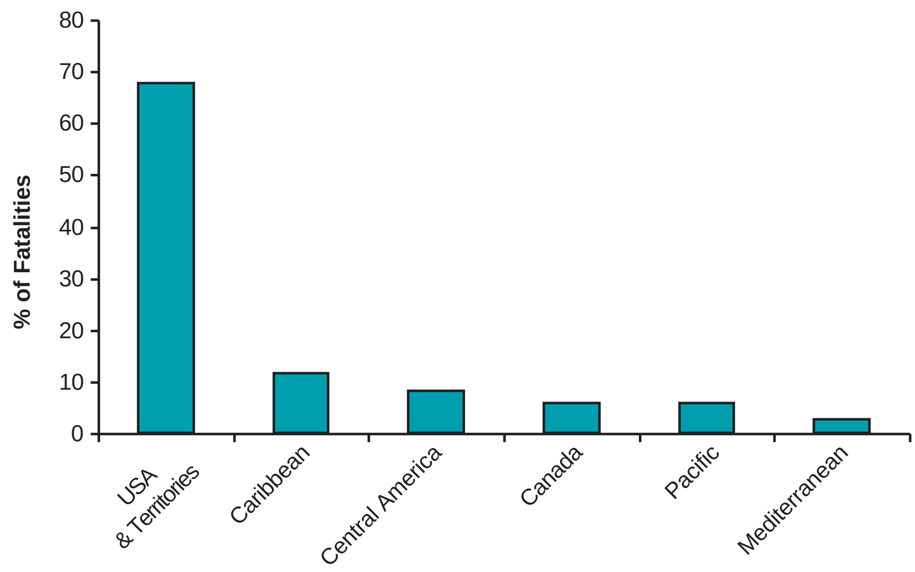


Figure 4.2-3 shows the international locations of fatalities that occurred in 2002. Sixty-seven percent of all deaths were in the United States or U.S. territories. The Caribbean basin was the next most common location, with 11 percent of all fatalities.

Figure 4.2-3 Locations where the fatalities occurred in 2002 (N=89).



Sixty-three percent of all diving fatalities occurred in the United States. Their distribution is shown Fig. 4.2-4. Thirty-seven percent of U.S. fatalities occurred in the Southeast region (North Carolina to Key West, Fla., including Tennessee and Alabama). The states in each of the six DAN U.S. regions are listed in the front of this report.

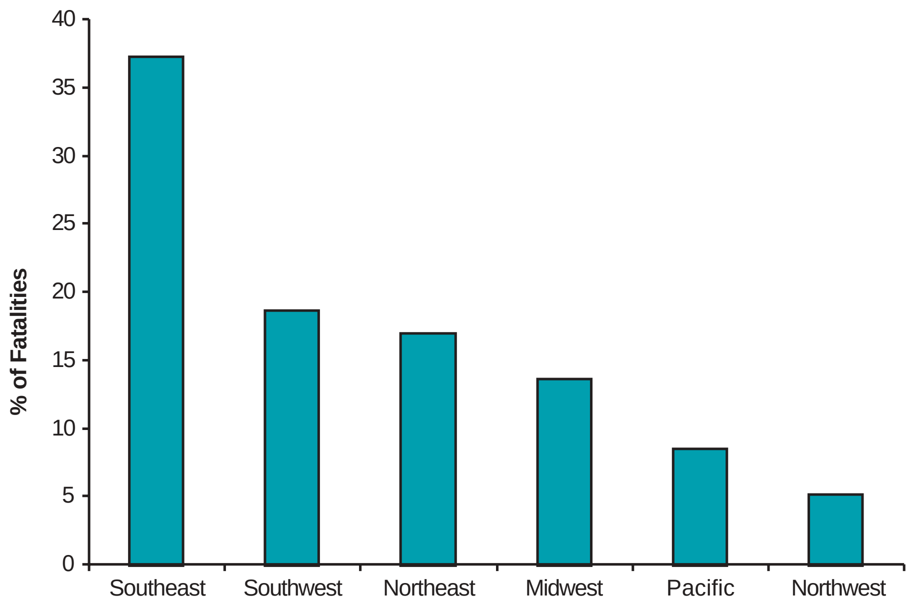


Figure 4.2-4 Distribution of U.S. fatalities in DAN regions in 2002 (N=60).

Figure 4.2-5 shows the water environments in which the fatalities occurred. The majority (79 percent) occurred in salt water.

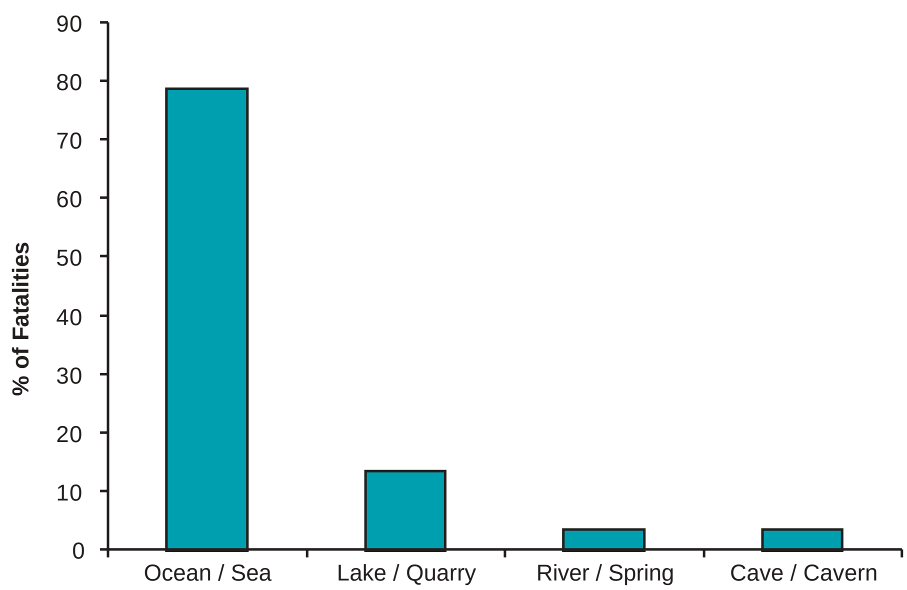


Figure 4.2-5 The environment the fatalities occurred in 2002 (N=89).

Figure 4.2-6 shows that 57 percent of male and 58 percent of female fatality victims were diving for pleasure or sightseeing. One-third of the female deaths occurred during training, and one female death occurred during a technical dive. One male died while performing an underwater task with scuba.

Figure 4.2-6 Activities of divers who died in 2002 (N=89).

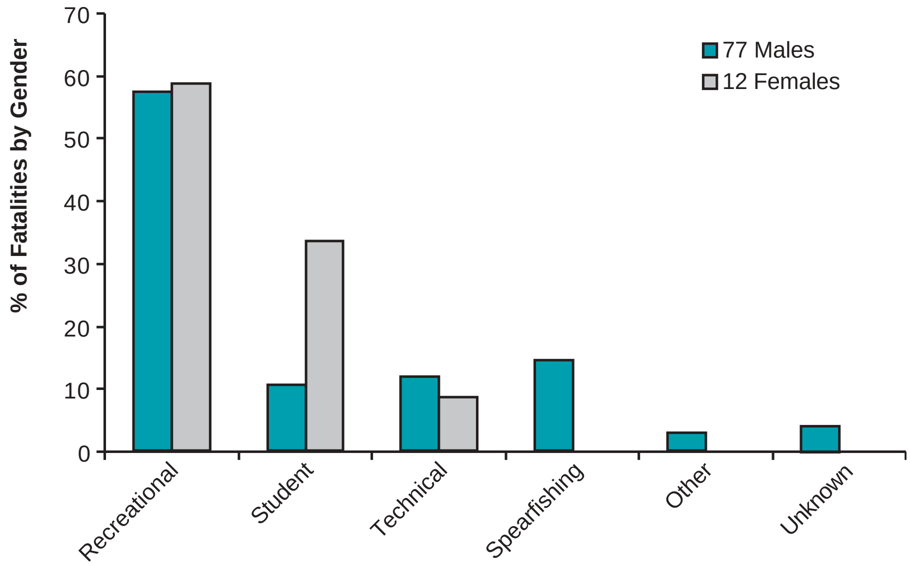


Figure 4.2-7 shows the dive platform from where the fatal dives began. Fifty percent began from a charter or private vessel, consistent with reports from previous years. Beach and shore diving were also similar to previous years. Liveaboard fatalities were uncommon.

Figure 4.2-7 Dive platform for divers who died in 2002 (N=89).

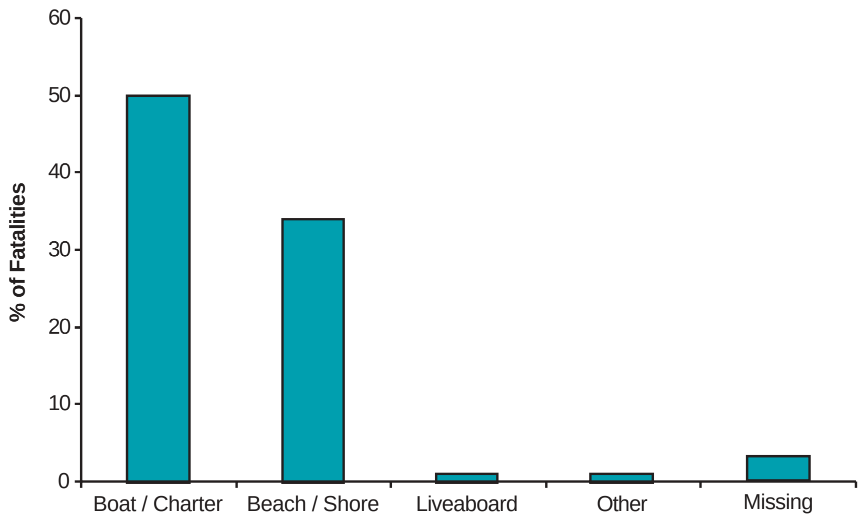


Figure 4.2-8 shows the thermal protection worn by divers who died. Most divers who died used a full or partial wetsuit. Drysuits were less common than diveskins or swimsuits.

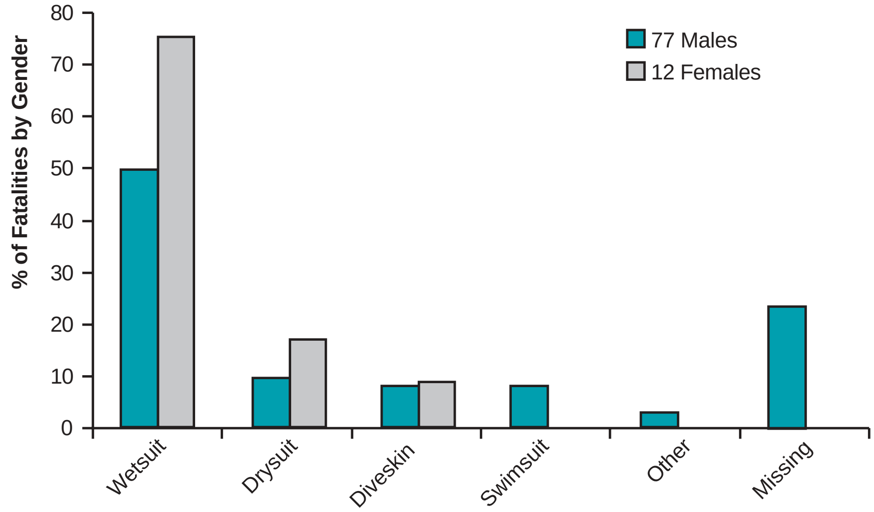


Figure 4.2-8
Thermal protection worn by divers who died in 2002.

Many fatalities occur on the first day of diving and on the first or second dive, but the exact number of days and number of dives prior to the fatal dive are not always known. On the day of the accident, 56 divers made one dive only, seven made two dives, and seven divers completed three dives. We do not have any information for 19 divers.

Figure 4.2-9 shows the distribution of maximum dive depths reported for the 2002 scuba fatalities. About 58 percent of both male and female fatalities occurred in depths less than 90 fsw / 27 msw. There were no female fatalities reported beyond 120 fsw / 36.5 msw.

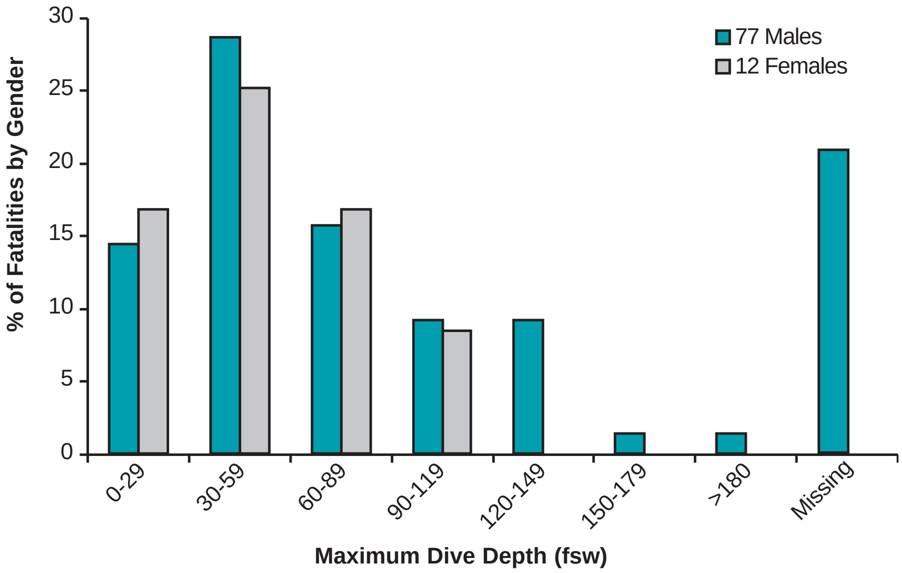


Figure 4.2-9
Maximum dive depth for divers who died in 2002.

Equipment problems were reported in 44 of the 89 scuba fatalities for 2002, as shown in Fig. 4.2-10. Problems with the buoyancy compensator device (BCD) and regulator continued to be the most common. Fewer equipment problems were reported in 2002 than in 2001.

Figure 4.2-10 Equipment problems for divers who died in 2002 (N=44).

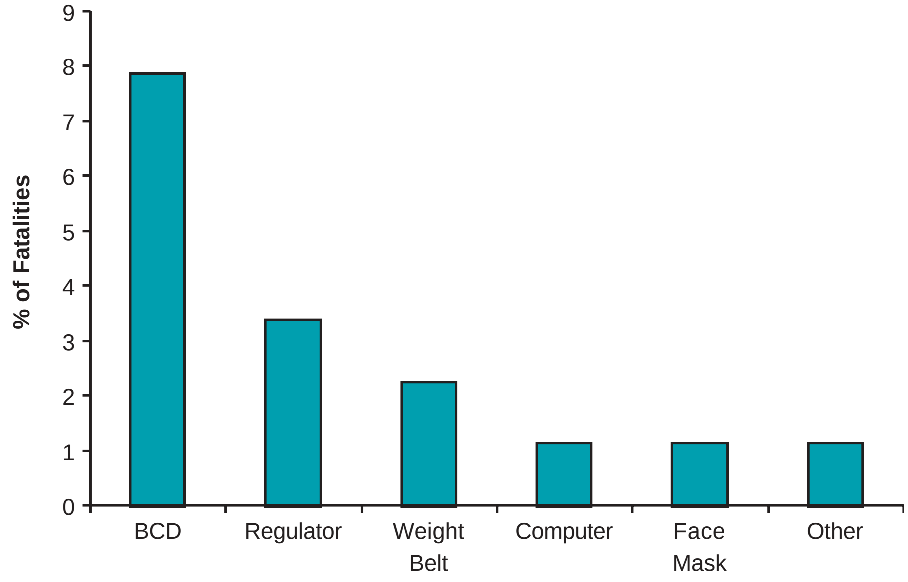


Figure 4.2-11 shows the procedural problems reported in scuba fatalities for 2002. A given diver may have experienced several problems. Buoyancy problems and running out of air were more common in fatalities than among PDE and injured divers. Divers were reported to have run out of air in 21 cases (24 percent), been low on air in eight cases, and shared air or attempted to share air in four cases. While equipment or procedural problems are of concern, they do not necessarily represent the event that led to death.

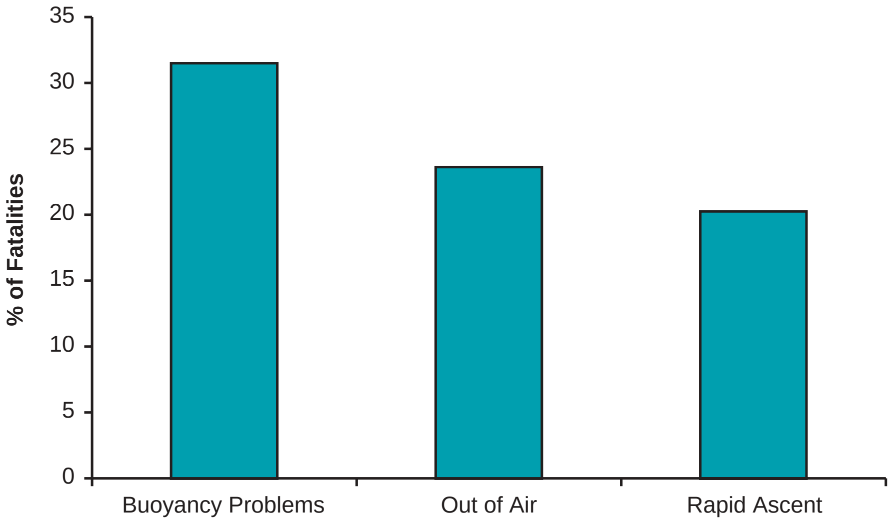


Figure 4.2-11 Procedural problems in divers who died in 2002 (N=89).

Scuba deaths frequently result from a cascade of events. Figure 4.2-12 shows the distribution of the cause of death in the judgment of the DAN pathologist who reviewed each case. In 53 percent of fatalities, the cause of death was believed to be drowning, a significant risk for any water-related activity.

As in previous years, air embolism was the second leading cause of death and was reported in 16 cases. However, air embolism was identified as a contributing factor in 16 additional cases, 11 of which led to subsequent drowning.

Eighteen of 27 AGE fatality cases also reported a rapid ascent, and insufficient air was reported in 14 of 27 cases. Cardiovascular problems (HBP / HD, or high blood pressure / heart disease) continue to be the most common medical condition associated with scuba fatalities.

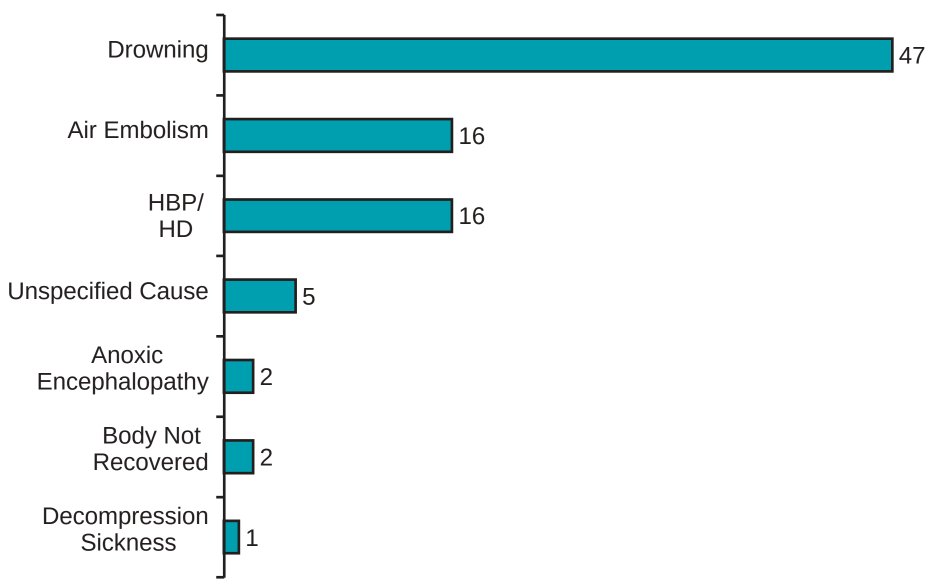


Figure 4.2-12 Suspected cause of death in divers who died in 2002 (N=89).

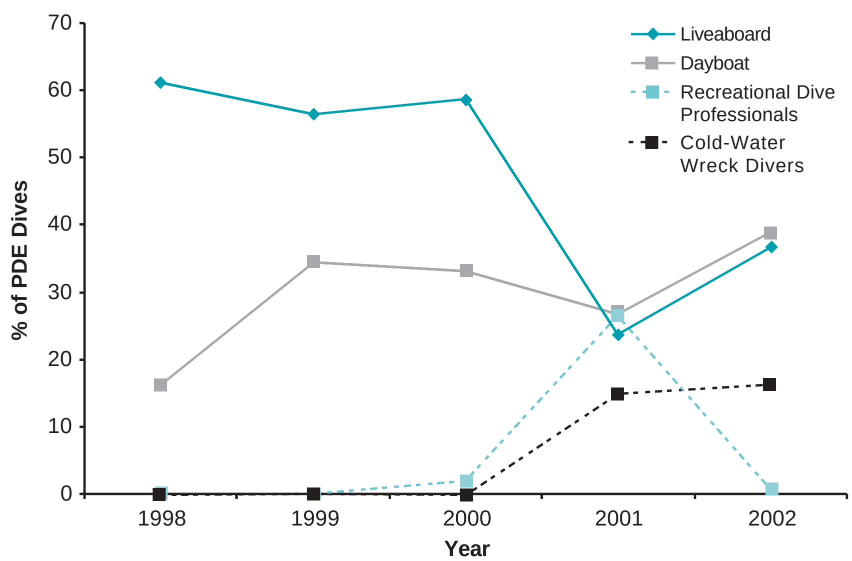
5. Five-Year Trends (1998-2002) in Diving Activity

The 2000 edition of the DAN *Report on Decompression Illness and Diving Fatalities* summarized data collected over 11 years (1987-1997). The 2004 edition of the Report describes injury and fatality data for 1998-2002 as well as data collected in Project Dive Exploration (PDE) during the same period. The objective of these summaries was to identify trends that may have taken place in recreational scuba diving. No graphs are shown in cases where there was little change. The data presented, however, are a limited sample of diving activity and are not representative of diving throughout the world.

5.1 Project Dive Exploration

Project Dive Exploration (PDE) began data collection in 1995. The rate of collection has accelerated as the sources of PDE data have evolved (Figure 2.2-1). From 1995-1997, volunteer Field Research Coordinators (FRCs) collected data in their local diving areas. In 1998, the liveaboard dive boat *Nekton Pilot* became the first PDE Data Collection Center, and liveaboard diving activity dominated data collection from 1998-2000 (Figure 5.1-1).

Figure 5.1-1 Sources of PDE data for 1998-2002.



The DAN Research Internship began in 1999, and in 2001 as a continuation of the program, three dive instructors in Cozumel, Mexico acted as FRCs. Also in 2001, Robert Forbes began a Data Collection Center in Scapa Flow, Scotland, with a new diver population: cold-water wreck divers in drysuits. The four diving populations – live-aboard, dayboat, dive guides, and cold-water wreck divers – have demonstrated that the risk of decompression injury is strongly influenced by the type of diving. Future PDE data collection efforts will diversify to other diving populations.

The mean age of PDE divers varied from 33-40 on an annual basis during 1998-2002, with no apparent trend and no difference between males and females. The participation of females varied from 26 to 29 percent, with no trend. The number of years since initial training was without trend. Males had 8.6 to 10 years, while females had 5 to 6.8 years.

Figure 5.1-2 shows the percentages of PDE divers by certification. The increase in divers with advanced certification reflects participation of cold-water wreck divers in 2001 and 2002.

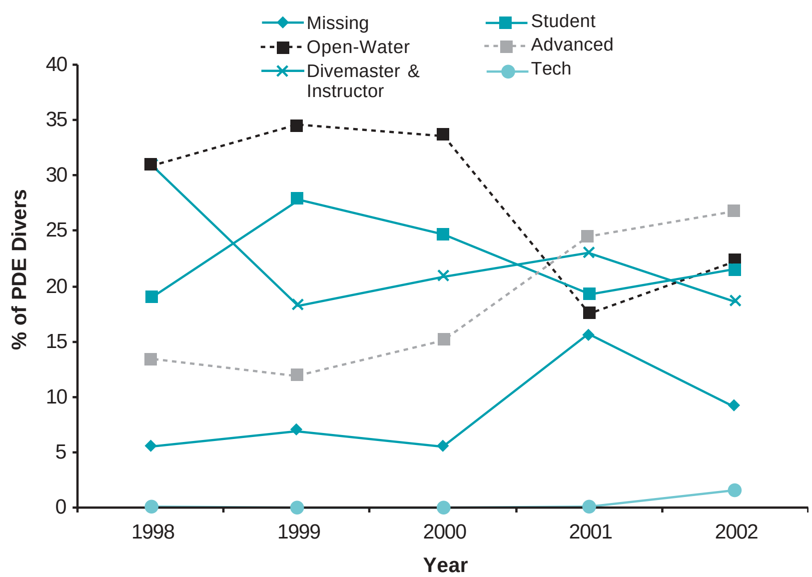


Figure 5.1-2 Certification levels of PDE divers for 1998-2002.

