Report on Decompression Illness, Diving Fatalities and Project Dive Exploration

The DAN Annual Review of Recreational Scuba Diving Injuries and Fatalities Based on 2001 Data

2003 Edition

by

DAN

Divers Alert Network

Dedicated to

Dr. Peter B. Bennett

The 2003 edition of this report is dedicated to Dr. Peter Bennett, who retires June 30, 2003, in recognition of his long-standing support of dive research and, in particular, his interest in decompression problems. Dr. Bennett had the foresight to recognize that difficult problems do not have easy solutions and that progress requires sustained effort over many years.

Divers around the world have benefited from his dedication and will continue to do so in the future.

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

DATA COLLECTION CENTERS

Nekton Rorqual (Caribbean)	2,745
Robert Forbes	2,413
Cayman Aggressor	2,069

DAN STAFF

Donna Uguccioni	975
Petar Denoble	270

DAN INTERNS (Summer 2001)

Robert Burke	1,096
David Powers	1,033
Clare Spooner	902
Daniel Klaus	268
Dana Burfiend	44

DAN INTERNS (Summer 2002)

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

COZUMEL DATA COLLECTORS

Mateo Guiterrez	3,174
Ricardo Cosio	2,266
Roberto Castillo	1,786

INDEPENDENT FRCS

Total Dives Collected: 1,157

Fabio Amorim
Jeffrey Bianchi
Scott Cook
Renate Eichinger
Gerald Finsen, Jr.
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Barry Hummel
Betty Kjellstrom
Mitchell Ligenza
Emmette Murkette
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INDIVIDUAL USERS OF COCHRAN AND DIVE RITE COMPUTERS (Level 3 Compatible Computers)

Total Dives Collected: 496

Jim Adams
Eric Belrose
Brent Clevenger
James Eager
Bo Harper
Richard Hodgson
Brian Johanek
Angela Lockhart
Manoli Manolis
George Radoczy
Jon Underwood
Sergio Aita
Chris Brown
David Cowan
Michael Graham
Richard Harris
Greg Holtzer
Gabriel Lamarre
Michael Long
Steve Muslin
Murilo Souza
Robert West

DAN Regions and Regional Coordinators for Hyperbaric Treatment

DAN uses a network of approximately 400 hyperbaric chamber facilities in the United States and around the world, of which approximately 200 facilities report decompression illness (DCI) injuries. The DAN U.S. network is now divided into eight regions, each overseen by a Regional Coordinator.

International Headquarters and Southeast Region – Alabama, Georgia, North Carolina, South Carolina and Tennessee
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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 System 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 sponsors, product sales and fund-raising to provide the high level of service the dive community has become accustomed to receiving.

DAN America's Services to the Recreational Diving Community

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 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 2002, DAN answered more than 2,991 calls for emergency assistance from its members and divers on the 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 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 8:30 a.m. to 8 p.m. Eastern Time. On the Medical Information Line, callers may make specific non-emergency medical inquiries.

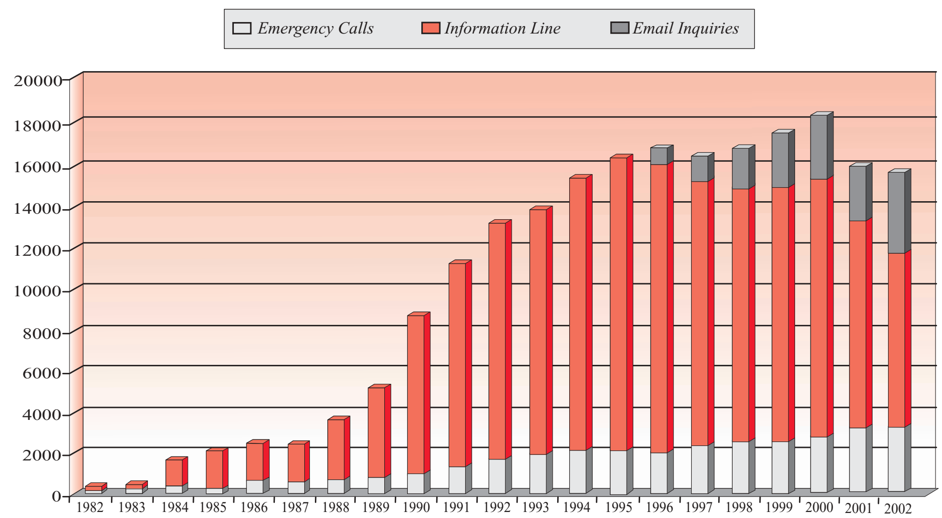
Also, divers can visit the medical pages of the DAN website — www.DiversAlertNetwork.org — where they can find answers to general questions on dive fitness and health.

In 2002, DAN answered more than 2,991 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 2002, DAN's Medical Department received 9,677 information inquiries (including 4,174 emails). Since its beginning in 1980, DAN has helped 225,759 callers through these services.

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

The DAN Research Department is dedicated to the study of diver health issues. Experimental research projects such as the U.S. Navy Flying After Diving and Ascent Rate studies are conducted in the hyperbaric chambers of the Center for Hyperbaric Medicine and Environmental Physiology at Duke University Medical Center (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 get involved, please call DAN Research at 1-800-446-2671 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) diving data. DAN Medicine and Research have published the annual diving report since 1987. Initially, it was a report on injuries and fatalities only but now includes the dive profiles from PDE, in which injuries are rare. The report has shifted focus over the last few years to include more comparison between the three different populations. As more data become available from the three populations, 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 cases as 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's Research Department 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 is currently being written up for publication in a scientific journal. After its publication in the scientific venue, DAN will provide this information to its members. For information on when and where the results will appear, please visit the DAN website.

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 diving to investigate what surface intervals after diving before flying aboard a commercial airliner were safe. In May of 2002, DAN hosted a 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 published in the November / December 2002 issue of *Alert Diver*. The full workshop proceedings will be published in the spring of 2003.

A second flying after diving study, funded by the U.S. Navy, began in May 2002. This study will investigate 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

Project Dive Exploration (PDE) uses recording dive computers to collect information about the depth-time profiles of volunteer recreational divers. As of December 2002, PDE had collected more than 52,000 dive profiles since beginning data collection in 1995. (See Figure 3 on page 23 for a PDE progress summary.) PDE goals are to create a database of safe dives as well as dives that result in injuries. This will provide insight into the behavior, dive profiles and characteristics of recreational divers and their risks of decompression illness (DCI).

Dive computer manufacturers Cochran, Suunto, Uwatec / Scubapro, DiveRite and dive recorder manufacturer ReefNet have strongly supported Project Dive Exploration. Cochran and DiveRite recently introduced 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 integral to PDE data collection. (See the Acknowledgments on Page 4 for a list of FRCs and DCCs from 2001 and 2002.)

Since 1998, DAN and Nekton Diving Cruises have been working closely together on PDE to make it a successful project for both companies. In 2001, DAN began working with the *Aggressor* Fleet liveaboard vessels to collect PDE dives, and in 2002, DAN started working with Peter Hughes Diving.

To participate in PDE while on a dive trip, please visit one of the liveaboard dive vessels currently collecting PDE data year round: *Nekton Pilot, Nekton Rorqual, Cayman Aggressor, Turks and Caicos Aggressor*, Peter Hughes' *Sun Dancer* in Belize, *Wind Dancer* in Turks and Caicos.

You can contact the individual companies to set up trips:

- To participate in a Nekton trip, call 1-800-899-6753 or visit www.nektoncruises.com
- To participate in an Aggressor trip, call 1-800-348-2628 or visit www.aggressor.com
- To participate in a Peter Hughes trip, 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

Aging Diver Study

DAN's Aging Diver Study uses PDE methodology to identify special concerns or issues for divers who are age 50 or older. Of particular interest is the occurrence of equipment problems, dive medical problems, non-dive medical problems and other diving-related incidents.

DAN Research Internship Program

The DAN Research Internship Program began in 1999 with the objectives of expanding Project Dive Exploration data collection and providing experiences that might motivate young people towards careers in diving science or diving-related fields. The Internship Program runs primarily from June through August, and interns are recruited largely from undergraduate students at colleges, universities and medical schools. (Non-student candidates, post-graduate students, and periods other than summer are considered, if appropriate.) 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.

The goals of the internship are to:

- collect dive profile data for Project Dive Exploration;
- provide the Interns with an experience in dive safety research; and
- educate the diving public about DAN and PDE.

Interns are often able to earn college credits for their summer work.

In 1999 the first DAN Research Intern collected more than 900 PDE dives at Discovery Diving in Beaufort, N.C. During the past two summers, DAN has trained a total of nine interns. In 2000, four U.S. interns worked with host dive shops on the East Coast and collected 1,631 dives in two months. In 2001, DAN trained five interns from the U.S. and one from England. The 2001 interns were placed on the East and West Coasts and in the Caribbean and collected more than 3,300 dives in three months.

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 2002, DAN trained six interns from the U.S. and placed them again in popular diving locations in the U.S. and Caribbean. These six interns collected 4,600-plus dives in three months. The application deadline for the 2003 summer program was January of 2003, and DAN received 13 applications from the U.S., Canada and England. DAN will choose eight interns for the summer 2003 program.

Applications for the DAN Internship should be submitted by January for the following summer. Contact the DAN Research Department for application procedures at 1-800-446-2671 or +1-919-684-2948 ext. 260, or visit the DAN website at www.DiversAlertNetwork.org.

Recreational Dive Professionals Study

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

In 2001, a year-round pilot study of recreational diving professionals (instructors and dive guides) was conducted in Cozumel. DAN trained three local dive instructors to collect PDE data from other dive instructors and divemasters. Since January 2001, the three interns have collected 5,248 dive profiles, which included five DCI incidents. Diving instructors and guides are particularly interesting because they dive often, have aggressive dive profiles and appear to have a relatively high DCI incidence (9.5 DCI per 10,000 dives) compared with liveaboard divers (0 DCI per 10,000 dives). This observation led DAN Research to begin a cohort study of diving professionals to determine if their apparently high DCI incidence was an aberration or a true phenomenon.

The Recreational Dive Professionals Study will collect and analyze the exposure and outcome data in dive professionals in Cozumel, Grand Cayman and Brazil. The project began in the spring of 2003 and includes 35 dive professionals from Cozumel, 25 from Grand Cayman and 20 from Fernando de Noronha, Brazil. Each subject in Cozumel and Grand Cayman will receive a dive computer (or an interface if he already owns a compatible dive computer) to record all their dives during two years. In Brazil, one trained Field Research Coordinator (FRC) will collect data from 20 dive professionals carrying DAN-supplied dive computers.

At enrollment, subjects will answer an extensive questionnaire regarding health status, dive training and personal dive practice. Divers will maintain a personal dive log and report outcomes for each dive. They will upload weekly electronic dive profiles from their dive computers to a database. The outcomes will be cross-checked with local recompression chambers for eventual recompression treatments of any subject from the cohort study. The study will be coordinated in the field by FRCs who have been trained and are experienced in PDE methods.

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 Project Dive Exploration. 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 Project Dive Exploration but is applicable in any other project that involves dive data collection.

The purpose of the Computer Recognition Program is to increase 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 Project Dive Exploration. The Sensus depth-time data logger manufactured by ReefNet is also PDE-compatible.

Ascent Rate Study

This study was designed to evaluate the relationship of ascent rate to decompression illness and venous gas emboli (Doppler-detected bubbles). The study objective was to determine if there are differences in the incidences of decompression sickness and venous gas embolism between 10- and 60-foot (3- and 18-meter) per-minute ascents after dives to 100 feet (30 meters). Study dives were conducted at the Center for Hyperbaric Medicine and Environmental Physiology of Duke University Medical Center.

DAN's Support to the Dive Medical Community

Through DAN's 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 and more savings at physicians' locations, hospitals and medical facilities nationwide. The plan is not insurance nor intended to replace insurance, but it does have access for more than 500,000 physicians' 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 while activating the local emergency medical services (EMS) and / or arranging for evacuation to the nearest available medical facility.

In DAN´s most recent dive accident report, fewer than 33 percent of injured divers received emergency oxygen in the field; of these, few received 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 individuals injured in a dive accident.

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 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 hazardous 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 serious cardiac emergency should always prompt an immediate call to the local emergency medical services, Automated External Defibrillators (AEDs) for Scuba Diving 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 new 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.

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 student 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 and the new Advanced Oxygen First Aid program, DAN Instructors and Instructor Trainers will now be able to offer a complete diving emergency program.

DAN Instructors and Instructor Trainers will now be able to offer a complete diving 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 and renew online. Shortly, newcomers to DAN will be able to sign up online as well.

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.

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, DAN's *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.

As of January 2003, more than 214,000 members support DAN in the United States, the Caribbean, Canada and Mexico, as well as members of International DAN affiliates. DAN America members receive the following dive and travel benefits.

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

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 DAN's website at www.DiversAlertNetwork.org.

DAN Tags

In 1995, DAN introduced the first medical ID tag created exclusively for divers: the DAN Tag™. Each clip-on tag is personalized with vital membership, medical and contact information in the unlikely event of a diving emergency. Only DAN members can purchase the DAN Tag. A portion of DAN Tag sales goes directly to support DAN's Diving Emergency Hotline and DAN dive research. As of January 2003, 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.

DAN Industry Membership Program

DAN Industry Membership is a unique membership class for dive retailers 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.

Participants receive special quantity pricing on DAN training materials and safety equipment and selected DAN products for resale. Under the points program, DAN Industry 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 Industry Members will receive *On Board*, the free quarterly official newsletter for DAN Industry Members. 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 Industry Membership 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 Industry Membership program provides its members with great benefits. Call 1-877-5DAN PRO (1-877-532-6776) or +1-919-684-2948 ext. 636 for more information on the program.

DAN Industry Membership is a unique membership class for dive retailers and professionals who want to show their support for dive safety and education.

DAN Diver Identification System (DIDS)

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

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 Industry 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 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

- **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; and
  - Post-dive activities that include the DAN Diver Identification System (DIDS) and dive debriefing.

All DAN PDS new applications and renewals are required to use the DIDS DAN Tag for post-dive roll call of divers. This system may be used in addition to the current required post dive activity, or at minimum it must be the system that is used. To facilitate implementation of the DIDS system, DAN will provide — at no cost to the operator — one board for each dive boat in the operation.

- **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 many divers.

- **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 Industry Membership at 1-877-532-6776 or +1-919-684-2948 ext. 619.

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, you provide your 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.

With the DAN Student Membership Program you provide your students with essential dive insurance that all open-water students should have.

Instructors who don't 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 (1-877-532-2776) or see the "Training & Education" section at the DAN website, www.DiversAlertNetwork.org. Use product code 821-0300 when ordering materials.

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

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 future goals of IDAN include standardization of services and member benefits, greater cooperation in areas of research, education and sharing of dive injury data.

To help reach the increasing diving community in Latin America, DAN provides promotional, membership and training material in Spanish and Portuguese. Also, in 2001, DAN created a dedicated Spanish / Portuguese language emergency hotline (+1-267-520-1507) and a network of chambers and dive physicians to serve all of Central and South America.

In April 2002 DAN Israel, a new DAN Europe affiliate, began operation. The affiliate has its own local emergency hotline.

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

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.

1. INTRODUCTION

Divers Alert Network (DAN) collected data during calendar year 2001 about divers who were injured, divers who died, and divers in Project Dive Exploration for whom injury was rare. These populations are described below. Figure captions give the number of divers on which each figure was based as applicable.

1.1 Diving Injuries

Figure 1 shows the annual record of diving injuries since DAN began collecting injury data in 1987. The upper line in Figure 1 represents the total count of diving injuries of which participating chambers notified DAN. Of 204 chambers, 23 did not treat any diving injuries, and 66 did not report in 2001. The middle line in Figure 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 2001, DAN received notification that 1,170 injured divers had been recompressed. For the first time this number includes reports from all IDAN organizations. DAN America reported 900 treated cases, DAN Europe 126, DAN SEAP 80, DAN Japan 53 and DAN South Africa 11. Each IDAN organization has retained reports from their regions. DAN America has received 522 reports out of 900 treated cases. In 474 cases, reports pertained to recreational divers who resided in the U.S. or Canada. The 522 written reports are described in subsequent sections.

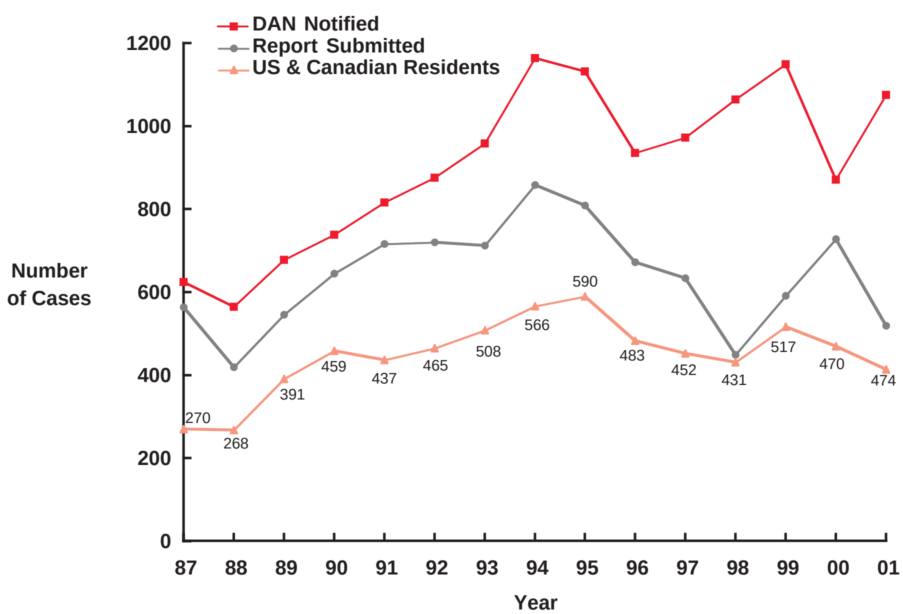


Fig 1
Annual record of dive injury cases.

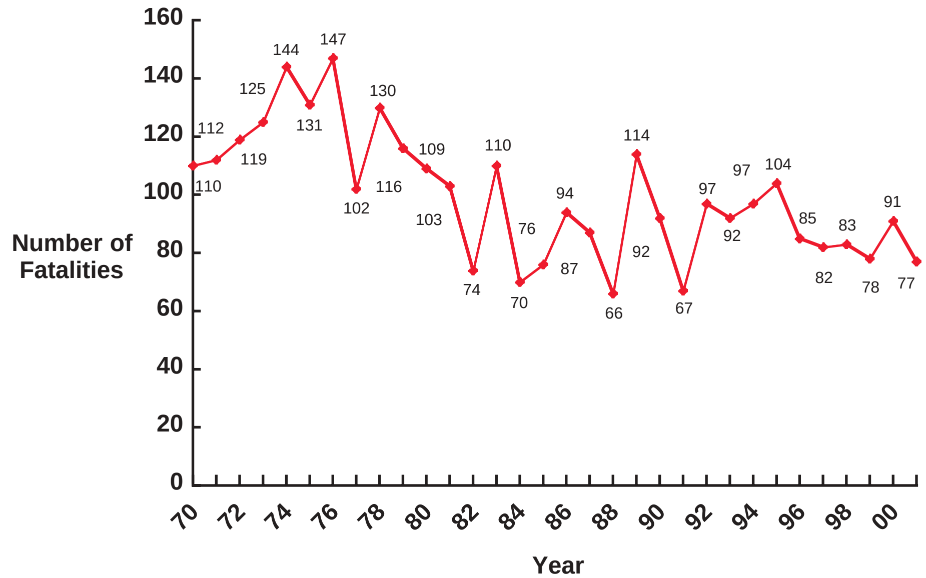
Of 522 reports submitted in 2001, 59 percent were DAN America members, 39 percent were not DAN members, and membership status was unknown for 2 percent. DAN made follow-up calls to divers who did not have total resolution of signs and symptoms upon completion of all recompression therapy at three months, six months, nine months and 12 months, or until they reported full resolution. A selection of representative or interesting case reports is presented in the Appendix.

1.2 Diving Fatalities

Figure 2 shows the annual records of U.S. or Canadian residents who died during recreational diving. 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 2. There were 75 U.S. and two Canadian diving fatalities to make up the 77 reports for 2001. Case summaries for all of these are presented in the Appendix.

Fig 2 Annual record of U.S. and Canadian recreational diving fatalities.



1.3 Project Dive Exploration

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) in this population and to investigate the relationship of DCS (see glossary for definitions of DCS, AGE and DCI) probability to the depth-time profile and diver characteristics. PDE also provides an injury-free control population that can be compared with the injury and fatality populations.

The PDE is funded by Divers Alert Network membership and donors. It was made possible by the development of the downloadable dive computer 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 3 shows the number divers who volunteered for PDE since data collection began in 1995 through 2001, the number of dives they made, and the number of divers who were recompressed for DCI. To date, there have been more than 36,000 dives by 3,750 divers, of whom 22 were recompressed. There has also been one fatality.

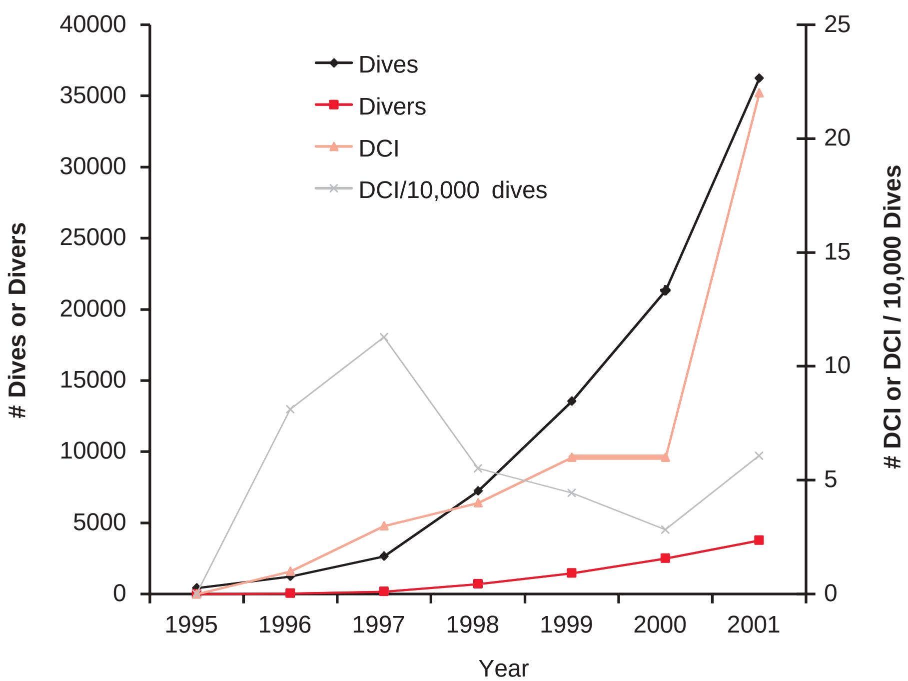


Fig 3
Project Dive Exploration progress.

2. Dive Injuries

2.1 Injury Data Description

In 2001, DAN received reports from 76 hyperbaric chambers that treated 525 injured divers. As in previous years, cases were included in the database if they met the following criteria:

(a) diving was involved and the injury required recompression;
(b) the injury was not a re-treatment of a previous injury (522 cases);
(c) the injured diver was a U.S or Canadian resident engaged in recreational diving (474 cases); and
(d) the report was complete or the follow-up provided required information.

Each case was submitted with a diagnosis assigned by the treating chamber. In previous years, reported diagnoses were accepted without reviewing the agreement between diagnosis and case information. As discrepancies were not uncommon, the diagnosis and case information were reviewed this year, and the diagnosis was updated if significant disagreement was noted, according to the definitions and criteria listed below.

The purpose of the review was to improve the accuracy of the diagnoses and, in particular, to better distinguish AGE from DCS, so that these injuries could be studied independently. In addition to case information submitted with the Diving Injury Report Form (DIRF), information was added from emergency call notes to DAN and subsequent follow-up calls by DAN medics to chambers and injured divers.

To support the diagnosis review, we used the arbitrary severity classification system introduced in the 2002 *Report on Decompression Illness, Diving Fatalities and Project Dive Exploration*. For this report, it is called the Perceived Severity Index (PSI). The PSI classifies cases according to our perception of their severity. The classifications are hierarchical. In order of assigned severity, they are:

1) Serious Neurological
2) Cardiopulmonary
3) Mild Neurological
4) Pain
5) Lymphatic / Skin
6) Constitutional / Non-Specific

Each case was assigned to the category corresponding to its most severe symptom as indicated in Table 1. For example, an injured diver with paresthesias of the feet (mild neurological symptom) would be categorized as a Serious Neurological case if bladder impairment was also present. The PSI was calculated automatically for each case by applying an algorithm based on reported symptoms and findings. We used the PSI as an aid for testing the consistency of reported diagnoses against the case descriptions.

Table 1 Perceived Severity Index (PSI).

Perceived Severity Index	Reported Signs or Symptoms
1. Serious Neurological	bladder or bowl dysfunction
	coordination, ataxia, gait
	consciousness
	hearing, tinnitus
	mental status, dysphasia, memory, mood, orientation, personality
	reflexes
	weakness, hemiparesis, motor weakness, paraplegia, paresis
	vision
2. Cardiopulmonary	cardiovascular, arrythmias, palpitations
	pulmonary, cough, hemoptysis, 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, swelling
	skin, burning of skin, itching, marbling, rash
6. Constitutional / Non-Specific	dizziness, dizziness / vertigo
	fatigue
	headache
	nausea, nausea & vomiting, vomiting
	chills, diaphoresis, heaviness, heavy head, lightheadedness, malaise, restlessness
	vertigo

Definitions and Criteria

Decompression Illness (DCI)

- Includes DCS and AGE
- DCI cases were reclassified to DCS or AGE based on definitions on page 26

Not DCI (differential diagnosis to exclude causes other than DCI)

- Cases with single dives to less than 30 fsw (feet of seawater / 9 meters of seawater, or msw) and symptoms that could not be attributed to AGE
- Symptom onset delayed for more than 48 hours of the last dive or altitude exposure
- Signs and symptoms likely due to a non-diving cause of injury upon review of medical history
- Symptoms resolving spontaneously without recompression in less than 20 minutes with first aid oxygen or 60 minutes without oxygen
- Cases with no response to recompression were reviewed extensively before classification as Not DCI

The majority of DCS II cases were classified as Mild Neurological.

Arterial Gas Embolism (AGE)

- Symptom onset in less than 15 minutes post-dive
- Cerebral neurological symptoms, signs or findings
- Symptom duration greater than 15 minutes
- Rapid ascent, out-of-air, or cardiopulmonary symptoms increased the confidence of an AGE diagnosis

Decompression Sickness (DCS)

- Minimum dive depth of at least 30 fsw
- Headache, dizziness, anxiety, general weakness, fatigue, and subjective numbness and tingling of both hands and feet were not classified as DCS in absence of other symptoms or without objective findings
- Type I DCS (DCS I) included PSIs of Pain, Skin / Lymphatic, and / or Constitutional / Non-Specific
- Type II DCS (DCS II) included PSIs of Serious Neurological, Cardiopulmonary, and Mild Neurological

Ambiguous DCI

- Cases with sufficient exposure but minimal or atypical symptoms

Lung Barotrauma

- Signs and symptoms of mediastinal emphysema, subcutaneous emphysema or pneumothorax, without neurological signs or symptoms

Final Classifications

After reviewing and reclassifying cases according to the definitions and criteria above, 414 cases were retained for analysis as shown in Table 2. At 41 percent, DCS I cases were most frequently reclassified out of 522 reports, followed by AGE (33 percent) and DCS II (12.5 percent). The majority of DCS II cases were classified as Mild Neurological. The majority of AGE cases were classified as Serious Neurological due to the presence of objective cerebral symptoms, such as altered consciousness, but there were a few clear cases of AGE having only mild neurological symptoms.

Several inconsistencies between diagnosis and PSI remained, with the following explanations:

- Three Mild Neurological cases were re-classified as DCS I from DCS II. The primary symptom in these cases was pain; however, mild tingling, paresthesia or change in sensation in the painful limb developed later and generally resolved before treatment, leaving pain as the only symptom.

• One case was classified by the chamber as DCS II, even though pain was the only symptom. We retained the DCS II classification because the pain had a dermatomal (an area of the skin associated with a particular spinal nerve root) distribution suggestive of neurological damage.

Table 2
Final classification of injuries retained for analysis.

Final Classification	# of Cases	Perceived Severity Index			
		Serious Neurological	Cardio-Pulmonary	Mild Neurological	Pain
DCS I	73			3	70
AGE	29	24	1	4	
DCS II	267	112	8	146	1
Lung BT	3		3		
Ambiguous	42	9	1	22	10
Total	**414**	**145**	**13**	**175**	**81**

It is important to understand all the original data were preserved in digital form as submitted and checked. No data were lost in applying the diagnostic criteria described above. These criteria constitute a filter through which the data passed to arrive at the final classification of Table 2.

2.2 Characteristics of Injured Divers

The age of injured divers varied between 13 and 73 years. The distribution of age by sex is shown in Figure 1. Males made up 69 percent of all injured divers and women 31 percent. This was fairly consistent with the sex distribution of previous years. There were five divers who were 16 years old or younger, comprising about 1 percent of the dataset.

The median age of the injured divers in 2001 was 38, nearly two years older than in years 1997-2000. The median age of injured females was the same as the males, which is also different from previous years, when females tended to be younger. Figure 4 indicates that there were proportionally more women in the 30-49 age group, and proportionally fewer who were younger than 30 or older than 50.

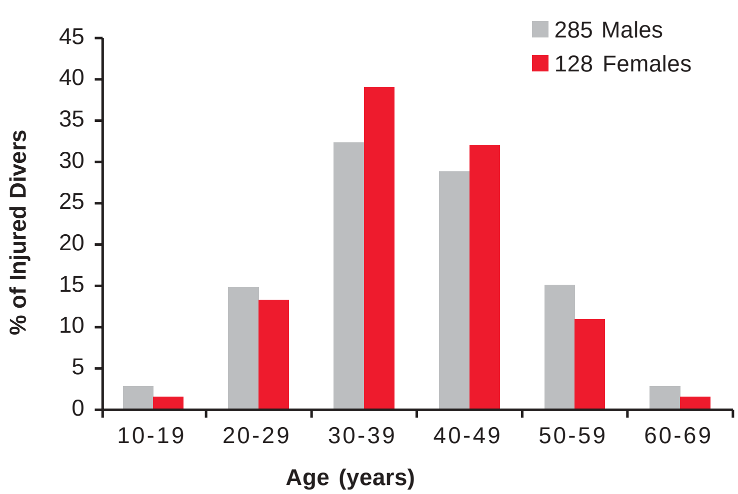


Fig 4
Age of injured divers by gender.

The pre-existing medical problems of injured divers are shown in Table 3. The most frequently reported health problem was upper respiratory infection (URI) or congestion. This category includes allergy and other conditions for which divers took decongestants. Musculoskeletal problems were reported in 53 cases and were the most commonly reported chronic health problem in injured divers. Thirty-six divers reported previous decompression illness (8.65 percent). Less than 10 percent of the injured divers reported that they smoked. There were very few individuals (less than 1 percent) who reported diabetes mellitus or heart disease.

Table 3
Divers health problems present before dive.

Health Problem	Frequency	%
URI / Congestion	78	18.62
Musculoskeletal	53	12.65
Smoking	39	9.31
Previous DCI	36	8.65
Back Surgery	27	6.44
Asthma	27	6.44
HBP	26	6.21
ENT	21	5.01
Seasickness	19	4.53
Psychiatric	12	2.86
Gastrointestinal	9	2.15
CNS	5	1.19
Infections	5	1.19
Diabetes	4	0.95
Heart Disease	4	0.95

Figure 5 shows the highest certification of the injured divers. Openwater and advanced open-water certifications were the most common type of certification, comprising 72 percent of the injuries reported. Instructors constituted 10 percent of reported injuries, and students comprised 2.1 percent. Technical divers are an increasing portion of the injury database and comprised 5.3 percent of the injuries for 2001. Women comprised a higher fraction of basic certification than men. Injured instructors comprised 12 percent of the injured males, yet only 4.5 percent of the females. Higher proportions of instructors and technical divers were male than female.

Fig 5
Certification of injured divers by gender.

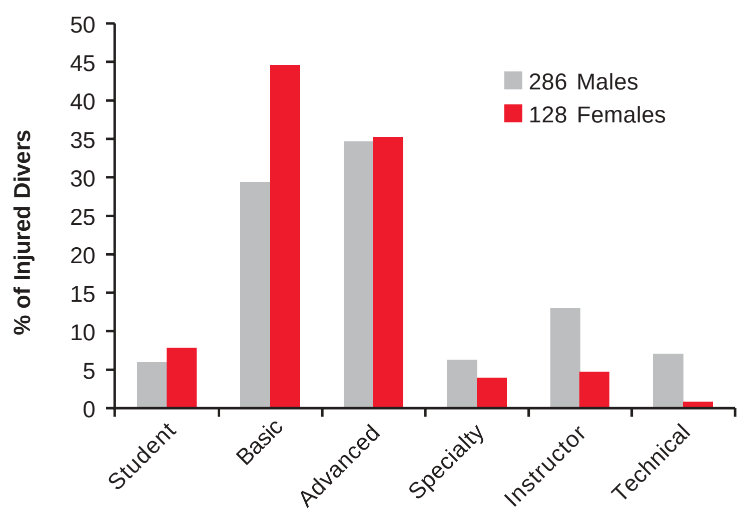


Table 4 indicates that 33 percent of injured students and 10 percent of divers with entry-level certification were classified as having AGE. Errors in diving technique are thought to contribute to pulmonary barotrauma and subsequent arterial gas embolism: students and beginning divers might, therefore, be more likely to have pulmonary barotrauma. The data is consistent with this hypothesis. While divers with students and entry-level certification had 39 percent of all injuries, they contributed 70 percent of the cases of cerebral arterial gas embolism.

Table 4
Diagnosis by certification of injured divers.

Diagnosis	Highest Certification of Injured Diver							
	Total	Missing	Student	Entry-level	Advanced	Instructor	Specialty	Technical
DCS 1	73	1	5	19	25	9	8	8
AGE	29	2	7	14	4	1	1	0
DCS 2	267	12	13	91	97	29	13	12
Lung BT	3	0	0	0	2	1	0	0
Ambiguous	42	0	2	17	16	3	1	3
Total	414	15	27	141	144	43	23	23

Figure 6 shows the years since initial certification. Women, on average, had been diving for 7.2 years and men for 9.6 years. The maximum number of years since certification was 36 for men and 34 for women. Fifty-two percent of injured divers had five years or less experience, 18 percent had five to 10, years and 30 percent had more than 10 years of experience.

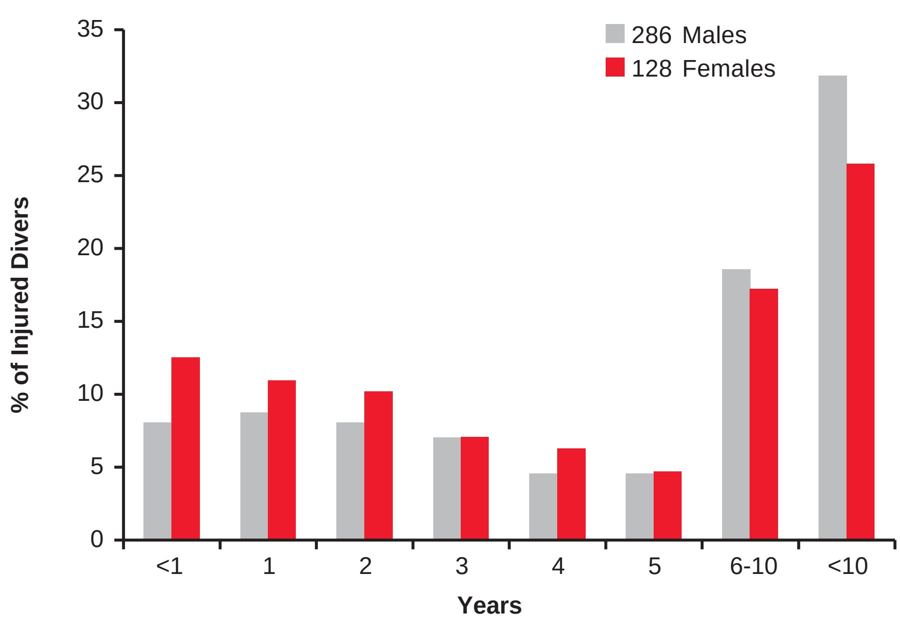
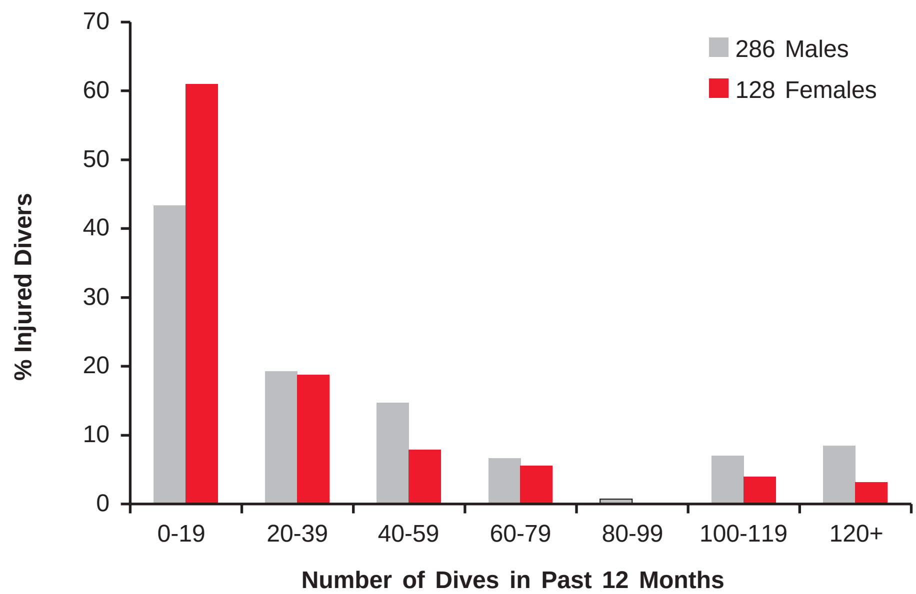


Fig 6
Years since initial certification by gender.

Figure 7 shows the number of self-reported dives in the 12 months preceding the injury. On average, men made 53 dives and women made 32 dives. Forty-five percent of injured men and 60 percent of women had less than 20 dives in the previous 12 months.

Fig 7
Number of dives in past 12 months by gender.



2.3 Characteristics of Dives by Injured Divers

Figure 8 shows the months in which diving injuries occurred for 2000 and 2001. The maximum number of injuries occurred in summer months, as expected. However, while the number of injuries during summer 2000 was relatively constant from May through September, in 2001 there was a peak in August, with a significant drop-off in September and October. This probably reflected the decline in diving tourism in the fall of 2001.

Fig 8
Month in which dive injury occurred.

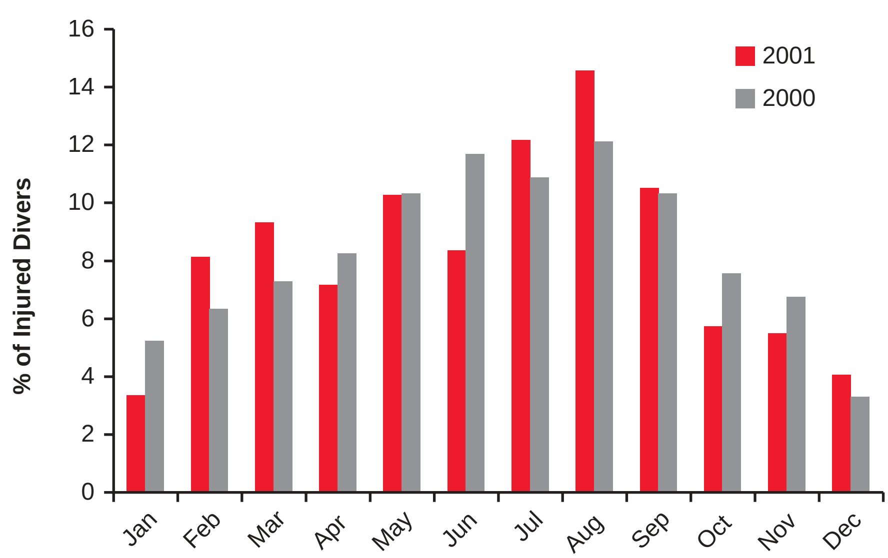


Figure 9 shows the time of day of the last dive before the diving injury. Most dives (89 percent) occurred during daylight hours. The number of injuries during the evening and night (11 percent) was similar to past years.

