Report on Decompression Illness, Diving Fatalities and Project Dive Exploration

DAN's Annual Review of Recreational Scuba Diving Injuries and Fatalities Based on 2000 Data

2002 Edition

DAN

Report on Decompression Illness, Diving Fatalities and Project Dive Exploration

The DAN Annual Review of Recreational Scuba Diving Injuries and Fatalities Based on 2000 Data

2002 Edition

by

DAN®

Divers Alert Network

Dedicated to the Memory of

Steve Barsky Photo

Dr. Hugh D. Greer III

1932-2001

Divers Alert Network Southwest Regional Coordinator
1981-2001

A lifetime of service to his family, community, country and recreational and professional dive health and safety.

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Cover photo by DAN member William M. Mercadante.
Layout and design by Rick Melvin.

Acknowledgments

Data for the 2002 *Report on Decompression Illness, Diving Fatalities and Project Dive Exploration* have been collected and assembled by DAN employees and associated staff. DAN wishes to recognize the following people and departments for their important contributions:

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

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DAN Regions and Regional Coordinators for Hyperbaric Treatment

Divers Alert Network uses a network of 317 hyperbaric chambers in the United States and around the world to report decompression illness (DCI) injuries. The DAN network is now divided into eight regions, each overseen by a Regional Coordinator.

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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 largest membership association of divers in the world.

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

DAN America's Services to the Recreational Diving Community

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 and books and videos about scuba safety and health.

The 24-Hour Diving Emergency Hotline is DAN's premier service. The DAN medics and physicians offer emergency consultation and referral services to injured divers worldwide. In 2000, DAN answered more than 2,908 calls for emergency assistance from its members and divers on the diving emergency hotline. In 2001, from January-October, DAN Medicine assisted on 2,569 emergency calls.

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 in the United States and Canada) is now available weekdays from 8 a.m. to 8 p.m. Eastern Time. On the Medical Information Line, callers may make specific non-emergency medical inquiries.

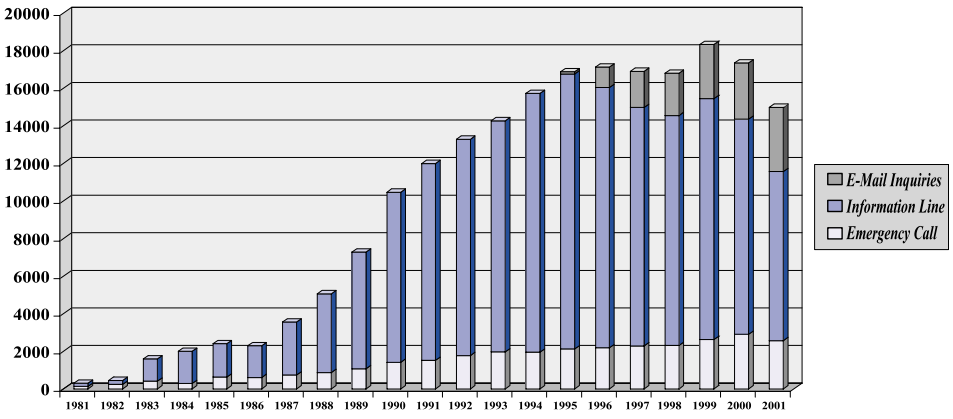
Also, divers can visit the medical pages of the DAN website — www.DiversAlertNetwork.org — where they can find answers to general questions on dive fitness and health.

The DAN medics and physicians offer emergency consultation and referral services to injured divers worldwide.

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 2000, DAN's Medical Department received 14,440 information calls (including 2,988 emails). From January to October 2001, DAN Medicine has received 8,997 information calls and 3,417 emails. Since its beginning in 1980, DAN has helped 203,081 callers through these services.

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



DAN Dive Health and Safety Research

DAN's Research Department is dedicated to the study of dive health issues. Prospective experimental research, such as the Ascent Rate Study, is conducted in the hyperbaric chambers of the Center for Hyperbaric Medicine and Environmental Physiology at Duke University Medical Center. Field research projects, such as Project Dive Exploration and the Aging Diver Project, are conducted at dive locations all over the world. DAN projects are privately funded through DAN membership and dive industry support.

Injury and Fatality Data Collection

This report is based in part on annual data collection of dive injury and fatality information that is gathered each year. To improve its timeliness, completeness, accuracy and correspondence with Project Dive Exploration, the collection, management and reporting systems are currently undergoing revision. In 2002, the revised injury reporting system will be pilot-tested at selected chambers.

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.