All PDE divers used dive computers or data loggers to record their depth-time profiles. These profiles provided exact values for the number of days of diving, the number of dives and the maximum depth of each dive. The mean number of days in a PDE dive series was three to four, and the median number of dives was two to three: there were no differences between males and females. The median number of dives in a series was three to six, with no consistent differences between males and females. For the past four years, the mean maximum depth has been 86-100 fsw (26-30 msw) without trend. In general, the mean maximum depth was about 5 fsw (1.5 msw) less for women than for men.

Figure 5.1-3 shows the breathing gas used by PDE divers. The percentage of divers using nitrox increased from 7 percent to 24 percent over the five-year period. The percentage of divers using helium-based mixes was negligible in the same period.

Figure 5.1-3 Breathing gas used by PDE divers for 1998-2002.

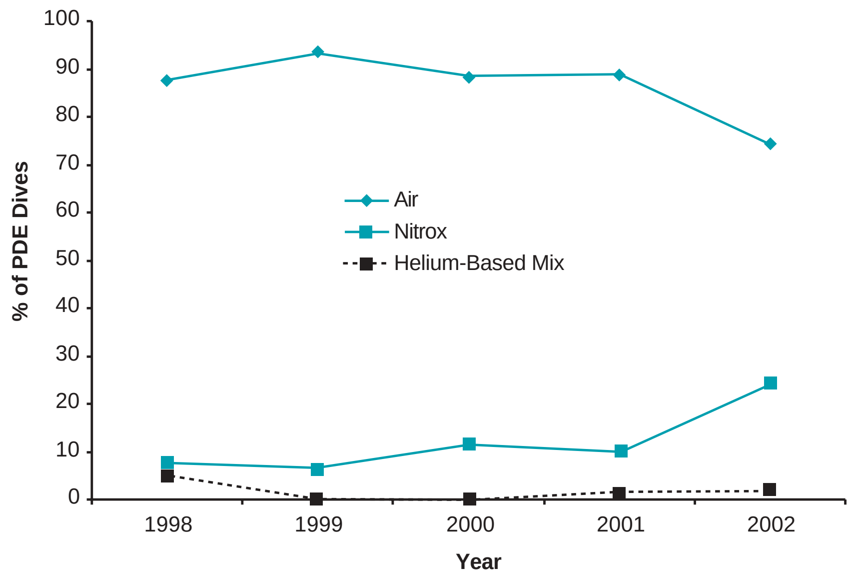
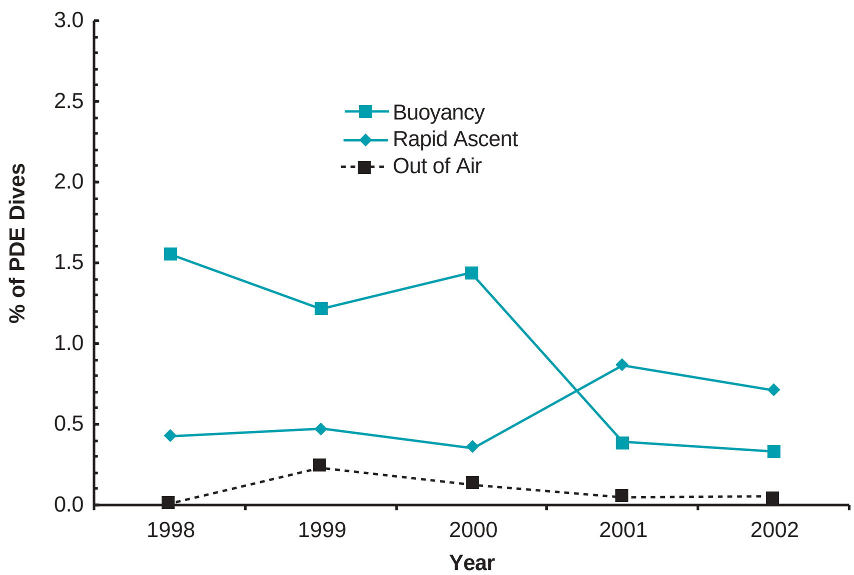


Figure 5.1-4 showed that proportions of PDE divers who reported having buoyancy problems, running out of air or ascending rapidly. Reported buoyancy problems appeared to decrease over the period. The incidences of rapid ascent and out of air were at least 10 times higher for injured divers (Figure 5.2-9, page 96).

Figure 5.1-4 Problems experienced by PDE divers for 1998-2002.



5.2 Dive Injuries

Figure 5.2-1 shows the international regions in which the dive injuries reported to DAN occurred. The percentage of injuries reported from U.S. chambers relative to other geographical regions declined slowly during 1998-2002, while the combined injuries in Central America and the Caribbean increased slowly to more than 40 percent of the total. This continues the trend observed for 1987-1997 noted in the 2000 Report.

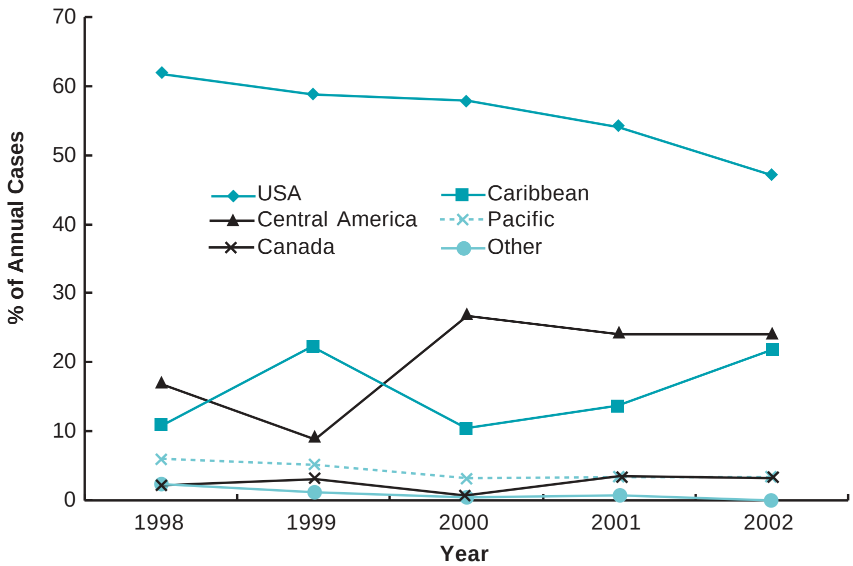
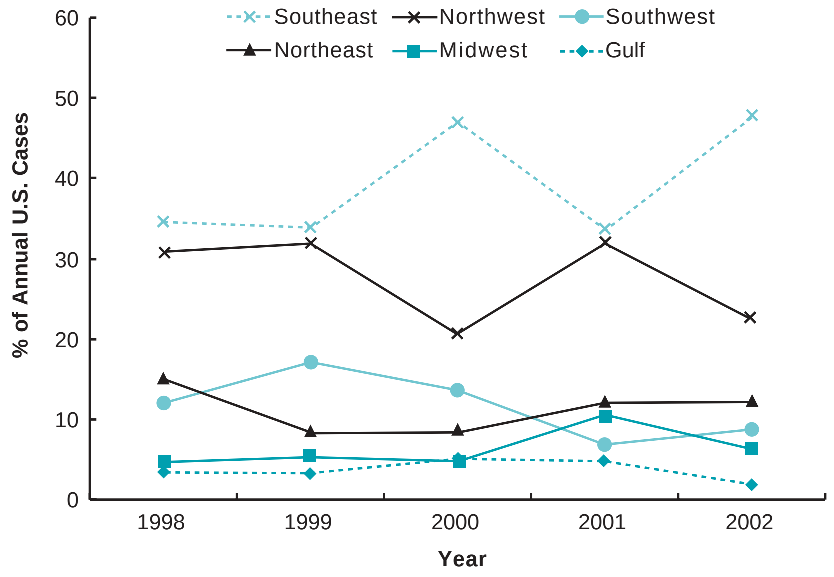


Figure 5.2-1 International region where dive injuries occurred for 1998-2002.

Figure 5.2-2 shows the percentage of injuries reported for each of the U.S. DAN regions. More than 60 percent of the reports were from the Southeast and Northwest. The Southeast includes Florida, a popular domestic diving destination. The Northwest region is popular with divers interested in temperate-water diving, but the relatively large number of cases from the Northwest may reflect better chamber reporting compliance rather than a higher volume of injuries.

Figure 5.2-2 U.S. regions for diving injuries for 1998-2002.



The mean age of injured divers increased from 33 years to 37 years during 1987-1997, while during 1998-2002 the mean age increased from 37 to 39 years. Divers aged 50 or older represented 7 percent of injured divers in 1997 and more than 15 percent in 2002. There was no difference in the mean age of male and female injured divers. The annual proportion of women among injured divers was 26-31 percent without trend. The mean time elapsed since initial training for injured divers during 1998-2002 was 5 to 7 years for women and 8.6 to 10 years for men.

Figure 5.2-3 shows the percentages of injured divers by certification level. The highest percentage held advanced certifications (including advanced and divemaster ratings), followed by divers with basic certification. The proportion of divers with technical certification has increased gradually since 1998.

Figure 5.2-3 Certification levels of injured divers for 1998-2002.

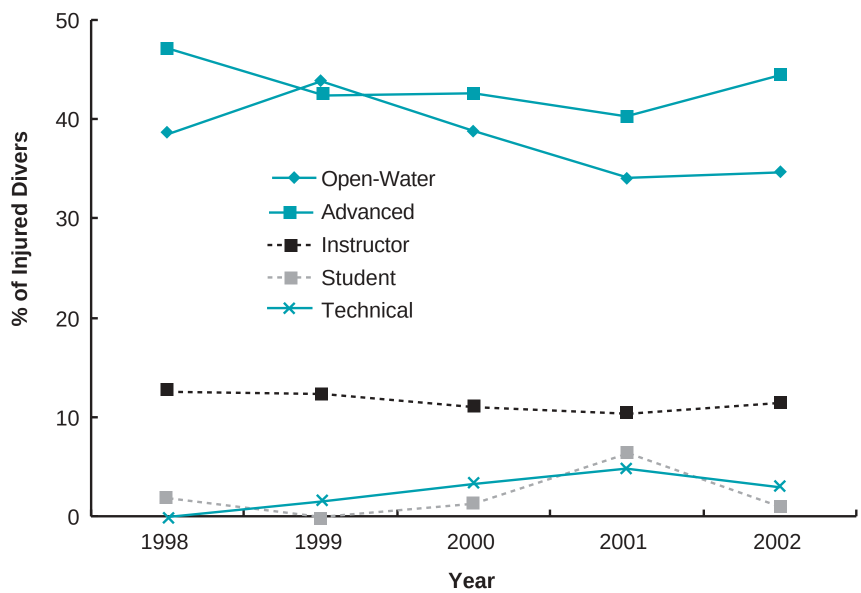


Figure 5.2-4 shows that the use of dive computers among injured divers grew from 60 to 70 percent from 1998-2002. This represents slow but steady growth from fewer than 20 percent of reporting divers in 1987, when DAN first began to publish dive injury data. This trend most likely reflects the continued growth of dive computer use rather than an increased risk of decompression injury. The risk of injury can be determined only if the number of divers at risk and the number of dives they make is known. These risks are estimated in Project Dive Exploration.

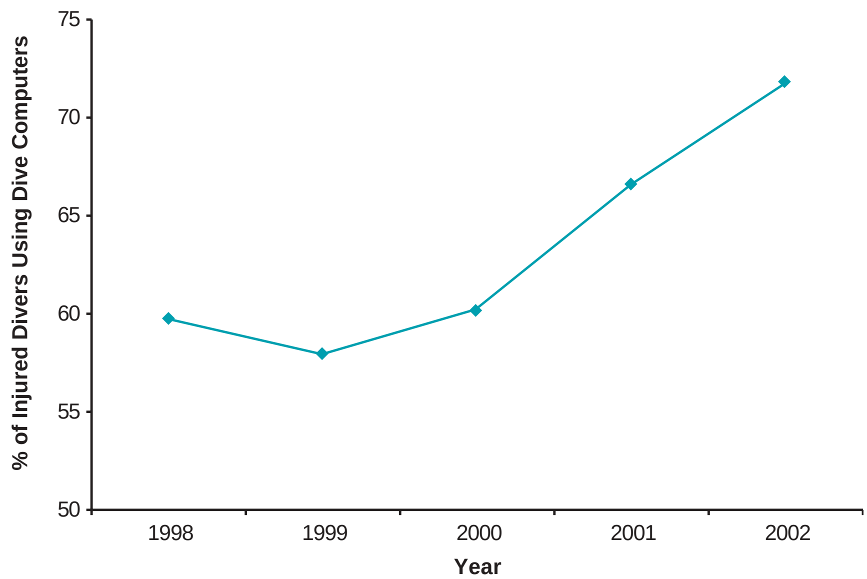


Figure 5.2-4 Percentage of injured divers who used dive computers for 1998-2002.

While injured divers commonly used dive computers, very few recorded depth-time profiles are available. (A new injury reporting system, the SERF — Scuba Epidemiological Reporting Form , described on page 52 — will emphasize collection of recorded dive profiles.) In their absence, we present features of dive profiles that are likely to be remembered with relative accuracy. These include the number of days of diving, the number of dives made, the maximum dive depth for each dive, the method of selecting the dive profiles, and whether there was any post-dive altitude exposure. This information is presented in the following graphs.

Figure 5.2-5 shows that the median number of days of diving for injured divers increased in 1998-2002 for both men and women. This could indicate improved dive safety during the first few days of a dive series or more divers making longer dive series. Females did multiday diving prior to injury more often than did males.

Figure 5.2-5 Median days diving for injured males and females for 1998-2002.

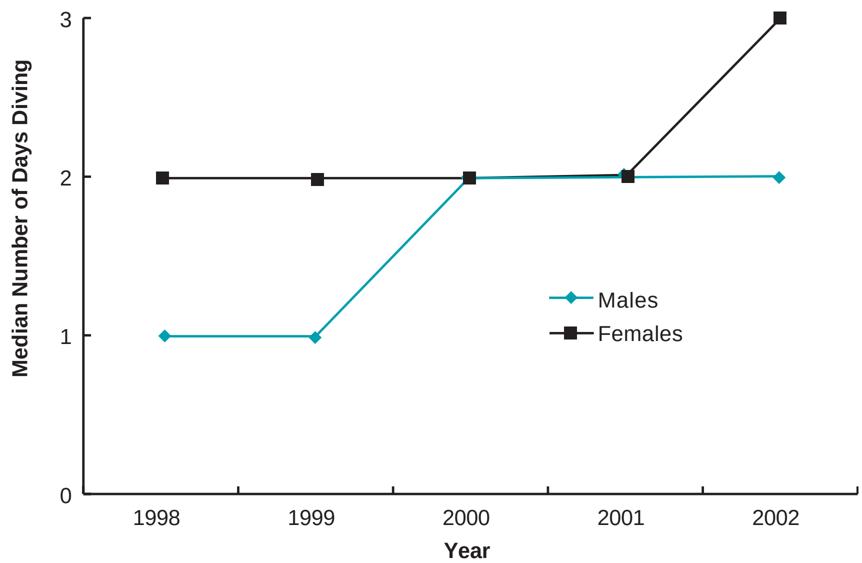


Figure 5.2-6 shows the median number of dives in the series for males and females. The number of dives by injured divers has generally increased from the 1987-2002 period. Men did one to two dives more than did women before injury. When compared with Figure 5.2-5, Figure 5.2-6 indicates that women made fewer dives over more days suggesting a lower diving intensity than for men.

Figure 5.2-6 Median number of dives for injured males and females for 1998-2002.

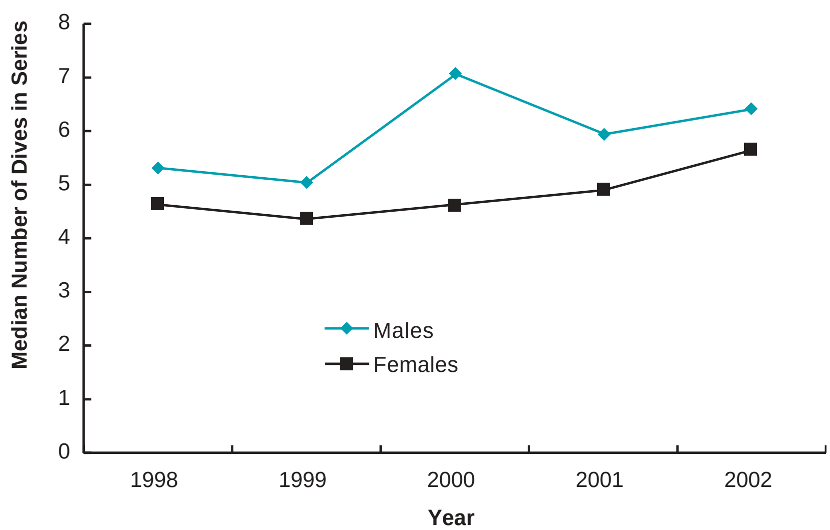


Figure 5.2-7 illustrates the mean maximum dive depth in the dive series by gender. The mean maximum depth of injured divers varied from 81-104 fsw (24.3-31.2 msw), about 10 feet (3 meters) deeper than during 1987-1997. During 1998-2002, men who were injured reported that they had dived an average of 10 fsw deeper than did injured women. This is another feature of male diving behavior that might put men at greater risk of decompression injury than women.

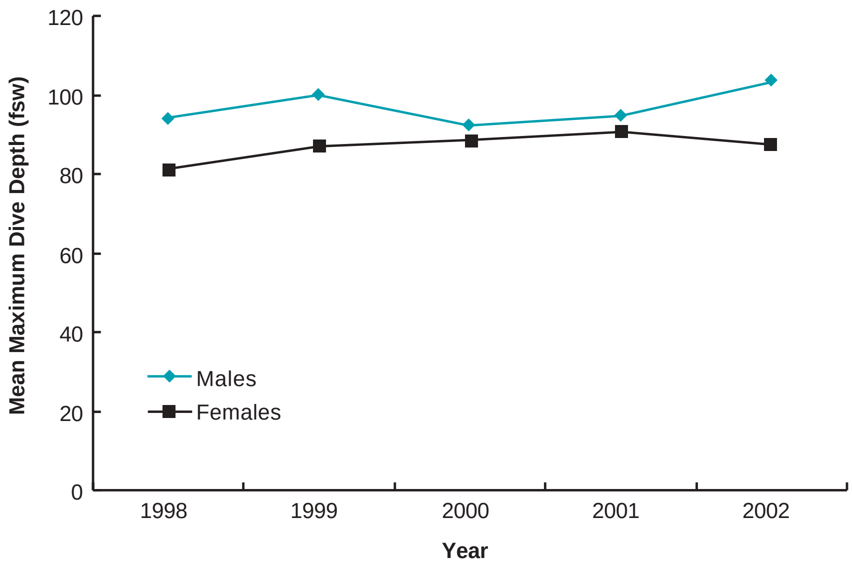


Figure 5.2-7
Mean maximum dive depth in series for injured males and females for 1998-2002.

Figure 5.2-8 shows the breathing gases used by injured divers. The proportion of divers who breathed air decreased from 88 to 83 percent during 1998-2002, while the proportion of nitrox increased from 6 to 12 percent. During the same period, the percentage of nitrox use by PDE divers increased from 7 to 24 percent (Figure 5.1-3). The percentage of injured divers using helium-based mixed gases showed no particular trend.

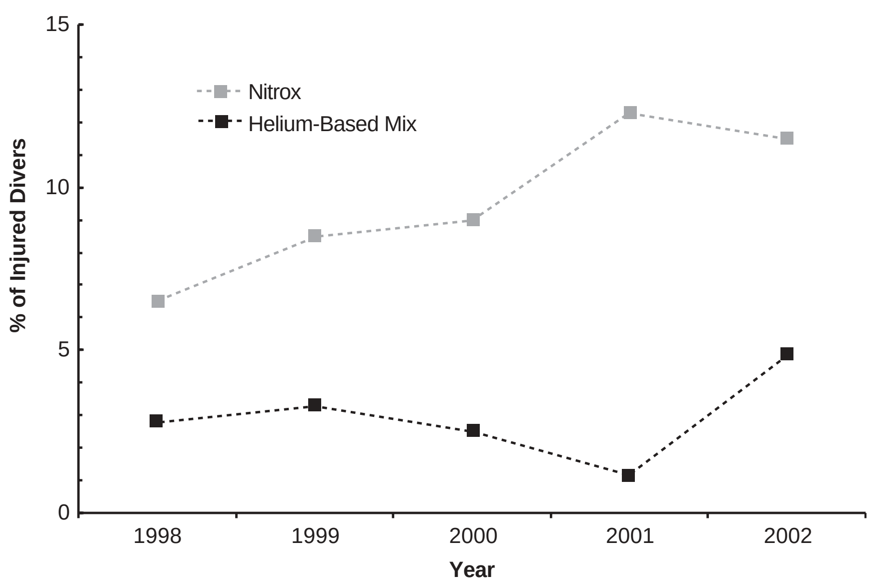


Figure 5.2-8
Breathing gas used by injured divers for 1998-2002.

Figure 5.2-9 shows the proportions of injured divers who reported running out of air or ascending rapidly. These are procedural problems often considered risk factors for decompression injury. Running out of air, one cause of rapid ascent, seemed to occur in about 5 percent of the 1998-2002 injuries, about the same as in 1987-1997. Rapid ascent continued to be reported about four times more frequently than running out of air. Rapid ascent is difficult to quantify, since one diver's understanding may differ from that of another, and dive computers are programmed to provide ascent rate warnings for a wide variety of rates. Thus, it can be difficult to retrospectively evaluate the contribution of rapid ascent to an injury. No trends were apparent during either 1987-1997 or 1998-2002. Rapid ascent and out-of-air emergencies were reported more than 10 times more often in injured divers than in PDE divers (Figure 5.1-4).

Figure 5.2-9 Problems experienced by injured divers during diving for 1998-2002.

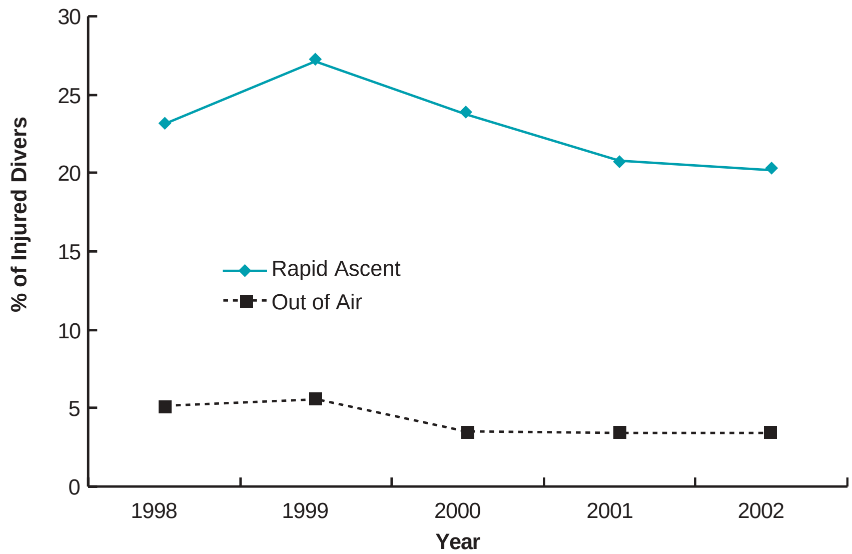


Figure 5.2-10 illustrates the percentage of injured divers who were exposed to altitude within 48 hours after diving. After diving, approximately 15 percent of all injured divers flew in pressurized or unpressurized commercial aircraft, with a slight downward trend. The downward trend may reflect the increasing proportion of injured divers treated outside the continental U.S. (Figure 5.2-1). Medical evacuation by air was reported in 4 to 6 percent of cases and flying by helicopter in 1 to 3 percent of cases.

In comparison to 1987-1997, there appeared to be a significant decrease of injured divers who flew during 1998-2002. This decrease coincides with the introduction of the Diving Injury Report Form (DIRF), which considered a case to involve flying after diving only if the surface interval before flight was shorter than 48 hours.