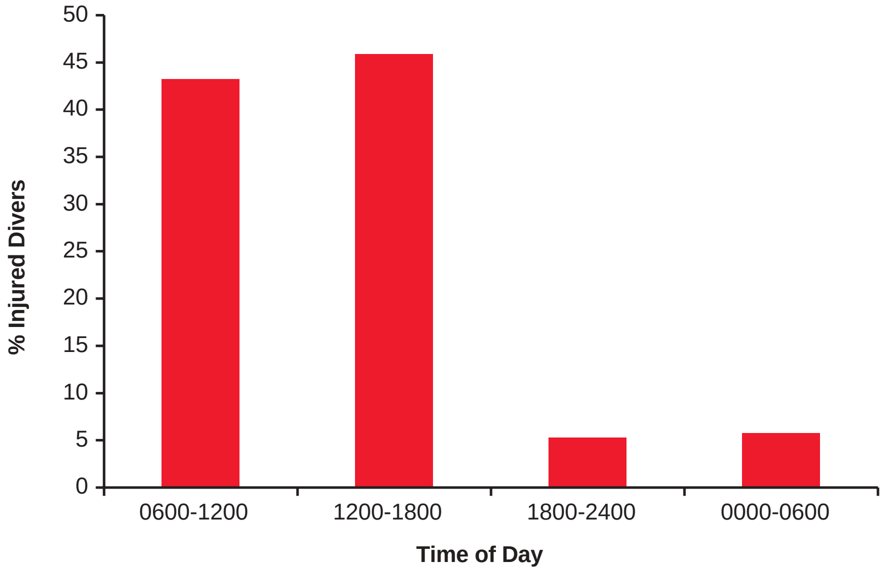


Fig 9
The time of the day of the last dive (N=414).

Figure 10 shows that 38 percent of the U.S. injuries for 2001 occurred in the Northwest and 32 percent occurred in the Southeast. There were nearly double the injuries in the Northwest in 2001 as compared with 2000.

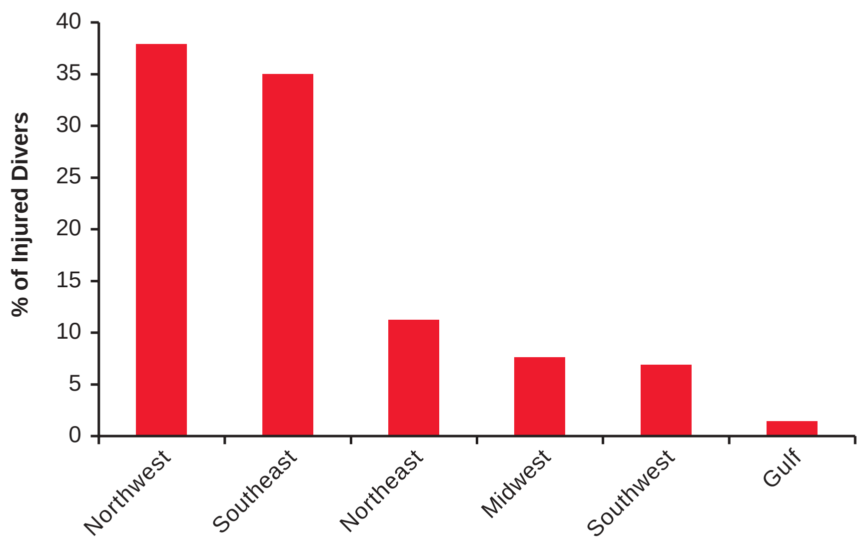


Fig 10
U.S. locations of reported dive injuries (N=277).

As shown on Figure 11, most diving injuries that occurred outside of the U.S. were reported from the Caribbean (192 cases), the most popular diving destination. In addition, there were 18 divers injured in the Pacific islands, 16 from Canada, eight from South America and four from Bermuda.

Fig 11
International locations of diving injuries (N = 238).

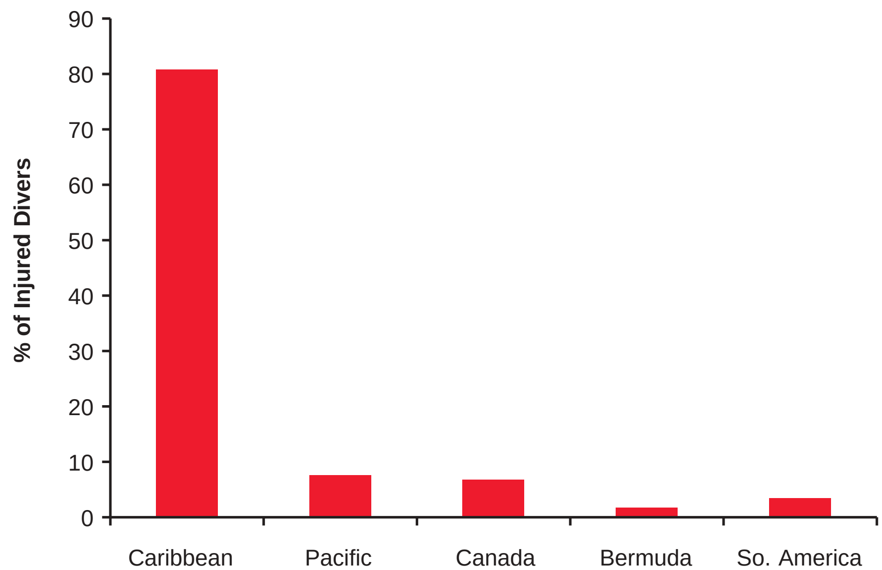


Figure 12 shows the environment in which the diving injuries occurred. The majority of dives (87 percent) took place in salt water, 9.1 percent in freshwater lakes and quarries, and 3.1 percent in caves or caverns.

Fig 12
The environment in which diving injury occurred (N=414).

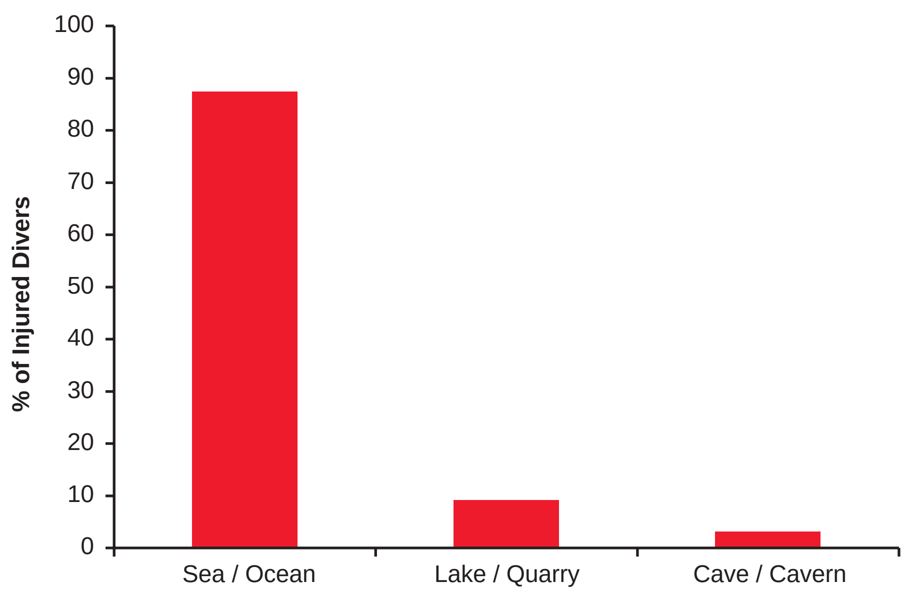


Figure 13 shows the purpose for diving reported by injured divers. As expected, most dives were recreational, including such activities as sightseeing and underwater photography. The second largest group of injuries occurred in divers attempting technical diving (9.8 percent) — this was a significant increase in comparison to 2000. Learning to dive was the main purpose in 8.7 percent of injuries and teaching or guiding dives in 3.1 percent.

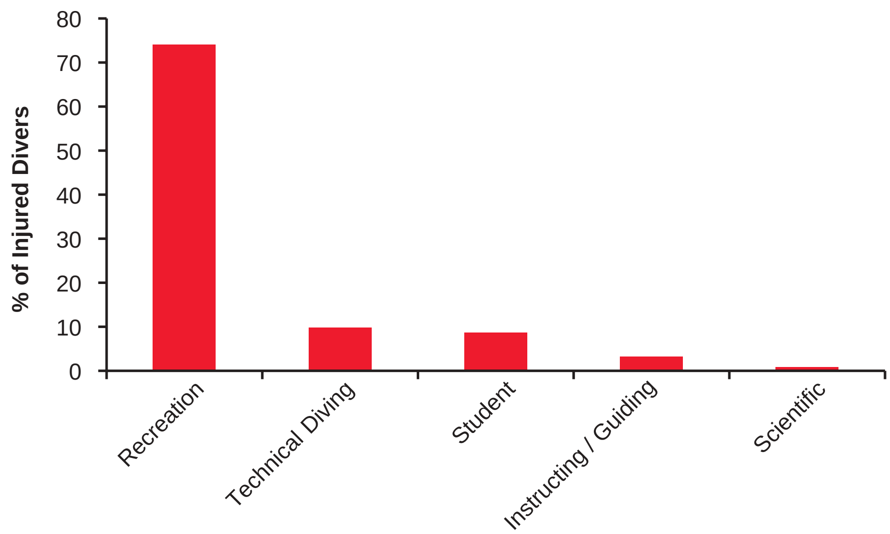


Fig 13
The purpose of dive reported by injured divers (N=414).

Figure 14 shows the thermal protective dress worn by divers. The most common thermal protection was a wetsuit, at 65 percent. Drysuit diving was observed in 17.4 percent of injured divers, somewhat higher than in recent years. Diveskins and swimsuits were both used in less than 10 percent of the dives that resulted in injury.

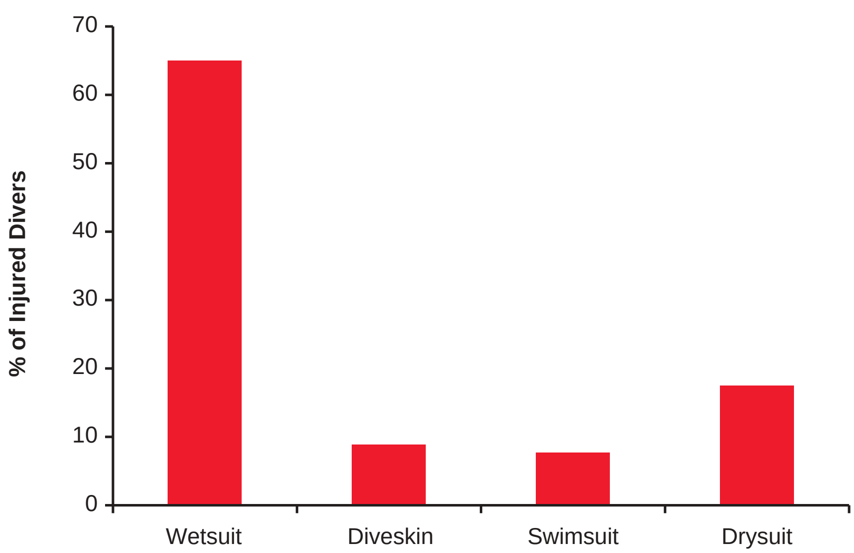


Fig 14
Type of thermal protective dress (N=414).

As in previous years, the largest percentage (96 percent) of the injured divers used open-circuit scuba. Only 3 percent reported using a rebreathing apparatus, and 1 percent was surface-supplied.

Figure 15 shows the breathing gas used by injured divers. Air was used by 85.4 percent of injuries, nitrox by 12.7 percent, and heliox or trimix by 1.2 percent. There was a slight increase in the number of injuries where a gas mix other than air was used, compared to year 2000 data. Injured male divers were twice as likely to use nitrox as women were.

Fig 15 Breathing gas used by injured divers.

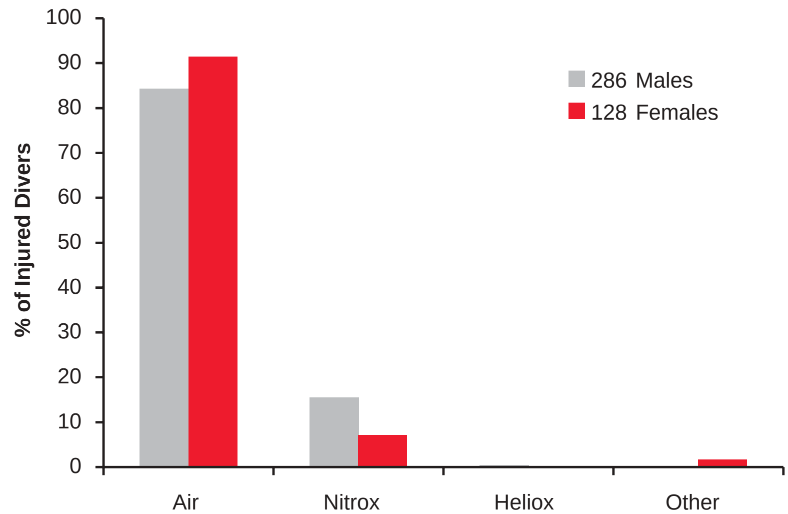


Figure 16 shows the dive planning methods used by injured divers. While the percent of injuries using dive computers (67 percent) was similar to 2000 (73 percent), the number of divers using dive tables is lower (13 percent vs. 20 percent), and the number of guided divers or those that did not report planning methods is higher than previous years.

Fig 16 Dive planning methods used by injured divers by gender.

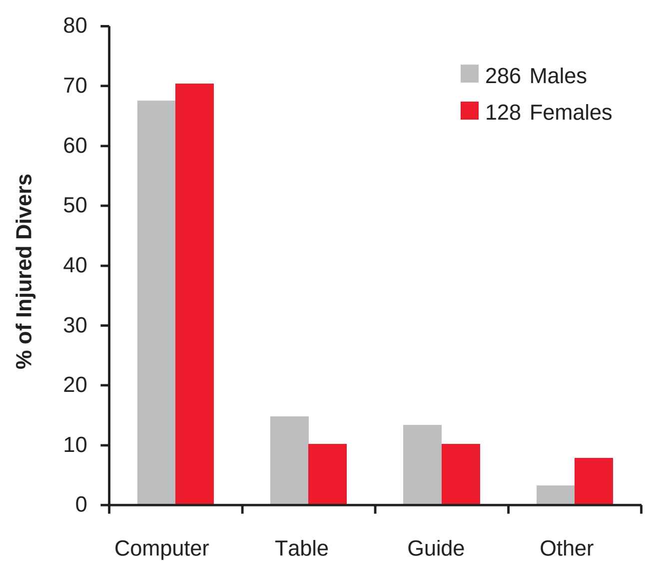


Figure 17 shows the number of consecutive days diving preceding the injury. Most injuries occurred on first day of diving (38.4 percent). The percentage of injuries with the increasing number of days in dive series declines linearly. It is notable that 70 percent of all AGE injuries were reported on the first day of diving.

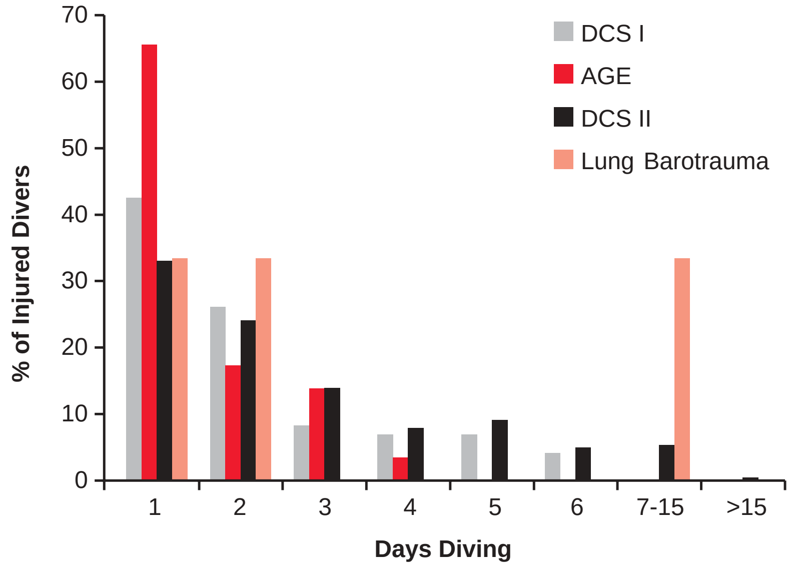


Fig 17
Number of consecutive days diving preceding the injury (N=414).

Figure 18 shows the total number of dives in the series. AGE occurred most frequently after the first dive (52 percent), and 86 percent occurred after five or less dives. DCS II occurred only in 13 percent of cases after the first dive and in 40 percent of cases after six or more dives.

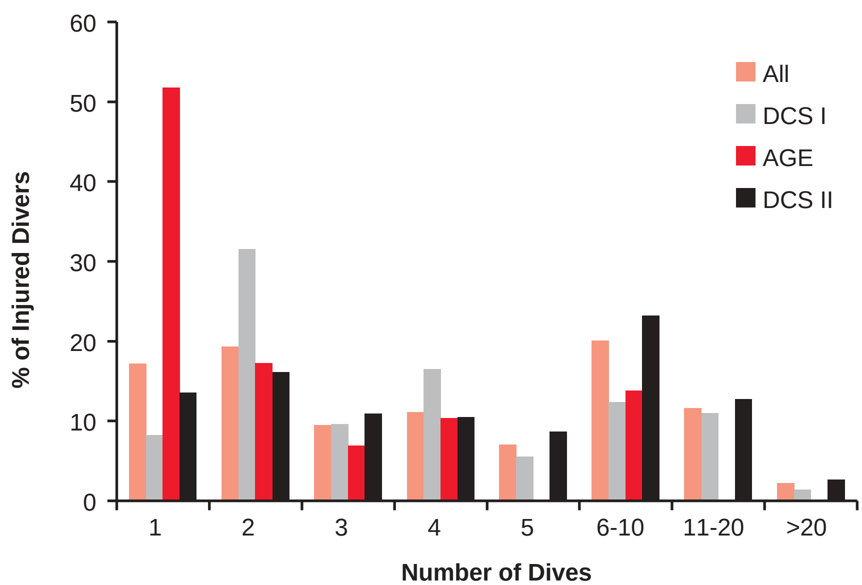
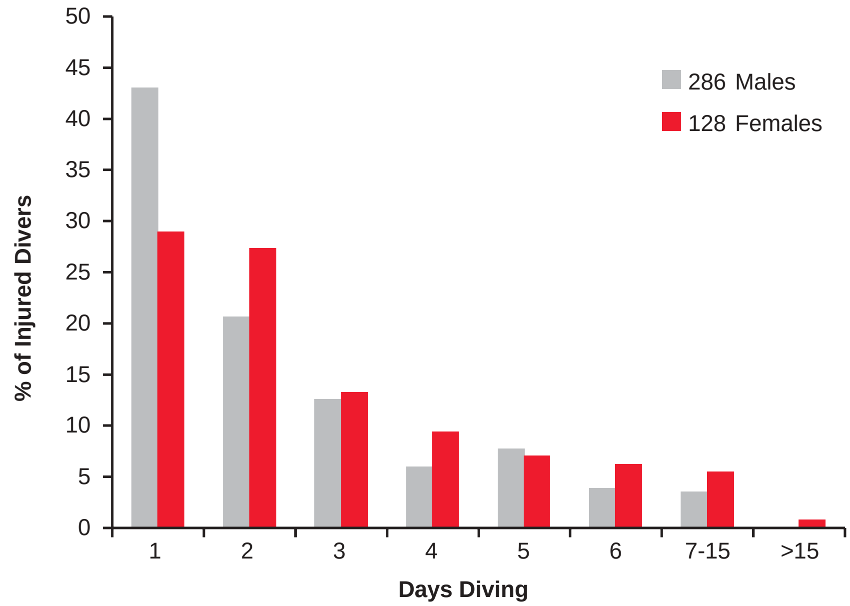


Fig 18
Total number of dives in series by diagnosis of injury (N=414).

Figure 19 shows number of days diving preceding the injury in men and women. Injured men had fewer days in their dive series than did women and were more likely to have been injured on the first diving day.

Fig 19
Number of consecutive days diving by gender.



Similarly, Figure 20 shows the total number of dives preceding the injury. The median number of dives prior to the injury was 4; the mean was slightly greater at 5.3. The median for men was 3, lower than the median for women, which was 4. This corresponds with a higher number of days in the diving series for women.

Fig 20
Number of dives preceding the injury in male and female divers.

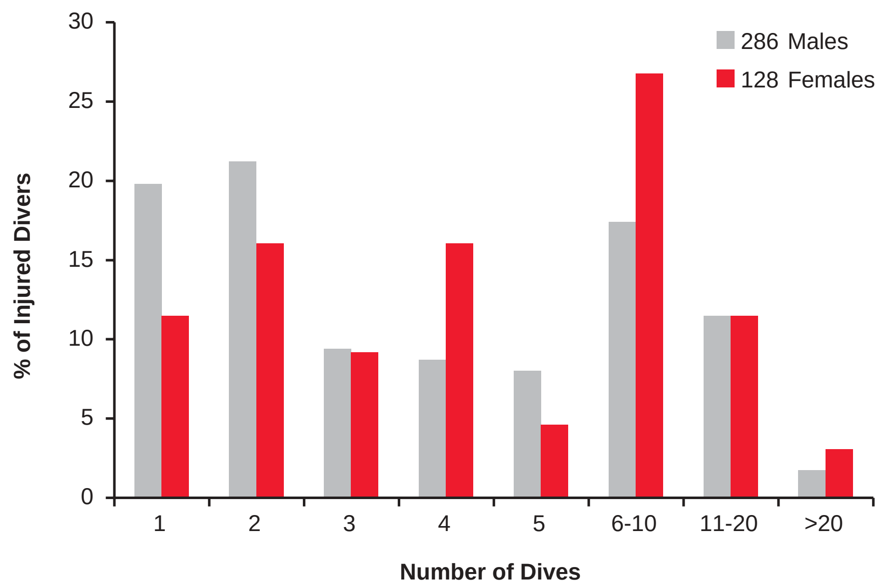


Figure 21 shows the maximum depth in the dive series reported by injured divers. This is not necessarily the last dive before the diver presented for treatment, nor necessarily it is the dive that caused the injury. The shallowest depth reported was 5 fsw (1.5 msw), for AGE; the deepest was 350 fsw (105 msw). The median depth in the series was 90 fsw (27 msw). The median depth for AGE was 75 fsw (22.5 msw), much shallower than the median for all diagnoses for DCS I (90 fsw) or DCS II (92 fsw). The difference in depth between DCS I and DCS II was not statistically significant.

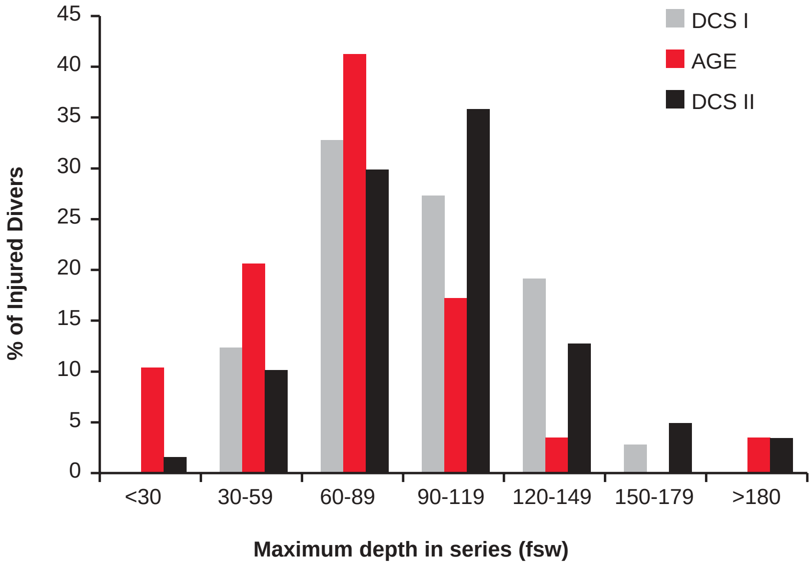


Fig 21 Maximum depth in dive series by diagnosis (N=414).

Figure 22 shows the maximum depth of the last dive by gender. There were some slight differences in distribution of depths by sex, but there were no differences between mean or median depth. This is a change from previous years, when men dived significantly deeper than women.

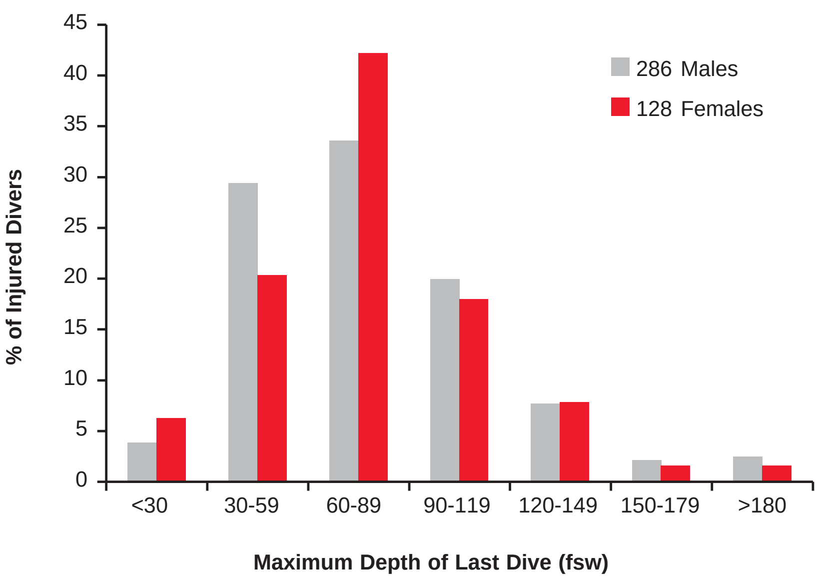
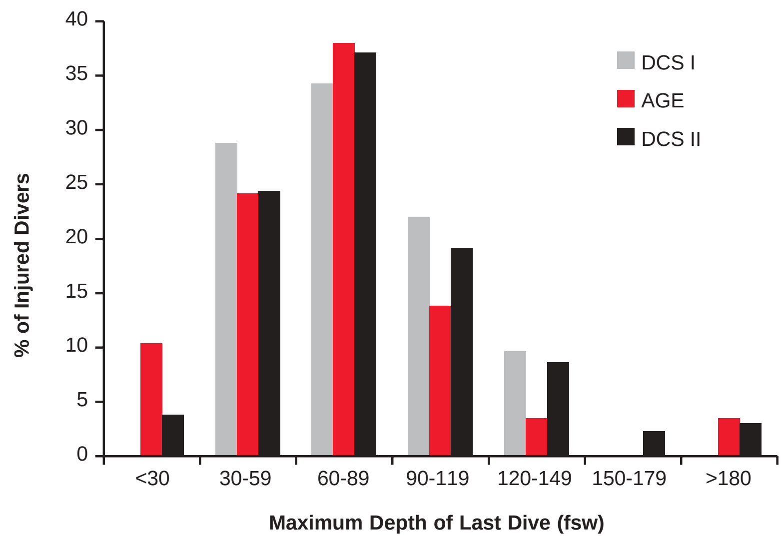


Fig 22 Maximum depth of last dive by gender.

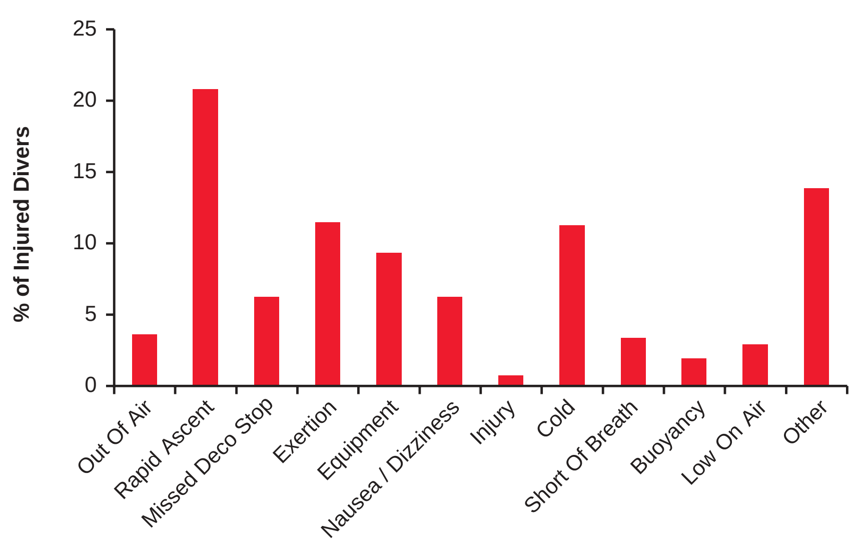
Figure 23 shows the maximum depth of the last dive in a dive series reported by injured divers. The last dive was not necessarily the dive preceding the injury, since about 15 percent of injured divers reported the first symptom onset before the last dive. The shallowest depth of the last dive was 5 fsw (1.5 msw); the deepest was 350 fsw (105 msw). The median depth of the last dive in series was 72 fsw (22 msw). Ten percent of the dives that resulted in arterial gas embolism occurred after dives to 30 fsw (9 msw) or shallower. The pattern of depths of AGE, DCS I and DCS II was the same as the pattern of maximum depth in the series. The maximum depth of the last dive was the shallowest for AGE, and there was no difference in the figures between DCS I and DCS II.

Fig 23 Depth of the last dive by diagnosis (N=414).



In 219 of the cases, or 53 percent, injured divers reported some kind of problem during the dive. Figure 24 shows the percentage of reported problems. The three most commonly reported problems were rapid ascent, feeling cold and exertion.

Fig 24 Frequency of reported problems during dive (N=414).



More than 23 percent of injured divers reported being exposed to altitude after diving. The type of exposure is shown in Figure 25. The most common exposure was during flight in a commercial airliner (54 percent). In 18.6 percent of cases, injured divers were evacuated by air ambulance. Exposure to altitude while traveling by ground over the mountains was reported in 13.4 percent of the injured divers, although it is not specified to what altitude the diver traveled. Flying in an unpressurized aircraft was reported in 8.2 percent and flying by helicopter in 6.2 percent of injuries.

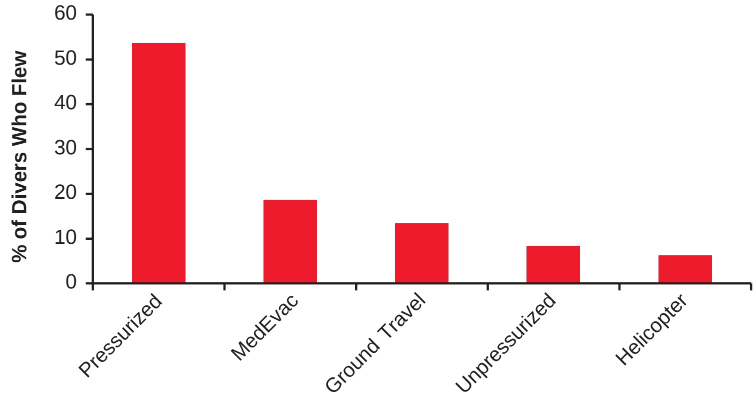


Fig 25
Flying after diving (N=97).

In more than two-thirds of commercial flights, symptoms occurred before flight, and in 24 cases, symptoms occurred during or after flight (Figure 26). As in previous years, injured divers often denied, ignored or did not recognize the fact that they might have DCI. In 60 percent of cases that developed symptoms during or after the flight, the surface interval before flight was less than 24 hours, and in 30 percent it was less than 12 hours. There was only one case with a reported surface interval of greater than 48 hours. When medical evacuations are excluded, there was no difference in the surface interval between those who flew with symptoms and those who did not.

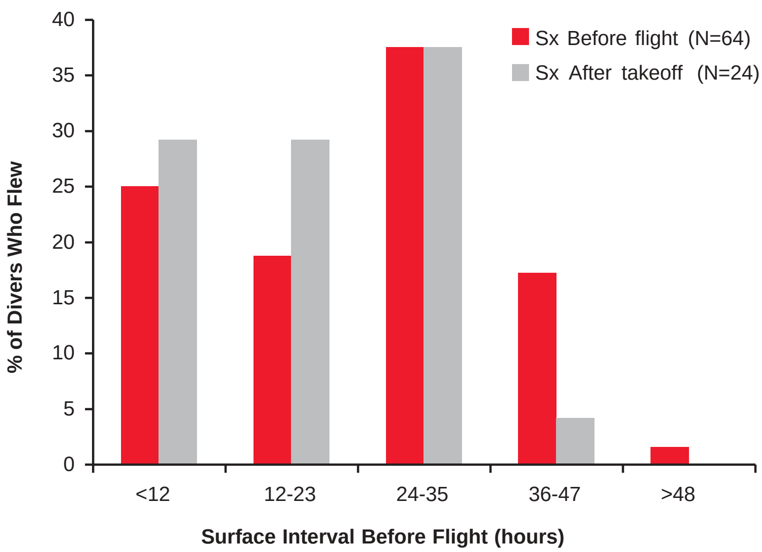


Fig 26
Surface interval before flying after diving and symptom onset.

2.4 Signs and Symptoms in Injured Divers

Figure 27 shows the onset time for the first symptom reported by injured divers. In 15 percent of the cases, symptoms reportedly occurred before the last dive. This indicates that the divers performed one or more dives after recognizing their first symptom. In 6.8 percent of cases, symptoms occurred during the last dive while still underwater. In 72.4 percent of the cases, symptoms occurred after the dive, and in 6.28 percent symptoms occurred during or after a flight.

In half of the cases, symptoms occurred prior to or within one hour after the dive. There were no clear cases of DCS that occurred more than 48 hours after the last dive, and five cases were ambiguous. In the injuries involved with flying after diving, the median symptom onset time was 29.7 hours (range two to 102 hours).

Fig 27 Symptom onset time (N=414).

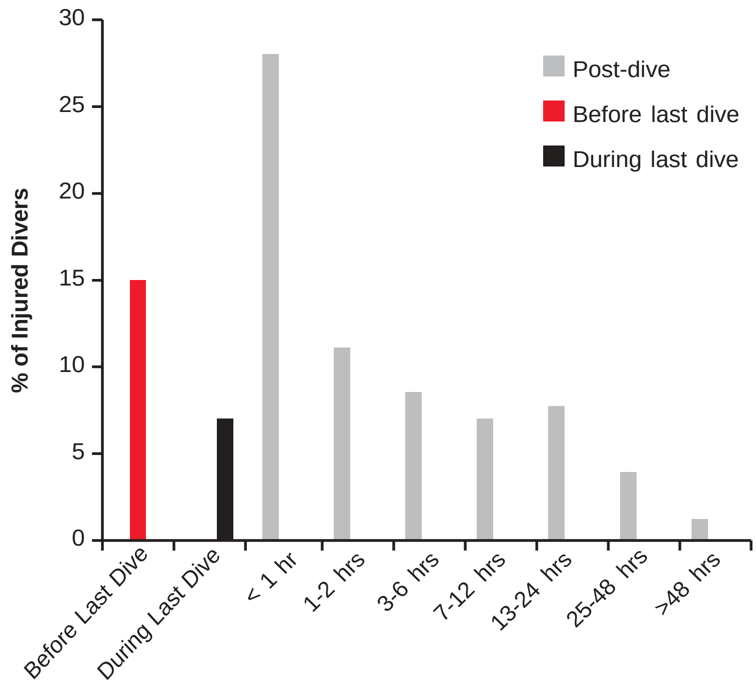


Figure 28 shows the symptom onset time for injured divers, categorized by diagnosis. According to our criteria, all cases of arterial gas embolism had to manifest symptoms within 15 minutes of the end of decompression. Most cases of AGE occurred during ascent or immediately upon surfacing. Most cases with first symptoms before the last dive (40) were classified as DCS II, and 17 were labeled as DCS I.

In one case, a diver made dives with symptoms because he tried in-water recompression. It is notable that in many other cases where divers made dives with symptoms, dives to the same or shallower depths failed to resolve the symptoms. Out of 28 divers who developed first symptoms while still underwater (during ascent), there was one case of AGE and four cases of severe spinal injury. Symptoms that occur in water are not necessarily severe. Four of the divers who reported symptoms before the end of the last dive were classified as Ambiguous.

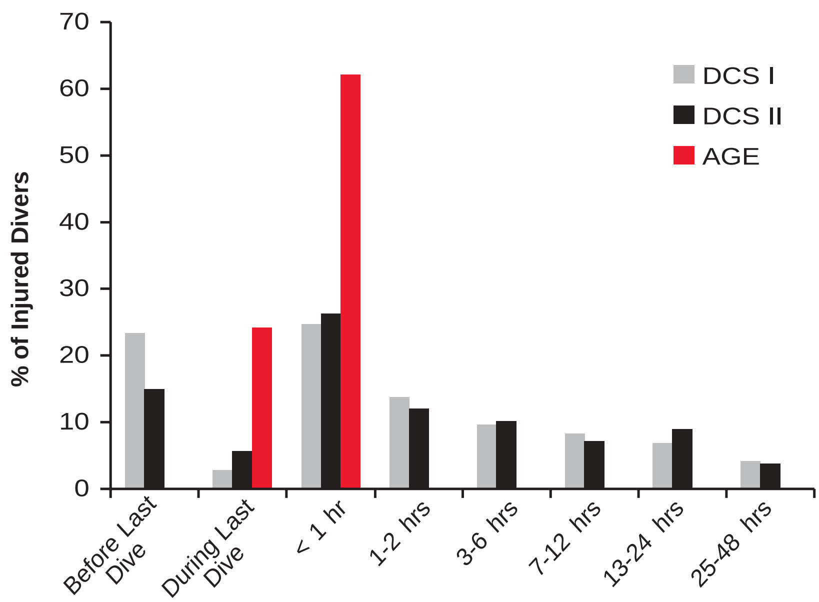
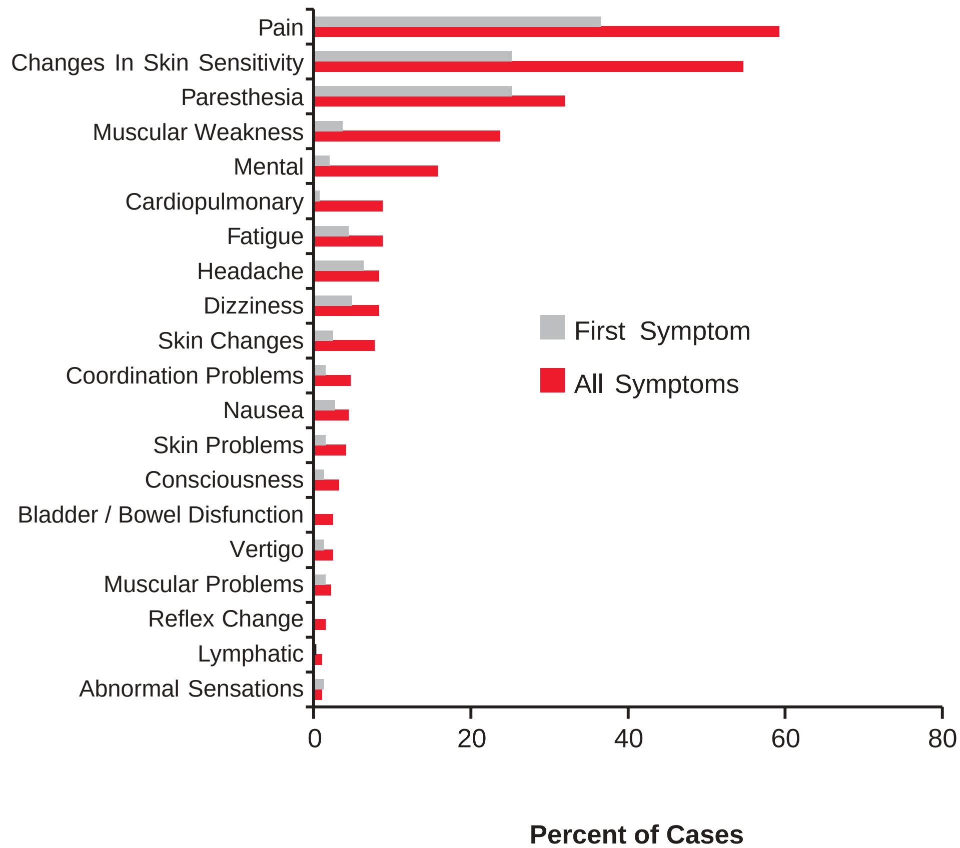


Fig 28
Symptom onset time by diagnosis (N=414).