Diabetes and Diving Project

DAN's project to determine the relative safety of divers with insulin-requiring diabetes was approved by DUMC's Institutional Review Board and collected data during 561 dives by 41 insulin-requiring divers and during 504 control dives by 43 divers without diabetes. The study tested guidelines for blood glucose monitoring and collecting data on blood glucose levels before and after diving. Data have been presented over the past several years at the Undersea and Hyperbaric Medical Society (UHMS) annual scientific meetings and to the American Society of Exercise Physiologists. A publication is currently in preparation.

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

Project supporters included:

- Aggressor Fleet Inc.
- Nekton Cruises Inc.
- Peter Hughes Diving Inc.
- Underwater Explorers Society (UNEXSO), Bahamas
- Bayer Corporation
- Can Am Care
- Buceo Medico Mexicano Hyperbaric Chamber, Cozumel
- Casa del Mar, Cozumel
- Del-Mar Aquatics, Cozumel
- AquaWorld, Cozumel
- Albatros Charters, Cozumel
- Blue Bubble Divers, Cozumel
- Caribbean Divers, Cozumel
- Cozumel Equalizer SA, Cozumel
- Dive Paradise, Cozumel
- Mako Tours, Cozumel
- Scuba Club Cozumel, Cozumel
- Sand Dollar, Cozumel
- Cha Cha Cha Divers, Cozumel
- Scuba Du, Cozumel
- Dive Palancar, Cozumel
- Aldora Divers, Cozumel

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 September 2001, PDE had collected more than 32,000 dive profiles since beginning data collection in 1995. (See Figure 4 on page 21 for a PDE progress summary.) PDE goals are to create a database of both safe dives and 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).

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

Dive computer manufacturers Cochran, Suunto, Scubapro/Uwatec and DiveRite have strongly supported Project Dive Exploration; Cochran and DiveRite recently introduced dive log software that allows divers to e-mail their PDE data directly to DAN. Volunteer Field Research Coordinators (FRCs) and Data Collection Centers (DCCs) are integral to PDE data collection. (See Acknowledgments for a list of FRCs and DCCs from 2000.) In 2001, DAN began working with the Aggressor Fleet of live-aboard vessels to collect PDE dives, and DAN will work with Peter Hughes Diving in 2002. For information about how to become an FRC, call DAN Research at 1-800-446-2671 or +1-919-684-2948 or visit the DAN website at www.DiversAlertNetwork.org

Flying After Diving Study

In 1998, 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. A second flying after diving study will begin in 2002 with U.S. Navy support. This study will investigate additional dive profiles and oxygen breathing in the surface intervals as a possible method for making the surface intervals shorter.

Aging Diver Study

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

DAN Research Internship Program

The DAN Research Internship Program began in 2000 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 operations that believe in the importance of research to improve dive efficiency and safety.

The goals of the internship are: (a) to collect dive profile data for Project Dive Exploration; (b) to provide the Interns with an experience in dive safety research; and (c) to 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, Kathy Coulombe, 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 over 3,300 dives in three months.

In 2000, DAN established a program to run year-round in Cozumel, Mexico. DAN trained three local dive instructors to collect PDE data from other dive instructors and divemasters. Diving instructors and guides are particularly interesting because they dive often, have aggressive dive profiles, and may have a relatively high DCI incidence. Since December 2000, the three interns have collected 5,500 dive profiles, which included four DCI incidents.

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; or visit the DAN website at www.DiversAlertNetwork.org

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) are distributing their products worldwide with an announcement that their dive computers are compatible with DAN's Project Dive Exploration.

The purpose of the Computer Recognition Program is to increase participation in PDE by increasing awareness of all dive computer users.

Ascent Rate Study

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

DAN's Support to the Dive Medical Community

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

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 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 new 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 make it easier for hyperbaric facilities to receive payment for their services.

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, less than 33 percent of injured divers received emergency oxygen in the field; few of those 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 those injured in a dive accident.

Oxygen First Aid for Aquatic Emergencies

Every year more than 4,000 Americans die from drowning and many more suffer from near-drowning events. For nearly a decade, DAN has emphasized the benefits of providing oxygen to injured scuba divers. During that time more than 80,000 people worldwide have been trained in this first aid skill. In March of 1999, DAN Services, Inc., a wholly owned for-profit subsidiary of Divers Alert Network, launched the Oxygen First Aid for Aquatic Emergencies (Aquatics) program. Its goal is to extend the lifesaving skills of oxygen first aid to people who live 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 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, DAN's newest training program educates the general diving (and qualified non-diving) public to provide first aid using Basic Life Support techniques and automated external defibrillators. This skill may prove to be lifesaving when you consider that diving is often conducted in remote locations, far removed from emergency medical help.