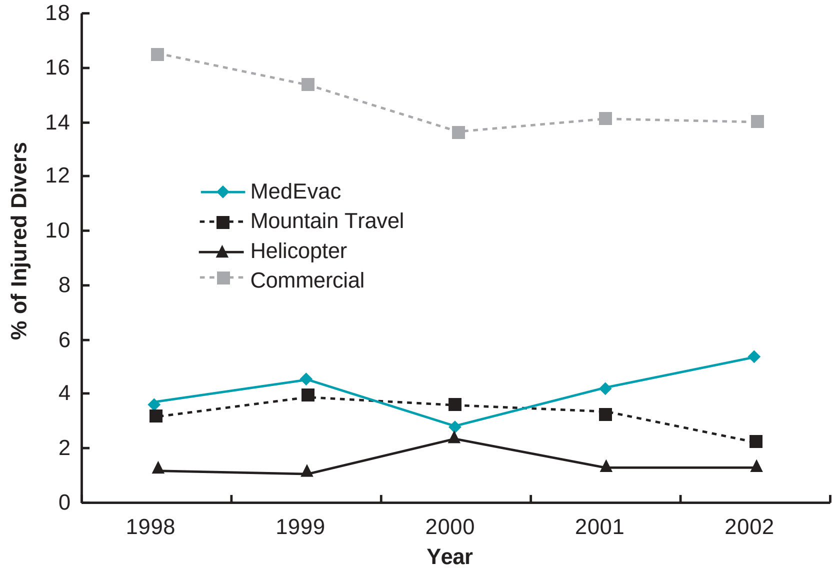


Figure 5.2-10 Injured divers who were exposed to altitude after diving for 1998-2002.

Figure 5.2-11 shows the relative occurrence of pain and paresthesia (numbness and tingling), the most common symptoms reported by injured divers. Pain and paresthesia occurred in about 60 percent of injured divers, similar to the corresponding figures in the 2002 Report. The lower percentage of paresthesia in 1998 may be associated with the transition to the Diving Injury Report Form (DIRF) from the Diving Accident Report Form (DARF) in which paresthesias were not specifically defined.

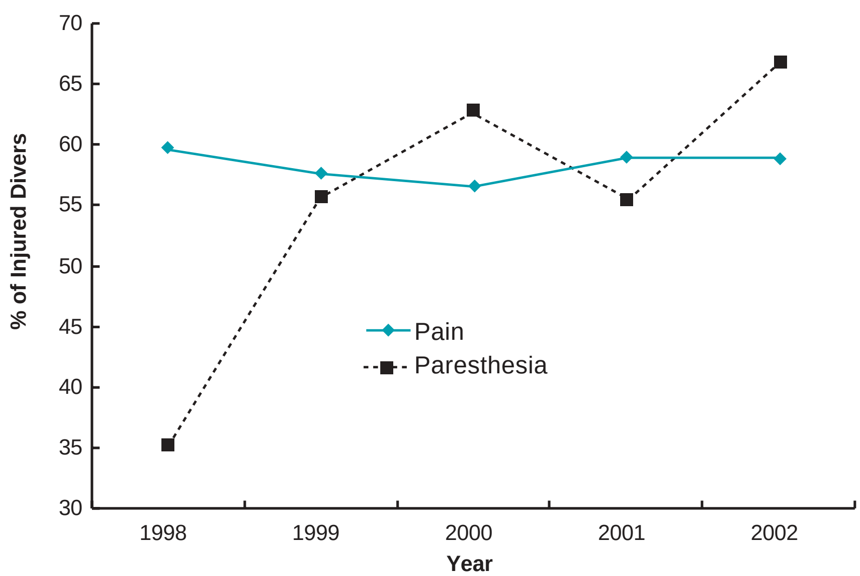
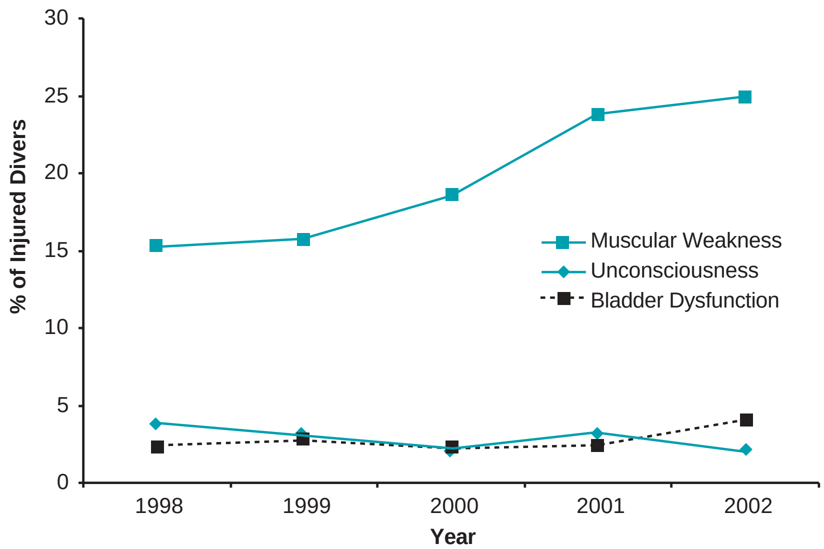


Figure 5.2-11 Percentage of reports of pain or numbness from diving injury cases during 1998-2002.

Figure 5.2-12 shows the relative occurrences of muscular weakness, unconsciousness and bladder dysfunction, some of the most severe symptoms experienced by injured divers. The fraction of injured divers who reported unconsciousness has been 2 to 3 percent for the past five years, continuing on gradual decline noted in the 2000 Report for 1987-1997. Bladder dysfunction occurred in 2 to 4 percent of injuries, similar to the previous decade except for 1996-97, when bladder problems were manifesting at less than half a percent. Muscular weakness increased from 15 to 25 percent during 1998-2002 and may reflect improved reporting since muscular weakness was not specifically addressed in the 1987-1997 data.

Figure 5.2-12 Percentage of dive injury cases involving unconsciousness, muscular weakness or bladder dysfunction during 1998-2002.



Diagnostic classifications were assigned to diving injuries for 1998-2002 after reviewing each case as described in Section 3. The proportion of AGE was 5 to 7 percent, similar to that described in the 2000 Report. DCS II remained relatively constant at 60 to 65 percent, also similar to the 2000 Report. DCS I appeared to decrease from 27 to 17 percent over 2000-2002, but this may reflect the more consistent classification of cases in the last two years.

Figure 5.2-13 indicates that 30 to 48 percent of injured divers received surface oxygen as first aid during 1998-2002, with the greatest frequency in 2001-2002. This was lower than the 50 to 56 percent in the 2002 Report for 1987-1997, which did not distinguish oxygen provided as first aid at the dive site from oxygen given at a medical facility.

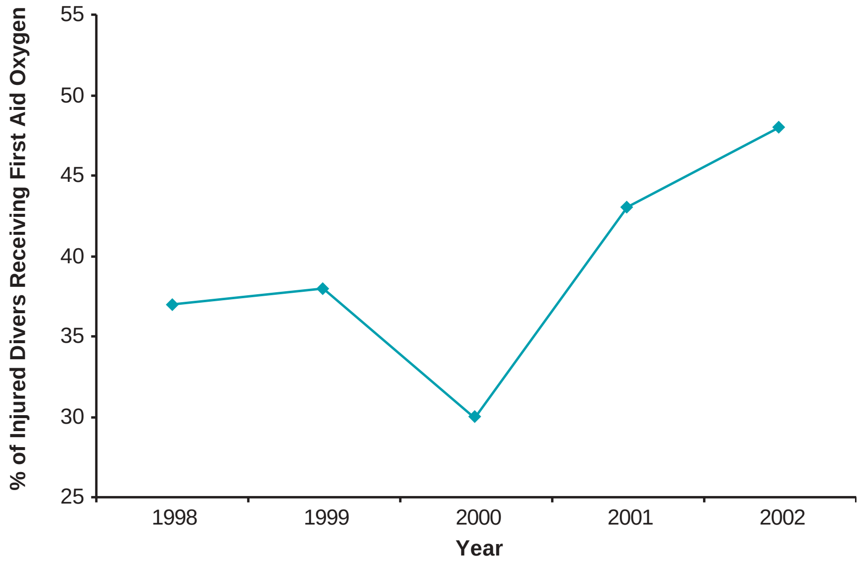


Figure 5.2-13
Use of surface oxygen as first aid for injured divers for 1998-2002.

Figure 5.2-14 shows that the median delay to recompression after symptom onset remained relatively constant at about one day during 1998-2002. This is similar to 1987-1997. The mean delay varied more widely, indicating that some divers had extremely long delays to recompression.

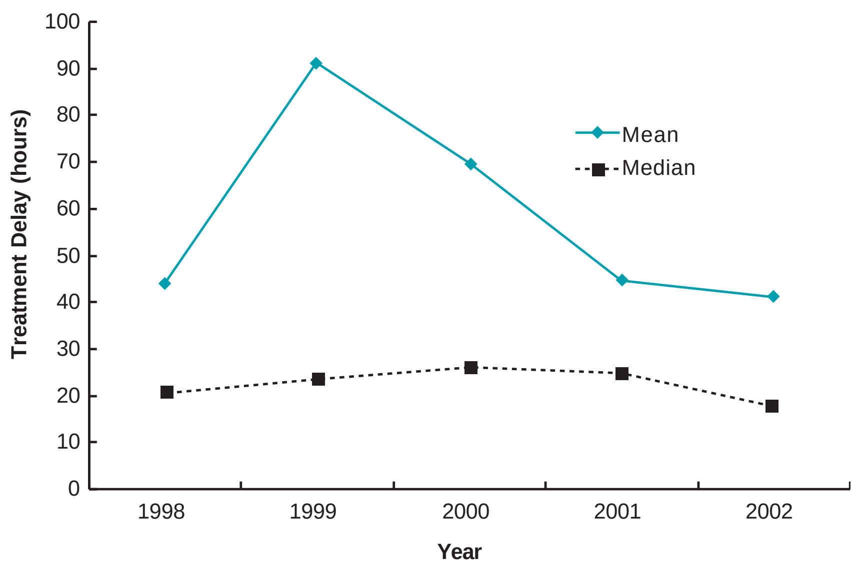


Figure 5.2-14
Delay to recompression after symptom onset for 1998-2002.

Figure 5.2-15 shows the recompression therapy table used for the first treatment. The U.S. Navy Treatment Table 6 was chosen for about three-fourths of recent injuries, similar to the 11 years of data described in the 2000 Report. The second most frequently used treatment protocol was the Hart-Kindwall table at 10 to 25 percent. U.S. Navy Table 5 was used for 5 to 10 percent of the first treatments. The use of Table 6A decreased from 4.8 percent during 1998-2000 to 2.3 percent in 2001-2002.

Figure 5.2-15 Recompression tables used for first treatment for 1998-2002.

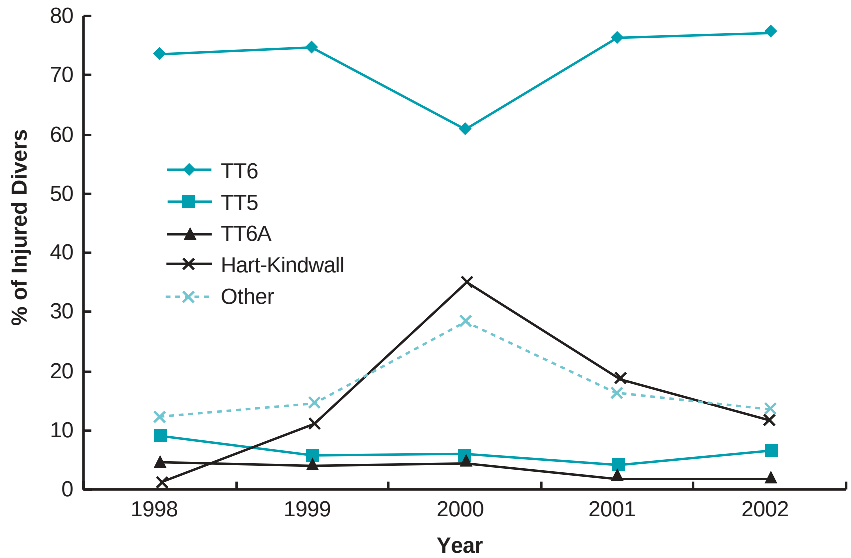
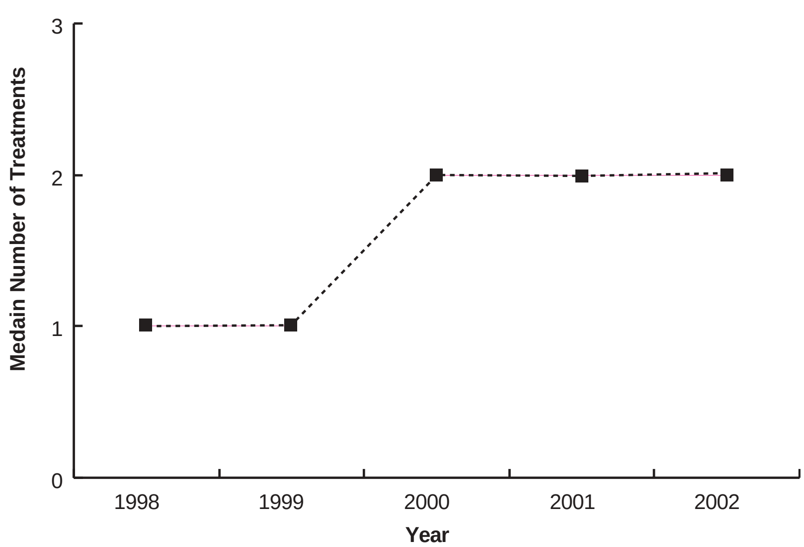


Figure 5.2-16 indicates that the median number of recompression treatments given to injured divers increased from one to two during 1998-2002. The mean number of treatments increased from two to three, indicating that a small group of injured divers was recompressed many times, even though the number of divers that received more than three treatments was decreasing. Overall, the median and means for 1998-2002 are similar to those for 1987-1997 in the 2000 Report.

Figure 5.2-16 Number of recompression treatments of injured divers for 1998-2002.



During 1998-2002, 56 to 70 percent of injured divers achieved complete relief at discharge after all recompression therapy. The level of complete relief appears to have reached a plateau at 70 percent during 2000 after a gradual increase from 50 percent beginning in 1989, as indicated in the 2000 Report. This suggests that the efficacy of recompression therapy may have improved during 1989-2002.

5.3 Dive Fatalities

Figure 1.3-1 (page 23) showed the number of fatalities reported from 1970-2002. The annual fatalities have fluctuated from a high of 147 in 1976 to a low of 66 in 1988. During the past seven years, there have been 80-90 fatalities per year.

The percentage of females among dive fatalities remained relatively stable during 1998-2002 at 15 to 20 percent, similar to the 1989-1997 period. In contrast, 25 to 30 percent of PDE or injured divers were female.

Figure 5.3-1 shows that the mean age increased by six years, from 42 to 48 years old, during the five-year period from 1998-2002. A similar trend was noted for the nine-year period of 1989-1997 in the 2000 Report, where the mean age increased by three years, from age 39 to 42. A similar trend was noted for divers with non-fatal injuries, where the mean age increased from 33 to 39 years old during the period 1987-2002. These observations suggest that the recreational diving population may be aging.

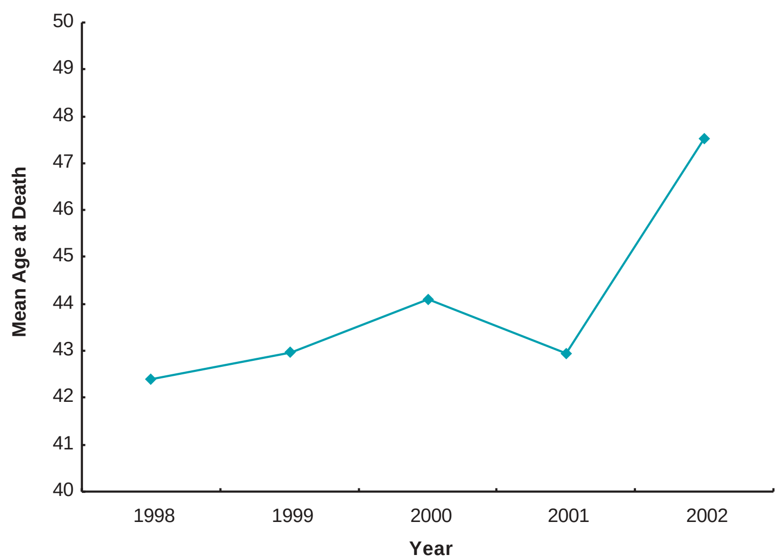


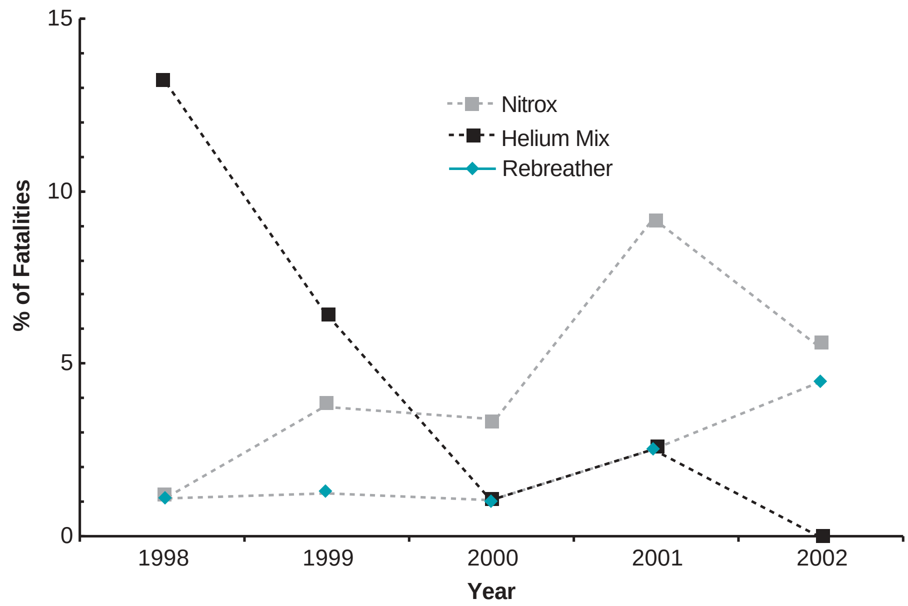
Figure 5.3-1 Mean diver age at time of death during 1998-2002.

The most common certification levels among divers who died were open-water (27 to 35 percent) and advanced (17 to 28 percent). In the 1980s, 30 to 40 percent of dive fatalities were non-certified. This decreased to about 5 percent in the 1990s, a proportion maintained to the present. Fatalities involving divers with technical certification fluctuated from 5 to 15 percent during 1989-2002, a greater fraction than the 0 to 5 percent among dive injuries (Figure 5.2-3). Fatalities were 5 to 8 percent among students and 3 to 6 percent among instructors.

The percentage of divers who were without a dive buddy when they died during 1998-2002 varied from 9 to 23 percent, and no trends were apparent. This was similar to the 1987-1997 pattern.

Air was the breathing gas used by 85 percent of divers who died during 1998-2002. Figure 5.3-2 indicates that the proportion of heliox or trimix fatalities declined, while the number of nitrox fatalities increased.

Figure 5.3-2 Breathing mix used by dive fatalities during 1998-2002.



Equipment problems were found during formal investigation in 15 to 30 percent of fatality cases during 1998-2002. This does not necessarily mean that a specific problem caused death, but a chain of events may have culminated in a serious outcome. (For example, initial hyperventilation due to physical or emotional stress may cause regulator insufficiency or malfunction, leading to rapid ascent and followed by air embolism.) The problems most often reported for the entire five-year period of 1998-2002 are shown in Figure 5.3-3. Problems with the buoyancy control device (BCD) were reported most often at 7.5%. Regulator malfunction (which may cause insufficient air) was reported in 6 percent of cases (up from 5 percent in 1987-1997). Weight belt problems were reported in 5 percent of fatalities in the past five years (up from 3 percent in 1987-1997).

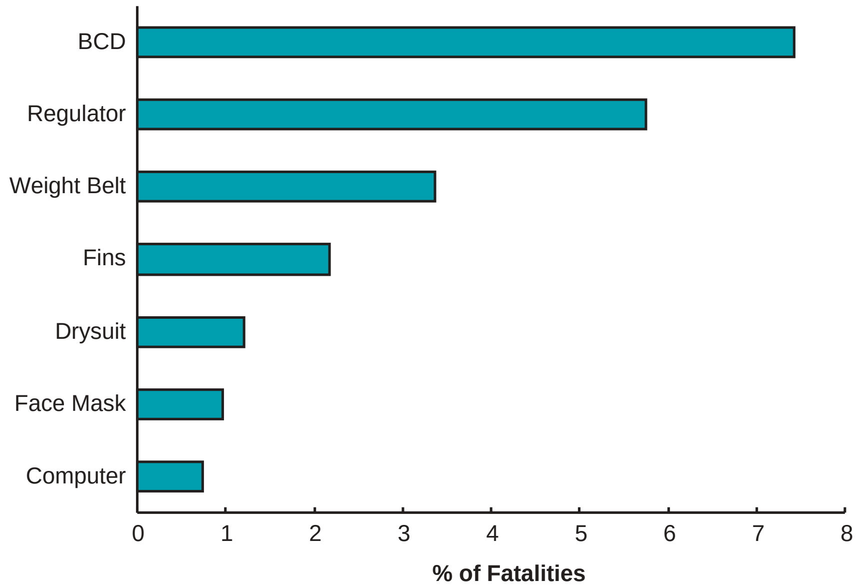


Figure 5.3-3 Selected equipment problems associated with dive fatalities for 1998-2002.

There were no apparent trends in the percentage of dive fatalities in which buoyancy control, out-of-air or rapid ascent problems were reported. At 40 to 50 percent, buoyancy problems were common in 1998-2002, up from 10 to 30 percent in 1989-1997. The proportion of out-of-air emergencies fluctuated as it had in 1989-1997, for the most part, between 20 to 30 percent. Rapid ascent also showed no particular trend and varied from 10 to 20 percent, as in 1989-1997.

Drowning often was the terminal event, but the proximate cause was unknown.

Figure 5.3-4 indicates that drowning, at 47 to 62 percent, was the most frequently cited cause of death. Drowning often was the terminal event, but the proximate cause, which is of greatest importance to diving safety, was unknown. As in the past, cardiovascular disease could be readily identified through post-mortem examination and increased steadily from 20 to 30 percent during 1998-2002, except for 2001. This was double the proportion of cardiovascular cases (8 to 14 percent) noted during 1989-1997. Arterial gas embolism was reported in 11 to 16 percent of cases, generally greater than the 8 to 10 percent during 1989-1997. No fatalities from decompression sickness were reported during 1998-2002.

The steady increase in cardiovascular deaths and in the average age of divers who die (Figure 5.3-1) may reflect accidental death due to age-related diseases. This suggests the importance of medical examinations for older divers.

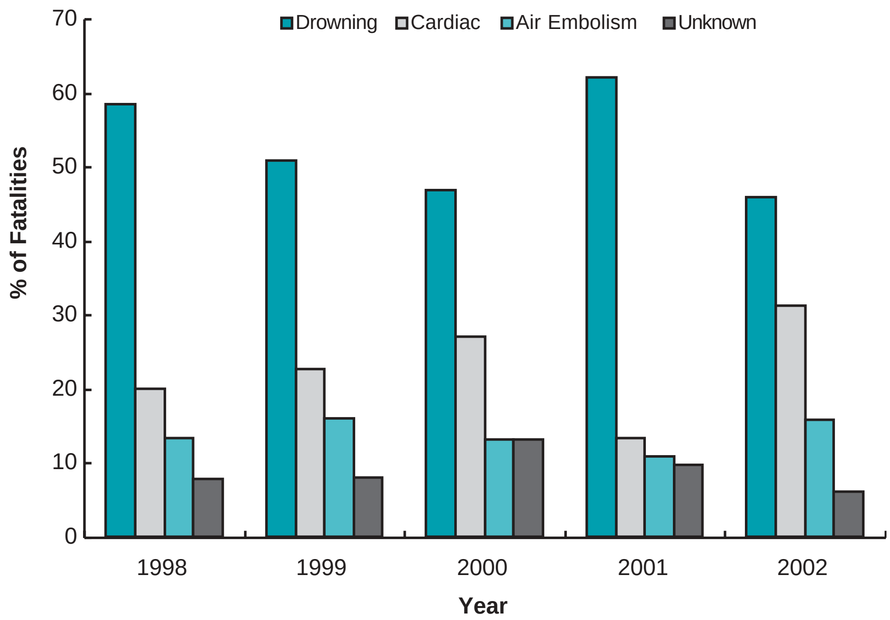


Figure 5.3-4
Causes of death in dive fatalities for 1998-2002.

6. Comparisons of PDE, Injury and Fatality Populations for 2002

The purpose of comparisons between PDE, injury and fatality population samples is to identify characteristics that may differ among the groups. These comparisons suggested that some factors were relatively more common in diving injury and fatality groups than for PDE divers. The factors identified will be tested for statistical significance in case-control studies.

6.1 Diver Characteristics

The average ages of the three populations are shown in Figure 6.1-1. Divers who died were oldest, as in previous years, while PDE divers and injured divers were close in age. On average, divers in 2002 were two to three years older than in 2001.