Figure 29 shows symptoms reported by divers and medical personnel at the chambers. The most frequent first symptom was pain (36 percent), followed by numbness and tingling (altered skin sensitivity and paresthesias) in 25 percent of cases. Similarly, among all reported symptoms that developed in the course of the disease evolution, pain (59 percent) and decreased skin sensitivity (numbness) were predominant (54 percent). Muscular weakness was reported in 24 percent of all cases, more often discovered by medical personnel than reported by divers. At 15.6 percent, problems with higher cerebral functions ranked fifth. Constitutional symptoms, such as headache and fatigue, were less common.

Fig 29 Reported symptoms (N=414).



Less common problems, presenting in 5-10 percent of the cases, included pulmonary symptoms, fatigue, headache, dizziness and skin changes. Two to 5 percent of the injured divers reported very serious neurological problems — vertigo, bladder dysfunction, vision problems, unconsciousness and coordination problems. There were some differences noted between the genders. Men reported pain in 62 percent of the cases, and women in only 48 percent of the cases. Some subjective neurological symptoms, such as cognitive changes and paresthesia, were more common in women. Nausea was also more common in women.

In Figure 30, paraparesis (partial paralysis of the legs) was the most common form of muscular weakness at 5 percent, followed by hemiparesis (muscular weakness or partial weakness affecting one side of the body) at 4 percent and quadriparesis (decreased strength in all four limbs) at 1.5 percent. Paralysis was reported as paraplegia (paralysis of the legs) in 0.5 percent of injured divers and as hemiplegia (paralysis affecting one side of the body) in 0.2 percent.

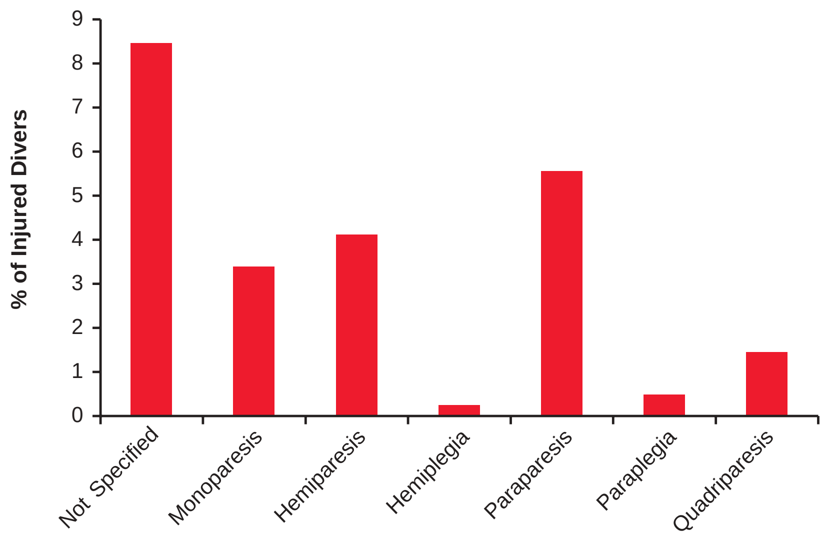


Fig 30 Distribution of muscular weakness.

Figure 31 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 and arms nearly equally. Arms and legs were rarely affected at the same time by any of the three symptoms.

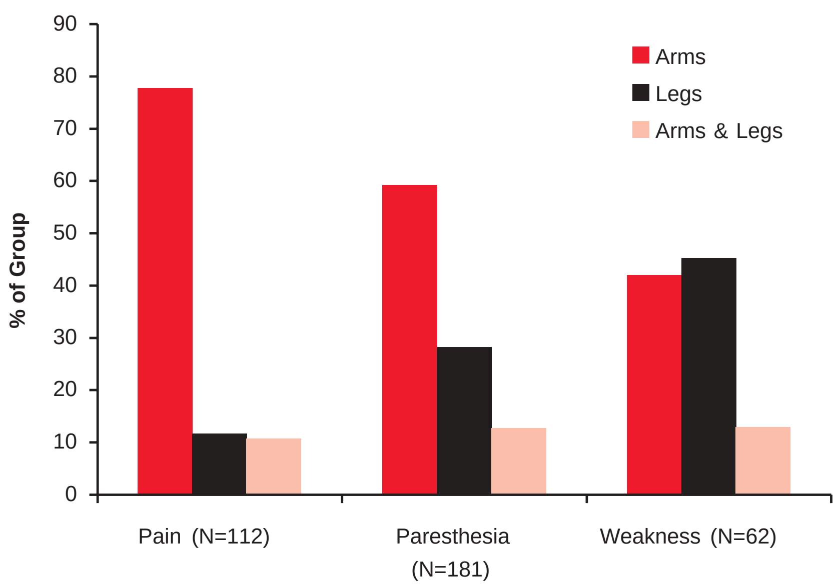


Fig 31 Distribution of pain, paresthesia and muscular weakness by limbs.

Each dive injury case was classified according to Perceived Severity Index (PSI; see Table 1, page 25 for description). Distribution of cases by PSI is shown in Figure 32. Most cases were classified as Mild Neurological (42.9 percent). The most severe DCI category, Serious Neurological, was the second most common with over one third (36 percent) of all cases. Pain was third with 20 percent, and Cardiopulmonary had less than 2 percent of cases. There were no cases of lymphatic or skin decompression illness. There were no confirmed cases of constitutional DCI after review. The Cardiopulmonary category includes three cases with symptoms of lung barotrauma without reported neurological symptoms.

Fig 32
Distribution of cases by PSI.

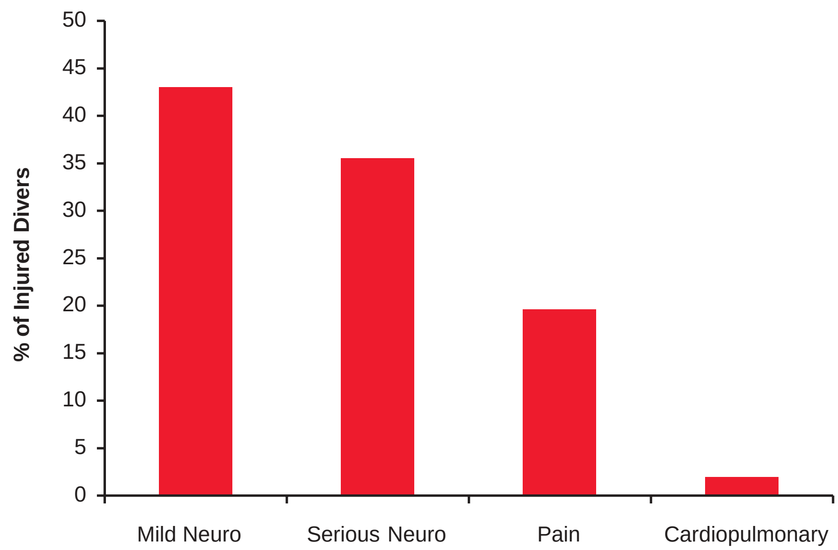
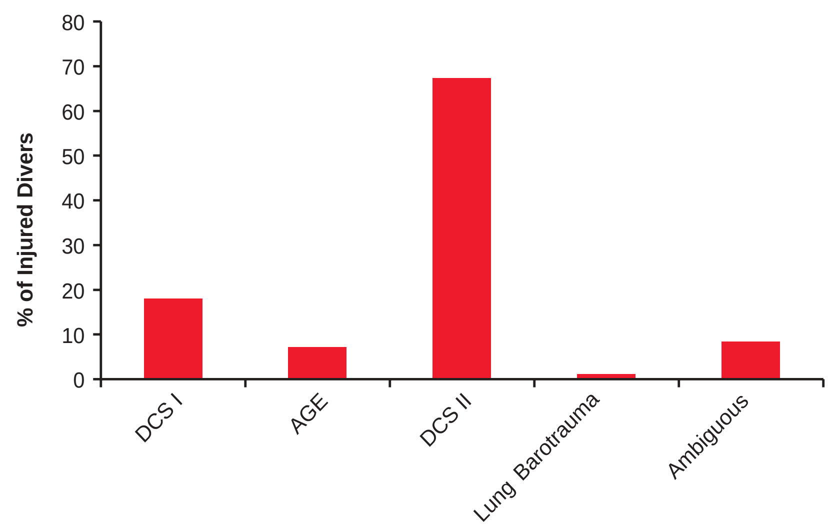


Figure 33 shows the distribution of cases according to reclassified diagnosis. Most cases were classified as Type II DCS (64.5 percent) followed by Type I DCS at 17.6 percent.

Fig 33
Distribution of cases according to Reclassified Diagnosis.



2.5 Therapy for Decompression Illness

There were 179 reports of surface oxygen use prior to recompression therapy. This is a significant increase in comparison to the previous year (43 percent of all injuries versus 20 percent in 2000). Figure 34 shows the method for delivering surface oxygen to injured divers. Systems providing oxygen on demand were used in 20 percent of cases, the same percent as in 2000. In general, it seems that the availability of emergency oxygen equipment with delivery on demand did not increase compared to the previous year.

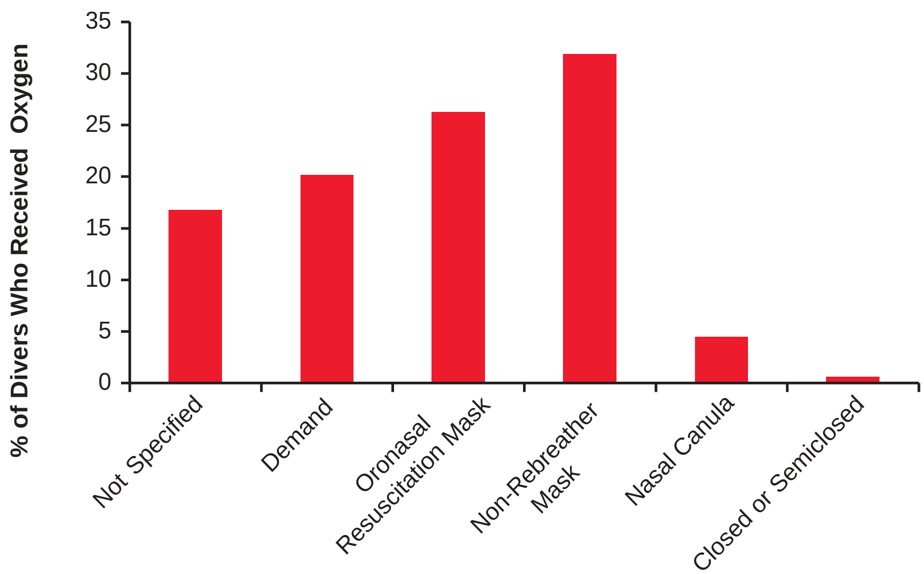


Fig 34
Method for delivering surface oxygen before recompression in injured divers (N=179).

The time of oxygen administration was available in 105 cases. In 52 of these, oxygen was provided within the first three hours after symptom onset.

Figure 35 shows the administration of surface oxygen by diagnosis. Individuals with arterial gas embolism were the most likely to receive surface oxygen, with almost 90 percent of the cases reporting pre-treatment oxygen administration. These symptoms occur immediately post-dive, while the diver is still at the dive site (Figure 25). They are usually serious and command the attention of the dive guide and other divers who are trained to recognize diving emergencies. Thus, most dive sites appear to have emergency oxygen available. Once the diver leaves the dive site, the likelihood that he or she will receive emergency oxygen shortly after symptom onset is less.

Fig 35 Administration of first aid oxygen by diagnosis.

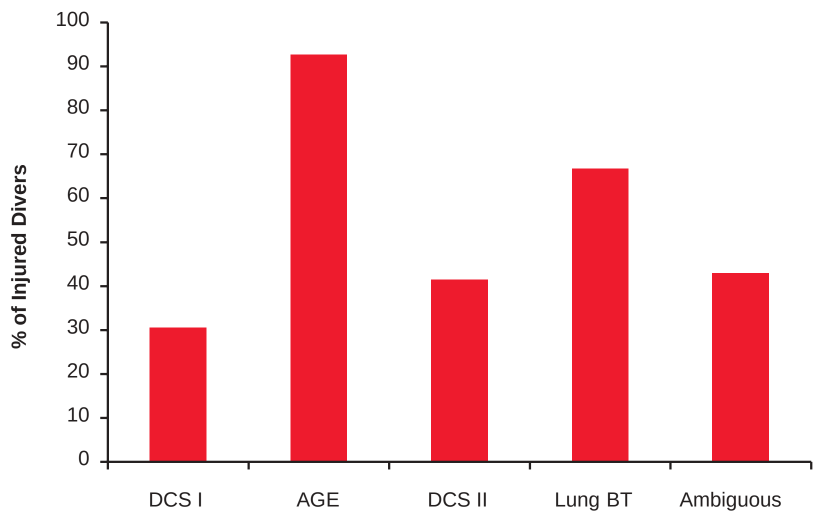


Figure 36 shows the delay to recompression for injured divers from time of first symptom onset. The median delay to treatment was 21 hours (mean 44 hours), with a range of less than one hour to 27 days. More than half of the cases were recompressed within 24 hours after symptom onset. In 36 percent of the cases, recompression delay was between one and five days, and in 7.6 percent of the cases, delay to recompression was greater than five days.

Fig 36 Delay to recompression from the time of first symptom onset (N=414).

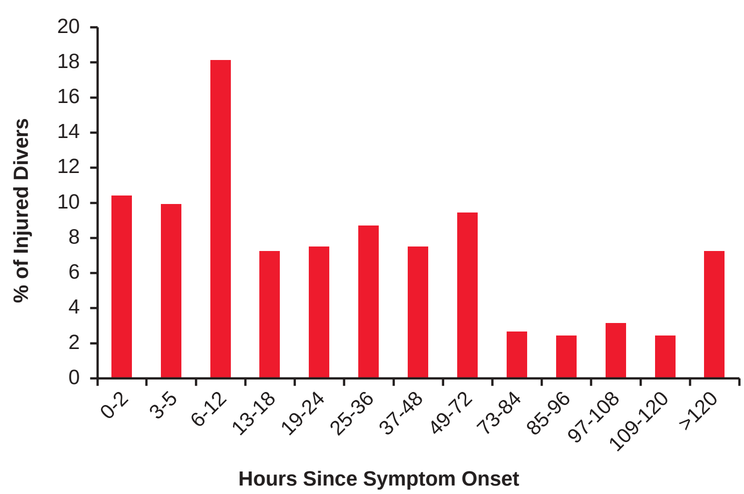


Table 5 shows the delay to recompression by diagnosis. There were statistically significant differences between all of the diagnostic categories. AGE cases were treated the earliest, probably for the same reasons that they were more likely to receive surface oxygen. DCS I and DCS II had significantly longer delays, but the delay to treat DCS II was shorter than that for DCS I. Ambiguous cases had the longest delay to treatment.

Diagnosis	N	Median (hr)	Range (hr)	Mean (hr)	Standard Deviation
DCS 1	73	26	1-277	55	65
DCS 2	277	17	1-648	40	68
AGE	27	6	1-52	14	16
Ambiguous	33	22	1-528	67	106

Table 5 Delay to recompression by diagnosis (N=414).

Table 6 shows the delay to recompression by PSI classification. Fifty percent of the Serious Neurological cases were recompressed within eight hours, while only 25 percent of Mild Neurological and Pain cases were recompressed in the same period.

Diagnosis	N	Median (hr)	Range (hr)	Mean (hr)	Standard Deviation
Serious Neurological	147	8	1-367	27	49
Cardiopulmonary	9	7	2-40	14	14
Mild Neurological	177	26	1-648	54	86
Pain	81	24	1-334	49	62

Table 6 Delay to recompression by PSI (N=414).

Figure 37 shows the type of recompression chamber in which injured divers were initially treated. As in previous years, most diving injuries were treated in multiplace chambers (77 percent).

Fig 37
Type of chamber in which injured divers were treated (N=414).

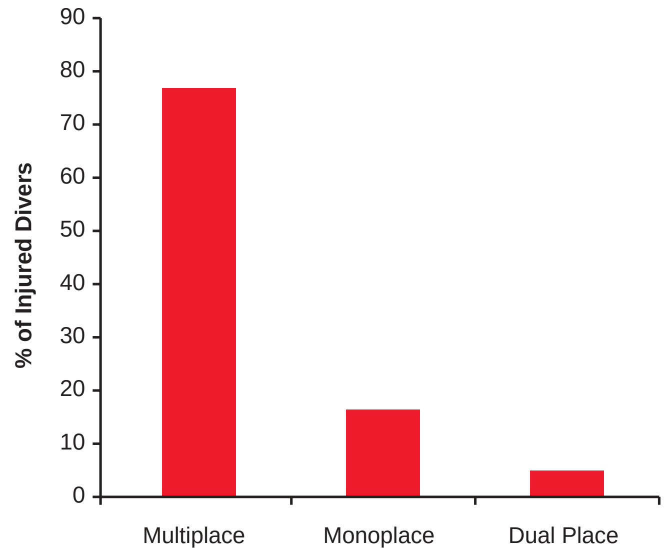


Figure 38 shows the initial treatment table used to recompress injured divers. US Navy Treatment Table 6 was used in 76 percent of initial treatments, which is a significant increase in comparison to 61 percent in 2000. Table 5 and Table 6A, with 4.1 percent and 2.2 percent respectively, were used less frequent than previous year (5.6 percent and 4.8 percent respectively).

Fig 38
The initial treatment table used to recompress injured divers (N=414).

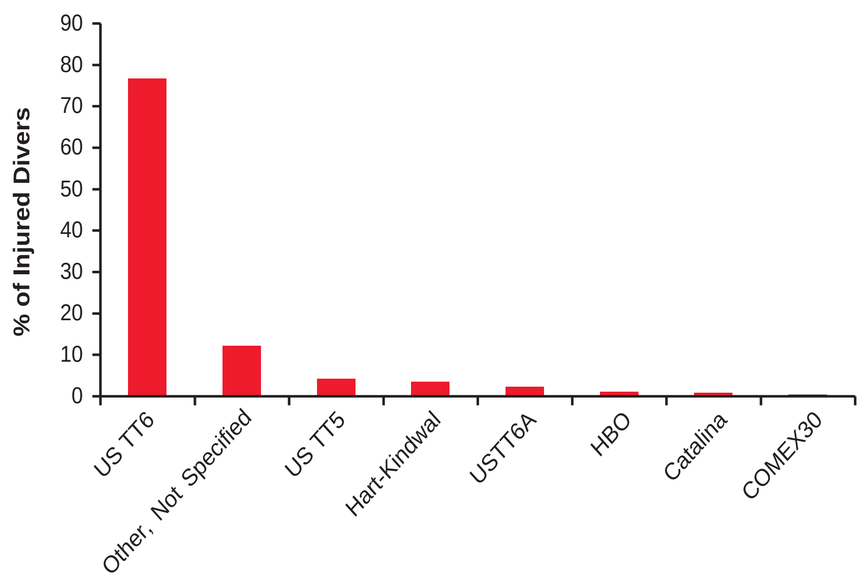


Figure 39 shows the total number of recompressions for injured divers. Nearly 80 percent of injured divers received one to three treatments. The median number of treatments was two, and the highest number was 13. Only 6 percent of injured divers received more than five treatments.

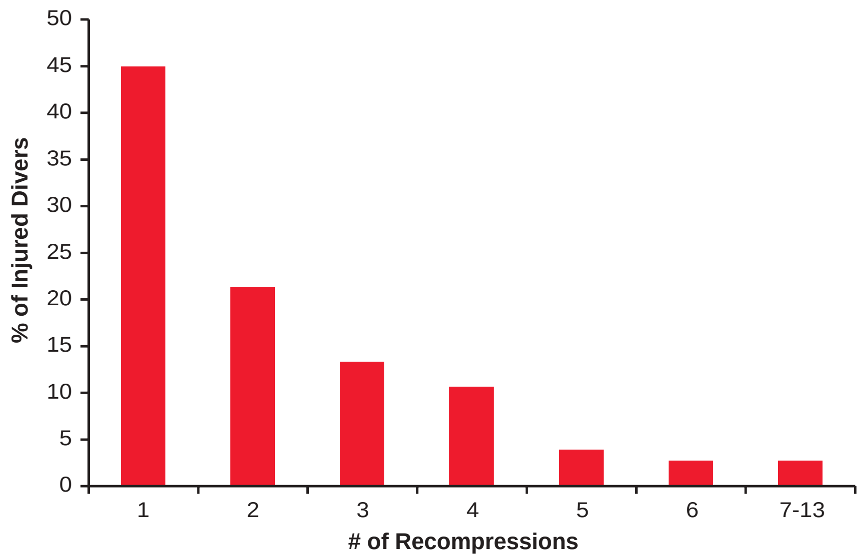


Fig 39
Total number of recompressions for injured divers (N=414).

Table 7 indicates that DCS I received the fewest recompression treatments while DCS II received the most. For the Perceived Severity Index, the PSI categories Pain and Cardiopulmonary had the fewest recompressions while Serious Neurological had the most.

Table 7
Number of recompressions by diagnosis and PSI.

Category		Recompressions			
Diagnosis	N cases	Median	Maximum	Mean	SD
DCS 1	73	1	5	1.5	0.8
AGE	27	1	7	2	1.5
DCS 2	277	2	13	2.6	1.9
BT	4	1	5	2.5	1.9
Ambiguous	33	1	5	1.8	1
Perceived Severity Index					
Serious Neurological	147	2	13	2.8	2.1
Cardiopulmonary	9	1	4	1.5	1.1
Mild Neurological	177	2	9	2.2	1.5
Pain	81	1	5	1.5	0.8

2.6 Therapeutic Outcome

Figure 40 shows the response of injured divers to surface oxygen prior to recompression. Improvement upon receiving oxygen was reported in 12 cases, and complete relief of symptoms before admission to the treating facility was reported in nine cases. There were also two reports of complete relief and two reports of improvement in excluded cases.

Fig 40
Effects of first aid oxygen on resolution before recompression (N=178).

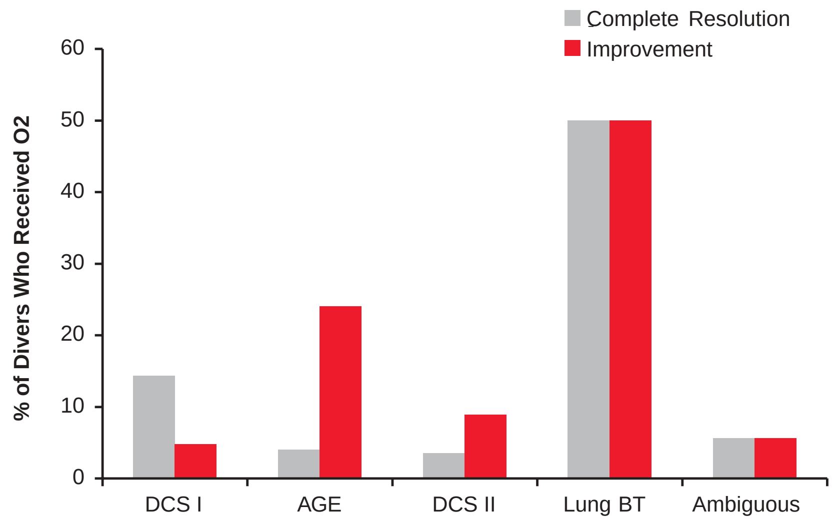


Figure 41 shows the effect of first aid oxygen (emergency O_2 - EO_2) on outcome at discharge. Divers who received first aid oxygen achieved complete relief significantly more often than divers who did not.

Fig 41
Effect of first aid oxygen on status at discharge.

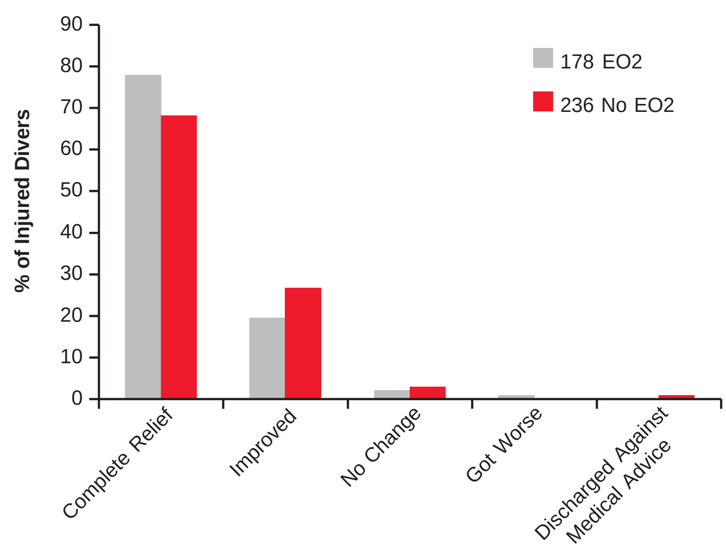


Figure 42 shows the health status of injured divers after the first recompression, at discharge after completed recompression treatment and at three, six, nine and 12 months' follow-up. Out of 245 cases that had residual symptoms at discharge, a complete follow-up was available for 116 cases at the time of writing this report. Nearly half of the cases that needed follow-up had incomplete contact information. There were 72.2 percent of cases with a complete resolution at discharge. Out of 61 divers with residual symptoms contacted at three months after discharge, 37 had a complete resolution. At a three-month follow-up, 80.4 percent of injured divers had a complete resolution. Complete follow-up data will be presented for a five-year period in the 2004 report.

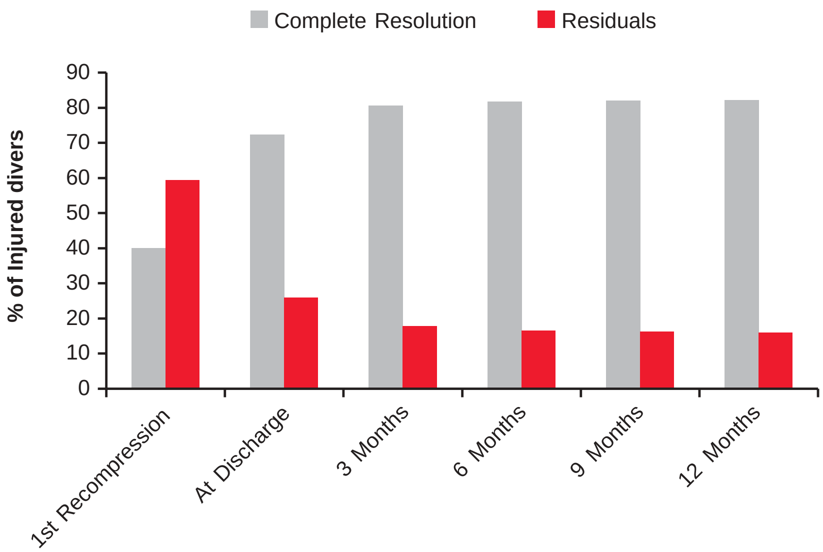


Fig 42
Outcome at specific intervals (N=414).

Figure 43 shows that AGE was more likely to have complete resolution than DCS. The percentage of incomplete resolution was highest in the Ambiguous category. Out of four cases with lung barotrauma, two had some residual symptoms after recompression.

Fig 43 Outcomes at discharge by diagnosis.

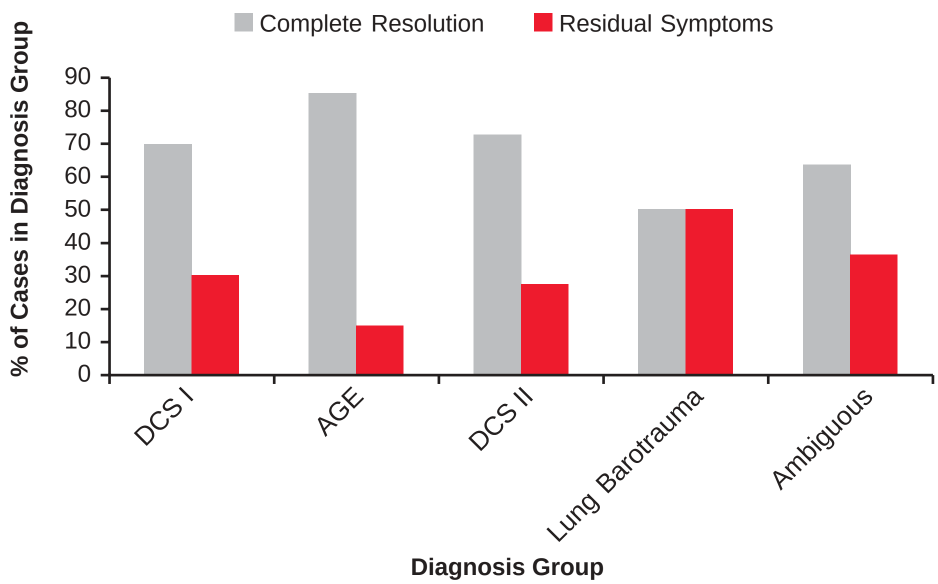
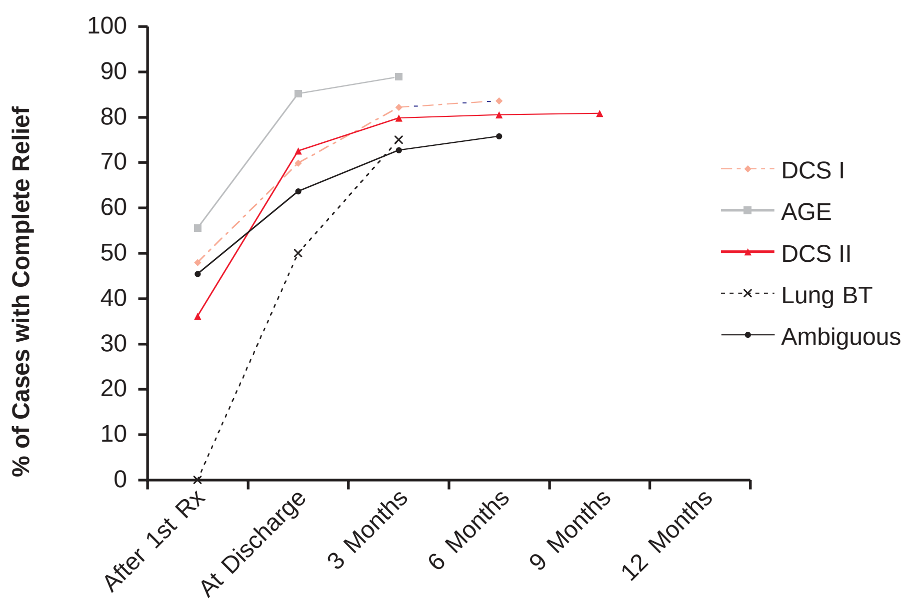


Figure 44 shows the percent of cases with complete relief achieved during the period of follow-up. The best results were recorded in the AGE group, with nearly 60 percent of cases achieving complete relief after the first recompression treatment (Rx) and 90 percent of cases within three months after injury.

Fig 44 Time to complete relief by diagnosis.



The effect of delay to recompression upon outcome was analyzed in 391 cases from regions that reported more than five cases (10 regions in North America and Caribbean including 66 chambers). Figure 45 shows the effect of delay to recompression on percent of cases with complete relief at discharge. In 160 cases that were recompressed within 12 hours after symptom onset, 79.4 percent achieved a complete relief at discharge, and in 237 cases with delay to recompression greater than 12 hours, only 65.8 percent of cases were completely relieved of symptoms. The difference in percent complete relief between less than 12 hours and greater than 12 hours was statistically significant.

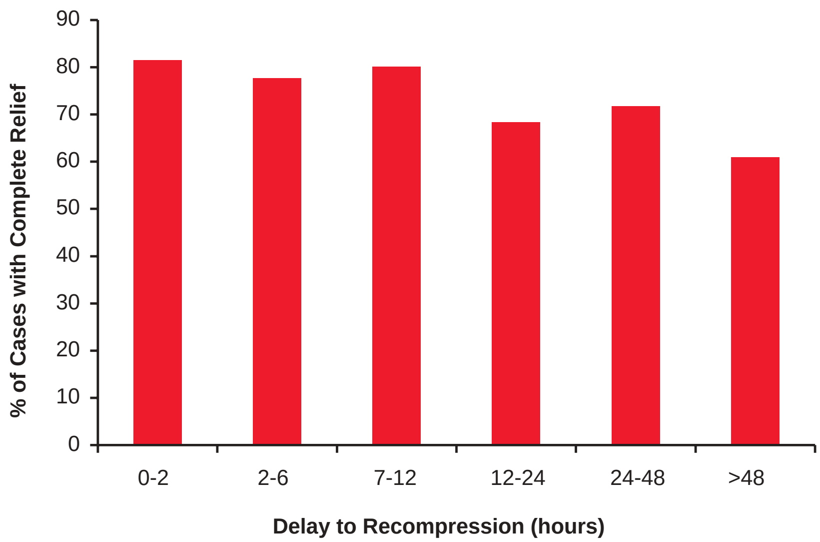


Fig 45
Percent of cases with complete relief at discharge (N=397).

Table 8 shows treatment outcome by region with Mean PSI and Mean Delay to recompression. The percent of injured divers achieving complete relief at the end of the treatment was greater in regions with shorter delays to recompression. The regions with the shortest delays to recompression were some of the most frequented diving destinations. This descriptive analysis suggests that delay to recompression may be an important factor in treatment outcome, but the conclusion is premature pending analysis to control for other variables.

Table 8
Outcome at discharge by region.

Region	# Chambers	# Divers	Mean PSI	Mean Delay to Recompression (Hours)	Complete Relief at Discharge	
					# Divers	%
Turks & Caicos	1	8	2.3	13.8	8	100
Mexico	3	51	1.8	20.0	44	86.3
Belize	2	27	1.8	44.9	22	81.5
US Northwest	5	95	2.6	39.8	77	81.1
US Southwest	8	21	2.6	52.4	17	81
US Gulf	5	14	3.1	41.0	10	71.4
US Southeast	17	101	2.6	62.8	65	64.4
Canada	4	10	2.8	55.1	6	60
US Midwest	10	31	2.8	93.8	17	54.8
US Northeast	11	33	2.8	95.0	17	51.5

3. Dive Fatalities

DAN is not the primary investigative agency for dive fatalities. DAN compiles dive fatality data based on various sources: newspaper articles, local contacts, medical examiners, eyewitnesses and family members. This information is often incomplete and less accurate than data for dive injuries or Project Dive Exploration. The precipitating cause of the fatalities and the cause of death are frequently unknown. Fatality investigation is limited to U.S. and Canadian residents, as it is difficult to collect information from abroad. However, all information obtained on each dive fatality case is reviewed by a forensic pathologist who is also trained in dive medicine.

There were 77 dive fatalities in 2001, involving 13 women and 64 men. Autopsy reports were available for 51 cases. In 11 cases autopsy was conducted but reports were not sent to DAN. Four cases were not autopsied, and the status of whether an autopsy was done in one case is unknown. The deceased diver was not recovered in 10 cases.

3.1 Characteristics of Divers Who Died

The age distribution for male and female dive fatalities is shown in Figure 46. Sixty percent of all fatalities were in the 40- to 59-year-old age group. The largest proportion of male divers who died (41 percent) was in the 40- to 49-year-old age group, and the largest proportion of females who died (39 percent) was in the 50- to 59-year-old age group. Five percent of all fatalities were in the 10- to 19-year-old age group. The average age was 43 for both male and female dive fatalities, with ranges of 17-66 for males and 17-69 for females.

Fig 46
Age and gender distribution of diving fatalities (n=77).

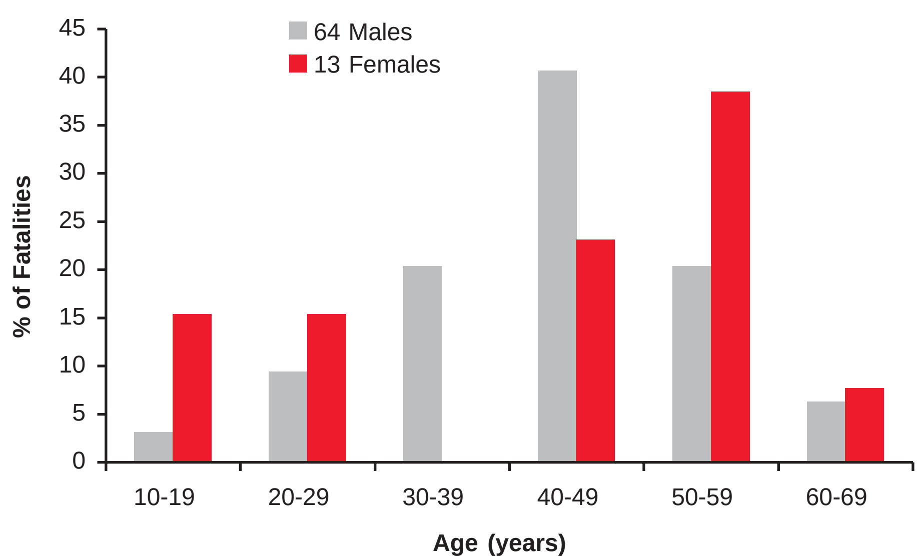


Figure 47 shows the chronic health conditions reported for divers who died. Any given diver may have been counted in several categories. The presence of a chronic (or acute) health condition is not necessarily a causative factor in death. Cigarette smoking and high blood pressure or heart disease (HBP / HD) were the most frequently reported at about 15 percent.

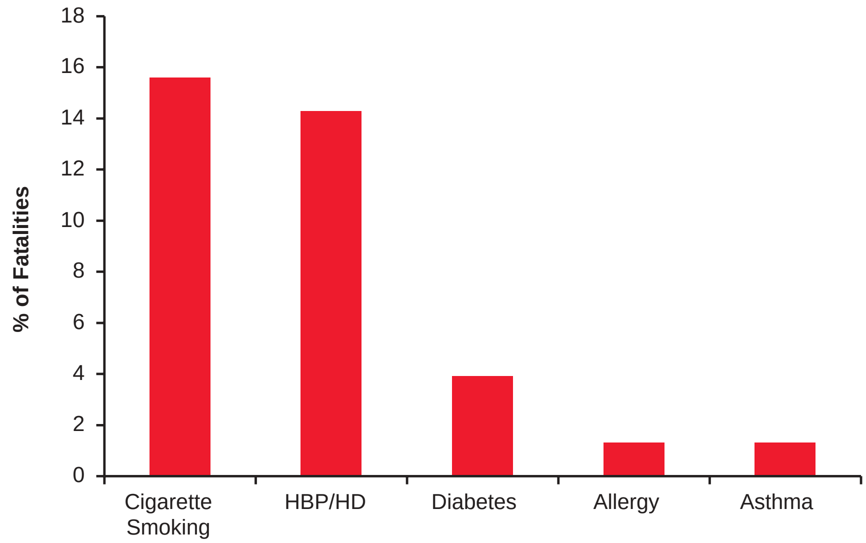


Fig 47
Chronic health conditions for divers who died (n=77).

Figure 48 shows the acute or recent health conditions reported for all causes of diver deaths where toxicology was available. Alcohol and / or drug use was found in about 10 percent of reported fatality cases. Although the leading contributing factors in diver deaths, 10 percent is much lower than the rate for drowning and vehicular accidents. A recent history of an orthopedic injury was found in 8.5 percent, and along with alcohol and drugs, were the most common acute health conditions.

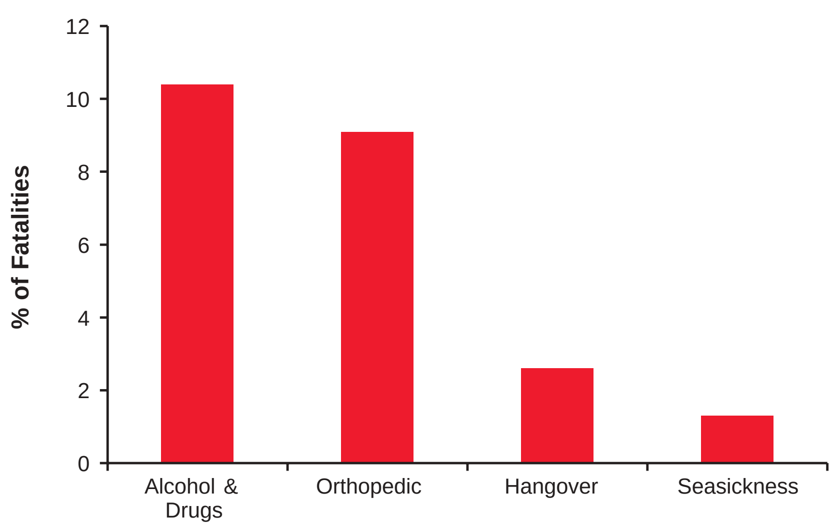


Fig 48
Acute health conditions for divers who died (n=77).