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 newcomers to DAN can sign up online.

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

DAN recommends that all divers be qualified to provide 100 percent oxygen in the field to those injured in a dive accident.

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 December 2001, more than 160,000 members support DAN in the United States, the Caribbean, Canada and Mexico, plus an additional 58,000-plus 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 now published monthly and as a bonus, DAN Members receive a special *Alert Diver* edition of *Skin Diver* magazine* in addition to the original *Alert Diver*.

The agreement with *Skin Diver* means more quality information is available to DAN members at a significant cost saving to DAN. These savings in turn allow DAN to provide additional services to further its mission. The collaboration and subsequent savings has allowed DAN to:

- Increase the DAN Medical Information Line's operating hours to provide evening and weekend access for all members. This also helps DAN to better serve its West Coast members;
- Increase funding for the DAN Recompression Chamber Assistance program, providing chambers with gifts of vital equipment such as oxygen and carbon dioxide analyzers, oxygen masks and compressor. In addition to training on current treatment tables, the program also helps provide continuing education to chamber staff to elevate and maintain the standard of care at remote facilities; and
- Provide additional support to DAN dive safety research projects.

* *The Alert Diver edition of Skin Diver is a $5.99 value and is not deductible from member dues.*

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 insurance — 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 helped fill a medical and financial need not being met by any other organization at the time, giving DAN members valuable additional benefits. Before these DAN programs were launched, injured divers could be saddled with large medical bills, because most health insurance would not cover some or all of the recompression and 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 members are eligible for three different levels in insurance — the Preferred, Master and Standard Plans.

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 November 2001, more than 55,000 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.

Charter Boat ID (CBID) Systems

Through this program, DAN donors may sponsor a board or boards bearing numbered DAN Tags for a dive vessel; the donor's name will go on the board. Dive operators assign each diver a tag with a specific number; each wears a tag when diving and replaces the tag on the board when they finish diving. With this safety system, the captain and divemasters know who is on board and who is in the water. The captain does not move from the dive site until all the tags are back on the CBID Board.

DAN Partners in Dive Safety

The PDS program includes safety measures in three major areas of emergency preparedness: staff, diver, and equipment.

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 Charter Boat Identification System (CBID) and dive debriefing. All DAN PDS new applications and renewals are required to use the CBID 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 CBID 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

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*, and several other bonuses, all for just an annual fee of $125.

DAN's Industry Membership program provides its members with great benefits. Call 1-877-5DAN PRO or +1-919-684-2948 ext. 295 for more information on the 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.

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 basic open water students should have.

Visit www.DiversAlertNetwork.org and enroll your students online in minutes and email the roster back to DAN. Be sure to give your students their Insurance Record and DAN membership application. Include your DAN number on the roster so you can earn valuable DAN points. Students will be enrolled when DAN receives the roster.

Instructors who 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 equipment and products.

To order your materials or learn more about the DAN Student Membership program, call 1-877-5DAN PRO (1-877-532-2776) or look at the "Training & Education" section at the DAN website, www.DiversAlertNetwork.org. Use product code 821-0300 when ordering materials.

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

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.

International DAN

IDAN is comprised of several 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 accident data.

To help reach the increasing diving community in Latin America, DAN provides promotional, membership and training material in Spanish and Portuguese. Also, beginning 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.

1. INTRODUCTION

Divers Alert Network® (DAN) collected data during calendar year 2000 on:

- divers who were injured;
- divers who died; and
- divers in Project Dive Exploration, for whom injury was rare.

These populations are described below and compared for significant differences in selected demographic, dive profile and breathing gas characteristics. Figure captions give the number of divers on which each figure was based as applicable.

1.1 Diving Injuries

Figure 2 shows the annual record of diving injuries since DAN began collecting injury data in 1987. The upper line in Figure 2 represents the total count of diving injuries reported to DAN by participating chambers. Of 200 chambers, 66 did not treat any diving injuries, 51 did not report, and seven closed in 2000. The middle line in Figure 2 represents all injuries for which written reports were submitted to DAN. The bottom line represents recreational diving injuries among U.S. and Canadian residents.

In 2000, DAN received notification that 1,042 injured divers had been recompressed. Written reports were submitted on about 728 divers; of these, 470 were recreational divers who resided in the U.S. or Canada. The 728 divers for whom written reports were submitted are described in subsequent sections.