Figure 6.1-1 Comparison of mean age by population for 2002.

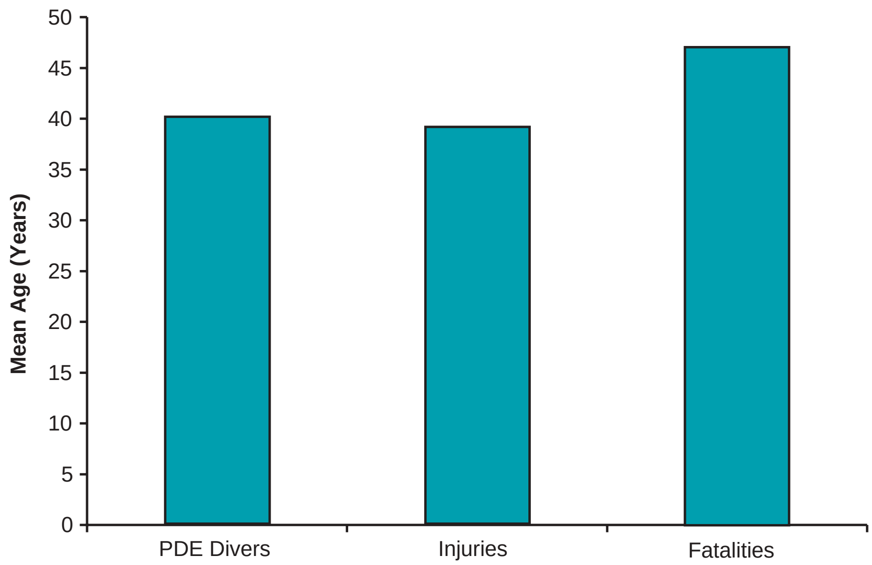


Figure 6.1-2 shows the proportion of males and females in each population for 2002. The distribution of genders among the populations was similar to that in 2001. Injuries and PDE had similar proportions of females (28 and 29 percent, respectively), while the proportion of females among fatalities was only 13 percent.

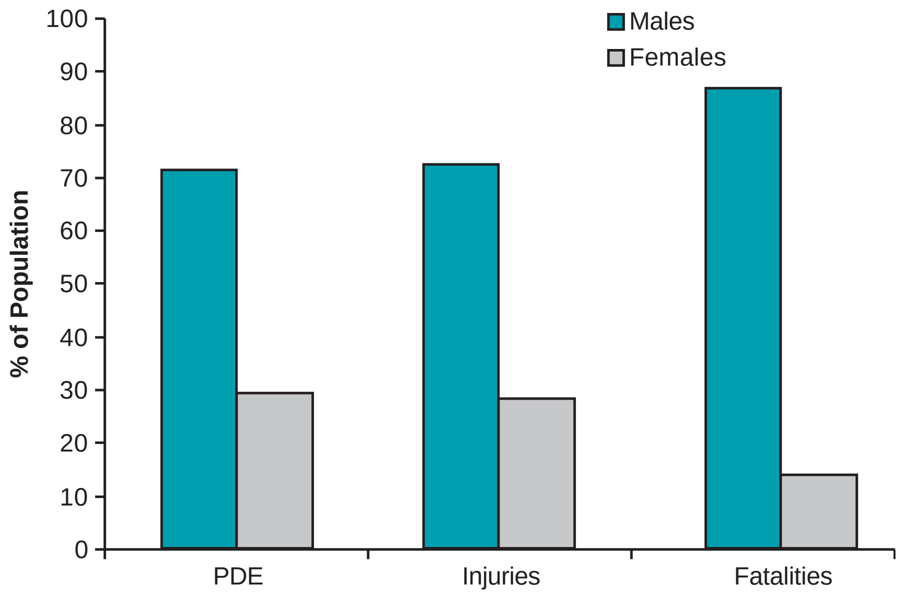


Figure 6.1-2 Comparison of gender distribution by population for 2002.

Figure 6.1-3 shows the certification level in the three populations for 2002. The differences among the populations vary from year to year. Additionally, there does not seem to be a consistent pattern, suggesting that factors other than certification may be the determinants of dive injuries or fatalities.

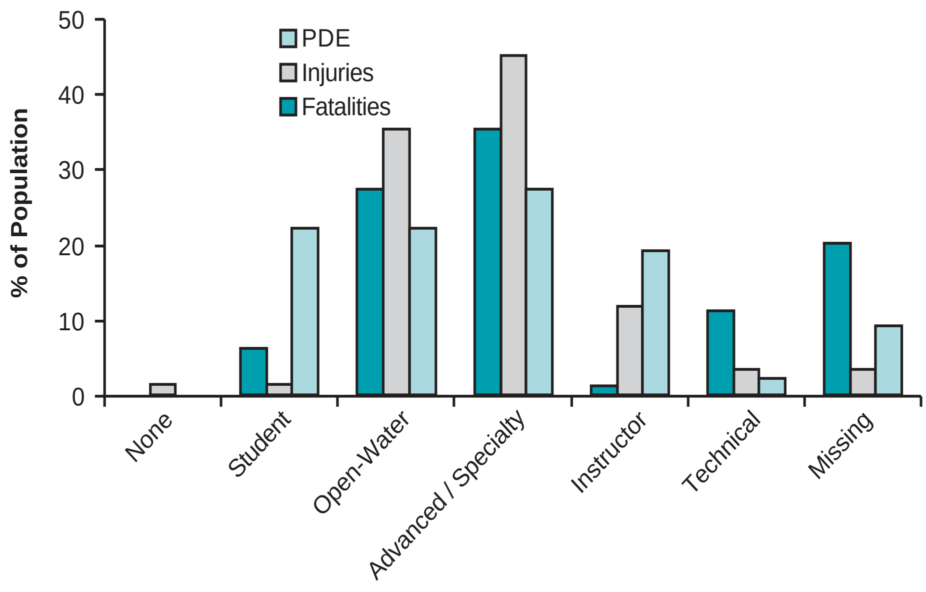
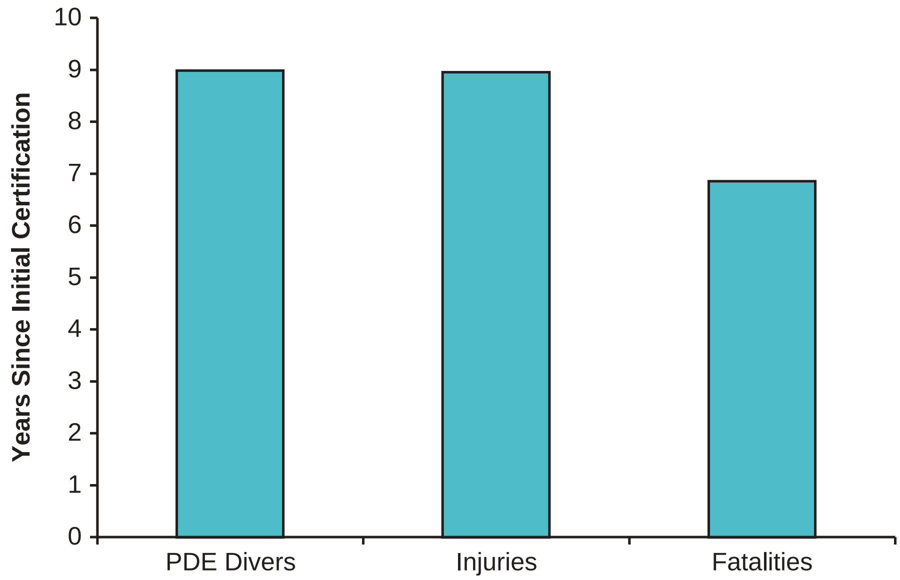


Figure 6.1-3 Comparison of certification by population for 2002.

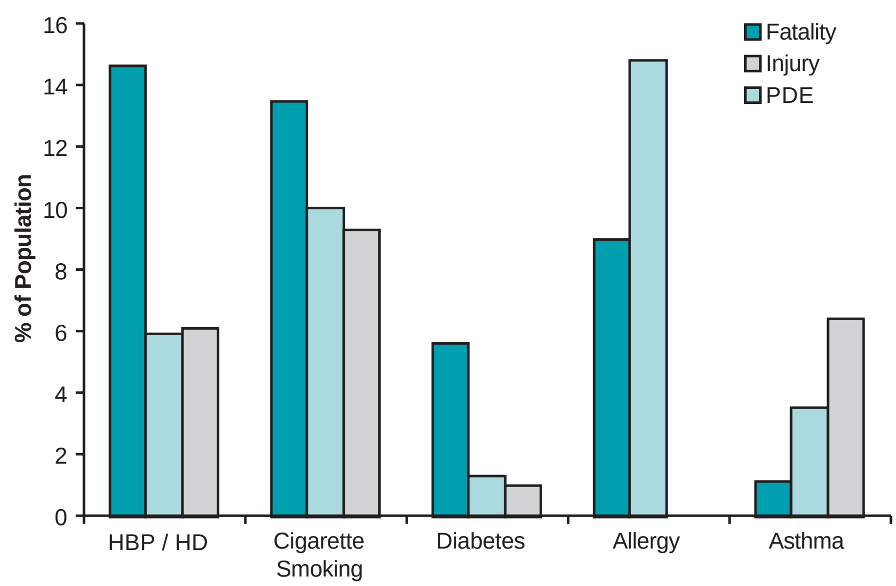
Figure 6.1-4 shows the average number of years since initial certification. Fatalities had fewer years since initial certification than injuries or PDE divers, as in the past.

Figure 6.1-4 Comparison of years since initial certification by population for 2002.



The pattern of major health issues depicted in Figure 6.1-5 is similar to that described in the 2003 Report. Heart disease / high blood pressure and cigarette smoking were highest among fatalities, while asthma was highest among injured divers.

Figure 6.1-5 Comparison of health problems by population for 2002.



Body mass index (BMI) is a height-to-weight comparison commonly used as a simple measure of body build.

Figure 6.1-6 depicts the average BMI for the three groups of divers (BMI was discussed on page 79). Obesity was proportionally more frequent among dive fatalities than in PDE or injured divers.

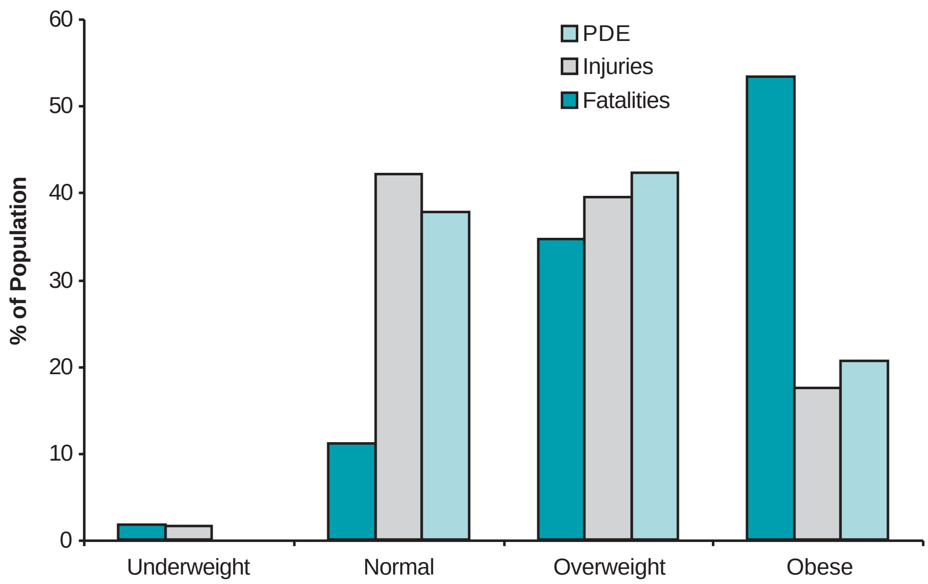


Figure 6.1-6 Comparison of health problems by population for 2002.

6.2 Dive Characteristics

Diving was most common for all populations in salt water, involving 78, 89 and 95 percent of fatalities, injuries and PDE divers, respectively. Figure 6.2-1 indicates that fatalities were over-represented in fresh water, particularly compared with PDE divers.

Figure 6.2-1 Comparison of freshwater dive environment by population for 2002.

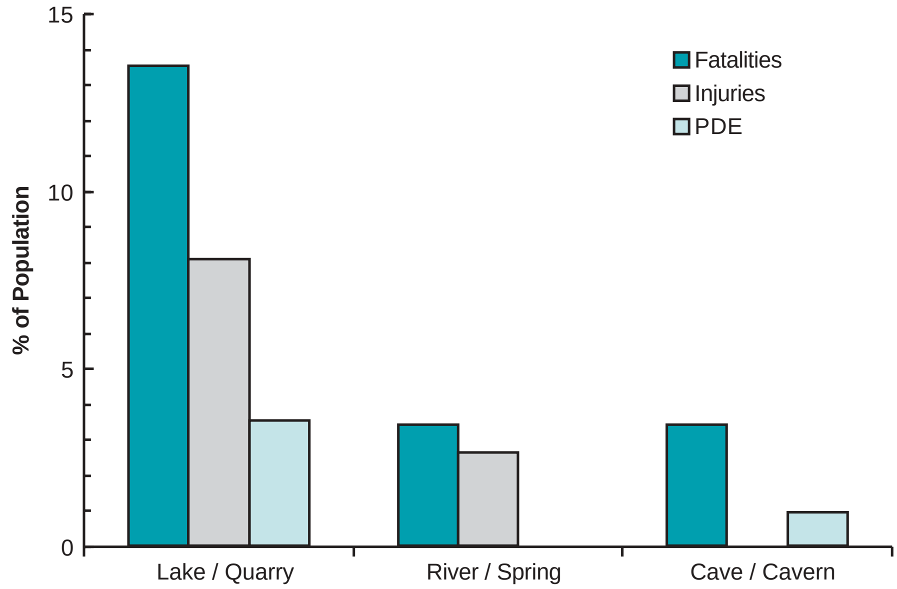
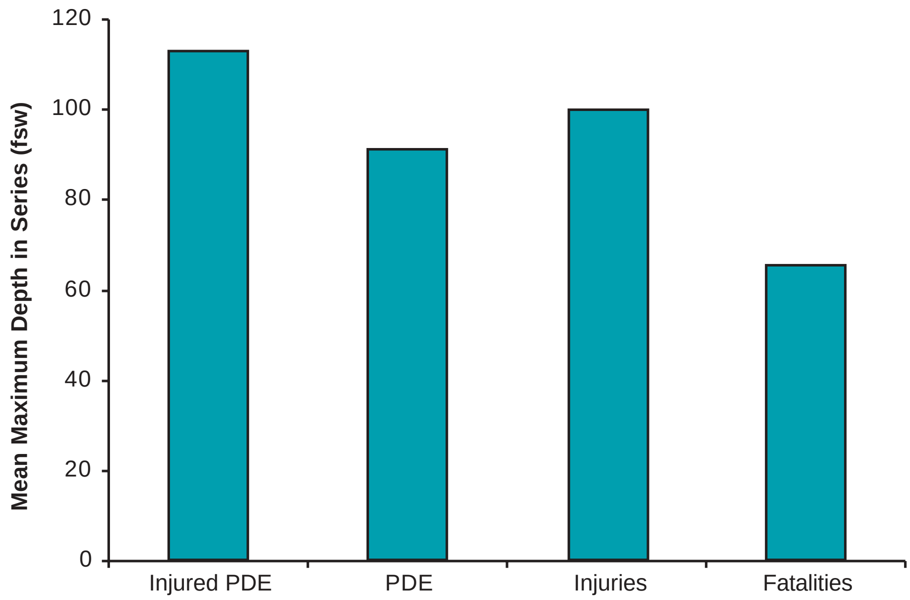


Figure 6.2-2 compares the populations for the mean maximum depth in the dive series. Fatal dives tended to be reported at shallower depths than injuries or PDE dives. Injured PDE divers had the deepest maximum depths, followed by other injured divers.

Figure 6.2-2 Comparison of mean maximum depth in series by population for 2002.



Figures 6.2-3 and 6.2-4 compare the PDE and injury populations over the mean number of dives per series and mean number of dives per day. (This information was not available for fatalities.) There were fewer dives per series among injured divers than among PDE divers, and injured PDE divers reported even fewer dives than did the injury population. PDE divers and injured divers made an average of about two dives per day (Figure 6.2-4), while injured PDE divers made only 1.5 dives per day. This suggests the hypothesis that multiday repetitive diving may not be inherently risky by itself and that decompression risk may be largely determined by the individual dives. This hypothesis will be tested in case-control studies.

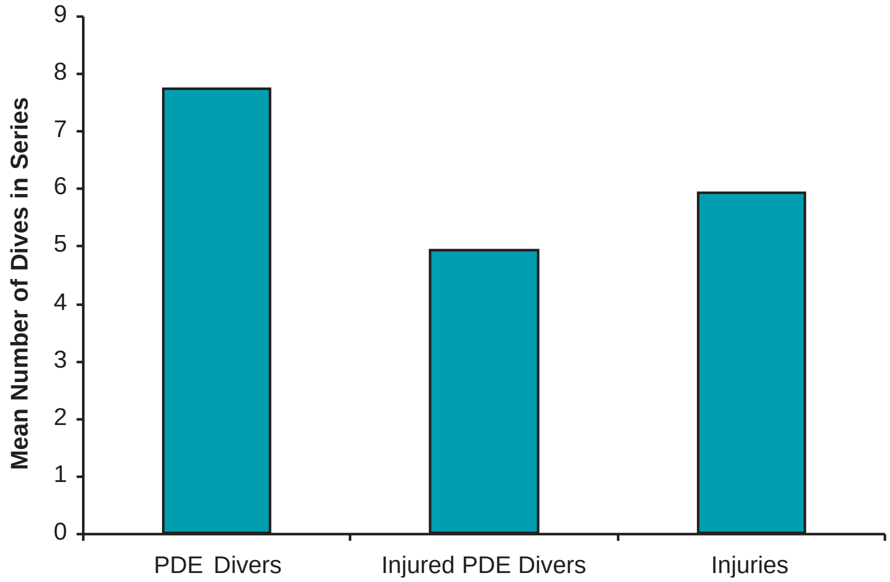


Figure 6.2-3 Comparison of total number of dives in series by population for 2002.

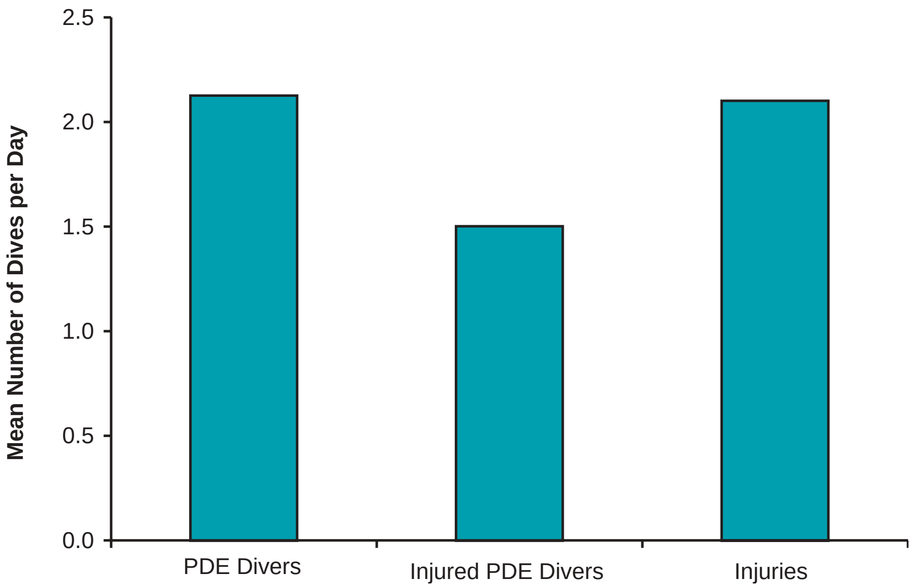
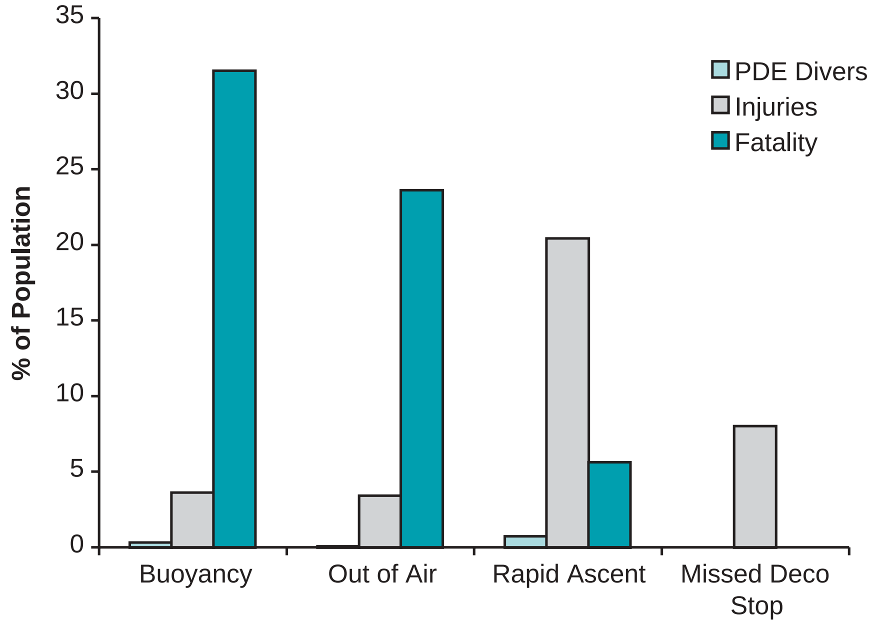


Figure 6.2-4 Comparison of number of dives per day by population for 2002.

Figure 6.2-5 shows large differences between populations with regard to buoyancy, rapid ascent, running out of breathing gas and missed decompression. Buoyancy and out-of-air emergencies were most common for dive fatalities, while rapid ascent was most common for dive injuries.

Figure 6.2-5 Comparison of diving problems by population for 2002.



7. Mixed-Gas Diving

Figure 7-1 shows the use of air, nitrox and either trimix or heliox within our samples of fatalities, injured divers and PDE. At over 70 percent for all populations, air was the most common breathing gas. Nitrox and trimix were used more often in 2002 than in 2001. The use of nitrox in PDE divers has increased from 10 percent in 2001 to 24 percent in 2002. Proportionately, nitrox was used more often by PDE divers than by injured divers or divers who died. Trimix or heliox was used relatively infrequently by PDE divers, but the number of injured divers using trimix increased from 1 percent in 2001 to 4 percent in 2002. Use of heliox or trimix among divers who died was not reported. Four of the fatalities (4.5 percent) were using rebreathers, but the gas mix was not reported.

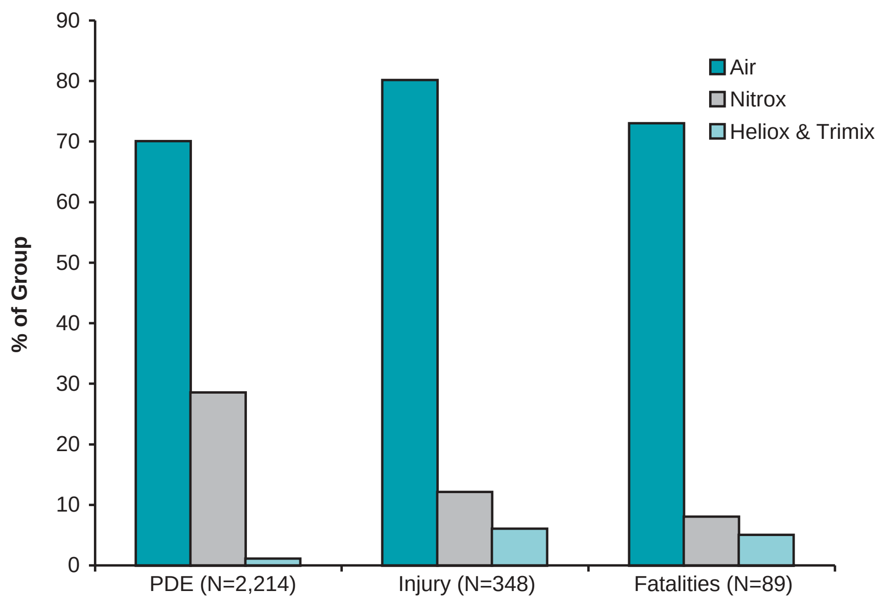
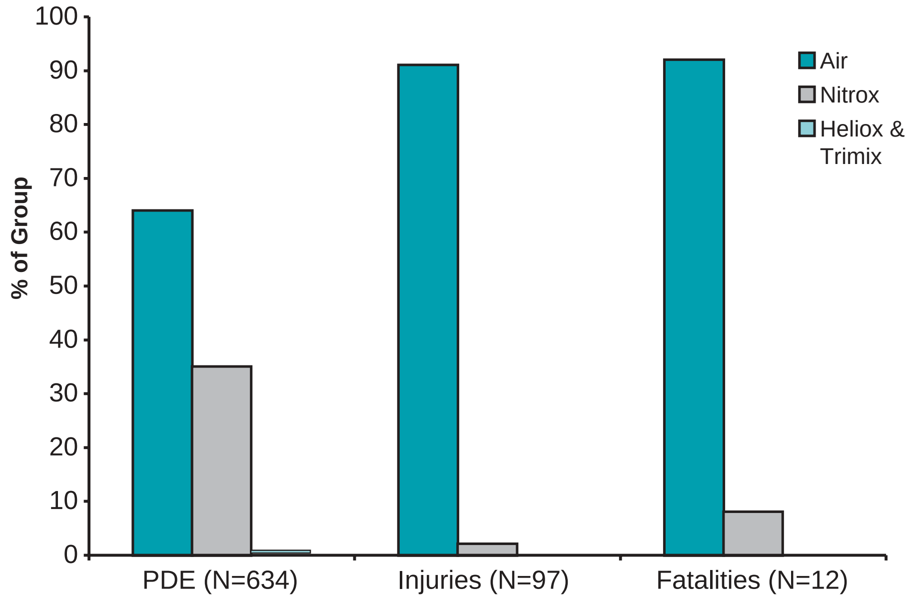


Figure 7-1 Proportions of air, nitrox and heliox or trimix divers among fatalities, injuries, and PDE divers for 2002.