Figure 49 shows the gender and certification levels of divers who died. About 45 percent were certified beyond basic open-water status, 35 percent were open-water certified, and the remainder included students or lacked certification. Male fatalities were more likely to be certified beyond open water than females, and slightly more likely to dive without certification.

Fig 49
Certification level of dive fatalities by gender (n=77).

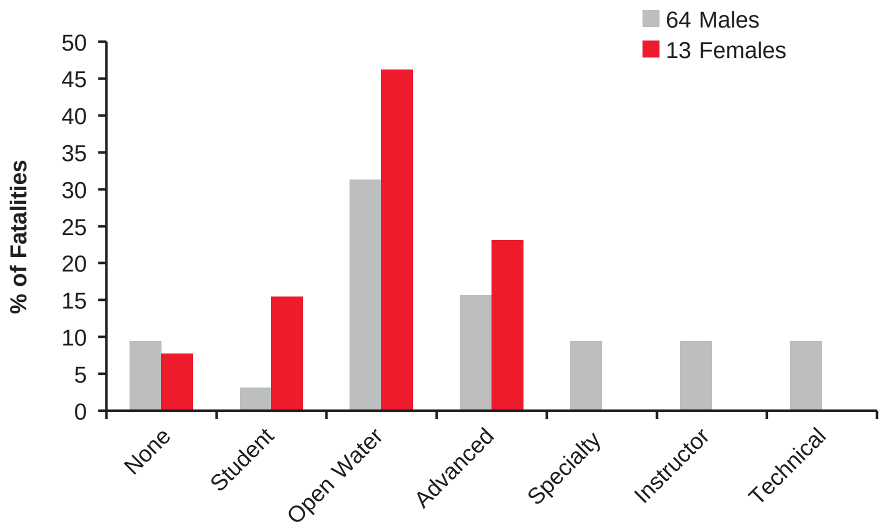


Figure 50 shows the number of years since initial certification of divers who died. As in previous reports, fatalities occurred most often in divers who had been certified for one year or less and for more than six years.

Fig 50
Years since initial certification of dive fatalities by gender (n=67).

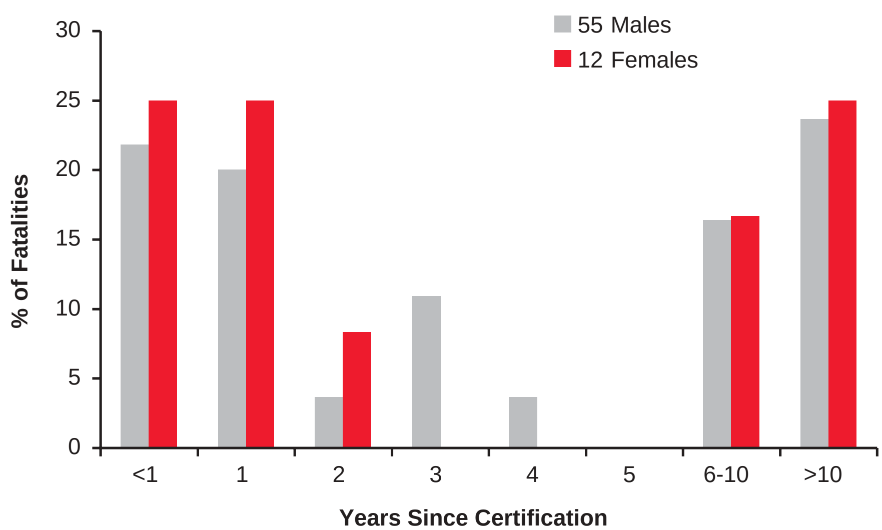


Figure 51 shows that as in previous reports, the majority of both male and female fatality cases made fewer than 20 dives in the previous 12 months. The range of number of dives in 10 female fatalities was 1-24 and in male scuba deaths 1-300.

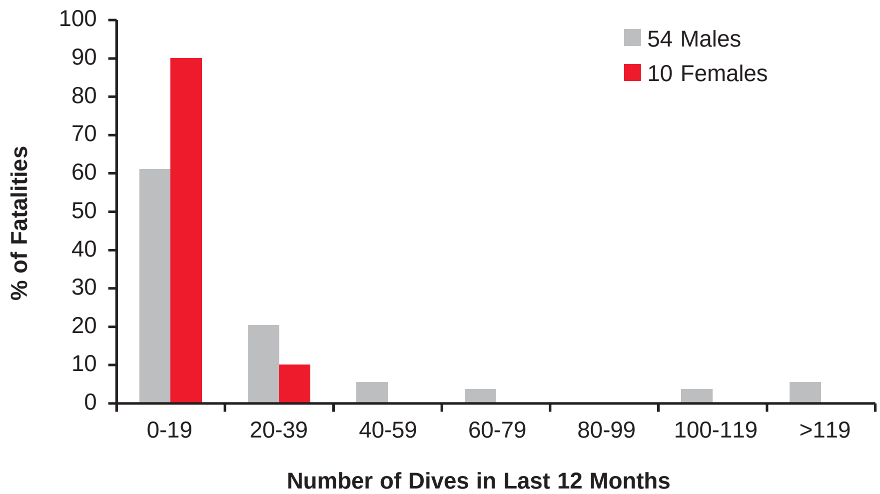


Fig 51
The number of dives in the past 12 months for dive fatalities (n=64).

3.2 Characteristics of Dives by Divers Who Died

The following figures describe characteristics of the fatal dives that may relate to death. These characteristics include dive purpose, environment, number of dives in the series, dive depths, decompression requirement and problems during diving.

Figure 52 shows the distribution of months where the dive-related fatalities occurred. As in the past, the peak month for diving fatalities was August. The monthly trend in scuba fatalities does not reflect the seasonality of recreational diving, as does the monthly dive injury incidence.

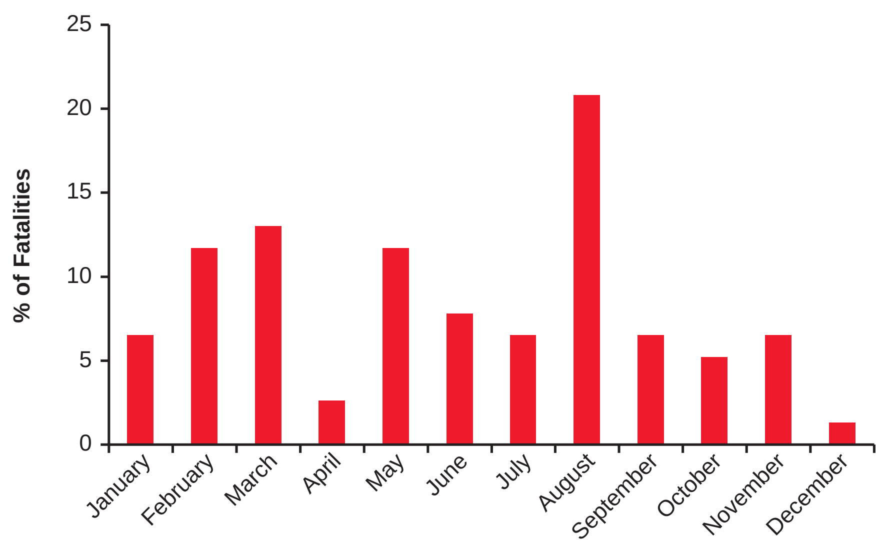
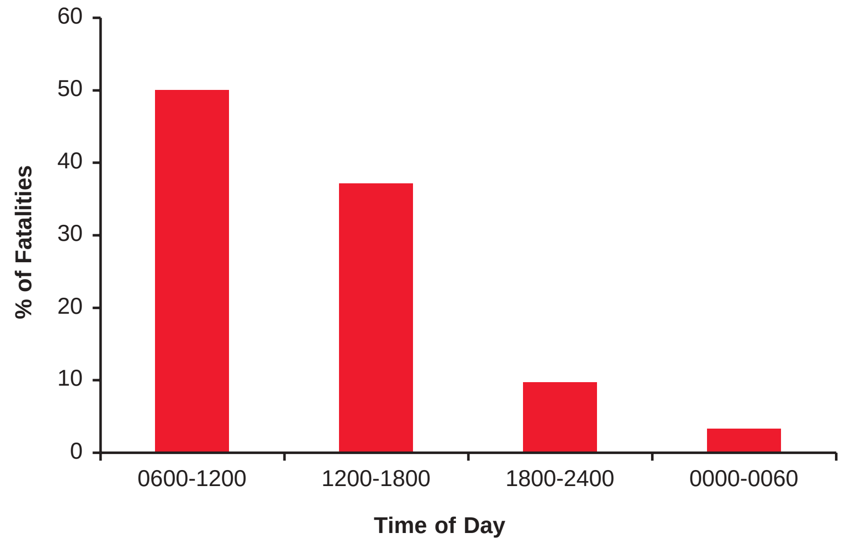


Fig 52
Months in which fatalities occurred (n=77).

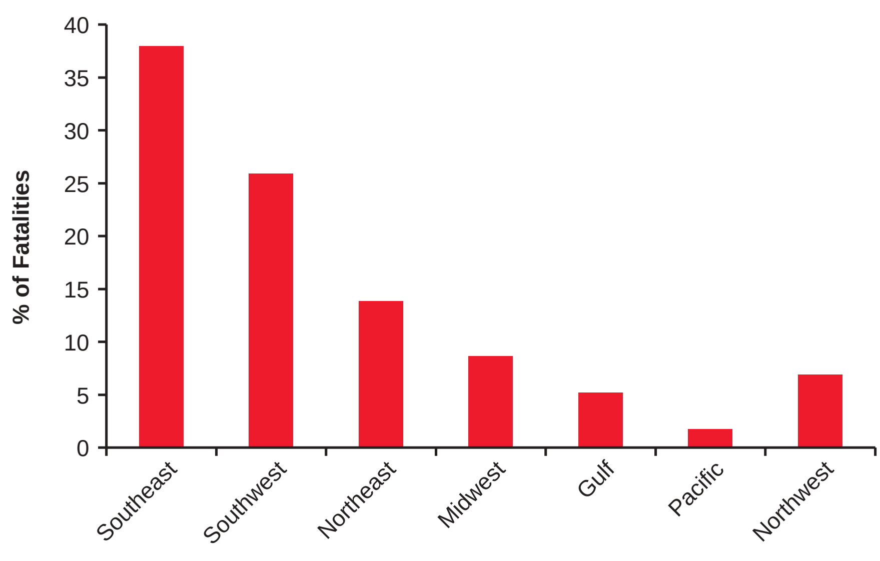
Figure 53 shows the time of day at which dive fatalities occurred. The morning was the most common period; afternoon was second in frequency of dive deaths. Only 10 percent of fatalities occurred after 6 p.m.

Fig 53 Time of day during which fatalities occurred (n=62).



Figures 54 and 55 show the distribution of fatal dives by U.S. and international regions. The greatest fraction of U.S. fatalities continued to occur in the Southeast, with an increase from 26 percent in 2000 to 38 percent in 2001. The Caribbean region includes both coastal (excluding U.S.) and island dive sites.

Fig 54 U.S. sites of diving-related fatalities (n=58).



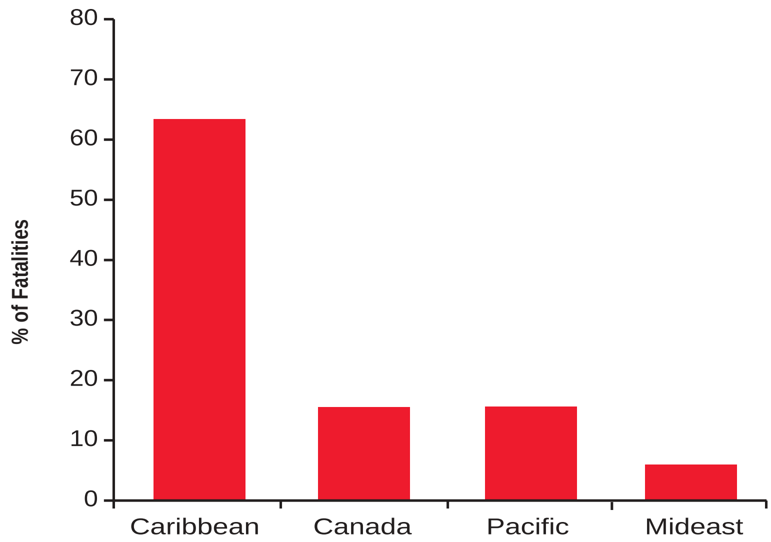


Fig 55
International sites of diving-related fatalities (n=14).

Figure 56 shows the distribution of the diving environments for dives that resulted in fatalities. Eighty percent of all fatalities occurred in salt water. The remaining 20 percent were in fresh water.

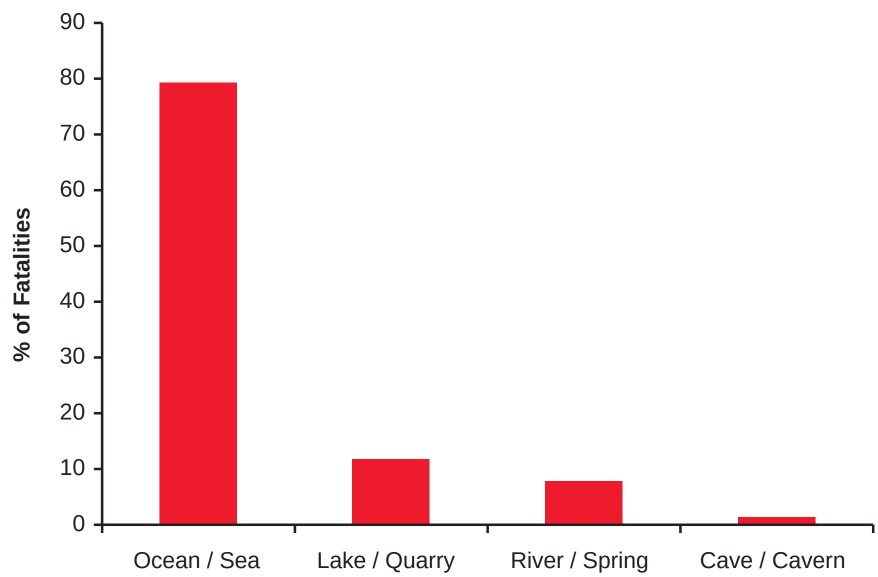


Fig 56
Environment in which fatalities occurred (n=77).

Figure 57 shows the distribution of purpose for dives that resulted in fatalities. Fifty-five percent occurred during recreational dives, 12 percent involved students during training and 20 percent took place during technical dives. “Other,” at 12 percent, included game collection and some personal work.

Fig 57
Purpose of dive in which fatalities occurred (n=77).

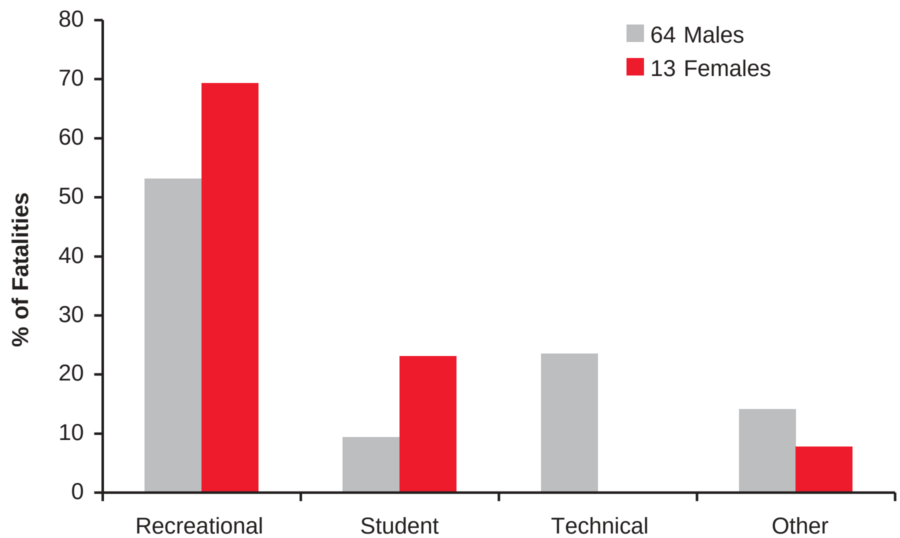


Figure 58 shows the platform from which dive fatalities began their dives. Fifty-seven percent began their dives from a day boat, 40 percent from the shore, one from a liveaboard and one from ice (“Other”).

Fig 58
Platform from which dive fatalities began their dives (n=77).

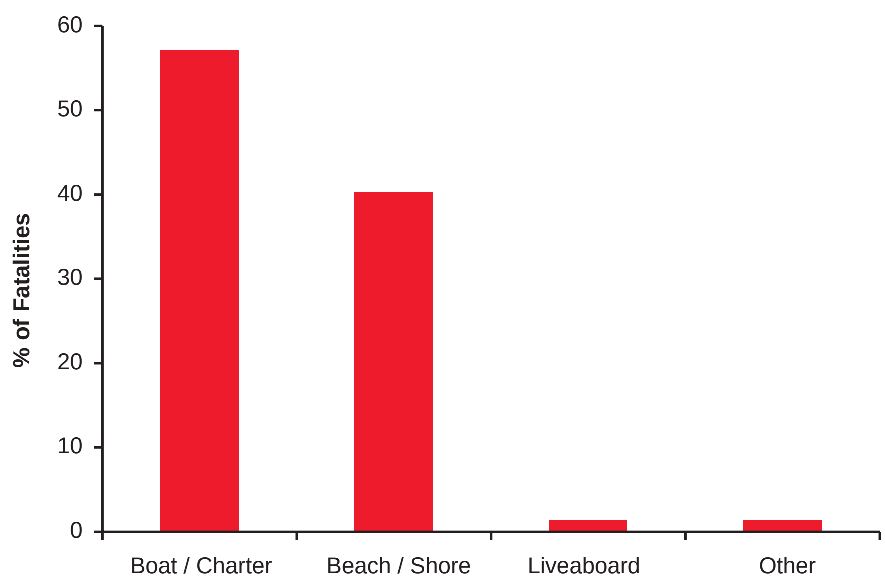


Figure 59 shows the thermal protection worn by divers who died. Of the 65 divers for whom data were available, close to 70 percent wore wetsuits, 15 percent wore swimsuits, and 15 percent wore drysuits. One diver who died was wearing a diveskin.

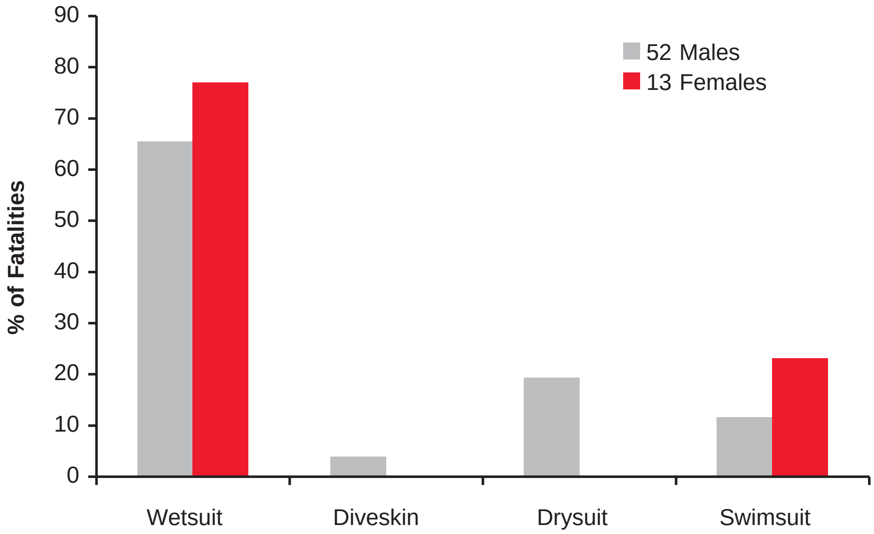


Fig 59
Thermal protection worn by divers who died (n=65).

While information was unavailable about the number of days diving in fatalities, most appeared to have died on the first day. Of the 77 fatalities, 89.6 percent died on the first dive, 7.8 percent on the second dive, and 2.6 percent on the third dive.

Figure 60 shows the maximum depth reported for dives that ended in death. The average maximum depth for all dive fatalities was 75.6 fsw (26.2 msw), and 31.2 percent of the divers went no deeper than 30 fsw (9 msw).

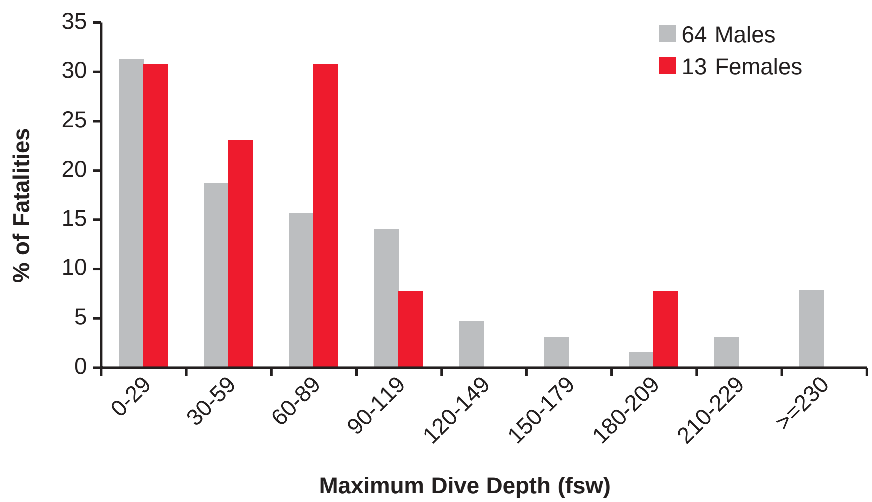


Fig 60
Distribution of maximum depth among dive fatalities (n=77).

Figure 61 shows the limited information that was available about problems with dive equipment. The occurrence of a particular equipment problem does not indicate that the indicated problem was the immediate (proximal) cause of the fatality. The buoyancy compensation device (BCD) was cited in 13 percent of fatalities, and the regulator or weight belt in 9 percent each.

Fig 61 Equipment problems during dives that resulted in fatalities (n=77).

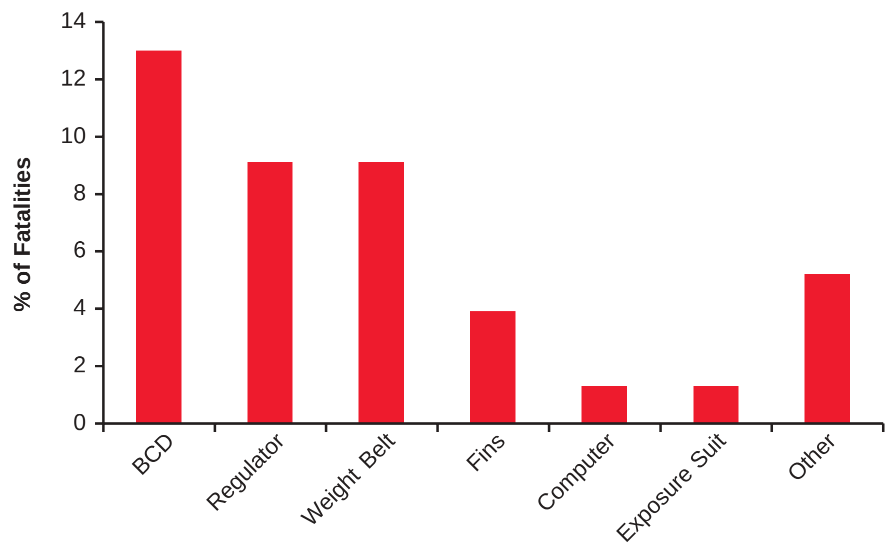


Figure 62 shows the distribution of procedural problems that were reported during dives that resulted in fatalities. Sixty percent of all fatalities had buoyancy problems, 31 percent ran out of air and 10 percent ascended rapidly. As with equipment problems, the occurrence of a procedural problem was not necessarily the immediate cause of the fatality.

Fig 62 Procedural problems reported during dives that resulted in fatalities (n=77).

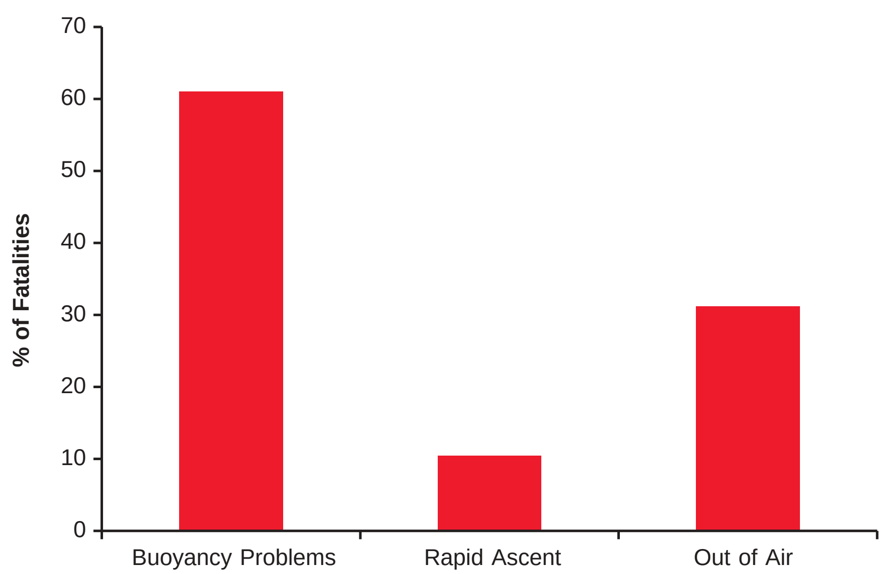


Figure 63 shows the distribution of cause of death in the judgment of the DAN pathologist who reviewed each fatality report. As in past years, drowning (62 percent) was the most commonly cited cause of death. Air embolism was reported in 12 percent, and decompression sickness in two cases. Anoxia (lack of oxygen) or asphyxia (deficiency of oxygen, usually caused by interruption of respiration) occurred in 6 percent.

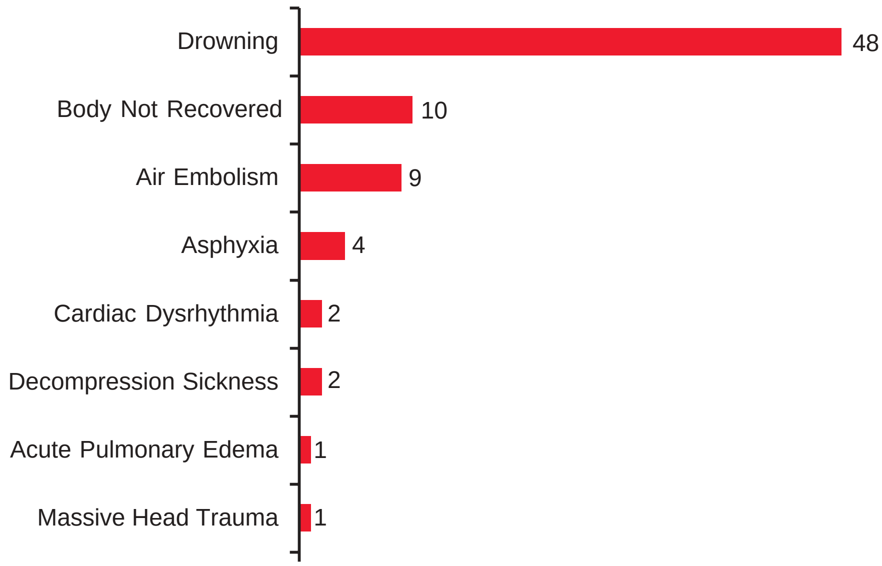


Fig 63
Apparent cause of death among diving fatalities (n=77).

4. Project Dive Exploration

4.1 Introduction

Despite more than 100 years of research, the physiology of decompression sickness (DCS) is still not well understood. DAN is addressing this scientific need by creating 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 recording dive computers worn by recreational divers.

PDE is an observational research study that collects and analyzes electronic pressure-time exposures from recording dive computers worn by recreational divers. The diver's status — before diving and at 48 hours after diving — 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 high-fidelity data for complex physiological modeling and hypothesis testing of diving-related conditions.

All participants in PDE must be certified recreational or student divers. Dive computers with a recording interval of at least every 20 seconds are used. Computers with a recording interval of every five seconds as well as altitude exposure recording are preferred, if available. 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; a signed parental consent is required for divers younger than 18 years of age. Most divers participate under the guidance of a Field Research Coordinator (FRC), trained by DAN in data collection. The FRC is a passive observer and is instructed not to interfere with the execution of any dive. FRCs do not screen divers for symptoms of DCS, nor do they play any official medical role in the event of a diving accident.

Divers are also encouraged to collect dive profiles on their own without the assistance of an FRC. Dive profiles downloaded from an individual's own dive computer can be emailed to DAN. Reporting forms are available at the DAN website at www.DiversAlertNetwork.org.

4.2 PDE 2001

The data described in this section summarizes the characteristics of the divers and dives sampled by PDE. It does not purport to be 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 9 on page 67). This case-control technique has recently been used with PDE data to study flying after diving. (JJ Freiberger, PJ Denoble, CF Pieper, DM Uguccioni, NW Pollock, and RD Vann. The relative risk of decompression sickness during and after air travel following diving. Aviat Space Environ Med 73:980-4, 2002)

PDE continues to grow. In 2001, Project Dive Exploration collected data on 15,385 dives in 1,960 dive series by 1,291 divers (Figure 64).

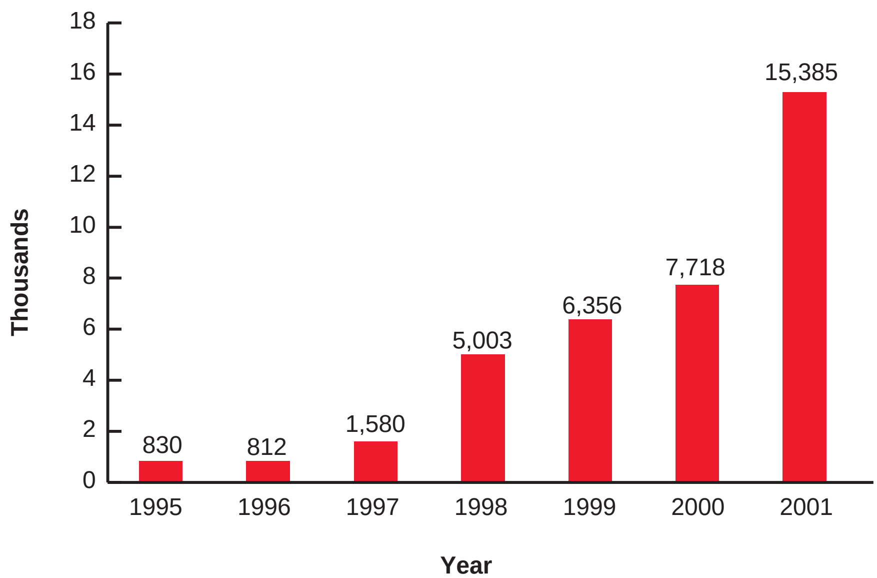
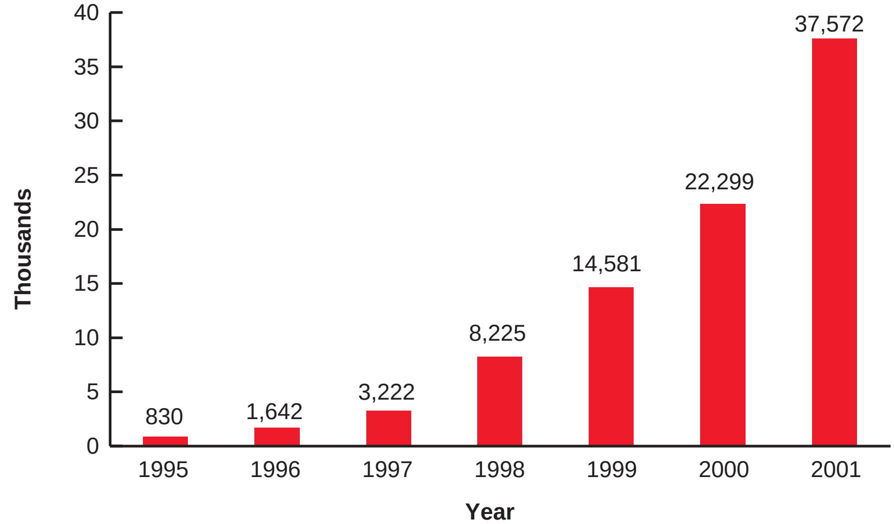


Fig 64
Annual data collection progress since 1995.

In 2001, the data collection doubled that of 2000, bringing the total number of dives in database at the end of 2001 to 37,572 (Fig 65).

Fig 65 Cumulative number of PDE dives collected.



Collection centers, FRCs and summer interns all contributed to the large increase in data collection. In 2001 DAN also began to receive data from individual divers using Cochran and DiveRite down-loadable dive computers. These computers can submit profiles directly to DAN from their dive log application.

As mentioned previously, PDE dives can be grouped into subsets for research purposes. Table 9 shows an example of the breakdown of dives by methodology of collection. PDE dives were collected from six main sources. Judging from the breakdown, it is easy to see why PDE divers do not necessarily represent the general diving population. Many dives took place in clear, warm tropical water, with the notable exception of the deep, cold dives that took place on the Scapa Flow off the Orkney Islands in the United Kingdom. Nearly half of the dives collected in 2001 were from a group of dive professionals in Cozumel, Mexico.

In Table 9, the PDE dives are categorized by sources where they were collected. These categories are:

1) recreational diving professionals acting as DAN FRCs in Cozumel, Mexico;
2) liveaboard dive boats;
3) 2001 DAN interns;
4) dives made at Scapa Flow in the United Kingdom;
5) individual FRCs; and
6) individual divers who independently reported to DAN.

Because the methodology of PDE data storage is flexible, it is possible to construct other possible subgroups if the research need arises.

Table 9
Sources of 2001 PDE data.

Source	# Divers	# Series	# Days	# Dives
Land-based group in Cozumel	132	608	2,809	6,113
Liveaboard collection centers	201	203	1,047	3,321
DAN Interns	654	781	1,479	2,665
Scapa Flow, Orkney, UK	233	241	1,318	2,413
Individual FRCs	61	92	250	802
Users of DL7 L-3 compatible dive computers	10	35	42	71
Total	**1,291**	**1,960**	**6,945**	**15,385**

Figure 66 indicates that data collection was relatively constant over the year, with a peak in the summer months. Those peak months correspond to the peak months both for recreational diving and for data collection.

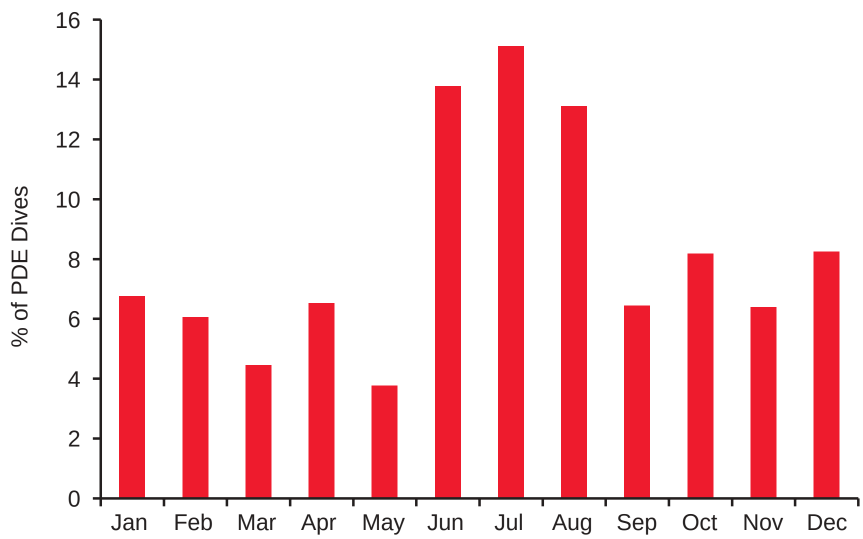


Fig 66
Month(s) in which dives occurred.

4.3 Divers

The following information describes the characteristics of the divers who volunteered to participate in PDE in 2001. During 2001, 1,389 divers participated in PDE, and 1,291 (93 percent) completed the study. Most incomplete cases were caused by failure to record or download the dive profile.

Tables 10 through 13 describe the diving intensity of PDE participants.

Table 10 Number of series per diver.

# Series	Frequency	Percent
> 20	6	0.5
10 - 19	25	2
5 - 9	18	1.4
2 - 4	95	7.4
1	1,132	88.7
Total # Divers	1,276	100

Table 11 Number of days diving.

# Days	Frequency	Percent
> 100	5	0.4
30 - 99	24	1.9
15 - 29	13	1
7 - 14	45	3.5
5 - 6	488	38.2
2 - 4	322	25.2
1	379	29.7
Total # Divers	1,276	100

Table 12 Number of dives per diver.

# Dives	Frequency	Percent
> 100	21	1.6
30 - 99	20	1.6
20 - 29	93	7.3
10 - 19	403	31.6
5 - 9	191	15
2 - 4	460	36.1
1	88	6.9
Total # Divers	1,276	100

Table 13 Basic statistics of divers participation.

	Maximum	Mean	Median
# Series	36	1.47	1
# Days	175	5.4	4
# Dives	351	11.4	7
# Dives Per Day	6	2.12	2

The median number of dives in a series was seven, and the maximum number of dive series contributed by any one individual was 31. Most of the volunteers (88 percent) contributed only one series. However, some recreational diving professionals were enthusiastic participants in PDE, and this subgroup (the Cozumel diving professionals) is analyzed along with three other diver-defined categories in a later section of this chapter.

The age and gender distribution for the 2001 PDE volunteers is shown in Figure 67. Most of the participants (75 percent) were between 20 and 49 years old. Divers over 50 represented 18 percent of the sample, and divers under 20 years of age represented 8 percent.

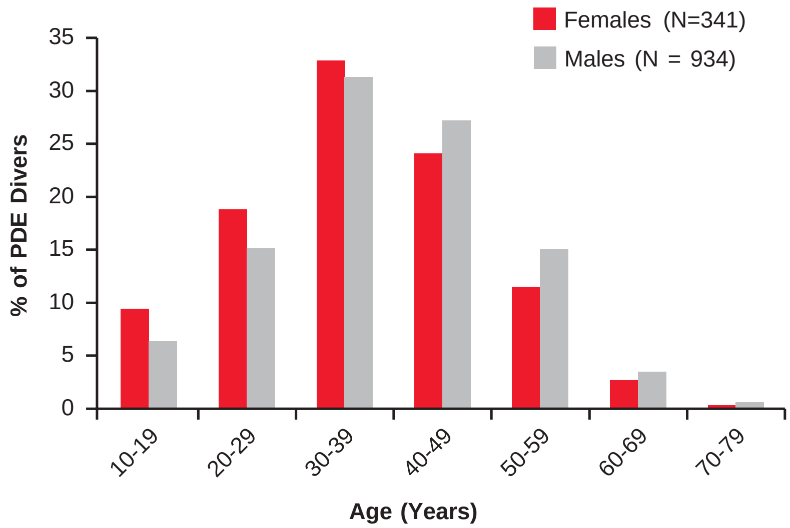


Fig 67
The age and gender distribution for the 2001 PDE volunteers.

In the population sampled in 2001, the participation of women as a percentage of all divers sampled declined with age (Figure 68). Overall, women comprised 27 percent of divers sampled.

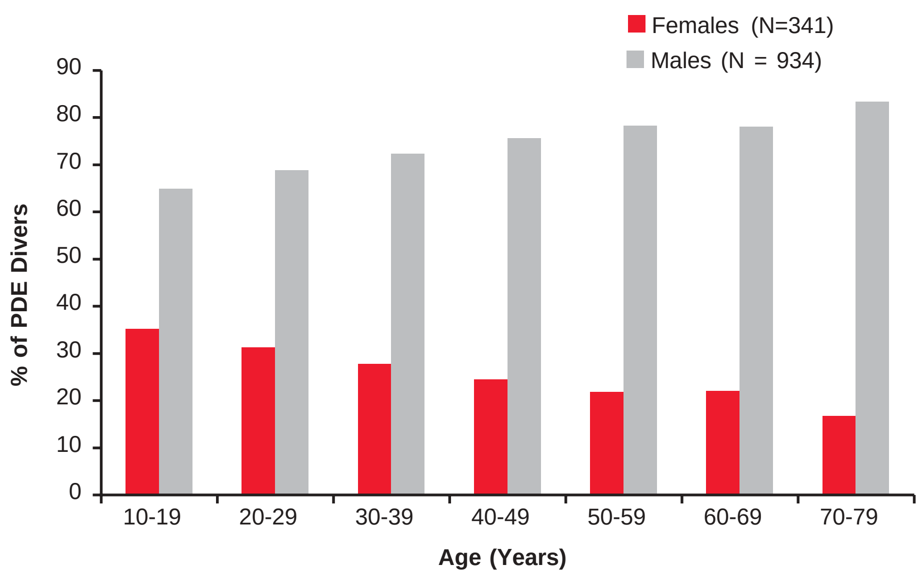
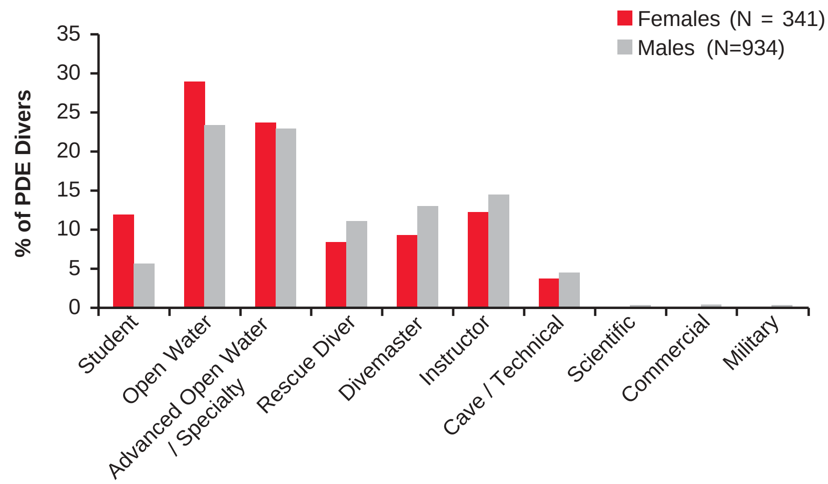


Fig 68
Participation of female and male divers by age group.

Figure 69 illustrates the certification level by gender of divers in the data set. In the 2001 sample a slightly higher percentage of the women were students and open water divers.

Approximately one quarter of all sampled divers had entry-level certification, one quarter had advanced categories, and another quarter was made up of instructors and divemasters. Students comprised 7 percent, and 5 percent were certified cave or technical divers. Women made up 43 percent of all students and 30 percent of the group with entry-level certification in our sample. The participation of women declined from an overall percentage of 26 percent to 20 percent in the divemaster, and 23 percent in the instructor categories (graphs for above narrative not shown).

Fig 69 Certification of divers by gender.



The number of years since a diver was first certified may be used as a proxy for diving experience (Figure 70). Forty-five percent of the sampled divers had 5 years of experience or less, and 25 percent had 10 years of experience or greater. Men were better represented in categories with more years since initial training, a pattern similar to that seen in certification level.

Fig 70 Number of years since diver was first certified.

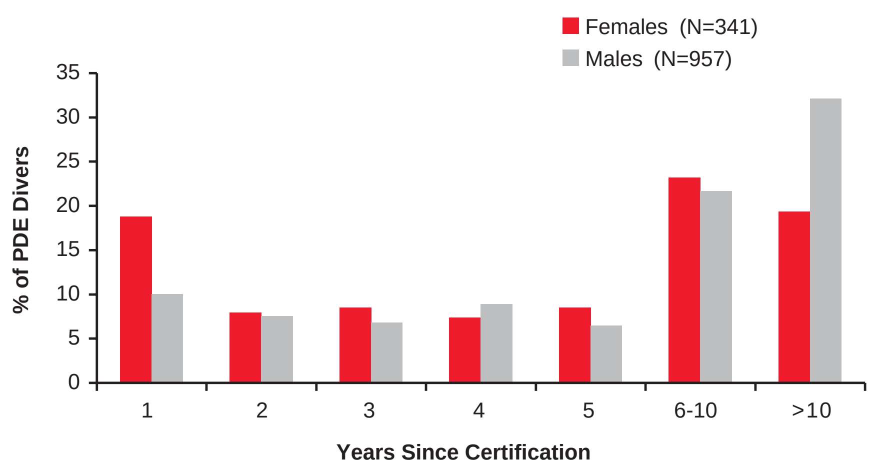


Figure 71 shows the chronic health conditions reported by the divers sampled for PDE in 2001. Seasonal allergy was the most frequently reported condition in our sample (13.5 percent). This was followed by orthopedic problems (12 percent). The term “orthopedic” refers to any bone- or joint-related condition or injury. Flu or acute infections were reported in 7.5 percent of divers, despite a general agreement that divers with these conditions should abstain from diving. Chronic ear and sinus problems were reported in 4 percent of divers. As is consistent with the prevalence of asthma in the general population, 3.5 percent of divers reported having suffered asthma in the past. In contrast to this, only 1.16 percent of the sampled divers had diabetes, which is a significantly smaller proportion than in the general population. Previous DCS was reported by 1.46 percent of participants. Forty-eight percent of participants denied any chronic or acute health problem. A total of 18.8 percent of female divers reported taking oral contraceptives.

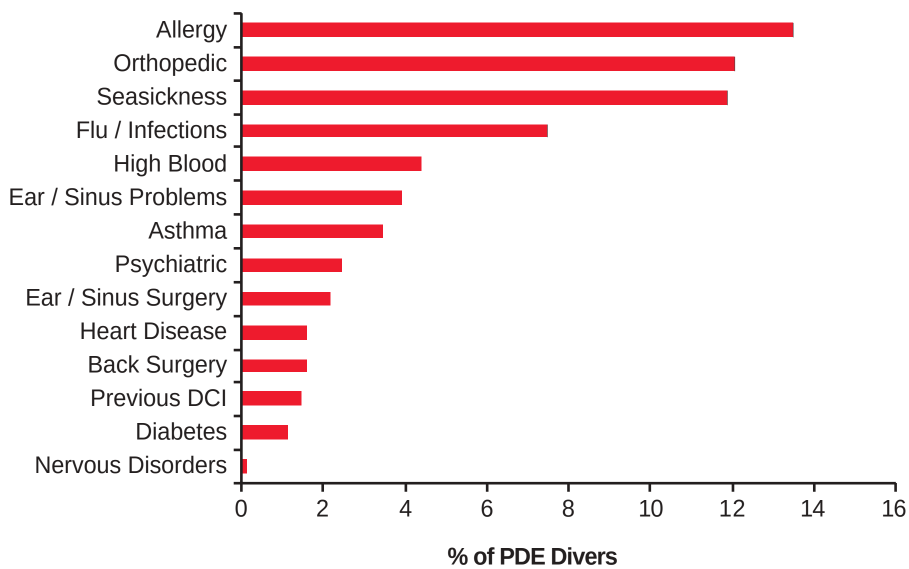


Fig 71
Medical history of PDE divers.

4.4 Dives

Most PDE data (97 percent) were collected during ocean diving (Table 14).

Table 14 Diving environment.

Environment	N Dives	%
Ocean / Sea	14,550	97.454
Lake / Quarry	42	0.281
Cave / Cavern	172	1.149
Pool	2	0.013
Other	9	0.053
Not Recorded	610	3.965

The distribution of our sample regarding dive platform is shown in Figure 72.

Most dives were boat dives (greater than 90 percent), and 24 percent of all boat dives were made on liveaboard trips, while about 70 percent were done on day trips from charter or private boats. Only 6 percent of dives were walk-in beach dives.

Fig 72 Dive platform (N = 15,118).

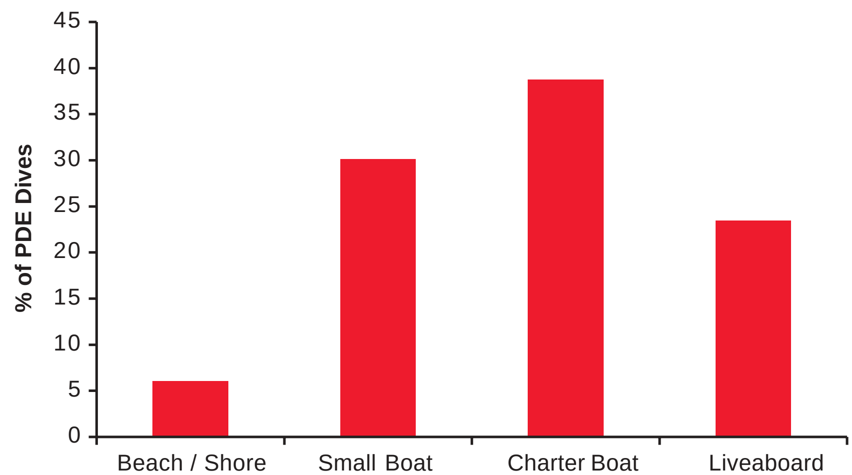


Figure 73 describes the breathing gas used by PDE volunteers. Ninety-nine percent of the divers in our sample used open-circuit scuba. Rebreathers were used in 45 dives and surface-supplied gear in 24 dives. Air was used in majority of dives (88 percent). Nitrox was used in 11 percent, and helium was part of the gas mix in 1 percent of the dives sampled.

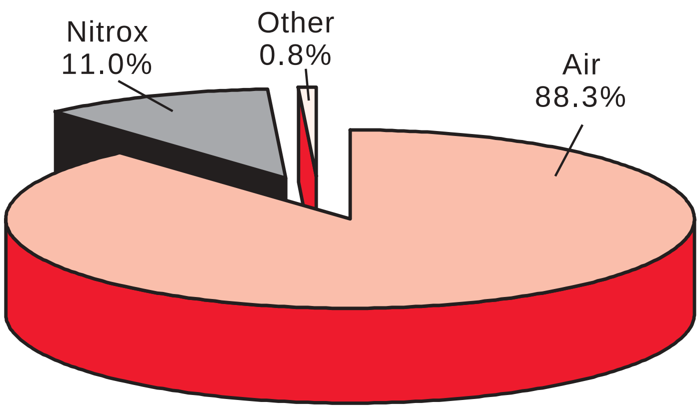


Fig 73
Breathing gas.

Thermal protection employed by divers in the sample depended on the geographic area where the dive was made. In Scapa Flow, nearly all divers (97 percent) wore drysuits. The percentage of drysuit use in the remainder of the sample was only 1 percent.

The reported purposes of the dives in our sample were as follows: sightseeing – 85 percent; teaching or learning – 3 percent; photography – 2 percent. In 9 percent of the cases, the purpose was not explicitly declared, although the dive was in a typical recreational setting.

4.5 Dive Series

PDE recorded 1,960 dive series in 2001. Figure 74 breaks down those series by the number of days of diving. Dive series comprised multiday diving in 65 percent of cases, single-day repetitive diving in 26 percent of cases and single dives in 9 percent of cases.

Fig 74
Type of dive series.

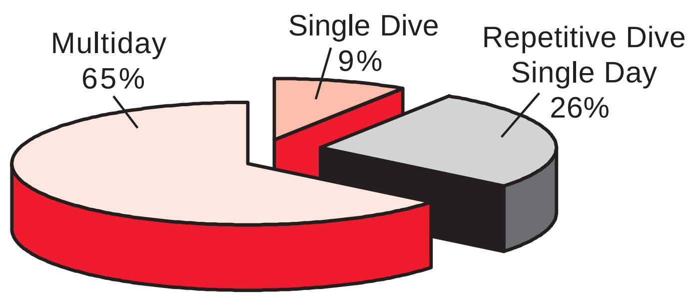


Figure 75 describes the number of days in the dive series for participants in PDE in 2001. An average dive series in our sample consisted of eight dives made over four days. However, the extremes of the sample ranged from one to 50 days and from one to 110 dives. Series consisting of six days of diving were common in liveaboard participants. Series with more than six days diving were, for the most part, contributed by the Cozumel dive professionals, who participated in PDE on a long-term basis.

Fig 75
Number of days in dive series.

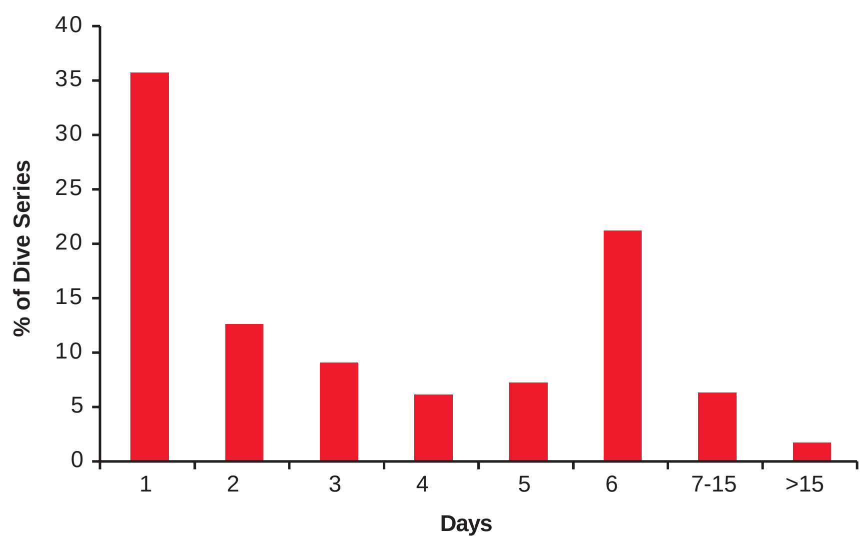


Figure 76 shows the distribution of the 1,960 PDE dive series by the number of dives made. The majority of the dives (65 percent) in a series had less than 10, although approximately 25 percent of the series had 10-19 dives.

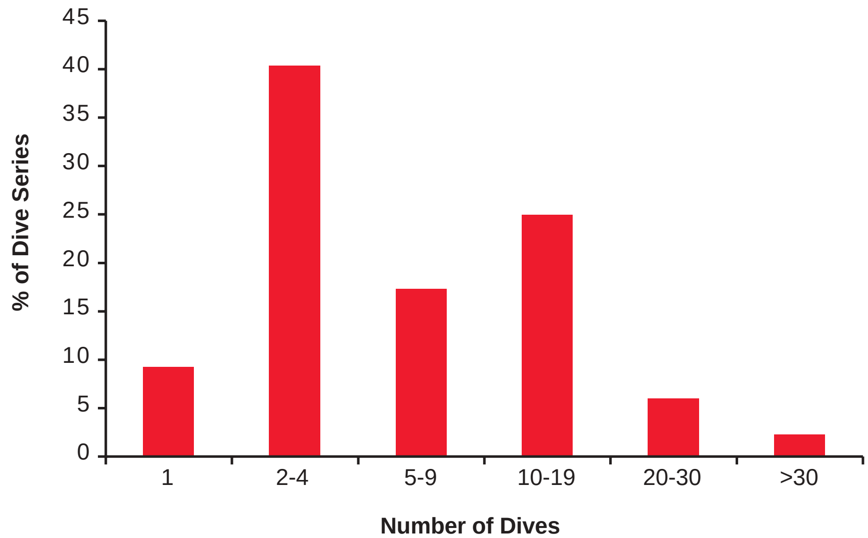


Fig 76
Number of dives in dive series (N = 1,960).

The maximum depth distribution for all dives sampled by PDE is shown in Figure 77. In 70 percent of the sampled dives, the maximum depth was between 30 and 90 feet of seawater (9 and 27 meters of seawater). In 8 percent of the dives, the maximum depth was less than 30 fsw (9 msw). In 5 percent of the dives, it was greater than 120 fsw (36 msw).

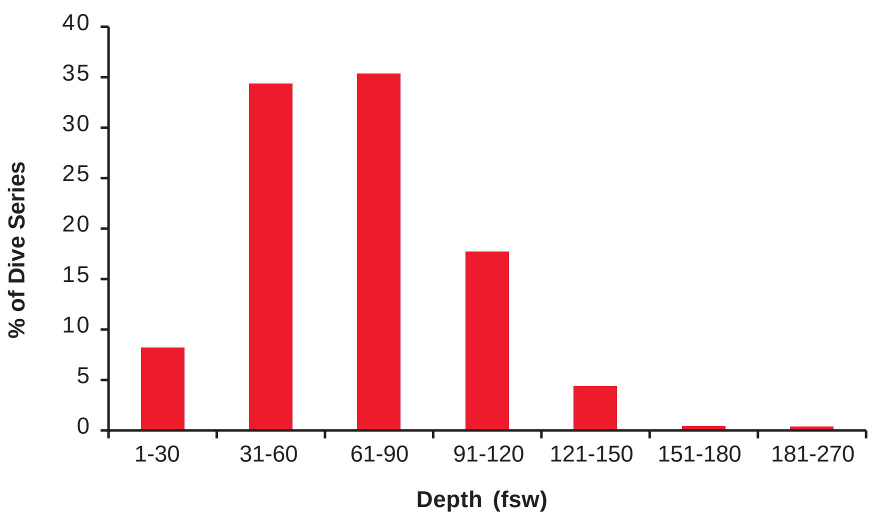
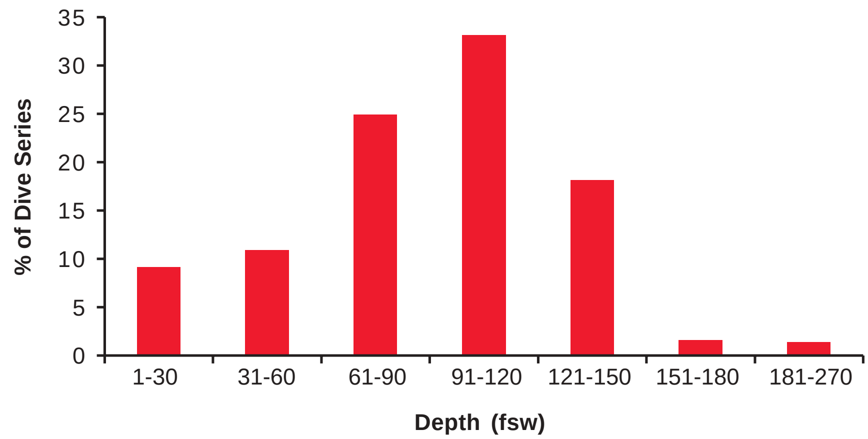


Fig 77
The distribution of maximum depth (N = 15,385).

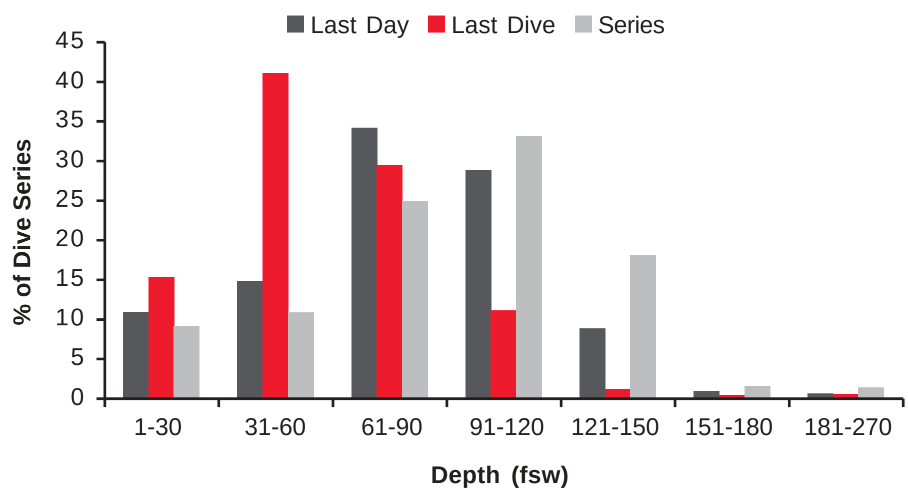
The maximum depth of the dive series (Figure 78) shows that more than 50 percent of divers went deeper than 90 fsw (27 msw), and 21 percent dived deeper than 120 fsw (36 msw) at least on one dive of their dive series.

Fig 78
Maximum depth in dive series (N=1,960).



Towards the end of the series, PDE divers dived more conservatively. This is indicated by Figure 79, which compares the maximum depth of the dive series to the maximum depth on the last day of diving.

Fig 79
Maximum depths on the last day of diving, the last dive and the dive series.



4.6 Dive Planning

Most divers in our sample used dive computers to conduct and plan their dives; however, 17 percent relied completely on others for their decompression planning by following a dive guide. Only 2 percent consulted dive tables without using a computer. Figure 80 illustrates the distribution of the dive planning methods recorded.

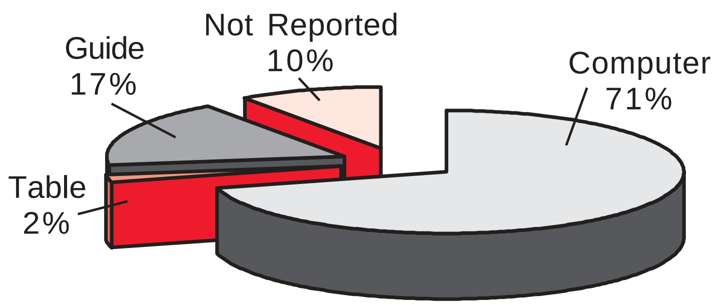


Fig 80
Dive planning.

Figure 81 shows the percentages of our sample who reported either decompression stops or safety stops. A safety stop was reported for 20 percent of all dives sampled. Most of the reported decompression dives were made at Scapa Flow.

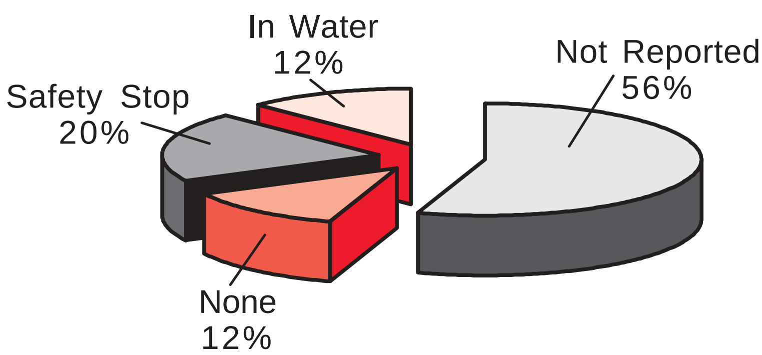


Fig 81
Decompression.

The workload reported by divers in the majority of dives was light. Only in 2 percent of all dives did the diver report a heavy workload (Figure 82).

Fig 82 Subjective workload.

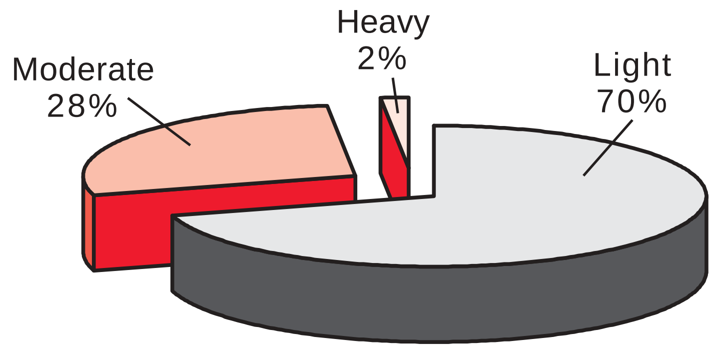
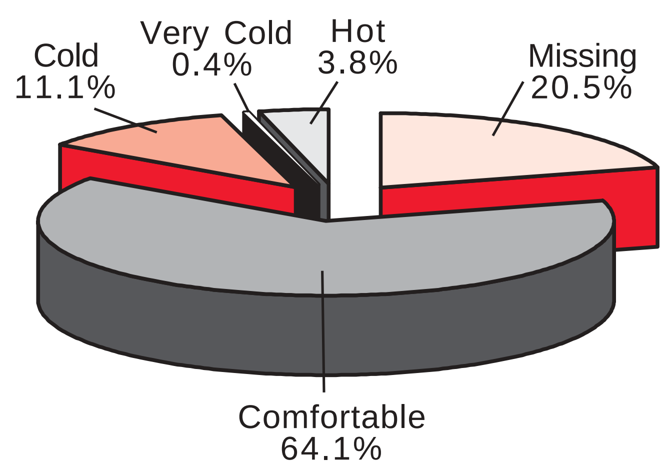


Figure 83 illustrates the reported thermal comfort of the divers in our sample. Most divers were thermally comfortable. Eleven percent reported feeling cold, 4 percent reported feeling hot. Only 0.4 percent reported feeling very cold. The subjective feeling of thermal comfort did not show any direct relationship to the minimum water temperature recorded by dive computers.

Fig 83 Thermal comfort.



4.7 Flying After Diving

If a diver was exposed to a secondary decompression stress from altitude change within 48 hours of his or her 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 maintain a cabin pressure equivalent to not more than 8,000 feet (240 meters) 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. Because most dive computers do not record altitude (only recent Cochran computers do), the pressure-time profile of the altitude exposure was unknown.

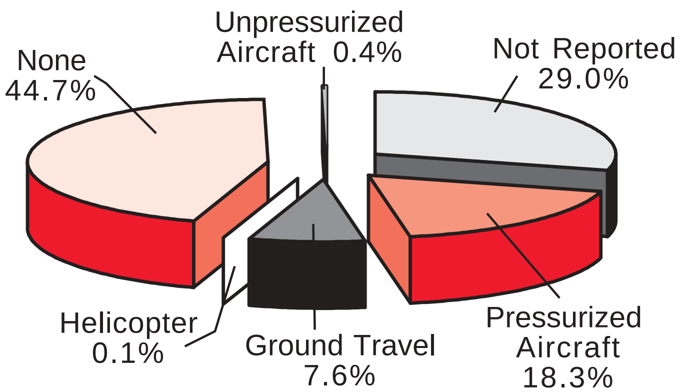


Fig 84
Altitude exposure after diving.

Figure 84 shows that 18 percent of all participants reported having flown in commercial airliners within 48 hours of their last dive. However, when the PDE sample was narrowed to exclude dive professionals who presumably dive where they live and divers from the United Kingdom who presumably drive to the dive site, the estimated PDE percentage of altitude exposure after diving (within 48 hours) increased to 47 percent. Figure 85 also shows that in that narrowed sample of U.S. recreational divers, 1 percent flew non-pressurized airplanes and 1 percent reported ground travel to the mountains.

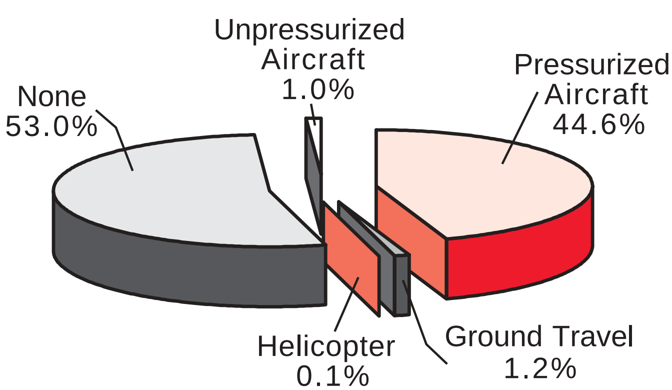
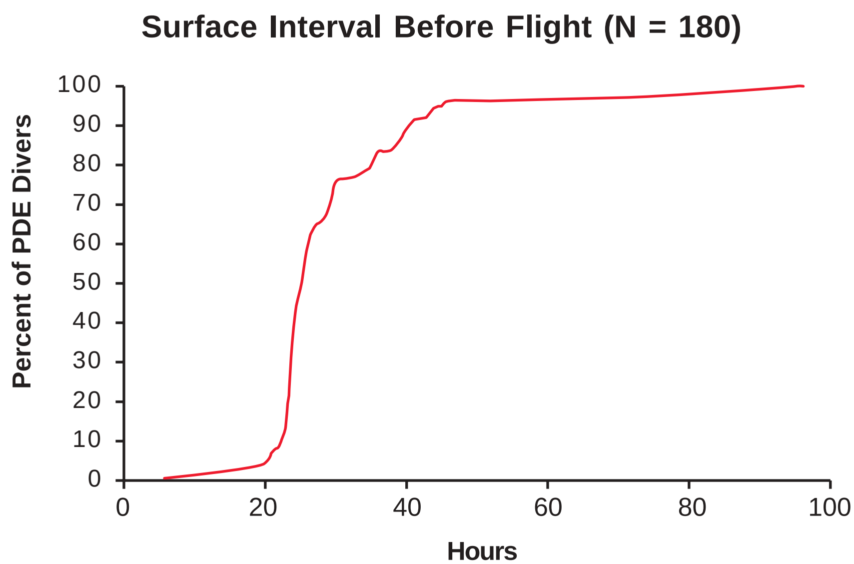


Fig 85
Estimated percentage of altitude exposure in U.S. recreational divers.

The pre-flight surface interval (PFSI, the time elapsed between the end of the last dive and the secondary decompression stress of post-dive altitude exposure) was available for 180 PDE divers. Most divers abstained from diving after noon on the last day of their vacation trip and flew home the next morning, at least 20 hours after the last dive ended. Our data indicate that this was a practice in 93 percent of cases. The shortest PFSI of six hours was reported by one diver (0.5 percent), 25 divers (13.5 percent) reported waiting between 14 and 24 hours, and 154 divers (86 percent) waited 24 to 96 hours (Figure 86). There were no DCI-related symptoms recorded from the 515 divers who reported altitude exposure within 48 hours of diving.

Fig 86 Pre-flight surface interval (N=180).



4.8 Comparisons Within PDE Subgroups

PDE data from four subgroups representing differing exposure patterns for recreational divers were separately analyzed and the medical outcomes compared. The four subsets include:

1) data collected from liveaboard trips;
2) data collected from shore or day-boat dives;
3) data collected from cold water wreck diving (the data from Scapa Flow); and
4) data collected from day-boat dive professionals (mostly from Cozumel).

The following section describes and contrasts the four data sets by diver characteristics, dive environment, dive style, number of dives and medical outcomes.

Figure 87 and Table 15 shows the mean and range of ages of divers in the four subgroups. The oldest divers were in the liveaboard group and had a mean age of 42 years.

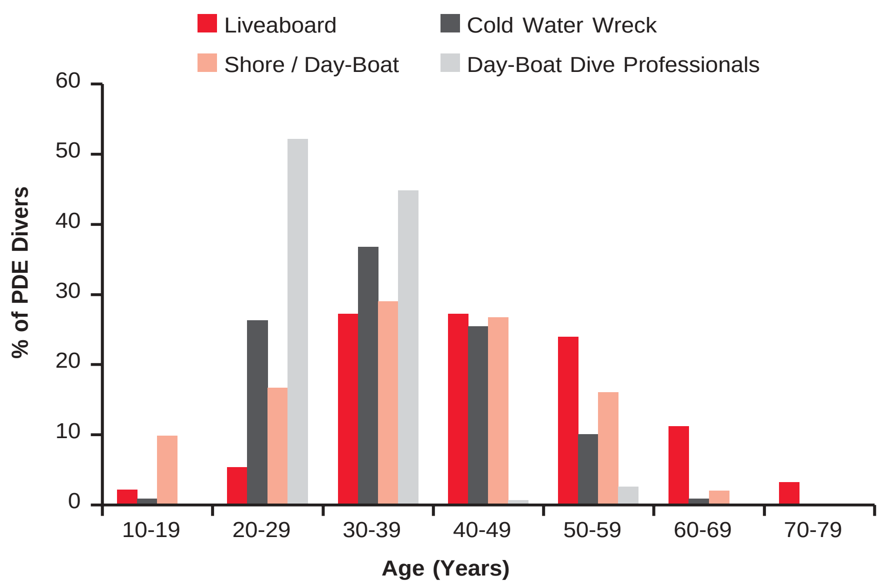


Fig 87
Age distribution in four subgroups of divers.

Diver experience as reflected by mean number of years diving did not differ much among the four groups (Table 15). The liveaboard divers were the most experienced with mean of 11 years and range of 1 to 42 years. The dive professionals had two to 22 years of experience. Figure 91 indicates the number of dives by certification category in each group. As expected, the highest certification levels were found in dive professionals, followed by Scapa Flow wreck divers. Divers in the liveaboard group held higher certifications than divers in the shore / day-boat group.

Table 15
The age and experience of divers.

Group	# Divers	Age (Years)		Years Diving	
		Mean	Range	Mean	Range
Liveaboard	290	42.3	13-74	10.8	1-42
Cold-Water Wreck	233	36.6	18-62	8.9	1-35
Shore / Day-Boat	705	37.4	17-77	8.3	1-44
Day-Boat Dive Professionals	48	31.4	22-55	9.2	2-22

Fig 88 Percentage of dives by certification of divers and by subgroup.

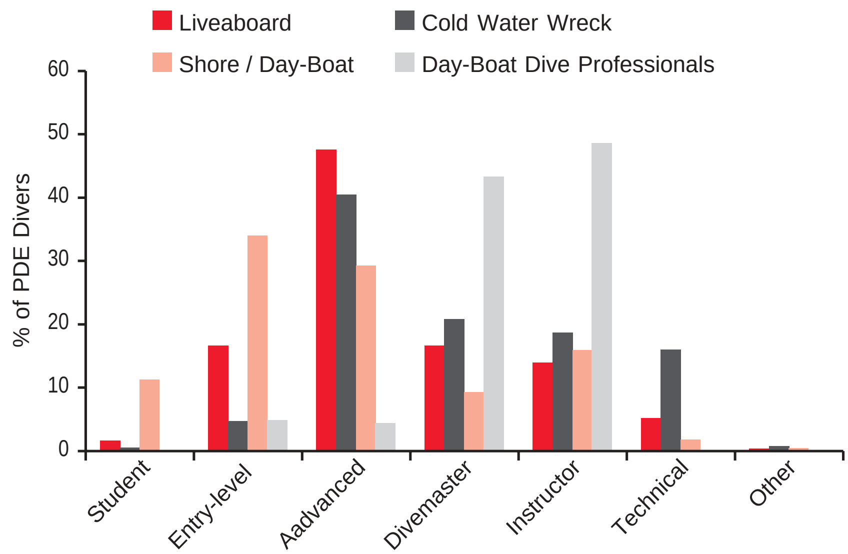


Table 16 shows the recorded PDE participation by subgroup. In the cold-water wreck (Scapa Flow) and liveaboard subgroups, most divers participated in PDE only once. Shore- / day-boat divers participated on average twice, and dive professionals in Cozumel participated on average 12 times, contributing 10 times more dives per diver than other groups.

Table 16 Number of dives and dive series per diver by subgroup.

Group	# Divers	# Dives Per Diver		# Series Per Diver	
		Median	Range	Median	Range
Liveaboard	290	13.0	1-167	1.0	1-29
Cold-Water Wreck	233	11.0	1-23	1.0	1-2
Shore / Day-Boat	705	4.0	1-36	1.0	1-16
Day-Boat Dive Professionals	48	103.0	6-351	10.0	1-38

The data on dive depths as categorized by subgroup is shown in Figure 89 and in Table 17. The mean maximum depth was greatest in the cold-water wreck (Scapa Flow) diving group — 88 fsw (26.5 msw). Half (50 percent) of all dives in that group were deeper than 90 fsw (27 msw). Dive professionals made most (85 percent) of their dives in the range of 30 to 90 fsw (9 to 27 msw); however, they also attained depths deeper than 120 fsw (36 msw) in approximately 2 percent of their excursions. The deepest reported dive was to 289 fsw (90 msw). The 289 fsw dive was made by a member of the Cozumel dive professional subgroup, presumably on a non-work-related dive.

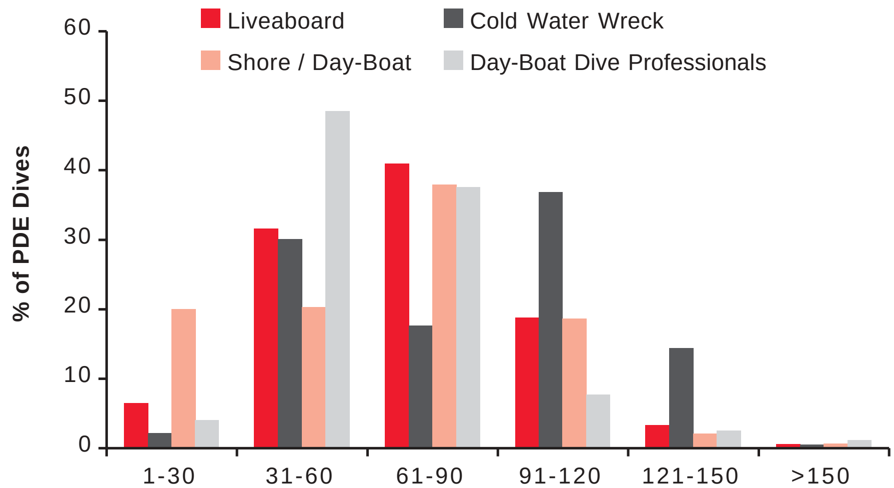


Fig 89 Maximum dive depth by subgroup.

Table 17 Maximum depth statistics.

Group	# Dives	Mean	Max
Liveaboard	3,928	70.1	216
Cold-Water Wreck	2,413	88.5	209
Shore / Day-Boat	3,796	66.1	271
Day-Boat Dive Professionals	5,248	64.6	289
Total	15,385		

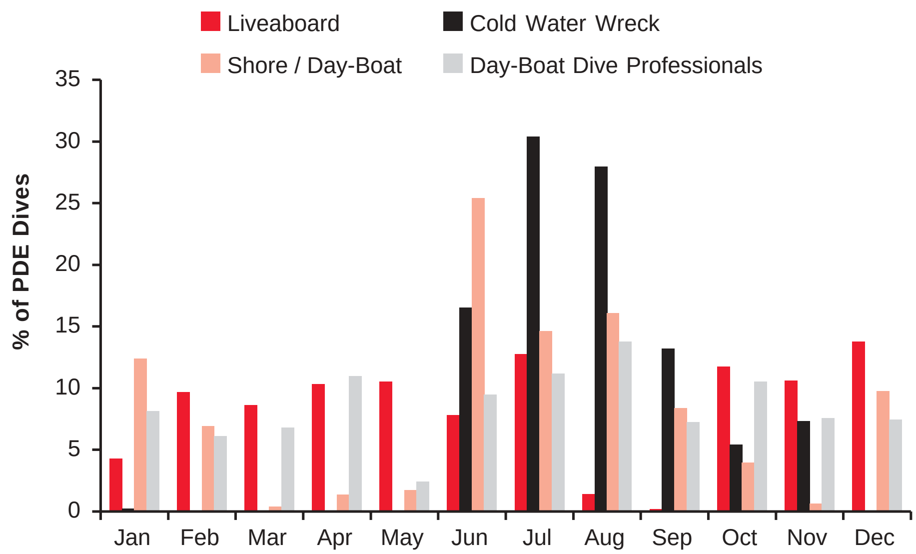
Table 18 describes breathing gases used. Compressed air was used in most dives (88 percent). Nitrox was used in 11 percent, and other gas mixes were used in 0.7 percent of the PDE dives recorded. In the cold-water wreck group, nitrox was used in 32 percent of the dives, and other gas mixes were used in 3 percent. Dive professionals used nitrox in less than 2 percent of their reported dives.

Table 18 Breathing gas.

Group	Air	Nitrox	Heliox/Trimix	Combination
Liveaboard	93.4	6.5	0.0	0.1
Cold-Water Wreck	65.2	32.2	1.3	1.3
Shore / Day-Boat	86.5	13	0.3	0.2
Day-Boat Dive Professionals	97.6	1.9	0.0	0.4

Figure 90 shows the month in which the recorded dives occurred by subgroup. Seasonal variation reflects the changing opportunities for both diving as well as for data collection.

Fig 90 Month of dive.