Figure 7-2 indicates that, proportionately, more female PDE divers breathed nitrox than did any other group. Thirty-five percent of PDE women, 12 percent of injured women and 8 percent of women who died breathed nitrox. Only 16 women of 167 PDE divers breathed trimix or heliox, and there were no fatalities or injuries among women on trimix or heliox.

Figure 7-2 Breathing gas used by female divers for 2002.



The mean ages of the populations and breathing gas groups ranged from 36 to 45 years, with no obvious pattern.

Figure 7-3 shows the mean years since initial diver certification. Divers who died while breathing air or nitrox had the fewest years since initial training among the three populations. In contrast, divers who died using heliox or trimix were more experienced than any other group.

Figure 7-3 Mean years since certification for 2002.

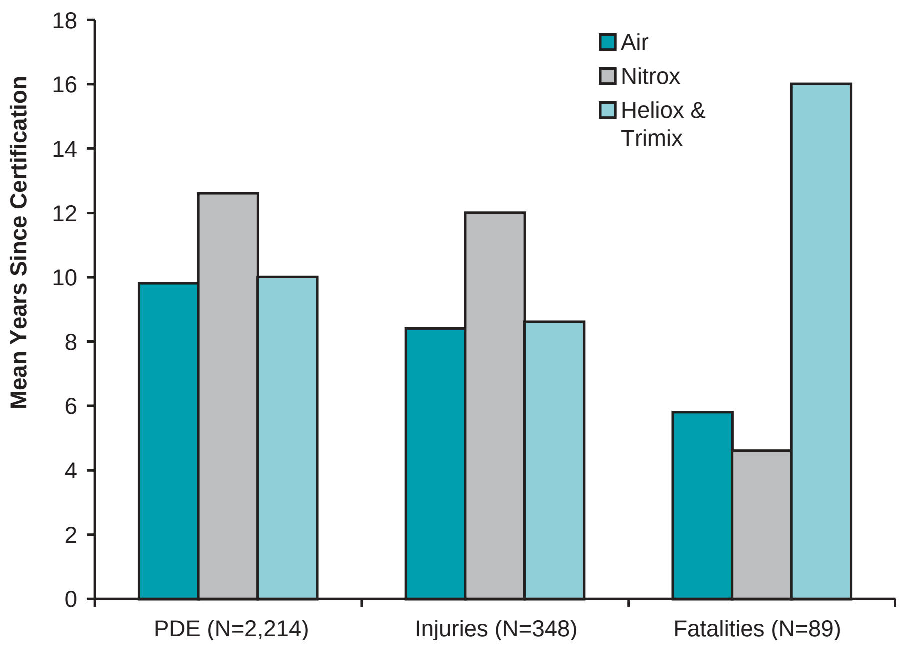


Figure 7-4 shows that injured divers had the deepest maximum depths in their dive series regardless of what breathing gas they had used, and diving fatalities had the shallowest maximum depths. These trends were also observed for the previous two years.

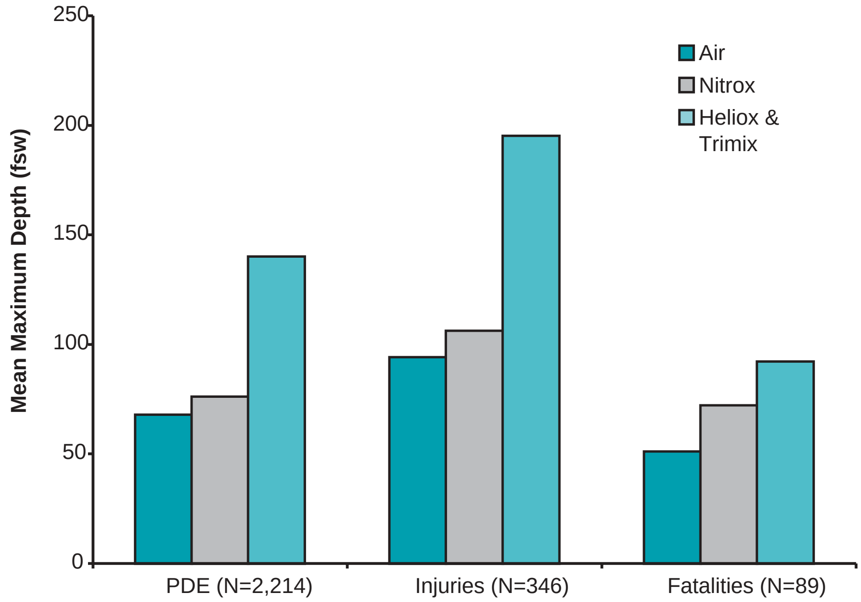


Figure 7-4 Mean maximum dive depth in the dive series for 2002.

Figure 7-5 shows the maximum oxygen partial pressure for injured divers and PDE divers who breathed nitrox. These partial pressures were determined by multiplying the oxygen fraction in the breathing mix by the maximum absolute pressure reported for the dive. Less than 15 percent of PDE dives exceeded a maximum oxygen partial pressure of 1.3 ata, while about nine percent of dives by injured divers exceeded 1.6 ata. No oxygen toxicity events were reported in these population samples.

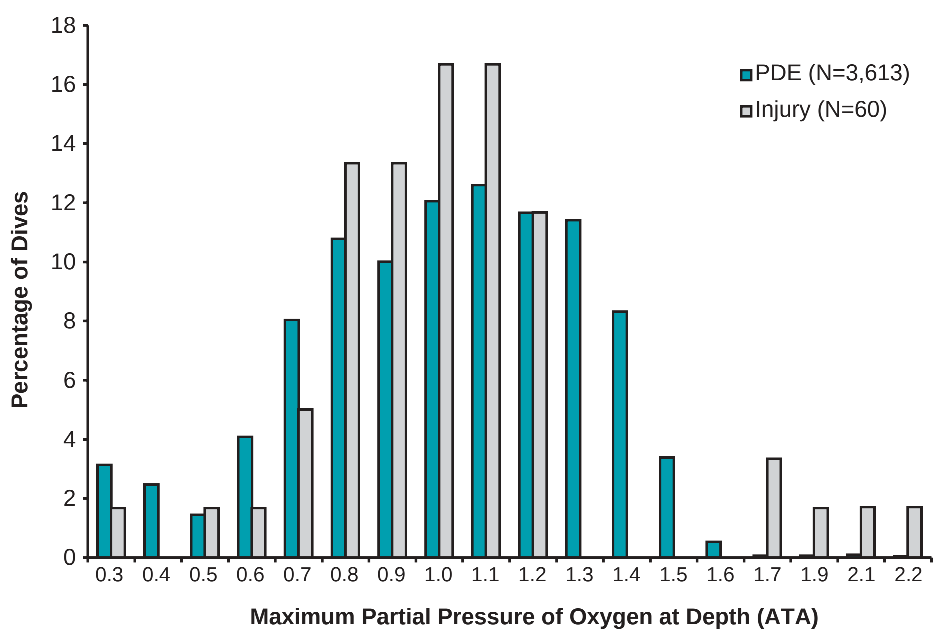


Figure 7-5 Maximum oxygen partial pressure during nitrox diving for injured divers and PDE divers for 2002.

The use of nitrox has become more common over the past several years in all our samples of recreational divers; trimix and heliox have become more common among injured divers and divers who died. The relative lack of trimix dives in PDE reflects the poor representation of technical divers. Dive profile data collection is more difficult in technical diving, where changes in breathing mix may occur several times during a dive. As this is a growing area of diving activity, DAN will work with the dive computer manufacturers and technical diving community to help develop a new generation of dive computers and to establish trimix / heliox data collection centers.

DAN has collected sufficient data to begin the analysis of absolute DCS risk in PDE and the relative risk of DCI using injury and PDE data. This analysis will start in the coming year.

Appendix A: Dive Injury Case Reports

Introduction

DAN maintains a list of 280 hyperbaric treatment centers around the world. When surveyed in 2003, 113 of these chambers treated divers and reported treating a total of 1,063 U.S. and Canadian divers in 2002. There were 517 case reports of decompression illness (DCI) submitted to DAN, from which 348 contained sufficient information to be included in the annual Report on Decompression Illness, Diving Fatalities and Project Dive Exploration.

When a diver calls DAN for assistance, he or she is referred to a physician for an evaluation. The goal of these medical examinations is to determine a diagnosis and provide appropriate treatment. Many cases of DCI demonstrate a similar presentation of symptoms after scuba diving. Most common are mild joint and muscle pain or paresthesia (numbing, tingling, burning) of the extremities and skin. Such symptoms can easily be attributed to DCI. Yet on occasion, some DCI symptoms can mimic other illnesses or diseases and make diagnosis difficult.

The following cases in this appendix are examples of some of the diagnostic problems medical practitioners face when evaluating divers. It is not possible to know if all cases were actually DCI, but in each case the diver was treated with an appropriate recompression table for DCI. All cases were selected based on the presentation or type of symptoms and the potential for there being alternative diagnoses.

Case 1 – Serious Neurological DCI With Symptoms Starting Prior to Exiting the Water

The diver was a 38-year-old male in good health, although he smoked a pack of cigarettes per day for 19 years and had a history of asthma. He had been certified for 12 years and reported making approximately 150 dives per year. He used nitrox for his breathing mix while scuba diving in the series of dives under discussion.

In two days he made a total of nine ocean dives, six of which occurred on the first day. These dives went to a depth of between 60 and 85 fsw (feet of sea water) / 18 and 25.5 msw (meters of sea water). He had no symptoms after his first day of diving. On the second day of diving, using 32 percent nitrox, he performed three multilevel dives. The first went to 55 fsw (16.5 msw); next was to 70 fsw (21 msw); the final dive was to 73 fsw (21.9 msw). These were all equivalent air depths, with bottom times between 33 and 43 minutes.

As the diver made his ascent on the last dive, his computer indicated a rapid ascent rate. During the safety stop at 10 feet / 3 meters, he began to experience weakness in his lower extremities, with diffuse tingling and some dizziness. Upon surfacing, he vomited immediately and had to be assisted into the dive boat, as he could not balance himself or walk. He was immediately given oxygen, and his lower extremity weakness began decreasing as the boat headed into shore.

His dizziness progressed to vertigo, however, and the nausea and vomiting continued. He also developed a red, marbled abdominal rash during the next 30 minutes. The onset of this rash was accompanied by abdominal pain and an increased sensitivity to touch. A Coast Guard helicopter evacuated him to a local hyperbaric facility for evaluation and treatment. He was not kept on oxygen during his transport by helicopter.

On examination at the facility, he had normal motor strength and sensation. His dizziness, vertigo and nausea continued, whether he was resting or moving. Evaluation of his ears did not reveal barotrauma to his tympanic membranes.

He was diagnosed with neurological DCI with inner ear involvement and skin bends. He underwent a U.S. Navy Treatment Table 6 with two extensions (i.e. additional time and oxygen). This did not completely resolve the vertigo or nausea and vomiting, but the diver could move on his own without assistance.

The dramatic and immediate onset of symptoms in this diver alerted his companions to the possibility of a serious situation. Once secure onboard the vessel, oxygen seemed to resolve the majority of his lower-extremity symptoms.

It is interesting to note that the diver reported to the treating physician two previous incidents of DCI. Both incidents occurred six weeks prior to his current problem, were less severe than this case, and both resolved spontaneously without treatment. It is difficult in this case to determine if his DCI was the result of increased diving depths, rapid ascent, an arterial gas embolism or a combination of factors, and to what, if any, extent his previous symptomatic incidents played a role. The treatment was appropriate and effective, leaving an improved diver at the end of therapy.

Case 2 – Neurological DCI in a Drysuit Diver

The diver was a 45-year-old female in good general health. She had experienced an episode of DCI three years prior to her current event. At that time, she had been certified for 10 years but was just starting to dive again. She had made more than 200 dives in her lifetime.

She performed a total of seven ocean dives over three days, using a drysuit and breathing nitrox. She exhibited no symptoms on the first two days. On her last day of diving she made two multilevel dives, the first of which was to 85 fsw (25.5 msw), followed by a 65-fsw (19.5-msw) dive. The last dive required a decompression stop that she performed according to her dive computer.

Approximately one hour after the last dive, she developed swelling in the index fingers of both hands, followed by numbness in her hands extending to her wrists. While she drove home, passing over a 4,100-foot (1,230-meter) elevation, her symptoms worsened. Since she had experienced similar symptoms with her first episode of DCI, she diagnosed herself and breathed low-flow oxygen by mask that evening for approximately 35 minutes, producing some relief of the numbness and tingling in her right hand and clearing her symptoms.

However, the following morning her symptoms returned, and she reported to a hyperbaric facility, where she was evaluated and diagnosed with neurological DCI. She received a modified monoplace U.S. Navy Treatment Table 6, after which the numbness and tingling were reduced to about half of the original intensity, and the swelling in her hands resolved almost completely. She was treated twice more with this same protocol and discharged with virtually no residual symptoms.

In drysuit divers, paresthesias can be difficult to assess. Tight wrist seals can produce symptoms similar to DCI by compressing the wrist and limiting blood flow. However, in this case, the diagnosis of DCI is supported by worsening during altitude exposure and improvement during oxygen breathing.

Case 3 – Mild Neurological Decompression Illness

The diver was a 32-year-old male in reasonable health but slightly overweight and with a history of untreated hypertension. He had been certified for six months and reported making a total of 26 dives.

He made two dives in one day in a local river; he wore a full wetsuit and was breathing air. During the course of an 11-minute, 67-foot (20.1-meter) dive, he made a rapid ascent to the surface. He immediately returned to 15 feet / 4.5 meters for a safety stop, where he stayed for four minutes before returning to the surface. After a two-hour surface interval, he made a 39-foot (11.7-meter) dive for 40 minutes. His second dive was uneventful, and he had no signs or symptoms of DCI that day.

The following morning, the diver awoke with a dull ache in his left shoulder and numbness in his left hand, both of which he described as mild. He did not seek evaluation for his symptoms. The second day after diving, he awoke with dull pain in the right shoulder and hand and bilateral numbness in his ankles and feet. These new symptoms resolved by the end of the day. On the third morning after his dives, he woke with a rash and itching over his left shoulder. At this point he sought medical evaluation and treatment.

On admission to the hyperbaric unit, only the diver's original symptoms of left shoulder ache and numbness and tingling in the left hand were present. His physical exam was normal. The diver was evaluated and treated at the local hospital hyperbaric center with a U.S. Navy Treatment Table 6, utilizing two extensions (i.e., additional time and oxygen) at 60 feet / 18 meters. His symptoms resolved after chamber treatment.

The original presentation of left shoulder pain and numbness and tingling in the left hand raise the suspicion of decompression illness and fall within a reasonable post-dive time period. However, the dives were not particularly provocative, and symptoms that develop more than 24 hours after the dive are usually unrelated to decompression illness. Additionally, the symptoms that came on the second day after the dive all resolved spontaneously. There was no evidence of these symptoms when the diver was examined three days after the dive. It is more likely these symptoms may have been due to exertion, normal activity, stress or another unknown cause. The resolution of these symptoms may have encouraged the diver to delay seeking medical evaluation.

Case 4 – Recurring DCI Symptoms Without Commercial Air Flight

The diver was a 35-year-old male in good health. He had been certified for three years and reported making approximately 70 dives per year. While on vacation he made 18 dives over a period of six days.

On the morning of his final day of diving, he experienced a sensation of tingling and muscle soreness in his upper back and in the right shoulder region. These symptoms resolved, and he made two dives that day. His first dive was multilevel, to 75 feet / 22.5 meters at its deepest for approximately 30 minutes. He then did a 50-foot / 15-meter level dive for 45 minutes, exiting the water before noon.

continued on next page

Approximately 24 and a half hours later, the diver flew home aboard a commercial airliner. Approximately 90 minutes into the flight, he developed numbness and pain in his right arm and shoulder, with tingling and numbness in his right hand and fingers. These symptoms persisted on landing, when he called for assistance and was referred to a local hospital with a hyperbaric facility. He received a U.S. Navy Treatment Table 6, with two extensions at 60 feet, and reported complete resolution of his symptoms by the end of treatment.

When divers experience symptoms that are only transient, they often do not recognize them as DCI. The recurrence and development of new symptoms during aircraft flight strongly suggest decompression illness to most divers.

Case 5 – Ambiguous Recurrence of Decompression Illness Symptoms

The diver was a 26-year-old healthy male in excellent physical condition. He had been a diver for 10 years and reported performing 50-70 dives each year, mostly during offshore ocean weekend trips. On this occasion he made five dives over two days on a liveaboard dive boat.

His first day of diving consisted of four multilevel dives while spearfishing, to a deepest depth of 160 feet / 48 meters. The first dive of his second day was a multilevel 130-foot / 39-meter dive to spearfish. Prior to his ascent from 130 feet, he had a free-flowing regulator that emptied his tank in less than 20 seconds. He buddy-breathed with his dive partner and made an ascent that exceeded the safe rate according to his dive computer. His computer also indicated that a 10-minute stop was needed at 15 feet (4.5 meters) prior to exiting the water. Unfortunately, his buddy ran out of air, and they ascended directly to the surface.

The diver requested a new buoyancy compensation device (BCD) and tank and attempted to go back to his 15-foot stop to decompress. Despite 10 minutes of trying, the diver was unable to maintain the 15-foot depth due to a buoyancy problem. He ascended to the surface and boarded the boat. As he removed his gear, he began feeling with what he described as "deep pain" in his left shoulder and upper arm. Within 30 minutes, the diver developed tingling in his left hand and fingers.

After breathing oxygen by free-flow mask for approximately two hours and taking several aspirins, his symptoms gradually dissipated over the following six hours. He was free of symptoms at bedtime.

The following day, the diver refrained from diving, and the boat headed back into shore. The diver remained free of symptoms all day. The second day, the diver did construction work involving hammering and carrying heavy beams. At that time, a dull ache returned to his left arm and shoulder, along with mild numbness around the shoulder.

When the symptoms did not resolve, as they did when he first experienced pain and numbness, he called for assistance and was referred to the local dive physician. He was treated with a U.S. Navy Treatment Table 6, which produced a 90-percent recovery. The residual symptoms resolved spontaneously over the next three days.

In this case, the diver expected he would have a problem when he missed his required decompression stop. When his symptoms cleared by nightfall, he noted that he felt he had "dodged the bullet" by breathing oxygen (even though a free-flow mask is likely to provide at best a 0.45-0.50 inspired fraction of oxygen) and taking aspirin. He made the correct decision to not dive the following day, which could have compounded his original problem. However, surface oxygen is not considered definitive treatment, and symptoms recurred after physical exertion.

Case 6 – Symptoms of Ambiguous Decompression Illness

The diver was a 53-year-old male, overweight, with hypertension. He was being treated with medication. He had been a diver for six years and reported performing approximately 70 dives per year.

His most recent dive trip was near a tropical island, where he made eight dives over three days. His first day of diving was uneventful, with three dives to no deeper than 90 feet / 27 meters. On the first dive of the second day, while ascending from a 90-foot dive, he recalled feeling "uncomfortable" (his words in the dive report, without specifying in what way he was uncomfortable) during the ascent. Onboard the vessel while removing his dive gear, although he did recognize his wife and knew where he was, he said he felt disconnected from his surroundings and could not remember the names of any of the people onboard with him. This episode lasted for approximately 15-30 minutes, after which it resolved completely.

The next day was a scheduled day off from diving. Two days after his loss of memory episode, he made two more uneventful dives. However, he did notice at the end of that day of diving he had developed a constant headache, a condition he had never experienced in the past.

The diver flew home the following day with no recurrence of symptoms. He consulted a local dive physician about his symptoms, but because he had no symptoms at the time, he was referred to his personal physician for a general medical evaluation for possible transient ischemic attack (a localized hypoxia, due to a lack of arterial blood flow). On the following day, his headache returned, and he developed subjective tenderness and pain in the muscles of his right shoulder. Physical and neurological examinations were normal. He returned to his diving physician, who treated him with a U.S. Navy Treatment Table 6, after which his headache and right shoulder pain resolved completely.

Although the recompression treatment alleviated this diver's symptoms, the ambiguous nature of his symptoms raises the possibility of another diagnosis besides decompression illness. Several weeks after recompression therapy, the diver had a series of neurological investigations, including an EEG (electronencephalogram), brain scan, cerebral vessel Doppler studies and a test for patent foramen ovale (hole in the heart). Although the tests did not pin down the diagnosis, there was no evidence of cerebral vessel damage or blockage. The diver has had no further symptoms since treatment.

Case 7 – Cardiovascular Symptoms Versus Arterial Gas Embolism

The diver was a 47-year-old student diver who was performing her initial dives for certification. She was in reasonable health; however, she was taking anti-anxiety and anti-depression medication. She was performing her first open-water dive in the local quarry. This was the first time she was diving in a full wetsuit with hood, gloves and her own buoyancy compensator and regulator.

The diver noted she was a little nervous on entering the water and not completely comfortable with wearing all of her equipment. After initial descent, the entire group met at the 10-foot (3-meter) staging area and began a group descent. She recalled that her chest was a bit uncomfortable, but she was not overly concerned, thinking it was just anxiety. As they reached their maximum depth of 20 feet (6 meters), she experienced a sensation of increased pressure in her chest. As the dive continued at 20 feet, her chest discomfort continued. She alerted the instructor of her discomfort, and they ascended to 10 feet for a safety stop, where she began to feel very uncomfortable. They then ascended to the surface.

The diver lost consciousness just before or immediately after reaching the surface. She had no memory of events after beginning her ascent until waking up in an ambulance on the way to the hospital. She received both cardiopulmonary resuscitation (CPR) and oxygen from lay people when she reached the shore (the CPR may not have been necessary). After arriving at the hospital via ambulance, a comprehensive neurological examination revealed no abnormality, although she was suffering from pulmonary edema or excess fluid in her lungs. Fortunately, the hospital had a hyperbaric chamber, and given the loss of consciousness at or near the surface, the physician felt it necessary to provide a U.S. Navy Treatment Table 6 to treat a possible cerebral arterial gas embolism. However, there were other possibilities, such as immersion pulmonary edema, with severe anxiety mimicking unconsciousness.

Case 8 – Recurrence of Symptoms – Flying After Treatment

The diver was a 38-year-old male with no current health problems other than being overweight for his height (he stood 5-foot-8 / 1.73 meters and weighed 220 pounds / 100 kilograms). He had been certified since the age of 12 and reported making more than 100 dives per year.

The diver took a two-week dive vacation, where he performed 14 ocean dives over nine days. His first dive on the ninth day was to 170 feet (51 meters) while breathing air. He decompressed using his personal computer and a special deep decompression profile. He made the scheduled decompression stops and exited the water without incident. Shortly after getting out of his gear, he developed acute pain in his right knee, wrist and elbow, both shoulders and his left ankle. He also developed numbness in his right forearm and hand. He was treated with a U.S. Navy Treatment Table 6, with complete resolution of all symptoms. He had a normal neurological examination after recompression.

The diver waited the required 72 hours before boarding a plane to fly back to the United States. His first flight was for one and a half hours and was uneventful. After a three-hour layover, he boarded a second flight, which was to be three and a half hours long. Approximately one and a half hour into the flight, he had a recurrence of his pain, but not the numbness. The pain persisted throughout the flight and did not resolve on landing.

After returning home, the diver self-reported to a local emergency room, complaining of joint pain. His neurological examination was normal. The diver received a U.S. Navy Treatment Table 6 and experienced partial improvement in his pain. He was discharged and advised to use a non-steroidal anti-inflammatory drug to treat his discomfort. His symptoms resolved over the next 48 hours.