The dive exposure was more intense in the Scapa Flow group (cold-water wreck diving) due to cold water, deep, square-profile diving and the use of complex equipment, gases and procedures. At Scapa Flow, most divers wore drysuits, and 30 percent of the divers made mandatory in-water decompression stops. In contrast, the other groups rarely reported decompression stops. Day-boat dive professionals dived most frequently and had fewer non-diving days, especially during the high tourist season. Most warm, coral reef dives were multilevel dives.

4.9 Outcomes

Four possible medical outcomes for the sampled PDE dive profiles were compiled:

1) uneventful (signs or symptoms denied);
2) an incident (a dive series that recorded a potentially dangerous event but in which no injury occurred);
3) a sign or symptom that did not result in recompression; or
4) DCI (either DCS or AGE).

The classification of an outcome as an incident was based on the occurrence of a procedural problem during the dive that could have but did not cause an injury. Potentially dangerous events that were reported in our sample are listed according to subgroup in Table 19.

Problems during a dive were reported in more than 4 percent of dives; the incidence of reported problems varied from 2 percent in dive professionals to 13 percent in the cold-water wreck group. Equalization was the most frequent problem (2 percent of all dives), followed by rapid ascent (0.8 percent of dives). Cold-water wreck divers (Scapa Flow) most frequently reported equalization problems and rapid ascents. Cold water, drysuits or lack of control during descent may have contributed to this finding.

Problems	% All	% Liveaboard	% Cold-Water Wreck	% Shore / Day-Boat	% Day-Boat Dive Professionals
Equalization	1.95	3.69	6.01	0.71	0.51
Rapid Ascent	0.84	2.70	4.39	0.08	0.32
Buoyancy	0.29	0.18	0.29	0.58	0.19
Vertigo	0.19			0.66	
Out of Air	0.05	0.03	0.04	0.11	0.06
Missed Deco Stop	0.04				0.10
Shared Air	0.03			0.03	0.04
Seasickness	0.03	0.10	0.17		
N Dives	15,385	3,928	2,413	3,796	5,248
% With Problems	4.14	3.59	13.22	2.58	1.70
Total	637	141	319	98	89

Table 19 Reported problems during dive.

Equipment problems were reported in 226 dives, or 1.5 percent of all dives (Table 20). This problem was more common in the Scapa Flow subgroup, as would be expected by the more technical, equipment intensive nature of the dives.

Equipment Problems	Frequency	% (of all)	% (of reported)
Mask	43	0.28	0.37
Fins	29	0.19	0.25
Weight Belt	33	0.21	0.28
BC	29	0.19	0.25
Thermal Protection	24	0.16	0.20
Computer	17	0.11	0.14
Depth Gauge	4	0.03	0.03
Pressure Gauge	2	0.01	0.02
Regulator / Breathing Apparatus	45	0.29	0.38
None	11,541	75.01	98.08
Subtotal	11,767	76.48	100
Not Reported	3,618	23.52	
Total	15,385	100	

Table 20 Reported equipment problems.

All PDE divers were asked to report any symptoms or signs after the dive 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 any symptoms or signs 48 hours after the dive or after the last flight. If a diver reported any symptom on the 48-Hour Report Form, DAN followed up the report to obtain the details necessary to properly classify the outcome.

In addition to injuries that were recompressed, 61 divers reported symptoms for which no recompression was given (Table 21). Headache was by far the most common of these. There was insufficient evidence to judge that any of these 61 divers had DCI.

Table 21 Reported symptoms that did not require treatment.

Headache	47
Tired and Achy	4
Pain in Arm	3
Ear Pain and Dizziness	6
Rash	1

A total of 18 divers underwent recompression treatment, and 16 of them were diagnosed with DCS. The breakdown by diving groups and classification is shown in Table 22.

Table 22 Treated cases.

	DCS 1	DCS 2	Ambiguous	Not DCI	Treated
Cold-Water Wreck	4	4	1	1	10
Shore / Day-Boat		2		1	3
Day-Boat Dive Professionals	1	4			5

In most cases, symptoms developed within the first hour upon surfacing; however, one case manifested 20 hours after surfacing. There were four cases in which divers continued to dive after developing symptoms. All divers responded well to recompression; only six cases required more than one treatment.

In the wreck diving group, the eight divers were all recompressed within six hours or less. Cases in the other groups were recompressed within 24 hours of their last dive. Oxygen first aid was used in most cases. In the dive professional group, three divers made dives with symptoms. In these cases, more than 24 hours elapsed from the first onset of symptoms before they received recompression treatment. For the three cases in the general recreational group, the delay to recompression was less than 24 hours.

Figure 91 is an example of a cold-water wreck dive profile that resulted in treatment for DCS. This is a dive profile from a 28-year-old male diver (6'2", 141 lbs. / 185 cm, 64 kg) who was first certified in 1998 and had 82 logged dives. He had chronic back pain and reported symptoms of "the flu" before the dive. He was taking anti-malarial, antidiarrheal and pain relief medications and decongestants. The last dive series consisted of six nitrox dives over three days. Figure 94 shows the profiles from his last day of diving. He developed joint pain three hours after his last dive. He was evacuated by the Coast Guard and treated within two hours after the onset of his symptoms. He reported complete relief after a U.S. Navy Treatment Table 6.

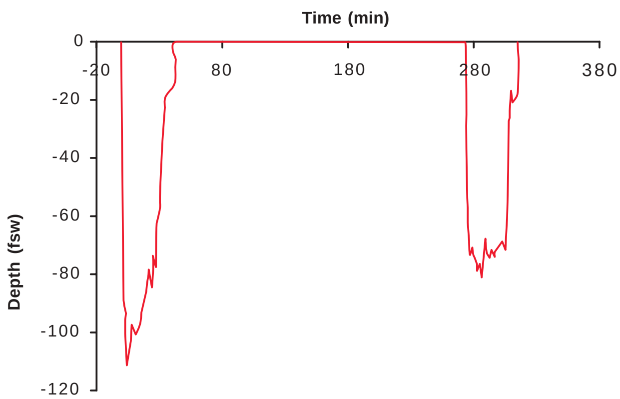


Fig 91
Profile of cold-water wreck dive causing DCS.

Figure 92 is an example of a series of dive profiles from a Cozumel diving professional that resulted in treatment for DCS. This profile is from a 26-year-old male (5'8", 141 lbs. / 170 cm, 64 kg) dive instructor who had made more than 3,000 dives in the past five years. In his last dive series he made 14 dives over a six-day period. The maximum depth of the series was 97 feet (29 meters) and the maximum depth of the last dive was 67 feet (21 meters). He dived on scuba while breathing air. Approximately six hours after his last dive, he developed pain in his left shoulder and tingling in his upper left arm. He was treated 12 hours after the last dive two times on a U.S. Navy Treatment Table 6 and a U.S. Navy Treatment Table 5 and had complete relief.

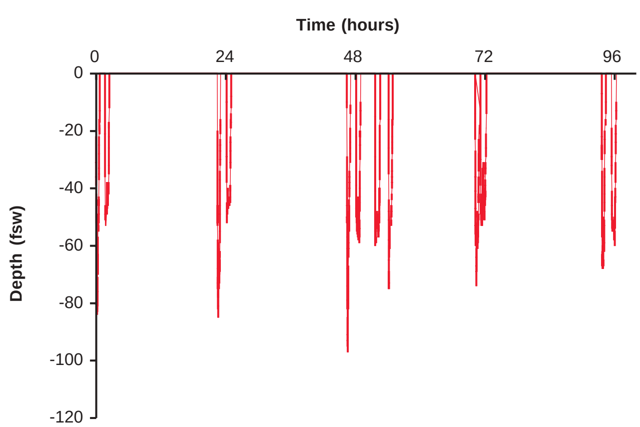


Fig 92
Profile of a day-boat dive professional dive causing DCS.

The incidence of DCS was different among the four groups. Table 23 shows that most cases were reported from the cold-water wreck group. The incidence of DCS, whether calculated per dive or per person, was lowest in the liveaboard group. This data indicates that there may be a significantly higher DCS incidence in cold-water wreck diving than in recreational diving in warm waters. However, although the incidence of DCS in each subgroup is the true incidence for that particular subgroup within PDE, it would be inappropriate to say that any of these groups are a representative sample of the entire population of divers.

A total of 18 divers underwent recompression treatment. Sixteen divers were diagnosed with DCS. Nine of these were Type II decompression sickness (DCS II), five were Type I decompression sickness (DCS I), and one was "ambiguous DCS." One diver was treated because of allegedly omitted decompression and another due to minor headache. These two divers were classified as having non-DCS injuries.

Table 23
The incidence of DCI in four groups of divers.

Group	# Divers	# Dives	# DCS	Incidence / 10,000 Dives	Incidence / 100 Divers
Liveaboard	290	3,928	0	0	0.00
Cold-Water Wreck	233	2,413	9	37	3.86
Shore / Day-Boat	705	3,796	2	5	0.28
Day-Boat Dive Professionals	48	5,248	5	10	9.53

The incidence of DCS was higher in divers with divemaster or instructor certification compared to divers with basic and advanced open-water certification (Table 24).

Table 24
The incidence of DCI by category of dive certification.

Group	# DCS Cases	Denominator		Incidence	
		# Dives	# Divers	Per 10,000 Dives	Per 100 Divers
Instructors & Divemasters	8	7,070	387	11	2.1
Open Water & Advanced Open Water	8	6,069	748	13	1.1
Total	16	13,139	1,135	12.2	1.4

5. Injury, Fatality and PDE Population Comparisons

Comparisons between the three populations this year revealed some similarities and some differences from the previous year.

5.1 Diver Characteristics

The average ages of the three populations are shown in Figure 93. As for last year, fatalities were the oldest, but injured divers were nearly four years older in 2001 than in 2000. PDE divers were on average three years younger in 2001 and the youngest of the three groups.

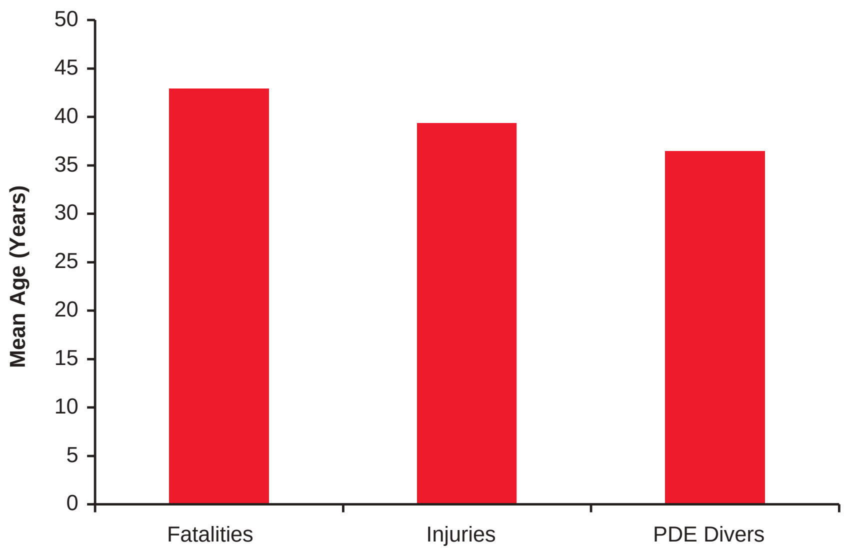


Fig 93
Comparison of mean age by population.

Figure 94 shows the proportion of males and females in each group. The gender distribution between populations was similar to the previous year. The highest proportion of females was among injuries and the lowest among fatalities.

Fig 94 Comparison of gender distribution by population.

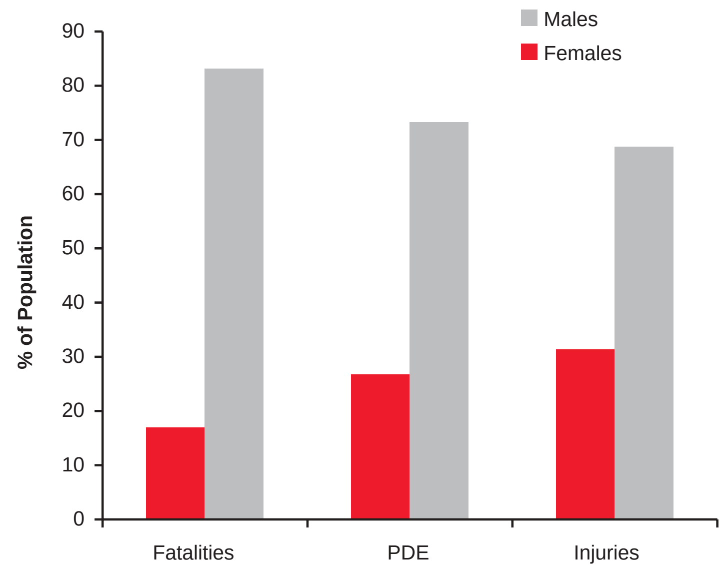


Figure 95 shows the level of certification reported in the three populations. Open water and advanced were again the most common certifications for all three groups.

Fig 95 Comparison of certification by population.

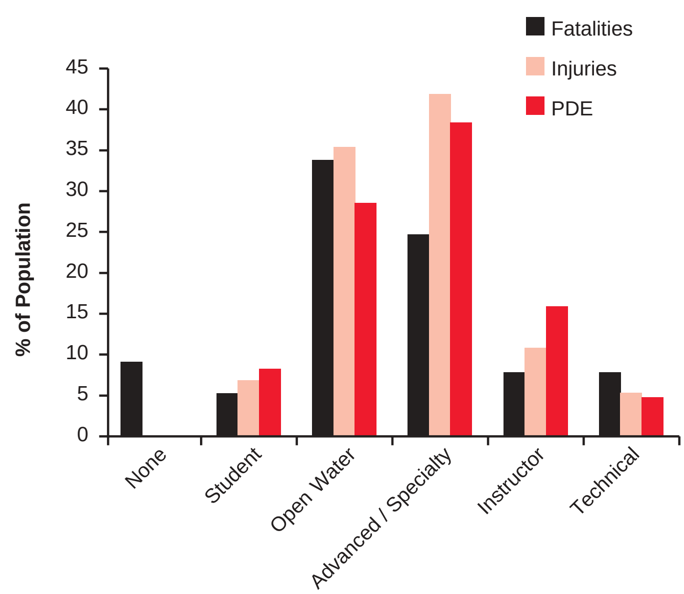


Figure 96 shows the average number of years since initial certification. In comparison to 2000 data, injuries and fatalities swapped places.

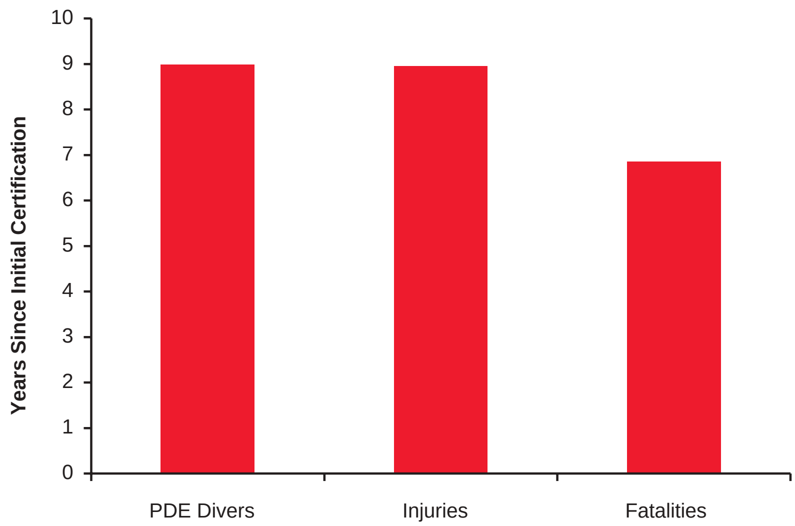


Fig 96 Comparison of years since certification by population.

Figure 97, a comparison of health problems, again indicates the highest prevalence of heart disease and high blood pressure among fatalities.

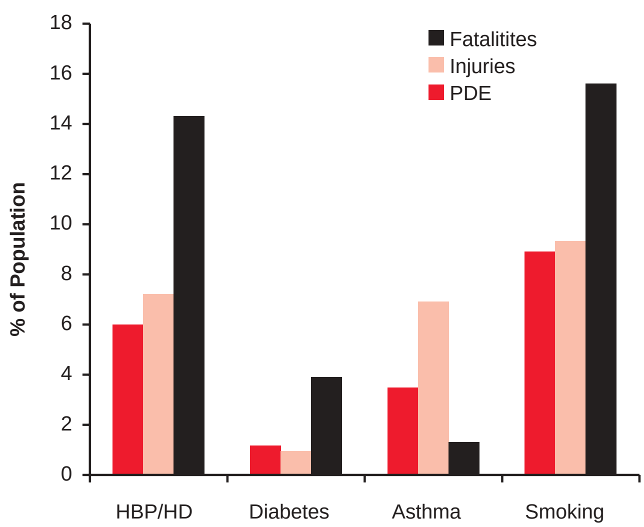
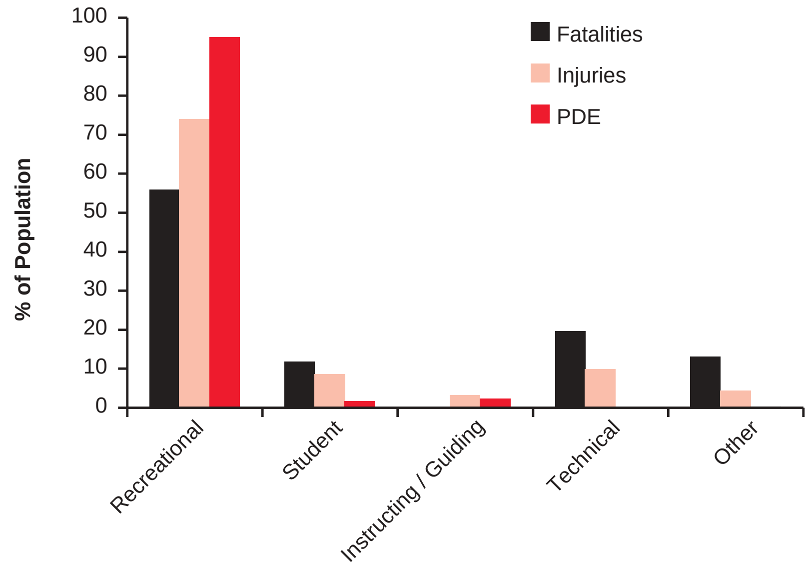


Fig 97 Comparison of health problems by population.

5.2 Dive Characteristics

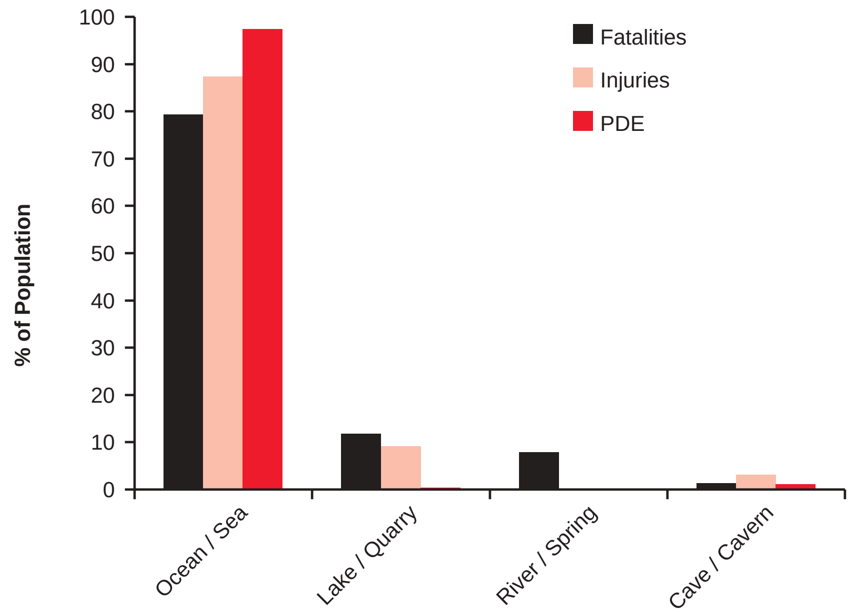
The following figures show some of the same measures used in previous sections to characterize the difficulty or risk of the dives. The reported dive purpose as seen in Figure 98 is similar to last year's report.

Fig 98 Comparison of dive purpose by population.



The proportion of dives in different environments varied across the populations as shown in Figure 99. Each group made most of its dives in the ocean or sea. The second most common environment was lakes / quarries for injuries and fatalities.

Fig 99 Comparison of dive environment by population.



Figures 100 and 101 show how the populations differed for maximum depth in the dive series and on the last dive in the series, respectively. Fatal dives tended to have the shallowest maximum depth. The injured divers in the PDE population had the deepest maximum depth but the mean depth of their last dive was same as in other PDE divers and lowest in comparison to fatalities and injuries.

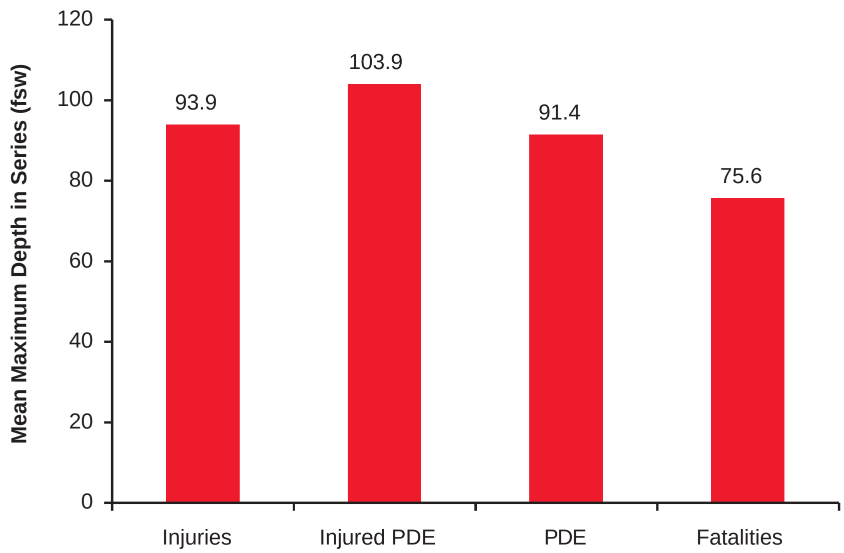


Fig 100 Comparison of mean maximum depth in series by population.

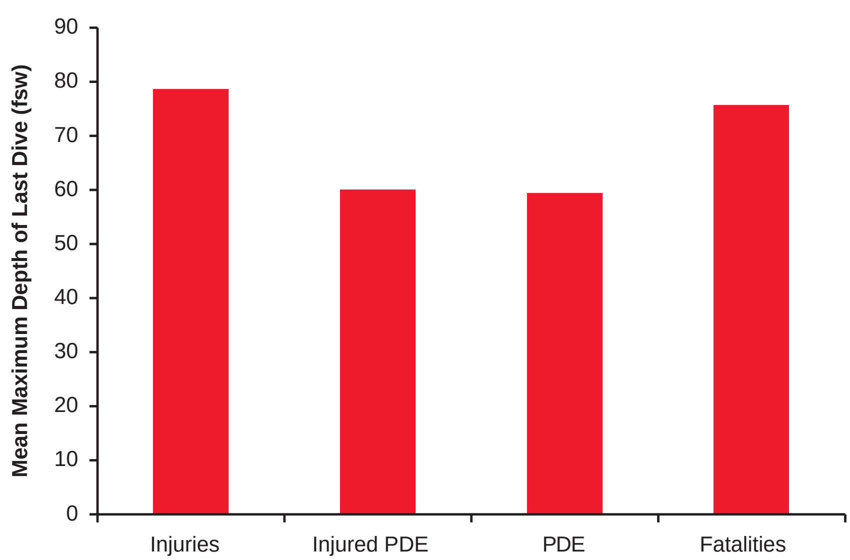


Fig 101 Comparison of mean maximum depth for the last dive by population.

Figures 102 and 103 show how the populations differed in number of dives per series and average number of dives per day. Fewer dives per series were reported among the injuries than for PDE. This information was not available for fatalities. The PDE and injured divers reported two dives per day on average versus 1.1 dives per day for the fatalities.

Fig 102
Comparison of total number of dives in series by population.

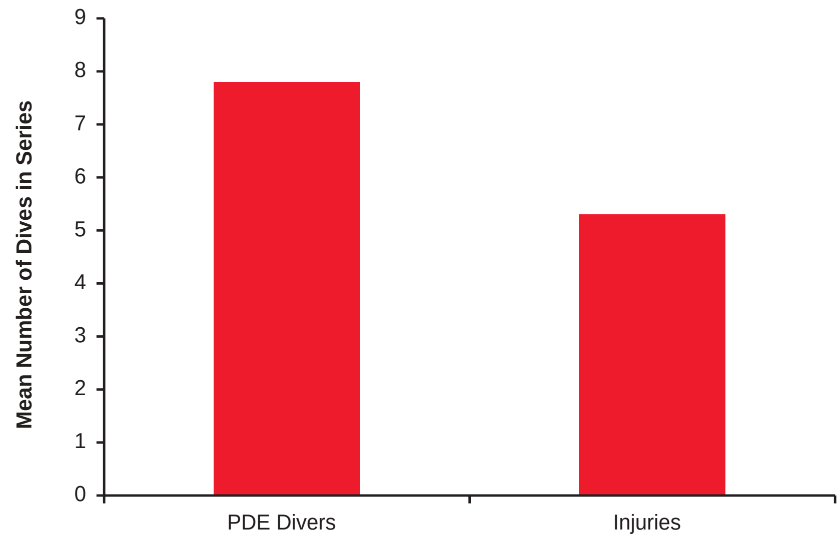


Fig 103
Comparison of number of dives per day by population.

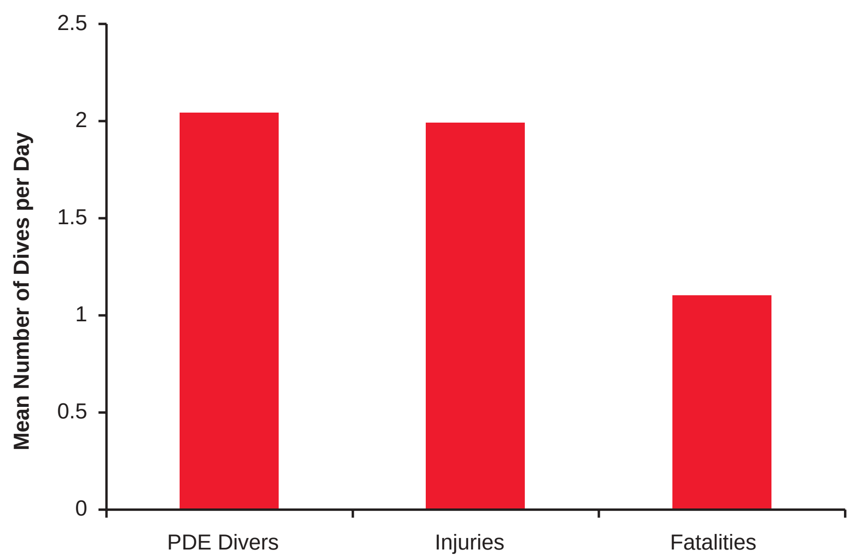


Figure 104 shows a comparison of the distributions of the total number of dives in the series for PDE and injuries. These data were not obtained for fatalities, although it appeared that most fatalities occurred on the first day of diving. There was a significant difference between the PDE and injuries populations, most likely due to the large proportion of six-day series in the PDE group. This probably reflects PDE dives collected on liveaboards. The distributions were similar to the previous year.

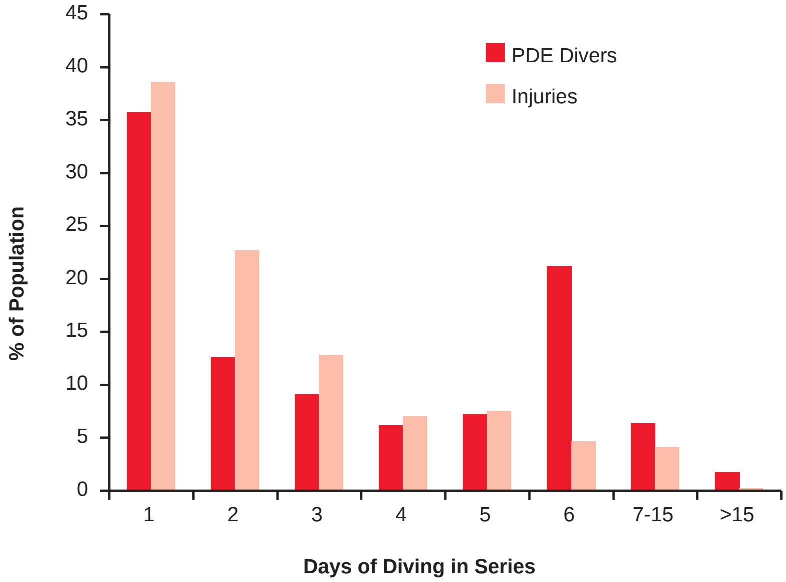


Fig 104 Comparison of the distributions of number of days diving by population.

Figure 105 shows that there were large differences between populations with regard to difficulty maintaining buoyancy, rapid ascents, running out of gas or missed decompression. The problems were reported to a significantly greater frequency by injured divers than by PDE divers. Since this information was based on subjective reports, it could not be compared to findings in fatalities.

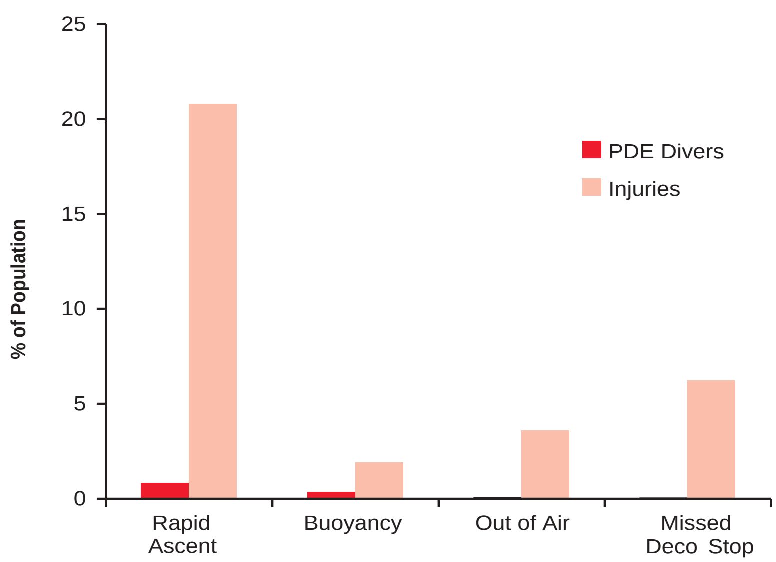
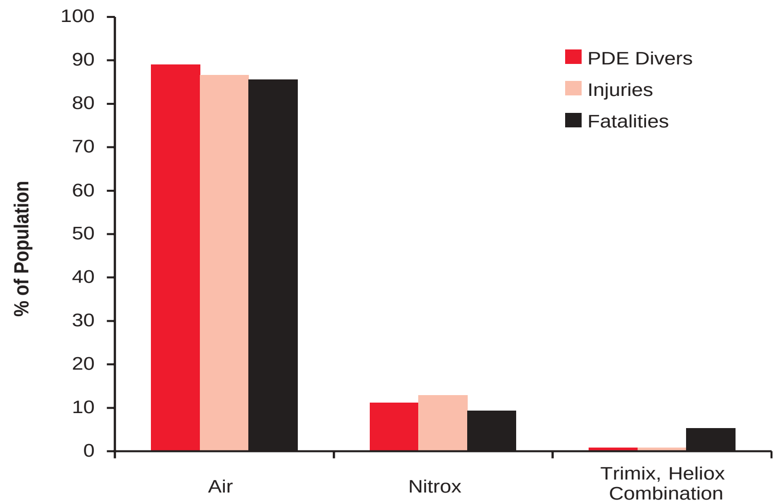


Fig 105 Comparison of diving problems by population.

6. Mixed-Gas Diving

This section offers comparisons of air, nitrogen-oxygen (nitrox), and helium-oxygen (heliox) or helium-nitrogen-oxygen (trimix) breathing gases for injuries, fatalities and PDE divers during the year 2001. Figure 106 shows the distribution of diving activity within the three populations and three categories of breathing gas. At more than 85 percent for all populations, air was the most common gas. There was no significant difference in use of nitrox (9.2-12.8 percent) among groups.

Fig 106
Proportions of air, nitrox and heliox or trimix divers among fatalities, injuries and PDE divers.



The percentage of female air divers was as great as 32.2 percent among injuries and as low as 16.1 percent among fatalities (Figure 107). Of 12 females in fatalities, two made dives while breathing nitrox and one breathed heliox / trimix. In Injuries, there were only five cases breathing helium / trimix, and three of them were females.

Fig 107
Proportions of female divers by breathing gas.

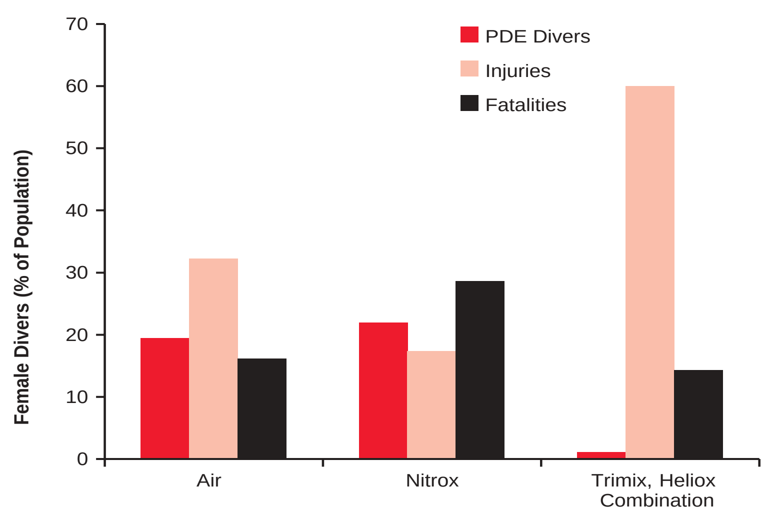


Figure 108 shows the mean ages of the population and breathing gas groups. The mean age of divers using air or nitrox did not differ much in three population groups, but the pattern has changed in comparison to previous years. The number of divers using helium / trimix was too small for statistical evaluation.

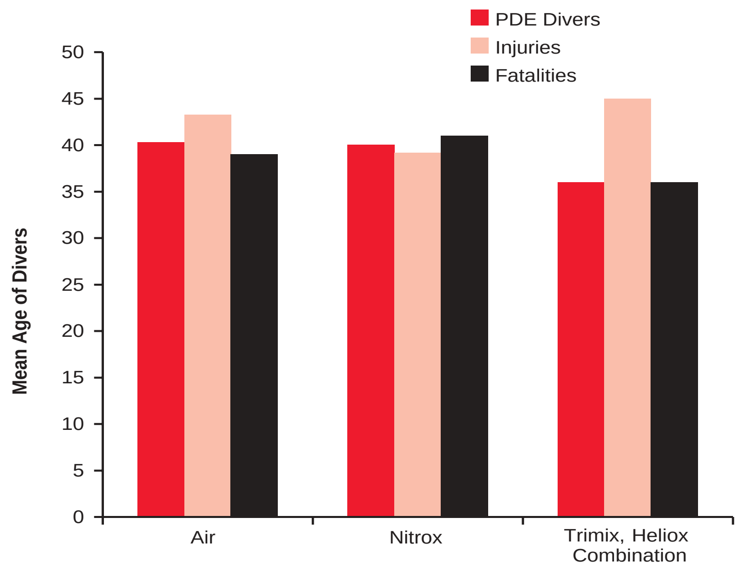


Fig 108
Mean diver age by breathing gas.

Figure 109 shows the mean years since initial diver certification. Divers who died were the least experienced among the three populations diving on air or nitrox. In contrast, divers with fatal outcomes using heliox / trimix were more experienced than injured divers and PDE divers using heliox / trimix, as measured by their years since initial certification.

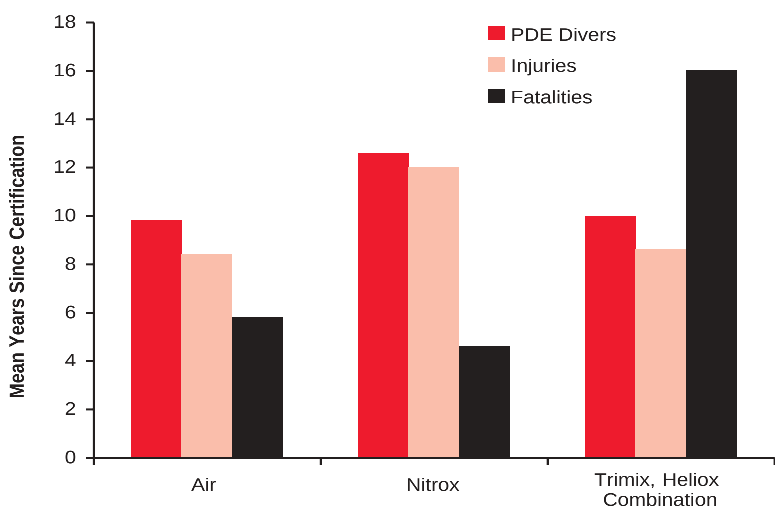


Fig 109
Mean years since certification by breathing gas.

Figure 110 shows that injured divers had the deepest maximum depths in their dive series regardless what gas they had used. This is the same trend as in the previous year.

Fig 110
Mean maximum dive depth in the series by breathing gas.

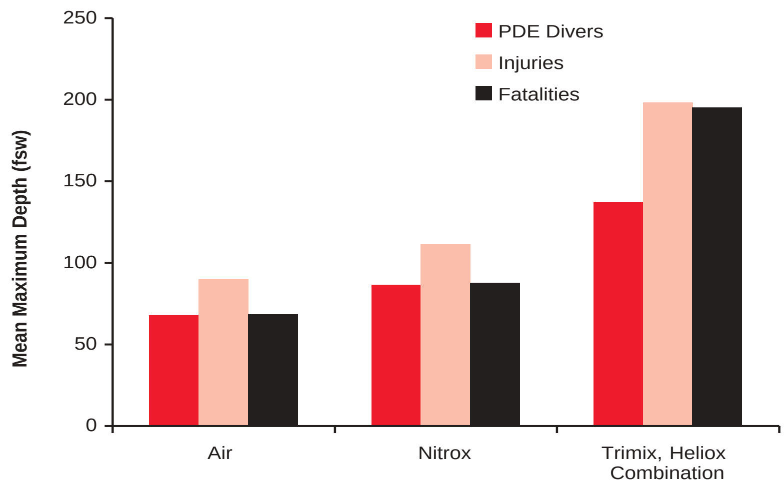


Figure 111 shows the distribution of dive computer use across the diving populations and breathing gases. More than 70 percent of all divers used dive computers. Information for divers who died was not available.

Fig 111
Dive computer use by breathing gas.

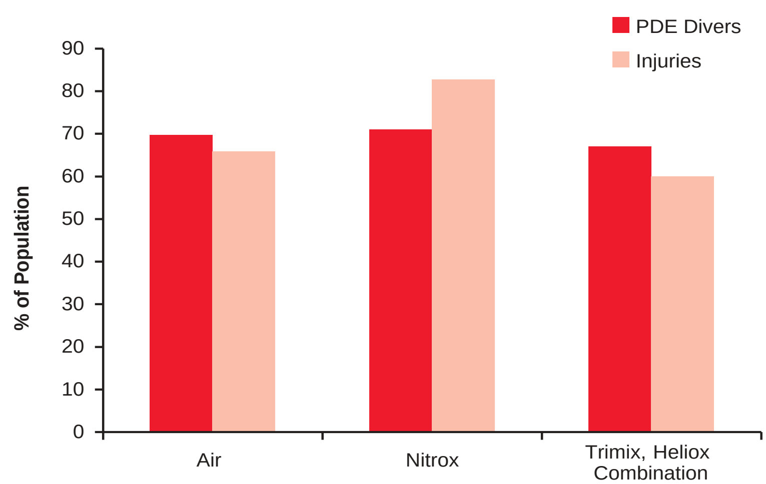


Figure 112 shows the maximum oxygen partial pressure (PO_2) for PDE divers and injured divers who used nitrox. Very few PDE divers had a PO_2 of greater than 1.4 atm, while divers with injuries had PO_2s as high as 2 atm.