The nature of these symptoms and the onset time relative to a deep dive strongly suggest DCI. Immediate evaluation and treatment resulted in the diver's complete recovery. The suggested 72-hour waiting period before going to altitude is reasonable and is a sufficient waiting period in the majority of DCI cases; however, some divers experience recurrent symptoms when flying even after 72 hours. Such recurrences are usually mild.

Case 9 – Neurological Decompression Illness With Vestibular and Cerebral Symptoms

The diver was an 18-year-old male in excellent physical health, taking no medications and having no complaints of chronic or acute health issues. He had been certified for three years and reported making no more than 12 dives per year. The first day of his ocean dive vacation followed his first evening after his 18th birthday, which he celebrated by drinking "a few beers."

He did a single dive to 97 feet (29.6 meters) for four to five minutes and then ascended to approximately 60 feet (18 meters), where he spent 45 minutes. He ascended to 15 feet for a safety stop at a stop bar. The diver ran low on air and used the regulator hanging at the stop bar. He then made a normal ascent to the surface. After getting out of his dive gear, he reviewed his computer and found that he had been at 97 feet, which was deeper than he previously thought he had gone, and that there was a rapid ascent alarm that had activated.

Approximately 30 minutes after his dive, he experienced the rapid onset of vertigo, followed by nausea and vomiting. Within minutes he could not maintain his balance and had to lie down, whereupon he had an overwhelming sensation of weakness. This was followed by extreme fatigue to the point that he felt he needed to go to sleep.

He was given oxygen on the boat, and while being transferred to a local medical clinic, he was also found to have nystagmus, the rapid darting back and forth of the eyes in an uncontrolled fashion. The diver was given anti-nausea medication and intravenous fluids, which helped his nausea and vertigo, and was then transferred to the local hyperbaric facility. At that point, he was unable to stand without two people helping him, and he continued to vomit.

On exam he had mild barotrauma in one ear, with slight redness of the tympanic membrane. The diver was a little dulled mentally, which could have been due to the anti-nausea medication. He was given a U.S. Navy Treatment Table 6, which improved his symptoms from severe to moderate, in the evaluating physician's opinion. The diver received two more Table 6's and two shorter modified tables over the next four days. He had only subjective symptoms, such as being lightheaded for the last two treatments, and his neurological exam was normal. The diver was permitted to fly home 24 hours after his last treatment. He used supplemental oxygen during the entire duration of the flight and had no symptoms.

There were several errors that likely contributed to this serious case of decompression illness. Drinking the night before diving may have resulted in dehydration and possibly a lack of rest and mental preparedness prior to the dive. Assuming that the 60-foot depth was the target, the depth violation at the start of the dive was severe. The diver's apparent post-dive surprise concerning the maximum dive depth and the ascent rate warning indicate a general lack of attentiveness. This case demonstrates that DCI that includes neurological involvement is often more difficult to resolve than pain-only DCS, frequently requiring repeated treatment.

Appendix B: Dive Fatality Case Reports

Proximate Cause: Air Embolism

02-20 Inexperienced diver with equalization difficulty lost consciousness at surface
Cause of Death: Air embolism

This 69-year-old woman had been a certified open-water diver for nine years but had made fewer than 20 lifetime dives. She had possibly suffered an episode of pulmonary barotrauma during a checkout dive in 1993 but did not seek formal medical care. After a dive the previous day, the decedent complained of difficulty with breathing and she was wheezing. The next day, she made a night dive to 40 fsw / 12 msw for 30 minutes during which she had difficulty equalizing the pressure in her middle ears. The decedent complained of difficulty with breathing at 15 fsw / 4.5 msw and then again on the surface. She lost consciousness while being assisted into the boat. This death was ruled a drowning by the medical examiner, but it was most likely an air embolism.

02-53 Intermediate diver on multiple days of diving lost consciousness at surface
Cause of Death: Air embolism

This 57-year-old male had received initial open-water certification eight months earlier and had made 20 lifetime dives. He was making a series of multiple dives for multiple days. The decedent and his buddy were diving from a boat in a large group. He signaled that he was going to ascend and, after what was reported to be a "normal ascent," he lost consciousness while climbing the ladder into the boat. The autopsy disclosed evidence of pulmonary barotrauma, and the cause of death was determined to be an air embolism.

02-55 Poorly conditioned open-water student panicked, lost consciousness on surface
Cause of Death: Air embolism

This 60-year-old female was a student in an initial open-water certification course. She was morbidly obese (having a BMI greater than or equal to 40 kg/m^2). She had no other known significant health problems. During the third certification dive, the decedent spat her regulator out while practicing recovery drills with her buddy. She panicked, and the buddy offered the diver his octopus regulator. The two divers proceeded to the surface. The decedent was initially fine on the surface but then abruptly lost consciousness and could not be resuscitated. An autopsy revealed the diver had mild coronary atherosclerosis, patchy myocardial scarring and a fatty liver. The most likely cause of death was an air embolism.

02-67 Poorly conditioned diver on open-water checkout dives lost consciousness at surface after the dive
Cause of Death: Air embolism

This 55-year-old male was in an initial open-water certification class participating in his third checkout dive. The diver was morbidly obese and had an elevated serum cholesterol level. After performing a controlled emergency ascent drill, the diver lost consciousness upon reaching the surface. Resuscitation efforts were unsuccessful. The autopsy disclosed air in both ventricles of the heart and in the arteries at the base of the brain. Although the diver had coronary artery disease, it was mild, and the history and autopsy findings support air embolism as a cause of death.

02-80 Inexperienced diver with heart condition made uneventful dive, lost consciousness after dive
Cause of Death: Air embolism

This 41-year-old woman had received her open-water certification two weeks earlier and was making her fifth lifetime dive. She took an unknown medication for a "heart condition." The dive was in a local quarry with a shore entry. Her dive buddy stated that the dive was uneventful, but after the dive, the decedent complained of chest tightness. After removing her equipment, the stricken diver lost consciousness. Resuscitation efforts were unsuccessful. The autopsy report was not made available, but the most likely cause of death was air embolism. Given the diver's history, a cardiac event cannot be completely ruled out.

02-09 Freshwater dive at higher altitude; diver had difficulty equalizing ears, lost consciousness at surface, died after hyperbaric treatment
Cause of Death: Air embolism due to rapid ascent

This 38-year-old female had advanced open-water certification with 40 lifetime dives during four years of diving. She was making a dive with a buddy at altitude in a deep freshwater lake. The diver was having difficulty equalizing pressure in her middle ears and aborted the dive after spending less than 15 minutes at a maximum depth of 28 feet / 8.5 meters. She separated from her buddy and made a rapid ascent to the surface, after which she complained of difficulty breathing. The diver was brought to shore and then lost consciousness. She was taken to a medical treatment facility and received hyperbaric oxygen therapy before she died. An autopsy was not performed, but everything in the investigation pointed to air embolism as the cause of death.

02-10 Inexperienced diver on wreck dive; rapid air supply used, lost consciousness at surface, tobacco abuse
Cause of Death: Air embolism due to rapid ascent

This 46-year-old male had open-water certification with three lifetime dives. The diver was obese (having a BMI between 30 and 39.9 kg/m^2) and smoked cigarettes. He complained of fatigue prior to making a wreck dive from a boat to 70 fsw / 21 msw. After nearly exhausting his air supply in 15 minutes and having difficulty with buoyancy and his weight belt, the diver ascended rapidly with his weight belt in his hand. He lost consciousness while ascending the ladder into the boat and, later that day, was pronounced dead at a local hospital. The autopsy disclosed evidence of coronary artery disease, including an acute myocardial infarction, as well as pulmonary barotrauma. The cause of death was concluded to be an air embolism.

02-30 Poorly conditioned, inexperienced rescue diver on wreck dive, lost consciousness at surface
Cause of Death: Air embolism due to rapid ascent

This 55-year-old male was a certified rescue diver who had not been diving during the previous two years. He was morbidly obese. The decedent and his buddy made a wreck dive off a boat to 74 fsw / 22.5 msw for 24 minutes. They had an uneventful dive until they reached the safety stop. At that point, the decedent's mask flooded, and he made a rapid ascent to the surface. While climbing the ladder to get back into the boat, the decedent collapsed and could not be resuscitated. The autopsy disclosed changes associated with an air embolism as well as marked cardiomegaly and coronary artery disease.

02-37 Intermediate diver with problem on descent, lost consciousness on way to surface
Cause of Death: Air embolism due to rapid ascent

This 59-year-old male received his initial open-water certification one year earlier and had made 26 lifetime dives. He was making a planned dive to 100 fsw / 30 msw, but had a problem on descent and indicated that he was going to ascend early. The ascent to 15 fsw / 4.5 msw appeared to be uneventful, but he then lost consciousness on the way to the surface from the safety stop. Resuscitation efforts were unsuccessful. The autopsy disclosed air in the heart, locally severe heart disease, and a fatty liver. The likely cause of death was air embolism.

02-40 Student diver in poor physical condition made rapid ascent, collapsed on surface
Cause of Death: Air embolism due to rapid ascent

This 43-year-old male was a student making his fourth checkout dive for initial open-water certification. His medical problems included hypertension and obesity. The class was making all four certification dives on the same day. The decedent had trouble descending and also had difficulty with buoyancy control. He finally made it down to 30 feet / 9 meters but then ascended rapidly and called for help before collapsing. The autopsy disclosed subcutaneous emphysema, an enlarged heart, and a fatty liver, but no coronary artery disease. The medical examiner determined the death to be due to a myocardial infarction, but the circumstances make an air embolism much more likely.

02-61 Poorly conditioned diver with diabetes, on game collection dive, lost consciousness at surface
Cause of Death: Air embolism due to rapid ascent

This 41-year-old male was obese and took oral medication to control his diabetes. He had made 25 lifetime dives, and it had been just three months since certification. The diver made a shore entry dive in a large group to collect lobster. He unexpectedly went to the surface and called for help. While the diver was being assisted to shore, he lost consciousness. The autopsy disclosed subcutaneous emphysema and mild coronary artery disease.

02-36 Experienced rescue diver on photography wreck dive ran out of air, lost consciousness at surface
Cause of Death: Air embolism due to rapid ascent, insufficient air

This 47-year-old male was a very experienced rescue diver making a dive to videotape a wreck. His dive buddy was engaged in a similar endeavor on the other side of the wreck. In order to keep the audio on the tape clear, the decedent turned off all of the alarms on his dive computer. The dive was made to 148 fsw / 44.4 msw for 16 minutes when the decedent noticed that he was out of air. He made a rapid ascent up the anchor line from 140 fsw / 42 msw up to 60 fsw / 18 msw, where the divemaster attempted to render assistance. The decedent would not take an alternate air source and appeared confused. He was assisted to the surface where he lapsed into unconsciousness and could not be resuscitated. An autopsy was not performed, but this most likely was an air embolism. The diver also had a history of hypertension.

02-49 Medically disabled diver ran out of air, made rapid ascent to surface Cause of Death: Air embolism due to rapid ascent, insufficient air

This 54-year-old male had advanced open-water and nitrox certification. His medical problems included asthma, a herniated intervertebral disc, and a 20-year history of HIV seropositivity. The decedent was on multiple medications and was officially medically disabled. He had complained of elbow pain after a dive three months earlier but did not seek medical treatment. The decedent and two other divers made two dives from a boat. The first dive was to 102 fsw / 30.6 msw for 29 minutes, and the second dive was to 98 fsw / 29.4 msw for 45 minutes. He ran out of air during the second dive and made a rapid ascent to the surface. The diver collapsed while climbing the ladder into the boat. He was pronounced dead in the emergency room of a local hospital. The diver's main tank and pony bottle were empty, and his computer confirmed the rapid ascent.

02-56 Experienced diver, spearfishing and separated from buddy, had buoyancy problem, ran out of air, made rapid ascent Cause of Death: Air embolism due to rapid ascent, insufficient air

This 56-year-old male had advanced open-water certification and was an experienced diver. He and a buddy were spearfishing on their third dive of the day. The decedent had been having difficulty with his weight belt all day, and this affected his buoyancy control. As was their practice, the divers separated on the bottom to go after fish. The decedent's buddy surfaced after his dive and eventually located the decedent, who was unconscious on the surface. Resuscitation efforts were unsuccessful. The autopsy disclosed abundant gas in the heart and great vessels, evidence of pulmonary barotrauma, and severe atherosclerosis of the coronary arteries.

02-58 Experienced diver made deep dive on air, ran out of air, made rapid ascent Cause of Death: Air embolism due to rapid ascent, insufficient air

This 50-year-old male was an experienced divemaster who routinely made very deep (in excess of 150 fsw / 45 msw) dives on air. According to his dive computer, he also made frequent rapid ascents. The decedent had a history of hypertension, but he refused to control it with medication. He and two other divers were making the last dive of a dive trip; the decedent had stated he wanted to make "a dive to remember." They descended to 200 fsw / 60 msw together, but the decedent continued down past 300 fsw / 90 msw. The divers used double tanks, but none used an octopus to aid with buddy breathing. During the ascent phase of the dive, the other divers saw the buddy ascend past them at the decompression stop and go directly to the surface. He immediately called for assistance on the surface before losing consciousness. The decedent had ascended from 300 fsw directly to the surface in seven minutes. He omitted nearly an hour of obligated decompression time. No autopsy was performed, but the cause of death was likely an air embolism secondary to a rapid ascent with nitrogen narcosis and decompression sickness as contributing factors.

02-11 Experienced but poorly conditioned smoker, low on air and separated from buddy, lost consciousness on surface Cause of Death: Air embolism due to insufficient air

This 56-year-old male was an experienced diver with advanced open-water certification. He was overweight and smoked cigarettes. The diver made a series of dives to 55 fsw / 16.5 msw for approximately 30 minutes each. Toward the end of the third dive he was running low on air and surfaced without his buddy. The diver pulled himself toward the boat along the surface line, but after making it half the distance, he lost consciousness. The autopsy disclosed evidence of pulmonary barotrauma, including bilateral pneumothoraces (both lungs were collapsed) and subcutaneous emphysema. The medical examiner concluded the cause of death to be "barotrauma," but this was an air embolism due to pulmonary overexpansion injury.

Proximate Cause: Drowning / Air Embolism

02-28 Inexperienced diver spearfishing and collecting game, separated from buddy, later found on the bottom, with no air in his tank
Cause of Death: Drowning due to air embolism

This 39-year-old male had received his initial open-water certification just four months earlier and was making his first open-water dive without an instructor. He and a dive buddy were hunting lobster and spearfishing during a dive to 65 fsw / 19.5 msw. The decedent signaled to his buddy that he was low on air and was going to ascend. The two divers became separated, and the dive buddy surfaced alone. When the decedent did not surface, the buddy went back down. Approximately 30 minutes later, the stricken diver was found on the bottom by the rescue team. His tank was empty, and the autopsy revealed extensive intravascular and intracardiac gas. The decedent also had a history of hypertension.

02-38 Inexperienced diver ascended, low on air, lost consciousness at surface
Cause of Death: Drowning due to air embolism

This 54-year-old male had advanced open-water certification with 12 lifetime dives. He and a dive buddy made a 45-minute dive to 45 fsw / 15 msw. The decedent reported to his buddy that he was down to 500 psi of air in his tank, and they agreed to ascend. The decedent lost consciousness while being assisted into the boat, and he went back under the surface for a few minutes before being pulled into the boat by other divers. The autopsy disclosed subcutaneous air, air in the heart, and changes consistent with drowning. The cause of death is drowning due to an air embolism.

02-24 Experienced diver on solo dive made rapid ascent but found on bottom
Cause of Death: Drowning due to air embolism, rapid ascent

This 38-year-old male had advanced open-water certification and six years of diving experience. He complained of a headache the previous day after completing a dive that included a rapid ascent. The decedent made a dive to 81 fsw / 24.3 msw from a boat in a group of seven divers but without a designated buddy. The decedent was found unconscious on the bottom, and an evaluation of his equipment revealed that he was out of air. An investigation revealed that the decedent had experienced buoyancy problems and made a rapid ascent after losing or removing his weight belt. The cause of death was ruled to be air embolism.

02-42 Poorly conditioned diver had drysuit and buoyancy problems, made rapid ascent
Cause of Death: Drowning due to air embolism, rapid ascent

This 53-year-old male was a certified diver with approximately 100 lifetime dives. He and a dive buddy made a dive to 120 fsw / 36 msw on a wreck to gather shellfish. The decedent had difficulty maintaining proper buoyancy and was unable to control his drysuit properly. He made an uncontrolled rapid ascent from the bottom, and the body was recovered two hours later. The autopsy disclosed evidence of pulmonary barotrauma and extensive intravascular gas. The diver was also obese and had a fatty liver.

02-83 Poorly conditioned diver training for advance certification in quarry brought to surface unconscious
Cause of Death: Drowning due to air embolism, rapid ascent

This 49-year-old male had been a certified diver for several years and had an unknown amount of diving experience. He was a student in an advanced open-water certification class. The diver was morbidly obese. After a shore entry dive to 80 feet / 24 meters in a quarry, the diver stopped during the ascent phase and began to sink toward the bottom. He was brought to the surface and could not be resuscitated. The autopsy disclosed changes consistent with drowning in addition to large amounts of gas in the heart, great vessels and the arteries at the base of the brain.

02-57 Infrequent diver ran out of air, panicked, made rapid ascent, died during hyperbaric treatment
Cause of Death: Drowning, due to air embolism, rapid ascent, insufficient air

This 57-year-old male had open-water certification with more than 30 years of diving experience, but he was an infrequent diver and had made nearly all of his dives in fresh water. This dive was in the ocean. The decedent made a dive from a boat to 80 fsw / 24 msw but ran out of air after 15 minutes. He indicated to his buddy that he was out of air and pulled his buddy's regulator from his mouth. The buddy attempted to establish air-sharing with the panicked diver but was unsuccessful. The decedent headed rapidly to the surface, where he became unconscious. The stricken diver was taken to a local medical facility, where he was placed in a hyperbaric chamber. He did not respond to treatment. The autopsy disclosed changes associated with drowning, in addition to severe hypertensive atherosclerotic cardiovascular disease and pulmonary emphysema. Intravascular gas could not be demonstrated at autopsy, but it would not be expected to be present after treatment with hyperbaric oxygen.

02-71 Reported divemaster on series of deep dives, had trouble with equipment, ran out of air, made rapid ascent
Cause of Death: Drowning due to air embolism, rapid ascent, insufficient air

This 41-year-old male had an unknown level of certification and experience, though he stated that he was a divemaster. The diver made a series of very deep dives on air and had difficulty with the auto inflator on his buoyancy compensator. During the third dive of the day, the decedent reported that he was out of air barely five minutes into the dive. He made a panicked, rapid ascent and lost consciousness upon reaching the surface. In addition to changes associated with drowning, the autopsy disclosed evidence of pulmonary barotrauma and pulmonary emphysema.

02-77 Diver spearfishing on oxygen enriched air (nitrox) and malfunctioning equipment, ran out of air, made rapid ascent
Cause of Death: Drowning due to air embolism, rapid ascent, insufficient air

This 29-year-old male was a certified open-water diver with an unknown amount of diving experience. He was making a series of dives using oxygen enriched air (nitrox) that he mixed himself, no buoyancy compensator and a malfunctioning dive computer. The diver was spearfishing, and he made several of his six dives that day without a buddy. The diver speared several large fish during these dives and did not use a new tank for each dive. After a dive to 85 fsw / 25.5 msw for 14 minutes, he made a witnessed rapid ascent and suffered what appeared to be a seizure as he hit the surface. The cause of death was determined to be drowning due to an air embolism.

02-81 Experienced technical diver on solo rebreather apparatus dive ran out of air, made rapid ascent, found later on bottom Cause of Death: Drowning due to air embolism, rapid ascent, insufficient gas

This 42-year-old male was a technical diver and dive instructor. He made shore entry dive without a buddy to test out a rebreather rig. He did not use any kind of backup breathing apparatus. The decedent made a rapid ascent after running out of breathing gas and was later found on the bottom, unconscious and with his mouthpiece out.

02-76 Diver with unknown level of experience doing underwater photography ran out of air, lost consciousness on ascent Cause of Death: Drowning due to air embolism, insufficient air

This 54-year-old female was a certified diver with an unknown amount of diving experience. She and a buddy made a shore entry dive to 80 fsw / 24 msw to take pictures. After running out of air at depth, the two divers began to buddy breathe, but the decedent lost consciousness on the way to the surface. She was pronounced dead at a local medical treatment facility.

Proximate Cause: Cardiac

02-65 Diver with unknown certification and experience level found on bottom of quarry Cause of Death: Cardiac dysrhythmia

Little information is available on the death of this 53-year-old male, including his diving experience and certification level. He was making a dive in a quarry, and his body was found at a depth of 15 feet / 4.5 meters two hours after he was determined to be missing. The autopsy report was not made available, but the cause of death was determined to be a cardiac event.

02-89 Poorly conditioned diver struggled, lost consciousness on surface pre-dive Cause of Death: Cardiac dysrhythmia

This 52-year-old male was a certified diver with an unknown amount of diving experience. He was markedly obese and had undergone gall bladder and knee surgery nine months previously. The diver was making a wreck dive from a boat with several other divers. He entered the water but never descended. Witnesses stated that the decedent struggled and panicked on the surface before losing consciousness. He was pronounced dead at a local medical treatment facility of what was presumed to be a cardiac event. If an autopsy was performed, the report was not made available.

02-04 Experienced but poorly conditioned diver with tobacco abuse, heart condition, died before descending Cause of Death: Cardiac dysrhythmia due to coronary atherosclerosis

This 69-year-old male had advanced open-water certification and was an experienced diver. He was morbidly obese, had a 100-plus pack-a-year history of cigarette smoking and had undergone coronary artery angioplasty with a stent placed. The diver entered the water but never descended. He swam back to the boat and collapsed. Resuscitation efforts were unsuccessful. The autopsy was limited to an examination of the chest only. Severe atherosclerosis of all four major coronary arteries, scarring from previous myocardial infarctions, and marked cardiomegaly were noted. The cause of death was determined to be a cardiac event.

02-07 Experienced instructor with diabetes, heart disease, lost consciousness at depth while photographing marine life
Cause of Death: Cardiac dysrhythmia due to coronary atherosclerosis

This 73-year-old male was a certified dive instructor with decades of experience. His medical problems included hypertension, adult onset diabetes and a low level of physical fitness. The decedent was making a dive to 65 fsw / 19.5 msw to videotape marine animals when he abruptly lost consciousness at depth. The autopsy report was not made available, but the medical examiner ruled that the cause of death was a cardiac event.

02-08 Certified rescue diver with multiple health problems, including heart disease, lost consciousness on surface
Cause of Death: Cardiac dysrhythmia due to coronary atherosclerosis

This 57-year-old male was a certified rescue diver. He had numerous health problems, including severe coronary atherosclerosis, elevated cholesterol, hypertension and obesity. The diver had undergone coronary angioplasty two years previously and had stents placed in his coronary arteries. After spending 15 minutes at 40 fsw / 12 msw, the decedent ascended and told the divemaster that he did not feel well. He then lost consciousness. The autopsy confirmed the severity of the diver's heart disease.

02-15 Experienced cave diver using nitrox; numerous health problems, including heart disease, found unconscious in a cave
Cause of Death: Cardiac dysrhythmia due to coronary atherosclerosis

This 58-year-old male was a divemaster and certified cave diver with numerous health problems including ischemic heart disease, hypertension, diabetes and obesity. He took several prescription medications. Using nitrox, the diver made a cave dive with a buddy to 70 feet / 21 meters. The divers became separated, and the decedent was found unconscious. He was pulled from the cave; attempts to resuscitate were unsuccessful. The autopsy confirmed the presence of severe ischemic heart disease, and the medical examiner ruled the cause of death to be a cardiac event.

02-19 Inexperienced and poorly conditioned diver, made dive on nitrox, lost consciousness on surface swim to the boat
Cause of Death: Cardiac dysrhythmia due to coronary atherosclerosis

This 54-year-old male had been certified as an open-water diver for 20 years but had made fewer than 40 lifetime dives. He was morbidly obese. The decedent made an uneventful dive from a boat using enriched air, for which he had no formal training or certification. At the completion of the ascent, there was a long surface swim back to the boat, during which the decedent lost consciousness. Resuscitation efforts were unsuccessful. The autopsy disclosed marked cardiomegaly and severe atherosclerosis of the coronary arteries.

02-26 Inexperienced diver, in poor health, lost consciousness on surface before dive
Cause of Death: Cardiac dysrhythmia due to coronary atherosclerosis

This 63-year-old male had been certified as a diver 30 years ago but had not made any dives in the past seven years. He was obese, had hypertension that was controlled with medication and had a history of a myocardial infarction six years ago. The decedent had a cardiac pacemaker in place. The decedent and two buddies were attempting a shore entry night dive during rough seas in kelp to collect lobster. Prior to descending, the diver struggled on the surface and lost consciousness. An autopsy was not performed, but the medical examiner determined the cause of death to be hypertensive atherosclerotic cardiovascular disease, based on the diver's medical history and the circumstances of the fatal dive incident.

02-44 Experienced diver with tobacco abuse had buoyancy problem, lost consciousness on surface swim to shore
Cause of Death: Cardiac dysrhythmia due to coronary atherosclerosis

This 60-year-old male had been diving for eight years and had advanced open-water certification with more than 100 lifetime dives. He had elevated serum cholesterol and smoked. The decedent made a shore entry dive with a buddy and had some buoyancy problems. After surfacing, the decedent had difficulty staying afloat, and his buddy inflated his buoyancy compensation device for him. The diver became unresponsive while being towed back to shore. The autopsy report lists the cause of death as a cardiac event.

02-46 Diver with advanced level of experience had trouble at surface predive
Cause of Death: Cardiac dysrhythmia due to coronary atherosclerosis

This 55-year-old male had advanced open-water certification with an unknown level of diving experience. He and another diver entered the water from a boat. The decedent complained of not feeling well, and as soon as he entered the water, he sank below the surface before putting the regulator into his mouth. The decedent was assisted into the boat before losing consciousness. An autopsy was not performed, but the death was determined to be due to a cardiac event.

02-52 Experienced diver made rapid ascent, lost consciousness at surface
Cause of Death: Cardiac dysrhythmia due to coronary atherosclerosis

This 62-year-old male was a very experienced diver with specialty certification. He and another diver made a dive to 70 fsw / 21 msw for 15 minutes. The decedent signaled to his buddy that something was wrong and made a rapid ascent to the surface. He then struggled on the surface and had difficulty breathing before collapsing as he was assisted into the boat. The autopsy report was not made available, but the cause of death was reported to be an acute cardiac event. An air embolism cannot completely be excluded.

02-72 Diver with diabetes, not medically cleared to dive, in open-water class, lost consciousness at surface after the dive
Cause of Death: Cardiac dysrhythmia due to coronary atherosclerosis

This 54-year-old male was a student in an initial open-water certification course. He had a medical history that included insulin-requiring diabetes and hypertension. His physician advised him not to begin the diving course and to at least have an exercise stress test prior to engaging an activity like that. The diver chose to ignore the advice. He made a shore entry dive for his very first open-water dive. After completing the skills test and spending some time at 15 fsw / 4.5 msw, he surfaced and complained of chest pain. The diver lost consciousness while being assisted to shore. The medical examiner determined the cause of death to be atherosclerotic cardiovascular disease. An air embolism would also be a possibility here, though there was no evidence of pulmonary barotrauma seen at the autopsy.

02-78 Poorly conditioned diver, with unknown dive experience, suffered cardiac event at surface
Cause of Death: Cardiac dysrhythmia due to coronary atherosclerosis

This 49-year-old male was a certified diver with an unknown amount of diving experience. He was morbidly obese and took prescription medication for hypertension. The diver had also suffered an episode of decompression sickness that required recompression therapy approximately 10 years previously. He was making a dive from a boat in a group of four divers. It was the third dive of the day, and they all had descended to approximately 30 fsw / 9 msw. The decedent made a safety stop, then ascended further and complained of chest discomfort. He eventually lost consciousness and could not be resuscitated. The medical examiner concluded that the death was due to a cardiac event. The possibility of an air embolism cannot be completely excluded, though it is less likely in an experienced diver.

02-62 Poorly conditioned diver, with multiple health problems, lost consciousness at surface post dive
Cause of Death: Cardiac dysrhythmia due to coronary atherosclerosis

The certification level and diving experience of this 48-year-old male are unknown. He had numerous severe health problems, including heart disease, a seizure disorder, bipolar affective disorder, obesity and a history of heavy smoking. The diver made a shore entry dive with a buddy, spending 25 minutes at 25 fsw / 7.5 msw. After surfacing from the dive, he became distressed on the surface and called for help. The diver lost consciousness, and resuscitation efforts were unsuccessful. The autopsy disclosed severe coronary atherosclerosis, valvular heart disease, pulmonary emphysema and evidence of recent and remote myocardial infarctions.

02-23 Poorly conditioned diver with alcohol abuse separated from buddy, ran out of air
Cause of Death: Cardiac dysrhythmia due to cardiomegaly

This 53-year-old male was a certified diver with two years of experience. His health problems included alcoholism and being overweight. The decedent and a buddy made a shore entry dive that was reported to be uneventful, but they became separated during the long surface swim to shore. The buddy located the stricken diver floating on the surface, face up and unconscious. The autopsy revealed marked hypertrophy of the left ventricle of the heart, and the death was ruled to be a cardiac event. An examination of the equipment revealed that the decedent's tank was empty.

02-18 Diver with unknown experience aborted dive after regulator was knocked out of mouth, and later on the boat, lost consciousness
Cause of Death: Myocardial infarction due to coronary atherosclerosis

When this 61-year-old male had the regulator knocked from his mouth upon entering the water, he decided to abort the dive. He went back to the boat and complained of feeling poorly before losing consciousness 40 minutes later. The autopsy disclosed severe coronary artery disease and marked enlargement of the heart.

Proximate Cause: Drowning / Cardiac

02-48 Experienced technical diver using rebreather, separated from buddy in strong current, found next day
Cause of Death: Drowning due to cardiac dysrhythmia

This 40-year-old male was a very experienced technical diver and instructor. He made a dive to 60 fsw / 18 msw for 53 minutes, with a buddy, and using a rebreather apparatus. Due to a strong current, the two divers became separated. The decedent surfaced from the dive and removed one of his fins. He then sank below the surface, and his body was not recovered until the next day. An autopsy disclosed moderate atherosclerosis of the coronary arteries and other changes that are consistent with drowning. The diver likely had a cardiac event that resulted in drowning.

02-16 Experienced divemaster in poor condition, fatigued, separated from buddies on surface swim, found an hour later
Cause of Death: Drowning due to cardiac dysrhythmia

This 41-year-old male was an experienced divemaster making a series of shore entry dives with two buddies. He was morbidly obese and complained of fatigue during the surface interval between the first and second dives. The first dive was to 101 fsw / 30.3 msw for 30 minutes. During the surface swim prior to descending for the second dive, the decedent told his buddies that he would catch up to them, and the divers separated. When the two dive buddies returned to the beach, they could not locate the decedent. His body was found an hour later. An autopsy report was not made available, but the death was ruled a drowning due to a cardiac event.

02-33 Shore entry diver struggled on surface prior to dive
Cause of Death: Drowning due to cardiac dysrhythmia

There is not much information available on the death of this 40-year-old male who made a shore entry dive with a group of divers. He lagged behind the other divers and then was seen on the surface struggling and calling for assistance. The stricken diver was brought to shore; resuscitation was attempted, though unsuccessful. The autopsy report was not made available, but the death was reported to be cardiac-related.

02-50 Experienced but poorly conditioned diver lost consciousness at surface after the dive
Cause of Death: Drowning due to cardiac dysrhythmia

This 58-year-old male had open-water certification and was an experienced diver. An investigative report stated that the decedent had a history of a "heart problem," and he was also obese. This was the diver's fifth day of diving. The diver made an uneventful dive to 55 fsw / 16.5 msw from a boat with a large group of divers. The last diver up, he signaled that he was fine. While hanging on the surface line after the dive, the decedent became unresponsive and could not be resuscitated. The autopsy disclosed changes associated with drowning as well as severe atherosclerosis of the coronary arteries.

02-59 Diver with unknown experience level lost consciousness on ascent
Cause of Death: Drowning due to cardiac dysrhythmia

This 66-year-old male had received his open-water certification 10 years earlier. It is uncertain what his experience level or frequency of diving was. He made a dive to 130 fsw / 39 msw from a boat with a buddy. Approximately eight minutes into the dive, the decedent indicated that something was wrong, and they ascended. The diver had a witnessed loss of consciousness at 40 fsw / 12 msw. Two autopsies were performed, but neither report was made available. Apparently, one pathologist concluded that the cause of death was drowning, and another decided that a cardiac event resulted in the diver's death. The most likely scenario is that the diver drowned because of a cardiac event.

02-60 Diver with unknown experience level separated from buddy to swim to shore, found unconscious on surface
Cause of Death: Drowning due to cardiac dysrhythmia

This 49-year-old male had been certified as an open-water diver for five years, but his experience and diving activity level are unknown. He and a buddy made a shore entry dive to hunt lobster, though the diver complained of an upset stomach prior to the dive. After eight minutes of bottom time, the diver signaled to his buddy that he did not feel well, and they separated so the decedent could return to shore. The decedent was seen floating on the surface by a witness on the beach. Resuscitation was attempted, but the diver was pronounced dead upon arrival at a local hospital. The autopsy disclosed cardiovascular disease as well as changes associated with drowning.

02-01 Inexperienced, poorly conditioned diver with heart disease attempted freshwater wreck dive, aborted at 30 feet, lost consciousness on surface
Cause of Death: Drowning due to cardiac dysrhythmia and cardiomegaly

This 49-year-old male had basic open-water certification and 40 lifetime dives over a two-year period. His medical problems included hypertension and obesity. The diver was making a wreck dive in a deep freshwater lake and complained of fatigue on the surface prior to descending. The dive was aborted at 30 feet during the descent when the diver was visibly in distress. After ascending, the decedent switched to his snorkel but then lost consciousness and sank back below the surface. The decedent's dive buddy released his weight belt and assisted him back to the surface. The diver could not be resuscitated. The autopsy disclosed marked cardiomegaly and changes associated with drowning. The death was determined to be due to drowning, likely secondary to a cardiac event.

02-03 Inexperienced, poorly conditioned diver with multiple health problems, including heart disease, lost consciousness on surface
Cause of Death: Drowning due to cardiac dysrhythmia and coronary atherosclerosis

This 52-year-old male had open-water certification with 20 lifetime dives over a period of 16 years. He had not made a dive in the previous 10 years. The diver had significant health problems including hypertension, diabetes, obesity and ischemic heart disease. He made a shore entry dive to 30 fsw / 9 msw under instruction but became distressed 10 minutes into the dive and surfaced. At that point, the diver told the instructor that his heart was beating fast and that he was having trouble breathing. Despite this, the decedent went back down but surfaced again with increased difficulty breathing. He then lost consciousness and could not be resuscitated. The autopsy disclosed severe atherosclerosis of the coronary arteries, a markedly enlarged heart and evidence of previous myocardial infarctions.

Proximate Cause: Drowning / Insufficient Air

02-31 Diver with unknown experience separated from buddy, found later on bottom, ran out of air
Cause of Death: Drowning due to insufficient air

This 41-year-old male was a certified diver with an unknown amount of diving experience. He and a buddy made a shore entry dive, but at the end of the dive, the decedent swam off by himself. He was found three hours later at the bottom, at a depth of 20 feet / 6 meters, with his regulator out of his mouth. The decedent's equipment was in disarray, and his autoinflator to the buoyancy compensation device was not connected. The air tank was also empty. The autopsy report was not made available, but the cause of death was listed as drowning.

02-43 Inexperienced overweighted solo diver lost, body found two days later
Cause of Death: Drowning due to insufficient air

This 48-year-old male received his initial open-water certification one month earlier and had fewer than five lifetime dives. He was out on a boat, fishing with several others, when he decided to go diving alone. When the bubbles were no longer coming to the surface, the people in the boat became concerned. The body was not found until two days later. The decedent had several weights in his pockets, making dumping weights very difficult. The medical examiner determined that drowning caused the man's death. Toxicology was positive for pseudoephedrine, diphenhydramine and phenylpropanolamine.

02-63 Wreck diver, separated from buddy, out of air, later found in wreck
Cause of Death: Drowning due to insufficient air

This 33-year-old male had been diving for 10 years, but his exact experience and certification level are unknown. He and a dive buddy became separated during a deep wreck penetration dive. When the decedent did not surface at the prearranged time, recovery divers went down to search for him. His body was found in a cargo hold of the ship later that day. The decedent's tank was empty; the divers had not used any type of safety line for the dive.

02-64 Cave diver with multiple health problems, including cocaine abuse, separated from buddy, body found one week later
Cause of Death: Drowning due to insufficient air

This 42-year-old male was a certified diver without any formal cave diving certification. He and another diver were in a water-filled mine, making a series of dives. On the third dive of the day, the dive reel holding the safety line jammed, and while the buddy attempted to fix it, the decedent disappeared. A week later, the body was found on the bottom (75 feet / 22.5 meters). The decedent had several medical problems, including hypertension, depression and a past history of cocaine abuse. He had reported being very fatigued between dives. The cause of death is most likely drowning, but a cardiac event or other natural disease process certainly may have been a contributing factor.

02-68 Experienced but poorly conditioned diver ran out of air, found next day at depth
Cause of Death: Drowning due to insufficient air

This 24-year-old male was an advanced open-water diver with 60 lifetime dives and nitrox certification. He and another diver planned a decompression dive to 150 feet / 45 msw on air. The diver was morbidly obese and had been drinking alcohol the previous night. The divers made a shore entry dive into a quarry. The decedent appeared to panic at depth and struggled with his buddy before losing consciousness. The buddy was being dragged deeper and eventually lost his grip on the decedent as he tried to pull the unconscious diver to the surface. The decedent's body was recovered the next day at 140 feet / 42 meters. Nitrogen narcosis likely contributed to the fatal outcome of this dive.

02-82 Diver training for deep diving certification, ran out of air, panicked, body found two days later
Cause of Death: Drowning due to insufficient air

This 33-year-old male was under instruction for deep diving certification, making a wreck dive and planning to go to 130 fsw / 39 msw for eight minutes. The diver was with his buddy as part of a larger group of eight divers. He ran out of air at depth and began to breathe from his dive buddy's octopus. The diver then panicked and began descending, dragging his buddy with him. The buddy broke free, made an emergency ascent to the surface, and was evaluated for possible decompression sickness at a local hospital. The decedent's body was found two days later. The autopsy report was not made available.

02-86 Inexperienced cave diver entered cave alone, body found days later
Cause of Death: Drowning due to insufficient air

This 47-year-old male was an experienced diver with advanced open-water certification, but no formal training or certification in cave diving. He was in a cavern with three other divers when he decided to enter a cave system alone and without any safety equipment. The other divers attempted to locate him, but a strong current and abundant silt prevented them from doing so. The diver's body was recovered several days later.

02-88 Diver training for open-water and advanced certification, panicked in poor visibility, body discovered two hours later
Cause of Death: Drowning due to insufficient air

This 37-year-old male was in an instructional course that combined initial open-water and advanced training. He was making a training dive in a quarry, attempting to complete a circle search pattern and employ a lift bag after finding a designated object. Visibility was poor, and for an unknown reason, the decedent panicked and began to struggle with his buddy, attempting to pull his mask off. The buddy went to the surface for assistance. The decedent's body was recovered two hours later. The medical examiner determined the cause of death to be drowning.

Proximate Cause: Drowning / Various Causes

02-02 Advanced open-water diver experienced equipment problems on surface before night dive, separated from buddies
Cause of Death: Drowning

This 46-year-old male had advanced open-water certification and an unknown amount of diving experience. He made a shore entry night dive with two other divers in a strong current. While the three divers were making the surface swim to the descent point, the decedent stated he had a problem with his buoyancy compensation device and told the other divers to go on ahead. The diver was not seen again until the Coast Guard recovered his body several hours later. The equipment was apparently in good working order, but the buoyancy compensator may not have been connected properly. In addition to changes associated with drowning, the autopsy disclosed moderate coronary artery atherosclerosis. The medical examiner ruled the death a drowning. Cardiovascular disease may have contributed to the outcome.

02-06 Experienced cave diver had possible seizure while making cave dive on nitrox
Cause of Death: Drowning

This 30-year-old female had technical diving certification and extensive diving experience. She made a cave dive to 100 feet / 30 meters for 86 minutes using nitrox (36 percent oxygen). The decedent had made one other dive during the previous 24 hours. During the second dive, the decedent was observed to twitch at depth during the ascent phase, but she did not have a witnessed seizure. The diver dropped the regulator from her mouth but would not take an alternate gas source. Her dive buddies, who skipped 22 minutes of obligated decompression time, brought her to the surface. The cause of death was determined to be drowning, though the contribution of oxygen toxicity, which would be unusual at that depth, cannot be excluded.

02-12 Diver on divemaster training dive, in poor physical condition, lost consciousness on surface
Cause of Death: Drowning

This 47-year-old male was an experienced rescue diver and under instruction for his divemaster certification. He was overweight and not physically fit. After surfacing from a dive, he complained of not feeling well and then rapidly lost consciousness while still in the water. The autopsy disclosed changes consistent with drowning, but the history is also consistent with an air embolism.

02-13 Inexperienced diver had trouble trying to assist buddy, found on bottom later
Cause of Death: Drowning

This 24-year-old female received her initial open-water certification seven months previously and had 15 lifetime dives. She and a buddy were making a dive to 60 fsw / 18 msw. The decedent's buddy was having difficulty with his weight belt, and she attempted to render assistance. While coming to her buddy's aid, the decedent dropped the regulator from her mouth; the buddy attempted to assist her. The dive buddy then lost his weight belt and had to surface. On the way to the surface, the dive buddy lost a fin, and his tank became unattached from the harness. The decedent was found on the bottom 15 minutes later, unconscious and with the regulator out of her mouth. The autopsy demonstrated changes consistent with drowning.

02-14 Solo diver with limited experience, improperly assembled equipment, struggled on surface, body found later the same day
Cause of Death: Drowning

This 46-year-old male received his initial open-water certification 14 months previously but had minimal diving experience. He made a shore entry dive into a shallow pond alone. He was seen to struggle on the surface and called for help. The decedent's wife could not pull him to shore, and other divers recovered his body later in the day. In addition to changes consistent with drowning, the autopsy disclosed moderate atherosclerosis of the coronary arteries. The decedent's buoyancy compensation device had not been connected.

02-25 Poorly conditioned diver lost consciousness at safety stop
Cause of Death: Drowning

This 32-year-old male with open-water certification made a dive to 90 fsw / 27 msw from a boat down to a wreck. He and his buddy did not penetrate the wreck. After 10 minutes, they aborted the dive due to an undetermined problem. The buddies made a normal ascent to the surface, but the decedent lost consciousness after the safety stop. The autopsy disclosed changes associated with drowning and no anatomic signs of arterial gas embolism. The medical examiner determined the death to be due to drowning. The decedent also had mild coronary artery disease and was obese.

02-27 Experienced but overweight diver lost consciousness at surface
Cause of Death: Drowning

This 57-year-old experienced certified diver made a dive from a boat with a buddy. He was overweight but had no other reported health problems. On the bottom, the decedent signaled that he was having problems. They surfaced, and the decedent lost consciousness. An autopsy was not performed. A cardiac event certainly cannot be excluded.

02-29 Specialty certified diver with unknown amount of experience lost consciousness on bottom
Cause of Death: Drowning

This 35-year-old male was a dive shop owner with specialty certification but an unknown level of diving experience. He made multiple dives on the first day of a dive trip; the final dive of the day was a night dive. The decedent and his buddy were making the dive from a boat. The dive buddy reported that the decedent suddenly lost consciousness on the bottom. Resuscitation efforts were unsuccessful. The cause of death was listed as drowning, but a cardiac event or cerebrovascular accident cannot be excluded without the autopsy report, which was not available.

02-34 Intermediate diver on night dive separated from group, body found later
Cause of Death: Drowning

This 39-year-old male had advanced open-water certification with approximately 40 lifetime dives and three years of experience. He made a shore entry night dive with two other divers. After five minutes at 30 fsw / 9 msw, the decedent was noticed to be missing from the group. The dive buddies then ascended to look for him. The body was recovered one hour later. The autopsy report was not made available, and the cause of death was determined to be drowning. Despite the fact that some witnesses reported hearing the decedent at the surface calling for help, the dive computer does not show an ascent at any time during the dive. A cardiac event cannot be excluded.

02-41 Advanced student on night dive, separated from buddy, found next day
Cause of Death: Drowning

This 27-year-old female had received her initial open-water certification three months earlier and had made only four checkout dives in the past. She was under instruction for an advanced certification and was making a night dive as the third dive of the day. The divers intended the shore entry lake dive to be to a depth of 30 feet / 9 meters, but they found themselves at 67 feet / 20.1 meters with poor visibility. The decedent signaled to her buddy that she was going to ascend. When he reached the surface, she could not be found. The body was recovered 24 hours later. Toxicology was positive for an antihistamine, acetaminophen and a muscle relaxant. The death was ruled a drowning.

02-45 Poorly conditioned solo diver with unknown certification, found with regulator out of his mouth
Cause of Death: Drowning

This 38-year-old male was a certified open-water diver, possibly with specialty or technical diving certification. He made a solo dive from a liveaboard dive boat and was found at 52 fsw / 15.6 msw, with his regulator out of his mouth. The autopsy showed an absence of coronary artery disease or other natural disease processes, except for obesity. The cause of death was determined to be drowning.

02-47 Inexperienced diver with multiple health problems separated from buddy, body found later
Cause of Death: Drowning

This 36-year-old male received basic open-water certification eight years earlier but had not made a dive in more than a year. He had surgery on his back for a disc problem two years earlier; he also had allergies and a sinus infection for which he was taking antibiotics. The decedent and a buddy made two reportedly uneventful shallow dives from a boat. After the safety stop during the second dive, the decedent's buddy went to the surface, but the decedent did not follow him. The decedent was found unconscious on the surface a short time later, and resuscitation efforts were unsuccessful. The autopsy report was not made available, but the cause of death was determined to be drowning.

02-51 Diver with unknown certification and experience level, separated from buddy, body recovered later
Cause of Death: Drowning

This 37-year-old female had an unknown certification status and level of experience. She made a shore entry dive with a buddy but was uneasy in the water and never descended. The decedent returned to shore, and her buddy continued to dive. When the buddy returned to shore, he found that the decedent had gone back into the water. Her body was recovered later, and an autopsy was performed. The report was not made available, but the cause of death was determined to be drowning.

02-54 Experienced solo diver found on surface, equipment not completely assembled
Cause of Death: Drowning

This 50-year-old male had advanced open-water certification and was an experienced diver. The diver had engaged in solo diving on many occasions. The diver made an initial dive with a buddy, but for the second dive of the day, he entered the water alone. A boater found the decedent floating on the surface unconscious. The diver's fins were clipped to his belt. The autopsy disclosed changes consistent with drowning, but no evidence of significant natural disease. It is unclear why the diver drowned.

02-69 Experienced dive instructor using rebreather apparatus separated from group, body found later
Cause of Death: Drowning

This 32-year-old male was a very experienced dive instructor. With two other divers, he made a shore entry dive into a quarry to provide instruction on a rebreather apparatus. Each of the two dives was made to approximately 40 fsw / 12 msw. At the completion of the dive, the decedent signaled to the others to go to the surface while he continued his dive solo. His body was recovered a few hours later. The autopsy lists the cause of death as drowning, without any contributing factors elucidated.

02-73 Diver with unknown certification and experience level separated from buddy, body recovered 11 days later
Cause of Death: Drowning

This 42-year-old male had an unknown certification status and amount of diving experience. He entered the water with five other divers, became separated from his dive buddy and did not return to the boat with the rest of the divers. The diver's body was recovered 11 days later; after an autopsy the cause of death was determined to be drowning.

02-75 Diver with unknown experience level lost consciousness at surface post dive
Cause of Death: Drowning

This 44-year-old male had open-water certification and an unknown amount of diving experience. Few details are available regarding this dive accident, but the decedent apparently surfaced and lost consciousness. He was pronounced dead at a local hospital. The cause of death was reported to be drowning, but is unclear whether an autopsy was performed. Air embolism or a cardiac event may certainly have been contributory factors.

02-79 Diver made night dive for game collection, descended solo, found on bottom
Cause of Death: Drowning

This 27-year-old male had been a certified diver for five years with an unknown amount of diving experience. He and four other divers were making a night dive from a boat to collect lobster. It was the first-ever night dive for the decedent. The divers entered the water and proceeded to the descent point. They had agreed to descend together, but the decedent submerged prior to the rest of the group. He swam part of the way to the descent point and then disappeared below the surface. The diver was found on the bottom in 30 fsw / 9 msw, unconscious and with the regulator out of his mouth. The autopsy failed to disclose any evidence of natural disease, and the diver had been in excellent physical shape. The cause of death was determined to be drowning.

02-05 Experienced but poorly conditioned divemaster, separated from buddies on ascent, body found entangled in wreck 10 months later
Cause of Death: Drowning due to entrapment in a wreck

This 50-year-old male was an experienced divemaster making a wreck dive with two buddies. He was morbidly obese. The three divers made a planned decompression dive to 125 fsw / 37.5 msw. The decedent signaled that he wanted to ascend. The three divers became separated on the way up. The diver's body was recovered by another group of recreational divers 10 months later. The body was entangled in the wreck, and the decedent had removed his weight belt, but it had become entangled in his catch bag. The autopsy report was not made available.