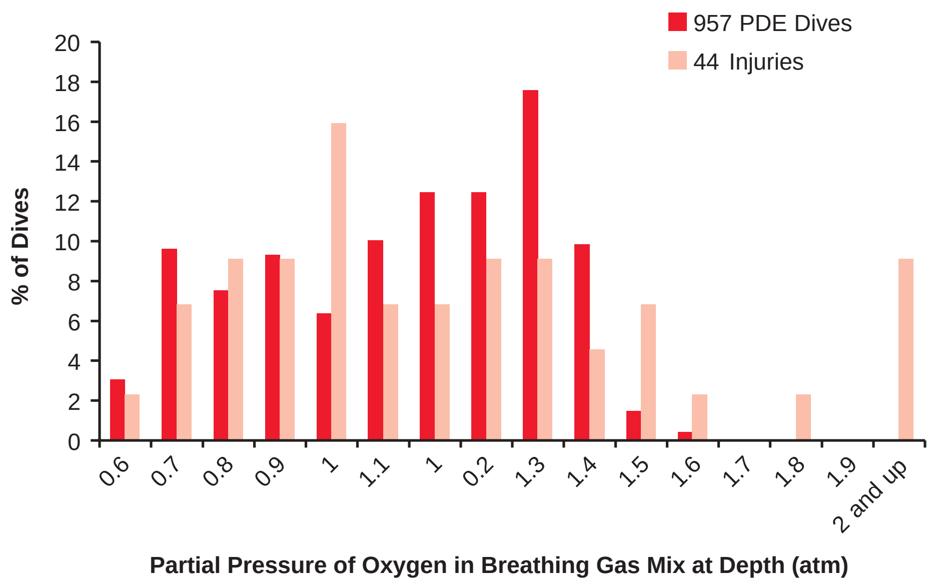


Fig 112
Maximum oxygen partial pressure during nitrox diving for injured PDE divers.

Glossary

AGE — Arterial Gas Embolism
Decompression injury caused by bubbles that enter the arterial circulation due to lung damage from breath holding during ascent ("burst lung"). The brain is the most commonly affected organ. AGE can occur during any dive, independent of depth-time exposure. AGE signs and symptoms generally occur within 10-15 minutes of ascent and affect some aspect of brain function.

DCC — Data Collection Center
A diving operation that collects data for Project Dive Exploration.

DCI — Decompression Illness
A general term for decompression injury that includes both AGE and DCS. Both are sometimes grouped together as DCI because they can be difficult or impossible to distinguish and because the treatment for both is the same – oxygen and recompression.

DCS — Decompression Sickness
Decompression injury caused by bubbles that form within the body during and after ascent. Unlike AGE, the risk of DCS depends on the severity of the depth-time exposure.

DCS I — Type I DCS
DCS symptoms that are not serious threats to diver health and for which complete recovery is likely. These include limb pain, itching, rash, fatigue or swelling.

DCS II — Type II DCS
DCS signs and symptoms that are potential threats to diver health and for which recovery may not be complete. These include decreased strength, abnormal sensation, heart or breathing problems, problems with thinking or consciousness, problems with vision, hearing, speaking, balance, coordination, and problems with bladder or bowel function.

DL7 — Dive Log 7 Standard
The DL7 Standard was drafted after a 1997 DAN Workshop in Cozumel that discussed the use of dive computers to collect open-water diving data. The DL7 objectives were to facilitate data exchange between dive log applications, scientific data acquisition software, and hyperbaric chambers or hospitals that treat decompression illness. The DL7 is available upon request from the Divers Alert Network.

FAD — Flying After Diving
An altitude exposure within 48 hours after ending a dive. FAD exposures include mountain travel and flying in pressurized or unpressurized aircraft.

FRC — Field Research Coordinator
Volunteers who assist divers in collecting and reporting data for PDE.

Median
The mid-point in a group of measurements such that half the measurements are less than the median and half are greater.

Mean
The "average." The sum of all measurements in a group divided by the number of measurements. A few extreme measurements may make the mean greater or less than the median.

PDE — Project Dive Exploration
PDE is a prospective observational study of dive profiles and medical outcomes in recreational diving.

PSI — Perceived Severity Index
A system for classifying the severity of diving injuries based on a perceived, but arbitrary, ordering of the severity of reported signs and symptoms. PSI first appeared the in 2002 *Report on Decompression Illness, Diving Fatalities and Project Dive Exploration*.

Technical Diving
For this report, dives on heliox, trimix or a rebreather, regardless of gas mix. This does not mean that the divers making technical dives were certified technical divers or were following guidelines of the technical diving agencies.

Appendix A: Injury Case Reports

Introduction

In 2001, close to 1,000 treated cases of decompression illness (DCI) were reported to DAN by the DAN worldwide network of referral hyperbaric chambers.

Many cases of decompression illness demonstrate similar patterns of symptoms and presentation, but dive profiles are often quite diverse. Instances of DCI can range from mild pain-only cases to severe neurological symptoms or complete paralysis. Despite similar symptoms, these cases had different responses to recompression. Why some cases are more resistant to treatment is not completely understood.

Surprisingly, although decompression illness and its symptoms are well known to most divers, these divers are often hesitant to report their symptoms or seek evaluation. The more moderate or mild symptoms can be confused easily with pre-existing injuries or other recent activities and may also contribute to the delay.

The following cases represent common examples of the variety of symptoms in decompression illness, symptom severity and outcomes after treatment. These cases were chosen randomly based on symptom presentation. Although complete dive profiles are not given here, they generally help in making a definitive diagnosis.

All cases were diagnosed as DCI, and this was the first episode of DCI for each diver. Two cases represent two DCI episodes in one year. In these cases, there was always more than one diver in the water at the time of injury, but only the diver mentioned in each case reported having any symptoms

Case 1. Serious Neurological DCI with Neurological Symptoms Prior to the Last Dive — With Complete Resolution

The diver was a 56-year-old male in reasonably good health. He had a vague history of back problems from more than 25 years ago and had not smoked in approximately five years. He was physically active without restrictions. He had been scuba diving for approximately one month and completed 13 dives. This was his first dive vacation, where he made nine dives over four days.

On his next-to-last day of diving, he surfaced from the last dive and experienced numbness in his right hand and tunnel vision in his right eye. These symptoms gradually lessened and finally resolved in less than 10 minutes. He had never experienced either symptom before, and he did not report his symptoms to his diving companion or to the boat captain. On the final day of diving, he started the day with a 102-foot (30.6-meter) dive. Within minutes of exiting the water, he experienced a complete right-sided paralysis.

The crew provided 100 percent oxygen as soon as they had removed his gear and placed him in a safety position. The diver reported no problems with his dive, which included a slow ascent and safety stop. Within an hour he could move his right arm and leg but was experiencing extreme weakness, general fatigue and lethargy. While still breathing oxygen, he was transported by helicopter to the nearest available recompression chamber. He was recompressed approximately five and a half hours after his symptoms began with a U.S. Navy Treatment Table 6. He experienced a near-total resolution of his symptoms. A second Table 6 the following day resulted in complete resolution.

This diver was fortunate because he received the benefit of high-flow 100 percent oxygen rapidly after serious symptoms developed; also, he was close enough to a major medical and recompression center where he could be evaluated. It is difficult to determine whether his apparent arterial gas embolism was a continuation of the previous day's injury or a separate incident. It is clear that symptoms on the previous day were not a sufficient indication for the diver that he had a problem. A post-incident pulmonary evaluation did not reveal pre-existing lung problems that could have contributed to a cerebral gas embolism and his strokelike symptoms.

Case 2. Neurological DCI Symptoms Prior to Mixed Cerebral and Spinal Cord Symptoms — With Complete Resolution

The diver was a 44-year-old male in good health. He reported no health problems but had been a smoker for the past 31 years, smoking approximately 10-12 packs per week. He had been certified for 10 years, making at least 300 dives per year, and was diving with 36 percent nitrox as his breathing gas on the day of his injury. His first dive was to 76 feet (22.8 meters), where he attached a mooring line to a shipwreck. The dive was uneventful.

Two to three minutes after surfacing from the first dive, he experienced some chest and neck pain and light-headedness. The diver took no action to address these symptoms. He then performed his second dive of the day, also on nitrox, to 24 feet (7.2 meters). He was using open circuit scuba, and towards the end of the dive he ran out of air. He made a rapid ascent with no safety stop. After surfacing from the dive, he immediately experienced a tingling from his elbows to his hands and in both feet. Although he considered these symptoms mild, he received high-flow 100 percent oxygen. During this time, he experienced an altered level of consciousness and was reported to have had two mild seizures. The diver later admitted no memory of any events after oxygen was provided. He was transferred to a hyperbaric facility, where he received a non-standard hyperbaric recompression. The diver was left with only very mild dizziness and skin sensation changes. The next day he was treated in the chamber once more, with complete relief of symptoms.

It would appear this diver experienced a pulmonary injury on his first dive during his attempts to attach the mooring line. This was then complicated by his rapid ascent on the second dive. Both exposures were minimal and would not seem capable of producing such a dramatic spinal cord injury. This is not uncommon in cases where spinal cord symptoms appear after an apparent arterial gas embolism (AGE). The immediate application of oxygen and transfer to a recompression chamber for treatment contributed to his complete recovery.

Case 3. Symptoms Occurring Before the End of the Dive and Evolving into a Cerebral Arterial Gas Embolism — With Complete Resolution

The diver was a 24-year-old male who lists no health problems but does take antidepressive medication. He has been certified for two years and has made a total of 20 dives. He had made 12 dives in the past 12 months and was traveling in the Caribbean on his current dive trip. On the first day of diving, he made a total of three dives, the deepest to 60 feet (18 meters). All three dives were multilevel and included a safety stop. He reported no problems during the dive, normal air consumption and normal ascents.

During the second day of diving, the diver decided to perform a deep dive to 130 feet (39 meters), deeper than he had ever dived before. After a descent and bottom time of eight minutes, he began his ascent and made a five-minute safety stop at 20 feet (6 meters). During his ascent to the safety stop, he began to experience numbness and tingling in his face and left arm. This continued throughout the safety stop. Within four minutes of surfacing he developed nausea, generalized weakness, a semiconscious state with headache, and an overall sensation of body numbness.

He was provided with 100 percent free-flow oxygen and transported back to shore, where he was recompressed at a local recompression chamber approximately one and a half hours after his symptoms began. He received a U.S. Navy Treatment Table 6 but had minimal improvement. The following day he received a second Table 6 with some relief. Over the next three days he received a U.S. Navy Treatment Table 5 daily. By the end of these five treatments he achieved complete relief.

The rapid onset and evolution of symptoms would seem to suggest a cerebral gas embolism, along with a serious spinal cord decompression illness. Despite the early administration of oxygen and chamber recompression, the diver's symptoms were initially resistant to therapy, indicating a more serious case of decompression illness.

Case 4. A Serious Case of Spinal Cord Decompression Illness with Symptoms Beginning at the Safety Stop — With Complete Resolution

The diver was a 43-year-old male with a history of recurrent back pain. He listed no other illness, disease or other health problems. He had been a certified diver for 10 years and was a current scuba instructor. He made approximately 250 dives each year.

He was on a one-week dive trip in the Caribbean; he had a total of six days of diving and 12 dives before he was injured. He had no problems during his dive days, made safety stops on all of his dives and was using air as his breathing gas. His deepest dive in the series was 157 feet (47.1 meters). He did multilevel diving, using a computer.

During his 20-foot (6-meter) safety stop on his last dive to 137 feet (41.1 meters), he began to experience numbness and tingling in his left leg. This eventually spread throughout his body. The numbness and tingling were accompanied by a twitching and shaking in his leg as well as an overwhelming sensation of dizziness. He descended to 25 feet (7.5 meters), and his symptoms seemed to resolve. He then exited the water. Shortly thereafter experienced an overall numbness and weak sensation over his entire body. He also noted a generalized pain in his muscles and joints. These symptoms were quickly followed by paralysis from the neck down.

He received oxygen by way of a demand valve while he was transported to the local chamber. The trip took a total of three hours and 25 minutes. The shaking, dizziness, pain and paralysis had resolved by the time he reached the recompression chamber. He received a U.S. Navy Treatment Table 6. He experienced some relief of his symptoms but could not walk on his own and still had a great deal of numbness. Later that evening, treating physicians attempted a second treatment. The diver became claustrophobic, so treatment was shortened. He was able to walk after these treatments treatment but still had significant body numbness and difficulty controlling his right arm. Arrangements were made to evacuate the diver to a hyperbaric facility in the United States.

He continued to experience mild tingling and numbness throughout his body, with extremity weakness and fatigue on admission to the

U.S. facility. He was placed in the chamber for a third treatment, a U.S. Navy TT6 approximately two days after his first treatment. After this recompression he was nearly free of symptoms. He was recompressed and once again the following day on a two-hour treatment schedule that completely alleviated any remaining symptoms.

Case 5. Mild Neurological Symptoms Occurring after the Dive, with Late Onset of Additional Symptoms, Including Slowing of Mental Activity — With Complete Resolution

The diver was a 36-year-old female who was a non-smoker and in good health. She was taking medication for a hypothyroid condition. These were her first two days as a certified diver. On the first day she made two dives, both shallower than 60 feet (18 meters) with no problems. On her second day of diving, she made three short dives. Her third dive was deepest, at 64 feet (19.2 meters) for 22 minutes.

During the ascent on her last dive, she lost control of her buoyancy at about 40 feet (12 meters). She made a faster-than-normal ascent, missing her safety stop. She had made all previous dives with safety stops at 15 feet (4.5 meters). Other than feeling a little tired before her final dive, and noting her buoyancy problem and panic, her two days of diving were uneventful. She had no symptoms immediately after her dive. She packed up her gear and drove home.

Approximately three hours after her last dive, she began experiencing very mild tingling in her lower leg and foot. Seven hours after her dive, she also began feeling mild tingling from her left elbow to her fingertips. Although she was concerned about her symptoms, she did not contact anyone for assistance or explanation. The following day, more than 24 hours after her dive, she experienced a dull ache in her left hip and knee, along with the persistent tingling. That evening she also developed a mild headache and felt as though she was not as sharp mentally as she had been before her dives. She decided to wait until the morning and gauge her symptoms then.

On the second day after her dives, approximately 48 hours after her symptoms first began, she called the DAN Diving Emergency Hotline for advice. She received an immediate referral to a local hyperbaric physician for evaluation and possible recompression. On admission, her symptoms had neither lessened nor intensified. She received a U.S. Navy Treatment Table 6; she experienced resolution of all symptoms except for a very mild tingling in her left arm and leg. On the following two days she received two additional treatments, and was eventually discharged from the hospital symptom-free.

The mildness of this diver's symptoms and her relative newness to scuba diving probably played a major role in her delay to seeking emergency care. This diver had never experienced prolonged tingling or joint pain in her life and was involved in no other activity at the time such as running or weightlifting which might produce symptoms of an injury. Indeed, her attitude of "waiting to see" if the symptoms would go away before calling is common among divers. Her decreased mental capacities occurring the evening after her diving is not usual, but could have been due to causes other than decompression illness. Fortunately, her mild symptoms responded well to hyperbaric therapy more than two days after they had begun.

Case 6. Delayed Onset of Mild Neurological Symptoms — With Residual Symptoms

The diver was a 50-year-old male advanced open-water diver, in good health and a non-smoker. He had been certified for seven years and had made approximately 150 lifetime dives. He had made three dives in the past 12 months. He scheduled a two-day dive weekend in the Great Lakes. His first two dives on Saturday were without problems.

He began his second day with an 81-foot (24.3-meter) dive for 32 minutes and a one-hour surface interval. His second dive was a 50-foot (15-meter) dive for 41 minutes, followed by a two-hour surface interval. His third dive went to 76 feet (22.8 meters) for 39 minutes. After a one-hour surface interval, he performed his fourth and final dive to 45 feet (13.5 meters) for 37 minutes, exiting the water at approximately 4:30 p.m. He made a total of six dives over two days. All dives were trouble-free, allowable by his computer, and other than a little fatigue that he described as normal, the diver felt fine.

At approximately 3 a.m., more than 10 hours after his last dive, he began experiencing tingling in his right hand. By 9 a.m. the following morning, his left leg, from his knees to his toes, began tingling. Shortly after that, both feet and both hands were tingling. He also experienced some nausea during this period. Because he felt his symptoms were getting worse, he contacted the local hospital, where he was evaluated and referred for recompression therapy. After a U.S. Navy Treatment Table 6, he experienced full resolution of his symptoms and had a normal neurological exam.

The following morning when the diver woke up, the tingling sensation in his hands and feet had returned. He was referred back to his original treatment facility, where he was treated for a second time. He emerged symptom-free. Over the course of the following three weeks, however, the tingling in his hands and feet continued to return for brief periods of time; it then resolved on its own. More than a year after his treatment, he occasionally experienced tingling in his fingers after doing a great deal of manual labor.

It is not unusual for symptoms to persist after hyperbaric therapy has been completed. Symptoms can often wax and wane before finally resolving.

Cases 7 and 8. Two Cases of Mild Pain and Neurological Decompression Illness in the Same Diver in One Year

The diver was a 34-year-old male who had made a total of 70 dives in three years. A divemaster, he had made nine dives in the past 12 months — in the course of one month (May) on the west coast of the United States. He had been in perfect health until March of the same year, when he was ill with pneumonia. This produced an asthmalike condition; he used an inhaler. He was on no other medication, was a non-smoker and very active.

His dive series consisted of three dives over two days. On his first day of diving he went to no deeper than 40 feet (12 meters) for approximately 45 minutes. During the second day of diving he completed a 40-foot dive, with an hour-plus surface interval. He then made a dive to 35 feet (10.5 meters). He made safety stops during both dives on this second day; each dive was at least 45 minutes in duration. His dives were allowable by his computer, and several dive buddies were doing the same profile. He exited the water at approximately 2 p.m. and felt fine. As the afternoon wore on, he began to experience some fatigue, a little stiffness and soreness in his shoulders, knees, elbows and ankles. He had never experienced these symptoms before, but they were mild. The only physical activity he experienced during the week was the three scuba dives.

At waking the next day, his symptoms seem the same. On the second day after diving he felt as though his symptoms were a little worse, but they were still mild. During the third day after diving, the aches and pains continued: they were at a level of 3 or 4 on a scale of 0 to 10, he noted. He also began to notice a tingling sensation that he described as intermittent and all over his body. Finally, on the fifth day after diving, he called DAN for information about his symptoms. He was referred to the local dive physician and evaluated.

After a single three-hour treatment in a monoplace chamber, he received good resolution, with the exception of some mild generalized stiffness in his joints. He returned for an additional treatment the following day, where all joint and shoulder aches resolved. He was advised to not dive for six weeks and to call back if his symptoms returned. Because of the relatively mild nature of his symptoms and his conservative dive profiles, the diver remained skeptical that he had experience dan episode of decompression illness.

Case 8. The Same Diver Gets a Second Case of DCI — With Residual Symptoms

The diver remained out of the water for approximately three months before taking a dive vacation to Mexico. He planned to dive conservatively; he started off his first day of diving with two shallow dives at depth shallower than 50 feet (15 meters) and 30 minutes in duration. He experienced no symptoms after these dives.

He then waited two days and did another day of diving, where his first dive was to 85 feet (25.5 meters) followed by an hour and a half surface interval. He the made a dive to 55 feet (16.5 meters). Shortly after this midday dive, he noticed very mild pain in his right arm and elbow. He took the next day off and did not dive: he felt as though his right arm pain was at about a level 3 of pain (on a scale of 0 to 10, as before), and his left elbow began to ache as well. He also experienced some dizziness. The following day he made two more dives; there were no changes to his joint pain or dizziness. After another day off from diving he returned home, flying almost 48 hours after his last dive. He did not feel like his symptoms changed significantly at this point.

The day after returning home, both his elbow and knee pain increased to about a level 6. He also had shoulder pain at approximately a level 3. At this point, he returned to the chamber that had treated him originally. There he was evaluated, and began a second series of treatments. He received a total of four treatments at his local hyperbaric facility, with symptom improvement after each day. He was discharged with only slight elbow and knee pain that persisted for several weeks. His pain gradually became more intermittent and eventually resolved. However, up to one year after his last treatment, he still experienced aches and pain after heavy work or exercise in the same joints, with similar distribution as his post-dive aches. He has not yet returned to diving, deciding to take two years off from the activity.

This case is unusual because the diver developed a persistent series of symptoms after very conservative dive exposures. Compared to more dramatic and serious cases, it is often difficult for divers to believe they have decompression illness because of the relatively minor manifestation of some symptoms. Being evaluated by a medical professional is necessary to rule out other causes of illness — such as a viral syndrome — before establishing a definite diagnosis. It is difficult to say whether a decreased pulmonary status may have contributed to the initial incident or whether his second injury may have been prevented if he had sought treatment earlier for his symptoms after the first episode.

Case 9. One Diver Treated Twice in the Same Year for Mild Pain With Residual Aches

The diver was a 28-year-old male; he had made a total of 100 dives in the past five years and 12 within the past 12 months. Certified for nine years, he was a divemaster. He had no current health problems, was a non-smoker and considered himself in excellent health.

He planned a 50-foot (15-meter) drysuit dive for approximately 45 minutes in relatively cold water. The purpose of this evening dive was to work on an underwater video. The diver experienced no problems on this shore dive until he began his ascent — up a rocky slope in a moderately strong current. He suddenly slipped and hyperextended his right arm, where he was holding his video camera housing. At the same time he tried to grab a rock to keep from being pushed downward.

At the surface, as he was removing his dive gear, he noticed a dull ache in his right elbow. He originally attributed this solely to the exertion of his near-mishap during his ascent. He noticed an increase in discomfort two hours after the dive. On the following day the pain was at about a level 3 on a scale of 0 to 10, he noted. It did not hurt with movement, but the discomfort was constant and ached more if he carried anything heavy with his right arm.

On the second day after the dive, he became concerned about his pain and contacted DAN for advice. He was referred to a local physician at a hyperbaric chamber, where he was evaluated and recompressed. He received a U.S. Navy Treatment Table 6, and the pain decreased. On the following day he received a shorter standard treatment, with complete resolution of the symptoms. The area was not tender, he had a full range of motion without pain, and he returned to all his normal activities.

The diver returned to diving approximately six months later in the same area. He made two shore dives in cold water similar to the dives he had previously made. The dives were no deeper than 60 feet (18 meters) and allowable by his dive computer. Shortly after his last dive, he felt shoulder, elbow and wrist pain in his right arm; he had performed no other strenuous or physical activity other than these two dives. He reported the following morning to the local hyperbaric chamber, where he was treated for decompression illness the second time. He felt little improvement this time. The treating physician ordered imaging studies and X-rays to rule out other medical conditions or injuries that might produce his symptoms, but all evaluations were negative. He continued to be symptomatic up to his last follow-up date, which was 16 months after his second treatment.

One of the greatest challenges for an evaluating physician is to determine an accurate diagnosis in divers where there could be more than one cause for the injury. It is especially difficult in cases where there is a minimal dive exposure. These cases often leave doubt in the mind of the examiner as to the correct diagnosis. In this case, despite excellent resolution after his initial series of treatment, his second series of treatment produced little, if any, resolution. Fortunately, his symptoms were mild, and he was able to tolerate discomfort during normal daily activities.

Case 10. Mild Arm Pain and Tingling — With Complete Resolution

The diver was a 33-year-old male with a rescue diver certification and eight years of experience. He had made 60 dives in the past five years; 17 of these dives were in the past 12 months. He was a non-smoker and non-drinker, took pain medications for tendonitis, participated in no exercise and was overweight.

The diver took a one-week trip to the Bahamas, for five days of diving. He performed two dives a day on the first two days and made three dives on the third day, the deepest dive to 87 feet (26.1 meters). Shortly after his seventh dive, he felt a dull ache in his right elbow that seemed to radiate down his forearm; he also experienced a minor tingling sensation on the top of both hands. He said his dives were rather effortless, with minimal exertion and no physical trauma.

He continued diving for two more days, making two dives a day to depths between 60-80 feet (18-24 meters). His last dive went to 62 feet (18.6 meters). The pain did not worsen, but this may have been due to taking a prescription pain medication. He returned home, and over the next three days, he continued to have persistent radiating pain from his right elbow down to his hand. The mild tingling sensation also continued.

Three days after his last dive, he was referred to a local hyperbaric facility, where he received a U.S. Navy Treatment Table 6. His right elbow pain improved by 60-70 percent, and his tingling disappeared completely with in an hour of being recompressed. He returned the second day for a second Table 6 and experienced complete resolution of symptoms.

This case represents a more typical presentation of decompression illness for the evaluating physician. The self-described pain, a mild 2-3 on a level of 0 to 10, was easily overlooked by the diver, especially while taking pain relief medication. The altered skin sensation is the only indication that there may have been some neurological involvement. Symptom response to recompression therapy after a three- or four-day delay or longer is not uncommon.

Appendix B: Fatality Case Reports

Proximate Cause: Air Embolism

01-19 Solo nitrox diver with motion sickness and poor physical condition
Cause of Death: Air embolism

This 42-year-old male was an experienced diver with nitrox certification. He was seasick prior to entering the water and planned a 100-fsw (30-msw) wreck dive on nitrox without a buddy. The decedent made it down to 28 fsw (8.4 msw) and surfaced three minutes later without the regulator in his mouth. He was talking on the boat before losing consciousness. Resuscitation efforts were unsuccessful. Contributing factors / significant diagnoses included obesity, motion sickness and tobacco abuse.

01-20 Inexperienced diver training for nitrox certification made rapid ascent
Cause of Death: Air embolism, rapid ascent

This 29-year-old female had been diving for two years but had made only 10 total lifetime dives. She was under instruction for nitrox diving certification, making a shore entry dive into fresh water. After approximately 14 minutes at 40 feet (12 meters), the decedent communicated that she was cold and made a witnessed rapid ascent to the surface. She possibly had the regulator out of her mouth during the ascent. On the surface, the diver complained of fatigue and abdominal pain before grabbing her chest and losing consciousness. The autopsy disclosed pneumothorax, mediastinal and subcutaneous emphysema and extensive intravascular bubbles. Contributing factor / significant diagnosis included pulmonary barotrauma.

01-21 Rapid ascent after weight belt released on the bottom
Cause of Death: Air embolism due to rapid ascent

This 49-year-old female was an experienced diver with open-water certification. Her medical problems included chronic renal insufficiency and depression. The decedent made a dive to 25 fsw (7.6 msw) and made a witnessed rapid ascent after she released her weight belt on the bottom. The autopsy findings were consistent with the investigation report that concluded the cause of death as an air embolism. Contributing factors / significant diagnoses included depression, medications and chronic renal insufficiency.

01-30 Uncertified diver separated from buddy, found 15 days later
Cause of Death: Air embolism

This 26-year-old male had no formal dive training but had made a few dives in the past. He entered the water with a buddy, but they became separated due to poor visibility. The decedent was briefly seen on the surface with the mask on his forehead and the regulator out of his mouth, but he quickly sank back below the surface. The body was recovered 15 days later.

01-46 Scallop collector makes rapid descent and rapid ascent
Cause of Death: Air embolism due to rapid ascent

This 50-year-old male diver had open-water certification and moderate experience. He was making his second dive of the day from a boat to collect scallops. The diver made a rapid descent and then made a witnessed rapid ascent without the regulator in his mouth. He was gasping for air on the surface and lost consciousness shortly after that. Resuscitation efforts were unsuccessful. Contributing factors/significant diagnoses included panic.

01-47 Infrequent diver with history of pulmonary emphysema
Cause of Death: Air embolism

This 55-year-old male had open-water certification and moderate diving experience. He had not made any dives in at least a year. The diver made a shore entry dive, but experienced an unknown problem during descent and aborted the dive after a few minutes (maximum depth 17 fsw / 5 msw). Once on the surface, the diver complained of chest pain and shortness of breath. He experienced difficulty during the surface swim and lost consciousness. The autopsy findings and history were consistent with air embolism. Additionally, the decedent had several natural disease processes, including pulmonary emphysema, coronary artery disease and obesity that likely contributed to his death. Pulmonary emphysema can especially predispose a diver to pulmonary barotrauma. Contributing factors/significant diagnoses included pulmonary emphysema, obesity, hypertension, elevated serum cholesterol, coronary atherosclerosis and cardiomegaly.

01-57 Alcohol use, prior to solo night dive off pier in search of cell phone
Cause of Death: Air embolism

This 47-year-old male, who was intoxicated at the time, dropped his cell phone off a pier and returned later with dive equipment in an attempt to recover the phone. The decedent made a night dive without a buddy off the pier to perform the search. He also did not use fins. A witness recalled seeing him exit the water at one point so it is unknown if he made a second dive or collapsed and fell back into the water. Fishermen found the decedent's body the next day. The autopsy revealed evidence of pulmonary barotrauma, intravascular gas and a blood alcohol concentration that was twice the legal limit for driving an automobile. Contributing factors/significant diagnoses included cardiomegaly, pulmonary barotrauma, acute ethanol intoxication (0.17 percent), hypertension and tobacco abuse.

01-58 Inexperienced diver on wreck dive, ran out of air, used pony bottle
Cause of Death: Air embolism due to insufficient air

This 48-year-old male had advanced open-water certification but only 20 lifetime dives. He completed a wreck dive to 91 fsw (27.7 msw) for 15 minutes with his son, who was making his first open ocean dive. The decedent ran out of air and used his pony bottle at the safety stop. He collapsed on the ladder while getting into the boat. Resuscitation efforts were unsuccessful. The autopsy showed the presence of intravascular and intracardiac gas.

01-62 Poor physical conditioned diver with pulmonary emphysema
Cause of Death: Air embolism

This 38-year-old male had been a certified diver for 20 years, but his level of experience and frequency of diving is unknown. After making a 140-fsw (42.6-msw) dive to a wreck, the decedent had a problem during the ascent phase of the dive: there is very little information on the circumstances of the dive. The autopsy revealed evidence of pulmonary barotrauma, coronary artery disease and morbid obesity. There was also evidence of preexisting pulmonary emphysema. Contributing factors/significant diagnoses included pulmonary emphysema, cardiomegaly, coronary atherosclerosis, pulmonary barotrauma and obesity.

Proximate Cause: Drowning / Air Embolism

01-10 Experienced dive instructor using nitrox with possible rapid ascent
Cause of Death: Drowning

This 40-year-old male was a very experienced dive instructor. He made a shore entry dive, without a dive buddy, to 100 fsw (30 msw) for 20 minutes on 32 percent nitrox. There were few details regarding the dive events, but one investigative report stated that there was a problem near the end of the dive, with a possible rapid ascent. The body was recovered 19 hours later. The autopsy findings were consistent with drowning, although an air embolism cannot be excluded. Contributing factor/significant diagnosis included rapid ascent.

01-13 Inexperienced diver panicked, found on the bottom
Cause of Death: Drowning due to air embolism

This 36-year-old male had open-water certification and seven lifetime dives. He made a 25-minute dive with six other divers but became separated from his buddy in a strong current. After the six other divers surfaced, the decedent was seen to hit the surface of the water and call for help. He failed to inflate his buoyancy compensator or drop his weight belt and rapidly sank back to the bottom. The stricken diver was pulled from the bottom after 45 minutes. Resuscitation efforts failed. The autopsy revealed subcutaneous air in the neck and chest, bubbles in cerebral and coronary arteries and intracardiac gas. Contributing factors/significant diagnoses included pulmonary barotrauma and panic.

01-15 Open-water certification diver with multiple health problems, separated from dive class
Cause of Death: Drowning due to air embolism

This 55-year-old male was in an initial open-water certification class, making his third lifetime dive. It was the class's second dive of the day, with a planned profile of 15 feet (4.5 meters) for 25 minutes. The diver had some difficulty with the descent, and upon reaching the bottom he signaled to his buddy that he wanted to ascend. The decedent separated from the class and was not seen again until a search was conducted after all the other students were on the surface. The decedent's body was found a quarter mile (400 meters) from the initial dive site. In addition to changes consistent with drowning, the autopsy disclosed subcutaneous and mediastinal air, pulmonary emphysema, fibrosis of the liver due to chronic viral hepatitis, and mild coronary artery disease. Contributing factors/significant diagnoses included pulmonary barotrauma, coronary atherosclerosis, hepatitis C, fibrosis of the liver and pulmonary emphysema.

01-28 Inexperienced diver with poor vision and significant heart disease
Cause of Death: Drowning due to air embolism, insufficient air

This 48-year-old male had open-water certification but had made fewer than five lifetime dives. The decedent's vision was so poor that he had to ask dive buddies to read his gauges for him (he did not dive with corrective lenses). After completing a dive to 40 fsw (12 msw) for 20 minutes, the decedent showed his gauges to one of his buddies and ascended to the surface alone. He surfaced, struggled and yelled that he was out of air before swimming toward a floating line. The decedent lost consciousness and sank below the surface. An autopsy showed evidence of cardiac disease, in addition to changes consistent with drowning. Contributing factors/significant diagnoses included coronary atherosclerosis, cardiomegaly, fatty liver and lymphocytic thyroiditis.

01-31 Experienced dive instructor with faulty equipment and overweighted, returned to decompress, holding tank in arms
Cause of Death: Drowning due to air embolism, insufficient air

This 53-year-old female was a very experienced diver and dive instructor making her second dive of the day. Her previous dive was to 100 fsw (30 msw) and was uneventful. During the second dive, the decedent's buddy ran low on air and ascended without her. She came to the surface with an empty tank but wanted to return to depth to decompress. The diver held a tank, regulator and buoyancy compensator with her hands while she returned to depth. The equipment floated up to the surface four minutes later; her body was recovered from the bottom 30 minutes after that. The diver was wearing a drysuit but it was improperly configured, and the quick-release valve for the integrated weights was inoperable. The diver was also significantly overweighted. An X-ray at autopsy showed gas filling both chambers of the heart. Other significant findings at autopsy included myocardial fibrosis and mitral valve prolapse. Contributing factors/significant diagnoses included myocardial fibrosis and mitral valve prolapse.

01-45 Diver found on bottom after making multiple dives to adjust anchor
Cause of Death: Drowning due to air embolism

This 36-year-old male had advanced open-water certification and moderate diving experience. He made quick excursions to depth to adjust the anchor line while his dive buddy waited on the bottom. The dive buddy found the decedent unconscious on the bottom. The death was certified only as a drowning, but the history indicates that the diver likely suffered an air embolism. Contributing factor/significant diagnosis included tobacco abuse. An incidental autopsy finding was the acquired loss of one kidney.

01-70 Uncertified diver separated from buddy and panicked, found on bottom
Cause of Death: Drowning due to air embolism

This 42-year-old male was making his third dive of the day off a boat with a group of other divers. He had no formal training or dive certification. He separated from his buddy toward the end of the dive when he panicked and went to the surface. His dive buddy later found the decedent, on the bottom and unconscious. Resuscitation efforts were unsuccessful. The medical examiner concluded that the diver had drowned after suffering an air embolism, and the autopsy findings and history are consistent with this finding. Contributing factors/significant diagnoses included fatty liver.

Proximate Cause: Cardiac

01-05 Diving without completed certification with multiple medical problems including heart disease
Cause of Death: Cardiac dysrhythmia due to coronary atherosclerosis

This 62-year-old male had not completed initial open-water certification course but was making dives outside of his formal course and without the instructor. The decedent made a dive to 105 fsw / 32 msw, without an assigned buddy, in a group of seven divers. He ascended due to an unknown problem and seemed to be fine at 40 fsw / 12 msw, but was later found unconscious. Resuscitation efforts were unsuccessful. The diver had a medical history that was significant for multiple medical problems, including coronary artery disease, hypertension and elevated cholesterol. This death was most likely due to a cardiac event. Contributing factors / significant diagnoses included cardiomegaly, obesity, hypertension and hypercholesterolemia.

01-44 Experienced diver with asthma and heart disease made unwitnessed solo dive
Cause of Death: Cardiac dysrhythmia due to coronary atherosclerosis

This 61-year-old male was a very experienced diver with advanced open-water certification. His medical history was significant for hypertension and asthma that were treated with medication, including an inhaler. He made a shore entry dive alone in poor visibility and was next seen floating on the surface approximately one hour later. The autopsy disclosed evidence of several natural disease processes, including hypertensive and atherosclerotic coronary artery disease and an old myocardial infarct. Even though the event was not witnessed, the dive profile and experience level of the diver led the medical examiner to correctly conclude that this diver most likely died of a cardiac event. Contributing factors / significant diagnoses included hypertension, old myocardial infarction and asthma.

Proximate Cause: Drowning / Cardiac

01-29 Advanced open water student with cardiac disease made solo shore night dive, found with no mask or fins
Cause of Death: Drowning

This 49-year-old male was a student in an advanced open-water certification course and had 15 lifetime dives. He was making a shore entry night dive and carried his mask and fins into the surf. When the decedent's dive buddy had to return to the beach, the decedent continued the dive. No one saw the decedent again until his body was recovered without his mask and fins. A cardiac event cannot be completely excluded since the autopsy revealed coronary artery disease. Contributing factor / significant diagnosis included coronary atherosclerosis.

01-35 Experienced cave diver with heart disease had possible hypoxic breathing mixture
Cause of Death: Drowning due to cardiac dysrhythmia and hypoxia

This 45-year-old male was a very experienced diver and certified cave diver. He had been hospitalized a few weeks earlier with a severe respiratory infection and was advised not to dive for at least six weeks. The decedent and his dive buddy made an uneventful excursion into a cave to 96 feet (29 meters) for 52 minutes. At the 20-foot (6-meter) stop, the diver lost consciousness and was brought to the surface. Resuscitation efforts were unsuccessful. The autopsy revealed evidence of cardiac disease, including coronary atherosclerosis and left ventricular hypertrophy. The equipment evaluation revealed that a tank, thought to be used by the decedent for a decompression stop, might have held a hypoxic mixture. The tank was empty according to the gauge, but a vacuum test on residual contents showed the contents had 13 percent oxygen, with the remainder being nitrogen and helium. A small sticker on the tank designated the contents as 100 percent helium. The tank had been filled months prior to the dive, according to an investigative report. A hypoxic breathing mix combined with ischemic heart disease to cause this death. Contributing factors / significant diagnoses included coronary atherosclerosis, left ventricular hypertrophy and focal myocardial scarring.

01-38 Insulin-requiring diabetic with severe coronary artery disease
Cause of Death: Drowning due to cardiac dysrhythmia and coronary atherosclerosis

This 48-year-old male had received his initial open-water certification six months earlier. His medical history included insulin-requiring diabetes mellitus and he had been recently hospitalized after suffering a seizure. The decedent made a dive to 40 fsw (12 msw) for 35 minutes and lost consciousness on the surface during the swim back to shore. He complained of shortness of breath prior to losing consciousness. Resuscitation efforts were unsuccessful. The autopsy disclosed severe coronary artery disease with near-total occlusion of the major coronary arteries. Contributing factors / significant diagnoses included diabetes mellitus and tobacco abuse.

01-39 Experienced diver with severe coronary artery disease was separated from buddy
Cause of Death: Drowning due to cardiac dysrhythmia and coronary atherosclerosis

This 59-year-old male was an experienced diver with open-water certification. He made a shore entry dive to 10 fsw (3 msw) with a buddy and they quickly became separated. The decedent was found unconscious on the bottom, and resuscitation efforts were unsuccessful. The autopsy disclosed evidence of severe coronary artery disease and previous myocardial infarcts. An inspection of the equipment revealed that the autoinflator hose on the decedent's buoyancy compensator was not attached. Contributing factors / significant diagnoses included myocardial scarring and tobacco abuse.

01-41 Inexperienced, poor-conditioned diver with heart disease, lost consciousness on surface
Cause of Death: Drowning due to cardiac dysrhythmia and coronary atherosclerosis

This 55-year-old male had initial open-water certification and five lifetime dives. He was on a liveaboard and made a dive to 85 fsw (25.5 msw) for 30 minutes. The diver had some buoyancy problems, but he and his buddy had a fairly uneventful dive. He and his buddy separated on ascent, but witnesses on the boat saw him surface and signal for pick-up with his signal sausage. The decedent lost consciousness while waiting to be picked up. The diver's size (he was morbidly obese) made getting him back into the boat extremely difficult and time-consuming. There were several medical personnel among the divers on the boat, but the diver could not be resuscitated. The autopsy disclosed coronary atherosclerosis and a large heart, as well as tunneling of the left anterior descending coronary artery. The death was attributed to drowning due to a cardiac event. Contributing factors / significant diagnoses included cardiomegaly, obesity, hypertension and fatty liver.