02-85 Open-water student, entangled in branches on bottom, separated from buddy, body recovered later
Cause of Death: Drowning due to entanglement in vegetation

This 33-year-old female was a student in an initial open-water class. She was making her very first checkout dive in a group that consisted of two buddy teams and an instructor. She and her male buddy became separated from the group and then became somewhat entangled in branches that were near the bottom. They signaled to each other to ascend, but the decedent did not follow him to the surface. The body was recovered an hour later.

02-39 Nitrox cave diver on fifth day of diving had seizure at depth, died later that day
Cause of Death: Drowning due to seizure

This 57-year-old experienced cave diver made a shore entry dive to explore a cave system with an equally trained buddy. This was their fifth day of diving. The divers were using enriched air (32 percent) and were at 95 feet / 28.5 meters when the decedent had a seizure that the buddy witnessed. The dive buddy put his alternate air source into the stricken diver's mouth and brought him to the surface. The diver was pronounced dead later that day in a local hospital. Toxicology was positive for pseudoephedrine, phenylpropanolamine and a sedating antihistamine. The death was ruled a drowning. Despite the contention by some individuals that the combination of enriched air and pseudoephedrine can cause seizures, the true cause of the seizure in this case is not known.

Proximate Cause: Unspecified or Body Not Recovered

02-35 Intermediate diver on cavern dive lost consciousness, body not found
Cause of Death: Unspecified cause (body not recovered)

This 59-year-old male had advanced open-water certification and 40 lifetime dives, with three years of diving experience. He made a dive to 90 fsw / 27 msw with a buddy as part of a large group. As the group went through a cavern, the two divers found themselves separated from the other divers and ascended. The decedent lost consciousness on the surface, and his dive buddy became disoriented. The body of the decedent was never recovered, and his dive buddy was treated for severe decompression sickness.

02-84 Experienced solo diver made rapid descent, lost consciousness, disappeared at surface, body never found
Cause of Death: Unspecified cause (body not recovered)

This 72-year-old male was an experienced certified diver who had a history of an elevated serum cholesterol level but no other known medical problems. The decedent made a solo dive to deeper than 100 fsw / 30 msw on air. He was in a large group but did not stay with a designated buddy. Another diver witnessed the decedent erratically drop down to 120 fsw / 36 msw before going up to a safety stop at 15 fsw / 4.5 msw. He lost consciousness at the surface. Another diver attempted to render assistance, but the decedent dropped below the surface. The body was never recovered.

02-17 Diver with unknown certification and experience on solo dive, possible suicide
Cause of Death: Undetermined cause

This 26-year-old male had an unknown level of dive experience, and it is not certain if he was a certified diver. He made a shore entry dive without a buddy and was not seen again until his body was recovered three days later. The autopsy disclosed one coronary artery with moderate atherosclerosis and evidence of significant head injury. It could not be determined whether the injuries occurred before death, and the cause of death remains undetermined. A suicide note was found with the decedent's personal effects.

02-21 Experienced but poorly conditioned divemaster lost consciousness after night dive
Cause of Death: Undetermined cause

This 56-year-old male was an experienced divemaster. He was taking chronic anticoagulant therapy for previous blood clots in his lower extremities, and he was overweight. The decedent made a night dive to 30 fsw / 9 msw for 20 minutes and surfaced from the dive complaining of difficulty breathing. He lost consciousness shortly thereafter. An autopsy was performed, but the report was not made available. The pathologist concluded that death was due to "heart failure," but that is unlikely. This may have been a case of immersion pulmonary edema or a cardiac event.

02-22 Diver with unknown experience level lost consciousness before dive
Cause of Death: Undetermined cause

This 59-year-old male had advanced open-water certification and an unknown amount of diving experience. His medical problems included hypertension that was controlled with medication and, for an unknown reason, chronic use of nonsteroidal anti-inflammatory drugs. The decedent entered the water for the first dive of the week for a buoyancy check and returned to the boat because he was uncomfortable in the water. He lost consciousness before getting back into the boat. An autopsy report was not made available. This was most likely a cardiac event as the cause of death.

02-70 Inexperienced, poorly conditioned diver in advanced class lost consciousness at surface post dive
Cause of Death: Death, undetermined cause

This 51-year-old woman had been a certified diver for less than one year and had made fewer than nine lifetime dives. She was a student in an advanced open-water class and made a dive to 80 fsw / 24 msw for 14 minutes. After ascending, she complained of difficulty breathing and lost consciousness. An autopsy was performed, but the report was not made available. The decedent was obese and had locally severe coronary artery disease. She was taking multiple medications. Without more information and the autopsy report, the cause of death could not be determined in this case. A cardiac event or an air embolism is the most likely possibility.

02-87 Diver with unknown certification, experience level lost consciousness on third dive of the day
Cause of Death: Death, unknown cause

There is little information available on the death of this 63-year-old male. His certification level and dive experience is unknown. The dive platform was a boat, and during the third dive of the day, the decedent signaled that he was in trouble and lost consciousness. It is not known if an autopsy was performed, and no specific cause of death was reported.

Proximate Cause: Other

02-66 Diver with unknown certification and experience level panicked at depth, made rapid ascent to surface
Cause of Death: Anoxic encephalopathy due to air embolism

The diving experience and certification level of this 50-year-old male is unknown. He was making a dive in a freshwater spring that included a cave system, but it does not appear that he entered the cave. He was seen to panic at depth, and he made a rapid ascent to the surface. The medical examiner determined the cause of death to be complications of decompression sickness, but it should more appropriately be stated as complications of air embolism.

02-32 Experienced divemaster lost consciousness on swim back to shore, died four days later
Cause of Death: Hypoxic encephalopathy due to near-drowning

This 26-year-old female was a very experienced divemaster making a shore entry dive to provide instruction for students. The dive was made in a kelp bed. After completing the dive, the decedent went back below the surface on the way back to shore and lost consciousness. Four days later in a local hospital, she died of complications of near-drowning. An equipment evaluation revealed that the auto-inflator hose for the buoyancy compensation device was not connected.

02-74 Experienced technical diver using mixed-gas rebreather apparatus ran out of breathing gas, made rapid ascent to surface, died after hyperbaric treatment
Cause of Death: Decompression sickness

This 54-year-old male was an experienced technical diver who had logged hundreds of dives. He was taking medications for depression and hypertension as well as an anti-seizure medication. The decedent was making a deep dive for wreck penetration, using a mixed-gas rebreather. After 30 minutes at 248 fsw / 74.4 msw, he ascended, out of breathing gas and went directly to the surface. He made no decompression stops. The diver was conscious at the surface and was taken to a medical treatment facility. He was treated with hyperbaric oxygen but had periods of cardiac arrest and died in the intensive care unit later that day. The diver’s equipment was inspected, and no irregularities were found. The decedent certainly suffered from decompression sickness, but a simultaneous air embolism cannot be excluded.

Glossary

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

Antihistamine
Drug that may be part of some "over-the-counter" medicines for allergies and colds. Some antihistamines cause drowsiness.

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

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

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

BMI (Body Mass Index)
The BMI is computed by dividing body weight in kilograms by the squared height in meters. The BMI is often used as a surrogate for more complex body composition measures. The range of BMIs include: underweight, less than 18.5; normal, 18.5 to <25.0; overweight, 25.0 to <30.0; grade 1 obesity, 30.0 to <35.0; grade 2 obesity, 35.0 to <40.0; and morbid obesity, greater than or equal to 40.0.

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

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

Cerebrovascular
Pertaining to the blood vessels of the brain.

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

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

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

Decompression Dive
A dive that requires decompression stops during ascent according to the dive tables or computer that is used.

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

Decompression Sickness (DCS)
A disease caused when the total gas tension dissolved in a diver's tissue exceeds ambient hydrostatic pressure and gas bubble formation occurs. The symptoms may include itching, rash, joint pain, muscle aches or sensory changes such as numbness and tingling. More serious symptoms include muscle weakness, paralysis or disorders of higher cerebral function, including memory and personality changes. Death can occur from DCS, although very rarely in modern times. See also Type I DCS and Type II DCS.

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

Dive Safety Lab (DSL)
A project similar to Project Dive Exploration developed and conducted by DAN Europe, with shared goals and methodology.

Dive Series
As applied to PDE, all the dives between a period of 48 hours without diving and 48 hours without diving or flying.

Diving Accident Report Form – See DARF

Diving Injury Report Form – See DIRF

DL-7 (Dive Log-7)
A standard computer format for recording information about divers, their dive profiles and medical outcomes..

EAN (Enriched-Air Nitrox)
A nitrogen / oxygen breathing gas mixture containing more than 21 percent oxygen, usually made by mixing air and oxygen. Also known as oxygen-enriched air.

FAD (Flying After Diving)
For this report, all flights within 48 hours after diving are considered "flying after diving." Flying after diving involves exposure of divers to a secondary decompression. The cabin altitude of pressurized commercial airliners must be maintained at 8,000 feet / 2,438 meters or less by law. However, most aircraft are only pressurized to around 6,000 feet / 1,800 meters, approximately 80 percent of the atmospheric pressure at sea level. In the first few hours after a dive, a diver may still have enough excess nitrogen dissolved in his body to allow the secondary decompression stress from flying to cause decompression sickness. Unpressurized aircraft may reach altitudes in excess of 8,000 feet. Divers may also be exposed to reduced atmospheric pressure by mountain travel.

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

FSW (feet of sea water)
A unit of pressure synonymous with depth in salt water. Thirty-three (33) fsw is equal to approximately one atmosphere, 1 bar, 14.685 pounds per square inch, or 0.01 kilopascals of pressure. The differences in density of sea water and fresh water result in small pressure differences at the same depth. Therefore, fsw must be distinguished from the ffw (feet of fresh water). The fsw term is traditionally used by Navy and was adopted by the dive industry, while the ffw is rarely used. For metric conversions, the term is msw (meters of sea water).

Heliox – See Mixed Gas

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

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

Lung Barotrauma – See Pulmonary Barotrauma

Mean
The arithmetic average calculated by taking the sum of a group of measurements and dividing by the number of measurements.

Median
The middle value in a range of numbers. Half the numbers are higher than the middle value and half are lower.

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

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

MSW (meters of sea water) - See FSW

Multiday Diving
Dives spread out over a period longer than 24 hours but where the surface interval between successive dives is less than 24 hours.

Multilevel Dive
A dive where the diver spends time at several different depths before beginning his final ascent to the surface. Usually associated with dive computers that allow a diver to ascend gradually from maximum depth while tracking the decompression status. (See page 44.)

Myocardial Infarction
Heart attack. Death of some of the cells of the heart from lack of adequate blood supply resulting from constriction or obstruction of the coronary arteries.

Nitrogen Narcosis
The euphoric and anesthetic effect of breathing nitrogen at greater than sea level. All gases except helium have an anesthetic effect when their partial pressure is increased. Because nitrogen is the principal component of air, its anesthetic effect is the most pronounced in divers at depth and may cause serious impairment of mental abilities. Nitrogen narcosis is first noticed when breathing air at depths of 60-100 fsw (18-30 meters of sea water), depending on diver susceptibility.

Nitrox – See EAN and Mixed Gas

No-Decompression Dive or No-Stop Dive
A dive where direct ascent to the surface at 30-60 fsw (9-18 meters of sea water) per minute is allowed at any time during the dive without a decompression stop.

Obesity – See BMI (Body Mass Index)

Oxygen-Enriched Air – See EAN

Oxygen Toxicity
The syndrome caused by breathing of oxygen at greater than sea level pressure. Oxygen toxicity primarily affects the central nervous system (CNS) and the lungs. CNS oxygen toxicity may come on immediately and be manifested by seizures, twitching, nausea and visual or auditory disturbances. It may occur in a highly unpredictable manner at partial pressures greater than 1.4 to 1.6 atm in an exercising diver. The manifestations of pulmonary oxygen toxicity take much longer to develop (hours) but can occur at a lower partial pressure of oxygen (>0.50 atm). Pulmonary oxygen toxicity is caused by inflammation of the lung tissue itself, resulting in shortness of breath, cough and a reduced ability to perform exercise.

PHI (Protected Health Information)
Information that could disclose the identity of a research subject, patient or decedent according to HIPAA. DAN does not disclose PHI to any party other than employees, representatives and agents of DAN who have a need to know.

PSI (Perceived Severity Index)
A measure of the severity of decompression injury (see page 48).

Paresthesia
Numbness or tingling of the skin; a common symptom of DCS in recreational divers.

Pneumomediastinum – See Mediastinal Emphysema

Pneumothorax
A collection of gas in the pleural space (the space surrounding the lungs) which results in collapse of the lung on the affected side.

Pulmonary Barotrauma
Damage to lungs from expanding gas. See Barotrauma

Pulmonary Emphysema
A medical condition commonly caused by smoking that leads to abnormal distension of the lungs resulting from the destruction of its supporting and elastic internal structure.

Pulmonary Overexpansion
Abnormal distension of the lungs. In divers, pulmonary overexpansion usually results from the effects of Boyle's law. It can cause rupture of alveoli and penetration of gas into various surrounding spaces, causing mediastinal emphysema, pneumothorax or arterial gas embolism.

Rapid Ascent
An ascent rate fast enough to put a diver at increased risk of decompression illness (DCI), usually at rates in excess of 60 fsw, or 18 msw, per minute.

Repetitive Dive
For the purposes of DAN's injury reporting, a repetitive dive is any dive occurring within 24 hours of a previous dive. The previous dive affects the decompression requirements of the repetitive dive. Some decompression computers carry over information from previous dives for 24 hours or longer, depending on the decompression model used.

Safety Stop
A halt in the planned ascent to the surface (usually for 3-5 minutes at 10-20 fsw / 3-6 msw) intended to reduce risk of decompression injury. A safety stop is not a decompression stop required by tables or a dive computer.

SERF (Scuba Epidemiological Reporting Form)
A new injury recording system for DAN that replaces the DIRF. It emphasizes collection of recorded dive profiles. (See page 52.)

Square Dive
A dive in which the descent is made to a given depth and where the diver remains for the entire dive before ascending to the surface. (See page 44.)

Subcutaneous Air (Subcutaneous Emphysema)
Air under the skin after pulmonary barotrauma. The most frequent location is around the neck and above the collarbones where the gas may migrate after pulmonary overexpansion.

Trimix – See Mixed Gas

Type I DCS (DCS I, Musculoskeletal DCS)
Decompression sickness where the symptoms are felt to be non-neurological in origin such as itching, rash, joint or muscle pain.

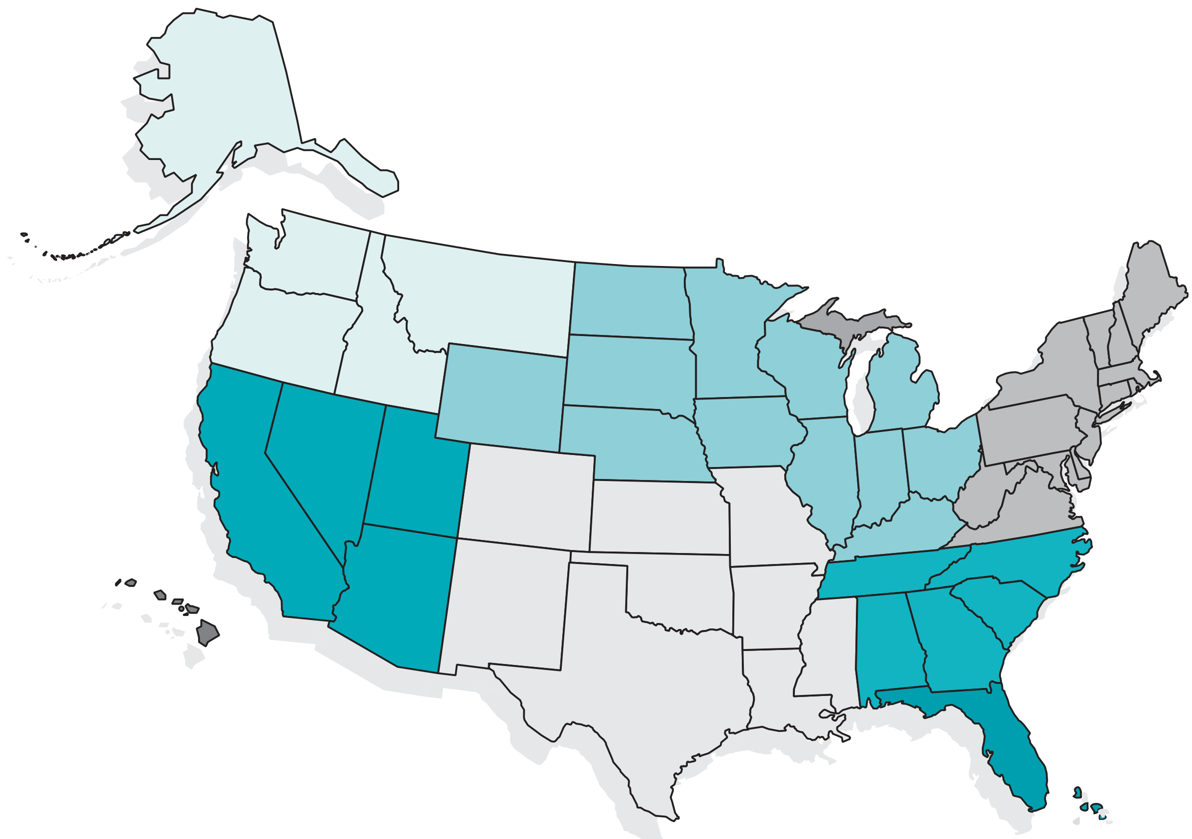
Type II DCS (DCS II, Neurological or Cardiopulmonary DCS)
Decompression sickness where there is any symptom referable to the nervous or cardiovascular system.

Type III DCS (DCS III)
A more serious type of DCS that is sometimes seen after long deep dives with a rapid ascent. Type III DCS is thought to be caused by the occurrence of arterial gas embolization after a dive where a large quantity of inert gas has been absorbed by the tissues. Presumably the arterial bubbles continue to take up inert gas and grow, causing a deteriorating clinical picture that becomes rapidly worse.

URI (Upper Respiratory Infection)
The most frequently reported acute health problem from the DAN sample of injured divers.

INJURIES & FATALITIES BY REGION & STATE 2002

(Total number used in report analysis)



Southeast Region	Fatality 4	Injury 11
Alabama	1	3
Georgia	1	0
North Carolina	2	7
South Carolina	0	1
Tennessee	0	0

Southwest Region	11	18
Arizona	0	0
California	11	18
Nevada	0	0
Utah	0	0

Northeast Region	10	29
Connecticut	0	0
Delaware	0	2
Maine	0	0
Maryland	0	0
Massachusetts	3	6
New Hampshire	0	1
New Jersey	2	5
New York	2	6
Pennsylvania	1	3
Rhode Island	1	3
Vermont	1	1
Virginia	0	1
West Virginia	0	1

Gulf Region	Fatality 2	Injury 6
Arkansas	2	0
Colorado	0	0
Kansas	0	0
Louisiana	0	0
Mississippi	0	1
Missouri	0	0
New Mexico	0	0
Oklahoma	0	1
Texas	0	4

Midwest Region	6	18
Illinois	0	3
Indiana	1	0
Iowa	0	0
Kentucky	0	0
Michigan	2	7
Minnesota	0	2
Nebraska	0	0
North Dakota	0	0
Ohio	3	1
South Dakota	0	0
Wisconsin	0	2
Wyoming	0	0

Northwest Region	Fatality 4	Injury 30
Alaska	1	1
Idaho	0	0
Montana	0	0
Oregon	1	0
Washington	2	29

Pacific Region	5	37
Hawaii	5	37
U.S. Territories	0	0

Caribbean Region	29	202
Florida	18	90
Caribbean	11	112

Mexico/Central America Region	6	105
Mexico	3	89
Central America	3	16

Other	12	50
Canada	4	19
Western Pacific	5	16
Middle East	0	1
Europe	2	0
South America	1	14

2003 Publications

Chapters

Caruso JL. Bodies Found In Water. In: Handbook of Forensic Pathology, 2nd ed. Froede RC , ed. College of American Pathologists, 2003.

Caruso JL. The Pathology of Diving Accidents. In: Bennett and Elliott's Physiology and Medicine of Diving, 5th ed. Brubakk AO, Neuman T, eds, 2003.

Hamilton RW, Thalmann ED. Decompression Practice. In: Bennett and Elliott's Physiology and Medicine of Diving, 5th ed. Brubakk AO, Neuman T, eds, 2003.

Moon RE. Treatment of Decompression Sickness and Arterial Gas Embolism. In: Diving Medicine, 4th edition. Bove AA, ed., 2003 (in press).

Moon RE, Gorman DF. Treatment of the Decompression Disorders. In: Bennett and Elliott's Physiology and Medicine of Diving, 5th ed. Brubakk AO, Neuman T, eds, 2003.

Vann RD. Inert Gas Exchange and Bubbles. In: Bennett and Elliott's Physiology and Medicine of Diving, 5th ed. Brubakk AO, Neuman T, eds, 2003.

Vann RD. Mechanisms and Risk of Decompression. In: Bennett and Elliott's Physiology and Medicine of Diving, 5th ed. Brubakk AO, Neuman T, eds, 2003.

Journal Articles

Buch DA, Moalem HE, Dovenbarger JA, Uguccioni DM, Moon RE. Cigarette smoking and decompression illness severity: a retrospective study in recreational divers. Aviat Space Environ Med 2003; 74(12): 1271-1274.

Mummery HJ, Stolp BW, Dear GD, Doar PO, Natoli MJ, Boso AE, Archibald JD, Hobbs GW, El-Moalem HE, Moon RE. Effects of age and exercise on physiological dead space during simulated dives at 2.8 ATA. Journal of Applied Physiology 2003, 94: 507-517.

Pollock NW, Natoli MJ, Gerth WA, Thalmann ED, Vann RD. Risk of decompression sickness during exposure to high cabin altitude after diving. Aviat Space Environ Med 2003; 74(11): 1163-1168.

Abstracts

Caruso JL, Uguccioni DM, Ellis JE, Dovenbarger JA, Bennett PB. Buddy versus solo diving in fatal recreational diving accidents. Undersea Hyperbar Med 2003; 30(3): 210.

Cronje FJ, Freiberger JJ, Denoble PJ, Vann RD, Dear GD. Computer-based, graphically-guided neurological recording system for neurological decompression illness - the diving neurocheck. Undersea Hyperbar Med 2003; 30(3): 210.

Denoble PJ, Vann RD, Uguccioni DM. The incidence of decompression illness among recreational divers: effects of geography and dive style. Undersea Hyperbar Med 2003; 30(3): 208.

2003 Publications

Denoble PJ, Uguccioni DM, Forbes R, Vann RD. The incidence of decompression illness in recreational divers is not homogeneous. Undersea Hyperbar Med 2003; 30(3): 208.

Robison JD, Reed WL, Freiberger JJ, Pollock NW. Perceived quality of life among previously injured recreational divers: a pilot study. Undersea Hyperbar Med 2003; 30(3): 212-213.

Wachholz CJ, Denoble PJ. Air ambulance evacuation cost not correlated to DCI severity or outcome. Undersea Hyperbar Med 2003; 30(3): 242.

Conference Proceedings

Pollock NW. Transthoracic echocardiography (TTE) – a tool to monitor unsafe decompression stress. In: Norton S, ed. Diving for Science 2003: 22nd Symposium. American Academy of Underwater Sciences: Nahant, MA, 2003: 65-71.

Vann RD. Pathophysiological basis of decompression sickness. In: Adjunctive Therapy for Decompression Illness. RE Moon (Ed). Kensington, MD: Undersea and Hyperbaric Medical Society, 2003, pp. 9-20.

Books Edited

Moon RE (Editor): Adjunctive Therapy for Decompression Illness. Proceedings of the 53rd Workshop of the Undersea and Hyperbaric Medical Society. Kensington, MD: Undersea and Hyperbaric Medical Society, 2003.

Notes

DAN®

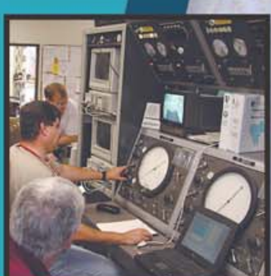
Always There for Divers

DAN VISION

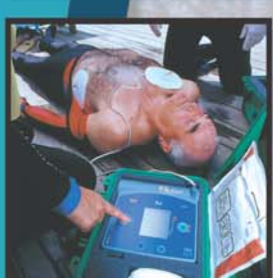
To be the most recognized and trusted organization worldwide in the fields of diver safety and emergency services, health, research and education by its members, instructors, supporters and recreational diving community at large.

The only 24-hour, worldwide dive emergency hotline staffed full-time by dive medical professionals, 365 days a year.

DAN *TravelAssist* — Worldwide emergency evacuation and medical assistance.



Scientific research leading to recommendations for improving dive safety for all divers.



Diving first aid and medical courses for recreational divers, instructors and medical professionals.

Divers Helping Divers

To Join DAN, or learn more call 1-800-446-2671 or visit our website at www.DiversAlertNetwork.org

ISBN 0-9673066-5-5

9 780967 306650