01-66 Open-water student with coronary disease separated from group and found near bottom
Cause of Death: Drowning due to cardiac dysrhythmia and coronary atherosclerosis

This 40-year-old male was a student in an initial open-water certification class. Witnesses recall the decedent being a little apprehensive prior to the dive. A total of six divers entered the water with the instructor and all except the decedent came back to shore after the evaluation. He was found near the bottom with the regulator out and unconscious. Resuscitation efforts were unsuccessful. The autopsy disclosed coronary artery disease, right ventricular dysplasia, and lymphocytic myocarditis. All of these conditions may result in abnormal electrical activity in the heart. The death was ruled a drowning due to a cardiac event. Contributing factors/significant diagnoses included dysplasia of the right ventricle of the heart and lymphocytic myocarditis.

01-72 Quarry dive with poor visibility and buddy separation
Cause of Death: Drowning

This 44-year-old male had advanced open-water certification and an unknown amount of experience. He and a dive buddy made a shore entry into a quarry where visibility was noted to be poor. There were also two dive instructors in the group. The decedent's buddy was less experienced and began to panic after developing equipment problems. The decedent went to get assistance and was not seen again during the dive. Eventually the dive buddy and two instructors surfaced. The decedent's body was found the next day. An autopsy report was not made available, but the medical examiner ruled the cause of death to be drowning. Contributing factor/significant diagnosis included hypertension.

01-73 Diver with coronary artery disease used poorly maintained equipment
Cause of Death: Drowning

This 40-year-old certified experienced diver was making a dive with another diver to look for fishing lures in a freshwater pond. The decedent reportedly was uncomfortable in water deeper than 20 feet (6 meters). The two divers went down to 12-15 feet (3.6-4.5 meters) and separated, according to a prearranged dive plan. Witnesses saw the decedent surface and heard him call for help. The diver then partially went back below the surface in a "fins up" attitude. Some fishermen came to his aid, but resuscitation efforts were unsuccessful. An equipment evaluation revealed that the decedent's regulator was in poor repair and failed in the closed position (unusual for a regulator) due to a loose screw. The buoyancy compensator could not be inflated, and there were weights in the pockets. The decedent did not have a depth gauge, and the mouthpiece on the second stage of the regulator had holes in it. He apparently did minimal equipment maintenance. The autopsy revealed changes consistent with drowning as well as coronary artery disease and an enlarged heart. Contributing factors/significant diagnoses included cardiomegaly, coronary atherosclerosis, and fatty liver.

Proximate Cause: Drowning / Insufficient Air

01-01 Experienced cave diver runs out of air, toxicology positive for drugs
Cause of Death: Drowning due to insufficient air and entrapment in cave

This 40-year-old male was a very experienced certified cave diver who was mapping out a complex cave system using mixed gas. The dive was to a maximum depth of 100 feet (30 meters), and he ran out of breathing gas. The decedent's body was recovered 150 feet (45 meters) from a fresh set of tanks that he had staged for use during the dive. In addition to changes consistent with drowning, the autopsy revealed toxicology positive for codeine and cannabinoids. Contributing factors/significant diagnoses included coronary atherosclerosis, toxicology positive for codeine, and toxicology positive for cannabinoids.

01-02 Diver with unknown experience, poor physical condition, multiple medical problems and overweighted
Cause of Death: Drowning due to insufficient air

This 54-year-old female was a certified diver with an unknown amount of diving experience. She was in a poor state of physical conditioning and had undergone gastric bypass surgery in the past. She and her husband made a dive to 32 fsw (9.6 msw) for 45 minutes, but they became separated late in the dive. The decedent was found on the bottom with the regulator out of her mouth. Her tank was empty. A heavy catch bag and weights in the pocket of her buoyancy compensator, in addition to her weight belt, weighed her down. Testing of her dive equipment revealed a free-flow problem with her regulator as well. The autopsy disclosed coronary artery disease, a thickened left ventricle and changes consistent with drowning. Contributing factors/significant diagnoses included coronary atherosclerosis, cardiomegaly, lymphocytic thyroiditis and multiple contusions.

01-16 Inexperienced, out of air diver, buddy breathing until buddy also ran out of air, and they separated
Cause of Death: Drowning due to insufficient air

This 63-year-old male possessed open-water certification and had made seven lifetime dives. He and two dive buddies made a dive to 145 fsw (43.5 msw) for 15 minutes. The decedent ran out of air, and he buddy-breathed with another diver until he panicked and grabbed the diver's primary regulator. The dive buddy also ran out of air and surfaced unconscious, but he recovered at a local medical treatment facility. The decedent's body was recovered 15 days later. An air embolism cannot be excluded. The decedent had buoyancy problems that other divers had witnessed and was overweighted; additionally, there was a hole in his buoyancy compensator.

01-17 Solo diver entangled in kelp ran out of air, found next day
Cause of Death: Drowning due to insufficient air, entangled in kelp

This 57-year-old male was a certified diver with three years of experience. He made a dive to 40 fsw (12 msw) to collect sea urchins without a dive buddy. He did not return from the dive and the body was recovered the next day. The diver's tank was empty. In addition to changes consistent with drowning, the autopsy showed mild coronary artery disease. Contributing factor/significant diagnosis included coronary atherosclerosis.

01-18 Experienced diver ran out of air, surfaces in rough seas
Cause of Death: Drowning due to insufficient air

This 64-year-old female had advanced open-water experience and extensive diving experience. She had a medical history that included hypertension and arthritis and complained of extreme fatigue after the previous day's diving. After the second dive of the day, the diver and her husband surfaced into a squall and rough seas. As the dive boat crew assisted the divers, the decedent was seen unconscious below the surface. Resuscitation efforts were unsuccessful. An equipment evaluation showed that the decedent's tank was empty. Her buoyancy compensator would not hold air, but the investigators were not sure that the damage to the BC existed prior to the rescue efforts to get the stricken diver into the boat. If an autopsy was performed, the report was not made available. Contributing factors/significant diagnoses included hypertension and arthritis.

01-22 Public safety diver who was overweighted was separated from buddy and ran out of air
Cause of Death: Drowning due to insufficient air

This 28-year-old male had advanced open-water and rescue diving certification. He was involved in a set of public safety training dives and made the second dive of the day without changing his tank. The decedent made a shore entry into a quarry with several excursions between the surface and the bottom during a 40-minute dive to 50 feet (15 meters). He became separated from his dive buddy, and no one noticed he was missing until all divers had exited the water. The diver was found on the bottom with his regulator out of his mouth. Resuscitation efforts were unsuccessful. The autopsy showed changes consistent with drowning as well as the presence of intravascular bubbles. The bubbles may have been an artifact (or, unrelated to diving), but air embolism cannot be completely excluded as a contributing factor in this diver's death. An evaluation of the dive equipment showed some free-flowing of the primary regulator and an empty air tank. The diver was also overweighted.

01-23 Underqualified diver and buddy separated from instructor and entered cave where they became lost and ran out of air
Cause of Death: Drowning due to insufficient air, entrapment in cave

This 19-year-old male received his initial open-water certification on the morning of the day he died. He and another diver (DAN Case #01-24, immediately following), who was also certified that day, entered a freshwater spring along with their instructor and the instructor's 12-year-old son. The two newly certified divers separated from the instructor and his son and entered an underwater cave system. This was not a planned cave dive. They became lost in the cave and ran out of air. The bodies of the two divers were recovered the next day, approximately 500 feet (150 meters) from the entrance to the cave. The autopsy findings on this diver were consistent with drowning. Contributing factor/significant diagnoses included tobacco abuse.

01-24 Underqualified diver and buddy separated from instructor and entered cave where they became lost and ran out of air; toxicology positive for sedating pain medication
Cause of Death: Drowning due to insufficient air, entrapment in cave

This 35-year-old male received his initial open-water certification earlier in the morning on the day he died. He and another diver (DAN Case #01-23, immediately preceding), who was also certified that day, entered a freshwater spring along with their instructor and the instructor's 12-year-old son. The two newly certified divers separated from the instructor and his son and entered an underwater cave system. This was not a planned cave dive. They became lost in the cave and ran out of air. The bodies of the two divers were recovered the next day, approximately 500 feet (150 meters) from the entrance to the cave. The autopsy findings on this diver were consistent with drowning and toxicology disclosed the presence of a very sedating pain medication. Contributing factor/significant diagnosis included toxicology positive for propoxyphene. Incidental autopsy findings included cerebral contusion, remote.

01-27 Solo nitrox diver with previous day DCS symptoms and multiple medical problems
Cause of Death: Drowning due to insufficient air

This 48-year-old male diver with significant diving experience made a planned deep dive from a boat on nitrox. He had symptoms consistent with decompression sickness (DCS) the previous day from a deep dive, but declined any medical evaluation. The decedent entered the water without a buddy and rapidly descended to 166 fsw (49.8 msw). His body was recovered nearly three hours later. The diver's tank was empty and, despite using nitrox, his depth would place him at risk for both nitrogen narcosis and oxygen toxicity. The autopsy findings were consistent with drowning, along with evidence of significant natural disease processes, including coronary artery disease and cirrhosis of the liver. Contributing factors/significant diagnoses included decompression sickness, nitrogen narcosis, cirrhosis of the liver, hepatitis C, coronary atherosclerosis, and toxicology positive for diphenhydramine.

01-32 Unqualified diver on nitrox became separated from group and lost in cave
Cause of Death: Drowning due to insufficient air, entrapment in cave

This 23-year-old male was an experienced divemaster but had no formal training in cave diving. He and six other divers, none of whom had cave diving training, made a deep cave dive using nitrox 24 or 26 percent oxygen. The divers went into the freshwater cave system to a maximum depth of 150 feet (45 meters). The other six divers made it out of the cave, but the decedent became separated from the group. His body was recovered 1,000 feet (300 meters) into the cave. The autopsy findings were consistent with drowning. With the use of nitrox at that depth, the contribution of possible oxygen toxicity cannot be excluded. Contributing factor/significant diagnosis included toxicology positive for antihistamines.

01-36 Inexperienced diver in rough seas ran out of air and panicked
Cause of Death: Drowning due to insufficient air

This 56-year-old female had been certified for one year with 12 lifetime dives. She and her buddy made two dives to 70 fsw (21 msw) in rough seas. During the second dive of the day, the two divers lost their orientation. The dive buddy surfaced to establish their position, and when he returned to depth, the decedent forcibly attempted to pull his regulator from his mouth. The dive buddy returned to the surface to get assistance. The decedent was found unconscious on the bottom. Her tank was empty. Both the tank and regulator were in poor condition. The autopsy findings were consistent with drowning. Contributing factor/significant diagnoses included panic.

01-43 Uncertified diver who planned to dive separately from buddy became lost and ran out of air
Cause of Death: Drowning due to insufficient air

This 17-year-old male had no formal dive training or experience. He and another diver entered the water at the same time but did not dive together. The other diver used a dive buoy, but the decedent had nothing to mark his location. The decedent's body was found after two days; his tank was empty. An air embolism cannot be excluded in this case.

01-53 Inexperienced solo diver ran out of air while moving a floating dock
Cause of Death: Drowning due to insufficient air

This 31-year-old male had open-water certification but little experience in the three years he had been diving. He entered the water alone to move a floating dock in an area where the water averaged 3-4 feet (1-1.2 meters) in depth. The decedent's brother waited on the dock. Fifteen minutes into the dive, the brother saw the decedent motionless under the surface. The toxicology report disclosed the presence of alcohol. A higher than usual carboxyhemoglobin level was present, but not to a level where impairment would be expected. A minimal amount of air remained in the tank. An investigation report concluded that overexertion was a contributing factor. Contributing factors / significant diagnoses included alcohol on toxicology and tobacco abuse.

01-54 Experienced cave diver ran out of air while on a solo cave dive
Cause of Death: Drowning due to insufficient air, entrapment in cave

This 46-year-old male was a certified cave diver with extensive diving experience. His medical history included elevated cholesterol, recent chest pain and an episode of pneumonia a year earlier. The decedent made an initial dive into a cave system with a buddy but chose to do a second dive without a buddy. After two hours of bottom time, his buddy called for assistance. Recovery divers found the decedent approximately 1,100 feet (330 meters) into the cave with entanglement between his safety reel and the guideline. An investigation revealed that the decedent did not use a continuous guideline for the dive. His tanks were empty. An autopsy report was not made available.

01-59 Alcohol and substance abuse prior to solo shore dive
Cause of Death: Drowning due to insufficient air

This 38-year-old male had advanced open-water certification. He had a history of alcohol and narcotic use. The diver made a shore entry alone after having a couple of beers with friends. The water at the dive site averaged 10-15 feet (3-4.5 meters). The decedent's body was not recovered for four days, and the tank was empty. Toxicology was positive for benzodiazepines and also showed evidence of recent cocaine use. The decedent's blood alcohol level was more than three times the legal limit for driving an automobile. Even if some increase in the ethanol level that occurs with decomposition is allowed for, this diver was heavily intoxicated when he entered the water. Contributing factors / significant diagnoses included acute alcohol intoxication, toxicology positive for benzodiazepines, recent (during the last three days) cocaine use, coronary atherosclerosis and fatty liver.

01-64 Uncertified diver with cave experience, but inappropriate equipment for cave dive, became wedged in cave tunnel with inappropriate equipment
Cause of Death: Drowning due to insufficient air, entrapment in cave

This 23-year-old male did not have documented open-water certification. His dive buddies claimed that he was the most experienced of the group in cave diving, and they were learning from him. There is no evidence, however, that the decedent had any cave diving training. The decedent had no dive buddy but was in a group of divers exploring a narrow freshwater cave system. After more than an hour at a depth of 14 feet (4.2 meters), the divers tried to enter a very narrow tunnel. They were unsuccessful, and the other divers decided to head back, but the decedent made one final attempt. He became wedged in the tunnel, and the other divers could not physically get him out. It took recovery divers two days and the assistance of heavy equipment to extricate the decedent from the cave.

01-68 Solo diver with surface-supplied air, became entangled and ran out of air
Cause of Death: Drowning due to insufficient air, entangled in chains

This 41-year-old male diver had open-water certification. He was using surface-supplied air to disentangle a mooring line and made the dive to 24 feet (7.2 meters) alone while his tender waited on the surface. The tender left the area to get more tanks, and when he returned, the surface tank was empty and the diver was still in the water. Rescue divers found the decedent entangled in anchor chains on the bottom. The findings at the autopsy were consistent with drowning. The decedent also had coronary artery disease. Contributing factors/significant diagnoses included coronary atherosclerosis, fatty liver, tobacco abuse, and toxicology positive for cannabinoids.

01-74 Experienced nitrox diver entangled on wreck, ran out of air
Cause of Death: Drowning due to insufficient air, entangled on wreck

This 26-year-old male had open-water and nitrox certification, with approximately 70 lifetime dives. He and a buddy made a deep air dive to 231 feet (69.3 meters) in fresh water in order to take pictures of a shipwreck. The decedent's equipment became entangled on the wreck early in the dive, but his buddy helped him to get loose. When the dive buddy ascended, the decedent did not follow him. After a decompression stop, the buddy surfaced and asked for assistance. Divers found the body entangled on the outer structure of the wreck several hours later. The medical examiner concluded that the cause of death was air embolism, based on postmortem X-rays and intravascular gas. Those findings were most likely artifact (or, unrelated to diving), since a significant ascent from such a deep depth would be required to cause an embolism. There is a possibility that the decedent surfaced and then sank back to the bottom after experiencing an embolism, but the dive buddy's account does not indicate that this occurred. Contributing factors/significant diagnoses included nitrogen narcosis.

Proximate Cause: Drowning / Various Causes

01-03 Open-water student struggled and died on surface
Cause of Death: Drowning

This 52-year-old female was a student in an initial open-water certification class. After a dive to 30 fsw (9 msw), she was vomiting, choking and struggling on the surface. The decedent then lost consciousness and could not be resuscitated. The autopsy showed aspiration of gastric contents and changes consistent with drowning. Contributing factors/significant diagnoses included aspiration of gastric contents, and history of migraine headaches.

01-06 Experienced diver ascends in rough seas and became separated from group, recovered the next day
Cause of Death: Drowning

This 45-year-old male was a very experienced diver who was making a night dive in a group of four divers. A storm came up during the dive and the sea state was rough as they ascended to the surface. The decedent became separated from the other divers. His body was not recovered until the next day when it was found between some rocks. An autopsy was performed, but the report was not made available. Contributing factors/significant diagnoses included contusions and abrasions.

01-14 Diver with improper assembled equipment loses consciousness during surface swim to shore
Cause of Death: Drowning

This 41-year-old male had received his open-water dive certification six months previously and had made five lifetime dives. He and a dive buddy made an uneventful shore entry dive to 70 fsw (21 msw) for 15 minutes using drysuits. The decedent was low on air at the end of the dive, but seemed to be doing fine, according to his dive buddy. The sea state was slightly rough, and the decedent lost consciousness during the surface swim back to shore. An examination of the equipment revealed that the regulator was improperly attached to the tank. An autopsy was performed, but the report was not made available.

01-33 Experienced, physically unconditioned diver separated from group
Cause of Death: Drowning

This 41-year-old male was an experienced, certified diver. He made a dive to 40 fsw (12 msw) with a group of divers and became separated from the others. Another diver saw him sinking toward the bottom motionless and went back up for assistance. The unconscious diver was brought to the surface but could not be resuscitated. A cardiac event cannot be completely excluded. Contributing factors / significant diagnoses included obesity and tobacco abuse.

01-34 Uncertified, inexperienced diver with improper equipment
Cause of Death: Drowning

This 17-year-old female had no training or experience in diving. She and another equally inexperienced diver were collecting sand dollars in 10 feet (3 meters) of water off a private boat. The decedent did not wear fins, and she began the dive with only a partially full tank. The two divers held hands during the dive, but the decedent let go at the surface and was not seen again until her body was recovered eight hours later. An autopsy was not performed and the medical examiner determined the cause of death to be drowning. An air embolism cannot be excluded and could very well have occurred in this case.

01-37 Experienced diver with multiple medical problems died at surface
Cause of Death: Drowning

This 51-year-old female was an experienced diver with open-water certification. Her medical history included non-insulin requiring diabetes mellitus, systemic lupus erythematosis and morbid obesity. She made a 30-minute, 103-fsw (31-msw) dive down to a wreck. After ascending, the decedent struggled on the surface and had problems getting back into the boat. She became short of breath and lost consciousness. Resuscitation efforts were unsuccessful. The autopsy findings were consistent with drowning. Contributing factors/significant diagnoses included morbid obesity, diabetes mellitus, lupus erythematosis, and fatty liver.

01-42 Diver becomes separated from buddy, found on bottom of quarry
Cause of Death: Drowning

Little information is available on the death of this 46-year-old male who had open-water diving certification. He made a shore entry into a freshwater quarry with another diver. The two divers became separated, and the decedent was found unconscious on the bottom. Resuscitation efforts were unsuccessful. The medical examiner certified the cause of death as drowning, but the autopsy report was not made available.

01-50 Experienced technical diver separated from buddy, possible shark attack
Cause of Death: Drowning

This 42-year-old male was a very experienced technical diver. He made a wreck dive to 268 fsw (80.4 msw) using a trimix rebreather to collect tropical fish. The diver and his dive buddy became separated on descent, but the buddy spent an hour on the bottom before returning to the surface. This was in accordance with the prearranged dive plan they had for buddy separation. The decedent's body was not recovered for four days, and there was extensive postmortem animal predation and decomposition present. At least one area of shark predation contained hemorrhage, which brings up the possibility of a shark bite occurring while the diver was still alive. Contributing factors / significant diagnoses included shark bites, obesity, coronary artery disease and fatty liver. Incidental autopsy findings included cholesterolosis of the gall bladder.

01-51 Uncertified diver using surface-supplied air with an experienced buddy; both ran out of air and were found a day later
Cause of Death: Drowning due to anaphylaxis

This 40-year-old female had no documented training or experience in diving. She and another diver (DAN Case #01-55, immediately following) used surface-supplied air to dive from a private boat. The other diver was experienced and possibly acting as an informal instructor. The air source was one long hose attached to a tank that split into two separate regulator lines for each diver to use. A passerby notified authorities that there had been no activity on the anchored boat for more than a day. Police divers found the bodies of the two divers under the boat with no sign of foul play or any struggle. The autopsies on both divers were consistent with drowning. Postmortem tryptase and histamine levels, which are elevated in cases of anaphylactic shock, were markedly elevated in both divers. One possible explanation would be envenomation by marine life such as a jellyfish, though it would seem somewhat unlikely that two people could be so identically affected.

01-55 Experienced diver using surface-supplied air with buddy; both ran out of air and were found a day later
Cause of Death: Drowning due to anaphylaxis

This 48-year-old male was an experienced certified diver who was using surface-supplied air to take another diver (DAN Case #01-51, immediately preceding) into the water. The other diver had no formal dive training. The air source was one long hose attached to a tank that split into two separate regulator lines for each diver to use. A passerby notified authorities that there had been no activity on the anchored boat for more than a day. Police divers found the bodies of the two divers under the boat with no sign of foul play or any struggle. The autopsies on both divers were consistent with drowning. Postmortem tryptase and histamine levels, which are elevated in cases of anaphylactic shock, were markedly elevated in both divers. This diver also had focally severe coronary artery disease. One possible explanation would be envenomation by marine life such as a jellyfish, though it would seem somewhat unlikely that two people could be so identically affected. Contributing factor / significant diagnosis included coronary atherosclerosis, focally severe.

01-60 Diver with minimal experience was overweighted and descended out of control to bottom
Cause of Death: Drowning

This 23-year-old female had made 24 lifetime dives, nearly all in warm, tropical water. She was making a planned dive to 50 fsw (15 msw) in a drysuit and was significantly overweighted. Her dive buddy saw her descending out of control to the bottom and returned to the surface to get assistance. Rescue personnel recovered the decedent's body from the bottom. The autopsy findings were consistent with drowning.

01-67 Inexperienced diver, diving solo, became trapped under ice
Cause of Death: Drowning due to entrapment under ice

This 31-year-old male had open-water certification and limited diving experience. He made a solo dive through a hole in the ice to prospect for gold. It was reported that this was not the first time the decedent had done this. He used line pull signals to communicate to his surface tenders. After signaling to them that he was coming up, the tenders were unable to pull him through the ice and the line broke. A recovery team described the conditions under the ice as “treacherous,” noting they had the body several times but could not pull it to the surface.

01-71 Uncertified diver made night dive while intoxicated, became separated from group and entangled in kelp
Cause of Death: Drowning due to entanglement in kelp

This 33-year-old male had no documented dive certification. He made a night dive from a boat with four other divers. After completing the first dive, three of the divers passed on making a repeat dive, and they returned to shore. The decedent and his buddy went back out, but they became separated during the dive. The dive buddy returned to the boat and waited a short time before taking the boat back to shore. He did not notify the local police until after he had already returned home, several hours later. A body was recovered four days later. The autopsy findings were consistent with drowning. The decedent’s blood alcohol level was three times the legal limit for driving an automobile. Contributing factor/significant diagnosis included acute alcohol intoxication (0.25 percent).

01-75 Inexperienced diver, low on air, in remote location surfaced in rough seas
Cause of Death: Drowning

This 54-year-old male had open-water certification but typically made only one dive trip each year. He and his wife made a dive to 60 fsw (18 msw) for 20 minutes, and the decedent signaled that he needed to ascend because he was low on air. On the surface the seas were rough, and the dive boat capsized. The decedent lost consciousness on the surface while awaiting assistance. There was no oxygen on the boat, and no one knew CPR. This dive took place in a remote location, and a formal investigation and autopsy were not performed.

01-77 Experienced diver using nitrox lost consciousness at depth
Cause of Death: Drowning

This 55-year-old female was an experienced certified diver on a liveaboard trip. She made a dive to 70 fsw (21 msw) using 32 percent nitrox and had a witnessed loss of consciousness at depth. One witness described seizure activity, although oxygen toxicity (a cause of seizures) would not be expected at this shallow depth. A limited autopsy report concluded that the cause of death was drowning, but contributing factors were not identified.

Proximate Cause: Unspecified, Body Not Recovered

01-04 Certified cave diver and instructor became separated from group, and lost in cave with poor visibility
Cause of Death: Death, unknown cause (body not recovered)

This 31-year-old male was a very experienced dive instructor and a certified cave diver. He made a cave dive in a group of six divers. The dive was beyond the level of cave experience that the decedent possessed, and visibility was poor. The diver swam ahead of the other divers and took a side route into a restricted passage at 270 feet (81 meters). He became separated from the group, and his body was never recovered.

01-09 Certified diver ascended with potential medical problems, then descended again; body not recovered
Cause of Death: Death, unknown cause (body not recovered)

This 58-year-old male was a certified diver with unknown experience. He and a buddy made a shore entry for a planned dive to 60 fsw (18 msw). The two divers descended together to 40 fsw (12 msw), and the decedent was witnessed to ascend, clutch his chest and then descend again. He was not seen again after that, and a body was never recovered. A cardiac event or air embolism comprise the two most likely diagnoses.

01-12 Diver low on air, separated from buddies and ascended alone into a strong current; body not recovered
Cause of Death: Death, cause undetermined (body not recovered)

This 53-year-old male was a certified diver with eight lifetime dives. He was in a three-person buddy team making a dive to 75 fsw (22.5 msw) in a strong current. The decedent showed his buddies that he was low on air and signaled that he was going to ascend. He ascended ahead of his dive buddies and was not seen again. The body was never recovered. Contributing factors/ significant diagnoses included insufficient air.

01-25 Technical diver descended without buddy and did not return
Cause of Death: Death, cause undetermined (body not recovered)

This 54-year-old male was a technical diver making a deep air dive from a boat on an oil rig. He entered the water before his dive buddy. Despite the buddy's encouragement otherwise, the decedent went below the surface before his dive buddy was even in the water. The buddy went down to their pre-arranged maximum depth of 233 fsw (70 msw) but could not locate the decedent. The dive buddy made an additional dive to 200 fsw (60 msw) to search for the lost diver, but he was unsuccessful in finding him. A body was never recovered. Contributing factors/significant diagnoses included nitrogen narcosis.

01-48 Diver with cardiac disease separated from buddy; body not recovered
Cause of Death: Death, cause unknown (body not recovered)

This 43-year-old male certified diver had a medical history that included two myocardial infarctions and significant coronary artery disease. He and a buddy made a dive to 130 fsw (39 msw) and became separated during the ascent at approximately 25 fsw (7.5 msw). The decedent's body was never recovered. Contributing factors/significant diagnoses included coronary atherosclerosis, myocardial infarcts, remote.

01-49 Experienced technical diver and divemaster attempted personal depth record, never returned
Cause of Death: Death, cause undetermined (body not recovered)

This 39-year-old male was a very experienced technical diver and divemaster. He routinely made very deep dives on air for the "narcosis high" and planned to set a personal depth record of 320 fsw (96 msw). He and another diver set up the dive without any staged decompression stops or any breathing gas other than air. Each diver descended alone, and the other diver first completed a bounce dive to 260 fsw (78 msw). The decedent then began his dive, and was believed to have descended below 300 fsw (90 msw). He was not seen again. The authorities searched for two days, but a body was never recovered. Contributing factors/significant diagnoses included nitrogen narcosis and tobacco abuse.

01-61 Novice diver lost control of buoyancy on descent, despite buddy assistance; body not recovered
Cause of Death: Death, cause undetermined (body not recovered)

This 19-year-old female was making her first dive since certification and her first dive in cold water. There was a strong current and poor visibility. She and her dive buddy planned a dive to 50 fsw (15 msw), but as they headed down the decedent continued past the 150 fsw (45 msw) mark. Her dive buddy tried to render assistance but could not bring her up from the 200 fsw (60 msw) bottom. The rescue attempt was complicated by the decedent being overweighted and unconscious. Before she lost consciousness, the stricken diver was seen having difficulty inflating her buoyancy compensator. The decedent's buddy returned to the surface and was treated for decompression sickness. Despite an extensive search, the diver's body was never recovered. Contributing factors/significant diagnoses included panic and nitrogen narcosis.

01-65 Diver low on air, became separated from buddy; body not recovered
Cause of Death: Death, cause undetermined (body not recovered)

This 31-year-old male had open-water certification and 20 lifetime dives. He made a shore entry dive to deeper than 120 fsw (36 msw) with his dive buddy. They became low on air and agreed to ascend, but the two divers became separated at approximately 60 fsw (18 msw). The decedent's buddy went down to 180 fsw (54 msw) trying to locate him, but a body was never recovered. Contributing factor/significant diagnosis included nitrogen narcosis.

01-76 Instructor made deep dive, became separated from buddy, and never returned
Cause of Death: Drowning

This 45-year-old male was an experienced dive instructor. He made a dive from a boat to check out a new dive site. The dive was planned to 270 fsw (81 msw), and he may have been experimenting with a nitrox mix. The diver and his buddy became separated five or six minutes into the dive. The dive buddy descended to 374 fsw (112.2 msw) searching for the decedent, but had no success. A body was not recovered. There are a few details regarding the dive that are missing from investigational reports. The decedent may have been on antidepressant medications, according to one report. If the decedent was truly using nitrox, oxygen toxicity cannot be excluded. Contributing factors/significant diagnoses included nitrogen narcosis.

Proximate Cause: Other

01-08 Advanced open-water student panicked and made rapid ascent
Cause of Death: Hypoxic encephalopathy due to air embolism, rapid ascent

This 53-year-old female had been certified as an open-water diver five months previously and had made 13 lifetime dives. She was a student in an advanced open-water class and made a deep dive to 109 fsw (32.7 msw) for 18 minutes. The diver made a controlled ascent to 40 fsw (12 msw), then panicked and made a rapid ascent to the surface. She had lost one fin and would not keep the regulator in her mouth during the final portion of her ascent. On the surface she was unconscious. She was transferred to a medical treatment facility, where she died two days later. An additional problem was that the diver was extremely overweighted. Contributing factors/significant diagnoses included panic.

01-11 Experienced diver made deep dive with rapid ascent using faulty equipment
Cause of Death: Decompression sickness

This 58-year-old male was a very experienced diver using mixed gas and a rebreather with a drysuit. He made a shore entry dive to 300 fsw (90 msw) and encountered buoyancy problems during the ascent. The decedent went directly to the surface, omitting a significant amount of obligated decompression time. The diver was taken to a medical treatment facility with a recompression chamber, but died during treatment. The autopsy report was not made available, but we were told there was no evidence of natural disease processes. The inflator to the drysuit had significant corrosion, likely creating difficulty in using it properly. Contributing factors / significant diagnoses included rapid ascent and panic.

01-26 Experienced solo diver made repeated deep dives, died during treatment for DCS
Cause of Death: Decompression sickness

This 39-year-old male was a very experienced diver with open-water certification, but he had not made a dive during the previous year. He had a past history of decompression sickness. The diver was a participant in a spearfishing contest and made a series of five repetitive solo dives to greater than 165 fsw (49.5 msw). He had computer and buoyancy compensator problems and used minimal surface intervals, exceeding the limits of any computer or table. His fourth dive was to 165 fsw (49.5 msw). He had a surface interval of less than 10 minutes before descending to a depth of 180 fsw (54 msw). The diver was experiencing symptoms of decompression sickness prior to his last descent, but he made the dive anyway. After surfacing from this final dive, he complained of respiratory distress. He was taken to a local recompression chamber, where he died after a U.S. Navy Treatment Table 6A. At autopsy he had some bubbles in the pericardium and superficial vessels of the brain, but he had been treated with hyperbaric oxygen for several hours before death. The medical examiner certified the cause of death as air embolism, but his dive history and symptoms are more consistent with cardiopulmonary decompression sickness ("the chokes"). Contributing factors / significant diagnoses included coronary atherosclerosis, cardiomegaly, brain cyst and nitrogen narcosis.

01-40 Experienced solo diver ran out of air under ice
Cause of Death: Asphyxia due to insufficient air

This 43-year-old male was an experienced certified diver making a solo dive under the ice using a full-face mask. The planned dive profile was 78 feet (23.4 meters) for 25 minutes. The diver used a line to the surface to communicate with his wife and daughter. When he failed to respond to line-pull signals, they attempted to pull him to the surface, but they needed assistance. He was finally pulled to the surface, but was pronounced dead at a local medical treatment facility. The decedent's tank was empty, and the second stage on his regulator free-flowed. He also had ice on the first stage of the regulator, and there was water and sand inside the face mask. No postmortem toxicology was performed, but an investigative report indicated that the diver was on antidepressant medication. Contributing factors / significant diagnoses included hypertension, elevated serum cholesterol, and gastrointestinal hemorrhage.

01-52 Open-water student with buoyancy problems treated for AGE and died the next day
Cause of Death: Anoxic encephalopathy due to due to air embolism

This 49-year-old female was a student in an initial open-water certification class making her first open-water dive. She made a shore entry into a freshwater lake for a planned dive to 40 feet (12 meters). The decedent had difficulty operating her buoyancy compensator, and she ascended to 15 feet (4.5 meters). She signaled that she was having trouble and then ascended to the surface. Shortly after surfacing, the decedent was short of breath and was taken to a local hospital. Her treatment included hyperbaric oxygen therapy, but her condition deteriorated. The diver died 36 hours after the accident. The autopsy showed changes of hypoxic brain injury and early bronchopneumonia. Contributing factors/significant diagnoses included bronchopneumonia and obesity.

01-56 Experienced technical diver surfaced in rough seas, struck by boat
Cause of Death: Massive head trauma due to being struck by boat

This 36-year-old male was a very experienced technical diver who was making a drift dive using nitrox. He completed a dive to 60 fsw (18 msw) without a dive buddy and ascended to be picked up by the boat. The sea state was moderately rough. The diver was struck by the same boat that was supposed to pick him up. He suffered severe injuries caused by the propeller. The driver of the boat was reported to have been under the influence of alcohol, as was the diver. Contributing factors/significant diagnoses included multiple injuries to neck, shoulders, and extremities, toxicology positive for ethanol, toxicology positive for diphenhydramine.

01-63 Instructor without designated buddy found on wreck; tanks shown to contain improper gas mix
Cause of Death: Asphyxia

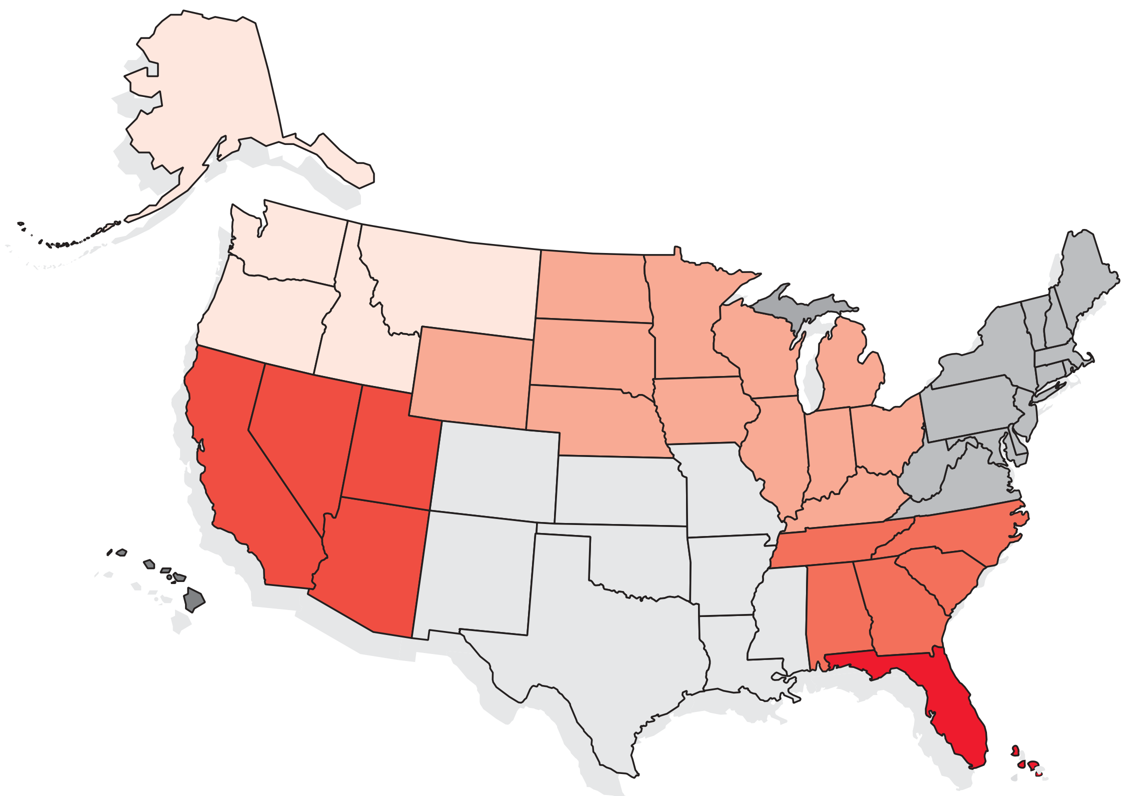
This 42-year-old male was an experienced dive instructor who worked in a dive shop and filled his own tanks. He made a wreck dive with eight other divers but without a designated buddy to 112 fsw (33.6 msw). Approximately 35 minutes into the dive, another diver found the decedent on the wreck and unconscious. The stricken diver was brought to the surface and, after some delay, they managed to get him into the boat. Resuscitation efforts were unsuccessful. An evaluation of the dive equipment revealed that one of the two tanks the decedent had been using contained less than 1 percent oxygen. That particular tank contained several ounces of rust-colored water, and the tank itself had extensive rust and pitting throughout its inner surface. The logical conclusion is that this tank had not been used recently. The oxygen that was originally present in the tank was likely consumed in the oxidation (rust) process. The tank did not have current visual inspection and hydrostatic testing. Contributing factor/significant diagnosis included obesity.

01-69 Diver struggled in cold water with strong current at surface predive
Cause of Death: Acute pulmonary edema

This 22-year-old male had insulin-requiring diabetes with open-water dive certification. He checked his blood sugar and injected insulin prior to the dive. The decedent made a dive from a boat and entered the water to wait for his dive buddy to join him. The water was cold, and there was a strong current. Almost immediately the decedent began to struggle and complained of shortness of breath. He was assisted back into the boat and lost consciousness. Resuscitation efforts were unsuccessful. The autopsy disclosed evidence of acute pulmonary edema and an enlarged heart. The history and autopsy findings are most consistent with immersion pulmonary edema. Hypertensive heart disease may have been a contributing factor. A postmortem vitreous glucose level was 3 mg/dl, but glucose decreases in the postmortem state, so one cannot conclusively state that he was hypoglycemic prior to his death. Contributing factors/significant diagnoses included cardiomegaly, hypertension, diabetes mellitus, obesity and panic.

INJURIES & FATALITIES BY REGION & STATE 2001

(Total number used in report analysis)



Southeast Region	Fatality 2	Injury 7
Alabama	0	1
Georgia	0	0
NC	2	5
SC	0	1
Tennessee	0	0

Southwest Region	Fatality 11	Injury 17
Arizona	0	0
California	11	15
Nevada	0	2
Utah	0	0

Northeast Region	Fatality 10	Injury 20
Connecticut	0	0
Delaware	1	0
Maine	1	0
Maryland	1	1
Massachusetts	1	1
New Hampshire	0	0
New Jersey	0	8
New York	3	1
Pennsylvania	1	3
Rhode Island	0	0
Vermont	0	2
Virginia	2	4
West Virginia	0	0

Gulf Region	Fatality 5	Injury 3
Arkansas	0	0
Colorado	0	1
Kansas	0	0
Louisiana	1	0
Mississippi	0	0
Missouri	0	0
New Mexico	1	0
Oklahoma	0	0
Texas	3	2

Midwest Region	Fatality 7	Injury 15
Illinois	2	3
Indiana	0	0
Iowa	0	0
Kentucky	0	0
Michigan	4	7
Minnesota	1	2
Nebraska	0	0
North Dakota	0	0
Ohio	0	1
South Dakota	0	0
Wisconsin	0	2
Wyoming	0	0

Northwest Region	Fatality 4	Injury 48
Alaska	0	1
Idaho	0	0
Montana	0	0
Oregon	0	3
Washington	4	44

Pacific Region	Fatality 1	Injury 39
Hawaii	1	39
U.S. Territories	0	0

Caribbean Region	Fatality 27	Injury 133
Florida	18	72
Caribbean	9	61

Mexico/Central America Region	Fatality 3	Injury 100
Mexico	2	68
Central America	1	32

Other	Fatality 7	Injury 31
Canada	3	14
Western Pacific	3	15
Middle East	1	0
Europe	0	0
South America	0	2

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Notes

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