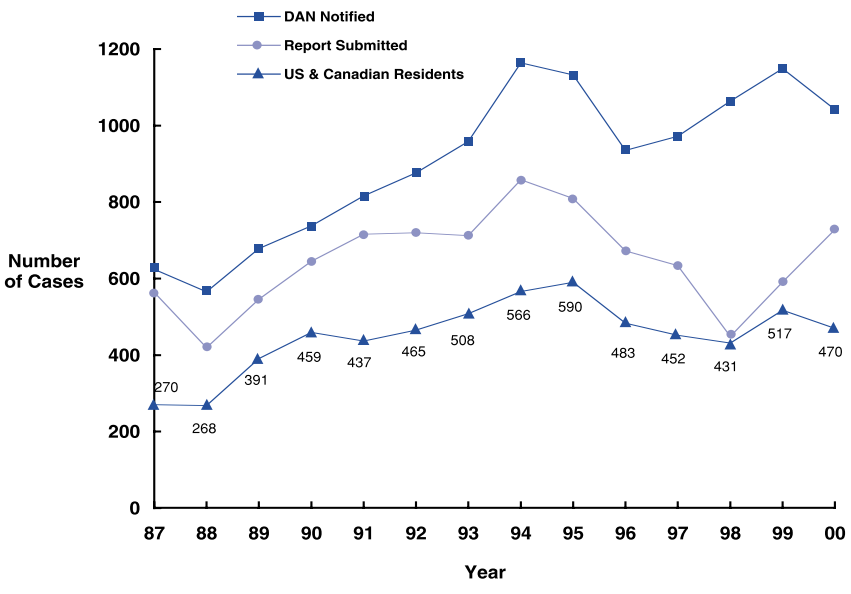


Fig 2
Annual record of diving injury cases.

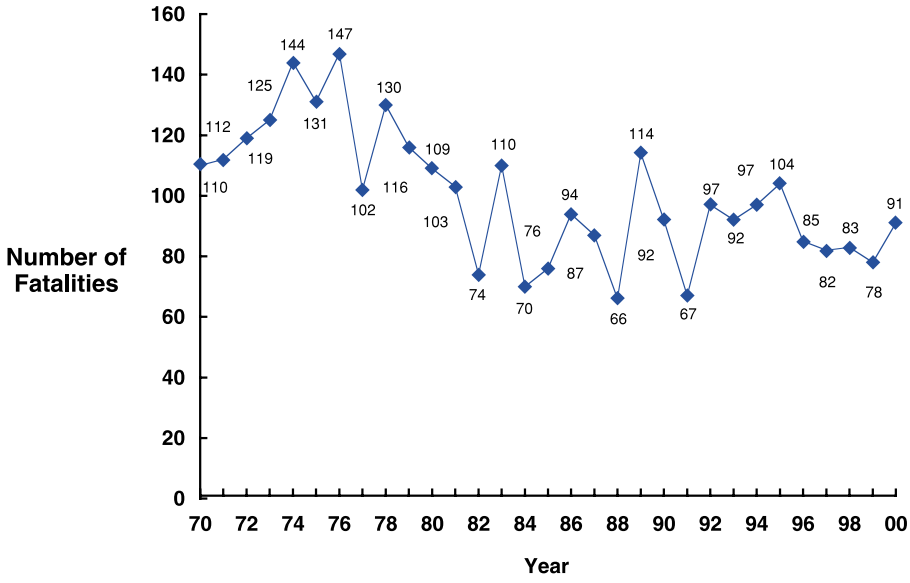
Of these 728 reports submitted in 2000, about 48 percent were DAN America members, 50 percent were not DAN members, and membership status was unknown for 2 percent. DAN made follow-up calls to divers who did not have complete resolution of signs and symptoms after completing all recompression therapy; DAN called at six months, nine months, and 12 months, or until the injured divers reported full resolution. A selection of representative or interesting case reports is presented in Section 2.

1.2 Diving Fatalities

Figure 3 shows the annual records of U.S. or Canadian residents who died during recreational diving. DAN gathers information about dive fatalities, but because 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 of divers who had resided in locations other than the U.S. and Canada could not be readily followed up and were not included in Figure 3. There were 91 U.S. or Canadian diving fatalities in 2000. Case summaries for all of these are presented in Section 3.

Fig 3
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 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.

PDE was made possible by the development of the dive computer and became practical with the support of the manufacturers Cochran, DiveRite, Suunto and Uwatec, who have made their dive computers PDE-compatible. Figure 4 shows the number divers who volunteered for PDE since data collection began in 1995, the number of dives they made, and the number of divers who were recompressed for DCI. To date, there have been over 32,000 dives by more than 4,000 divers, of whom 11 were recompressed. There has also been one fatality.

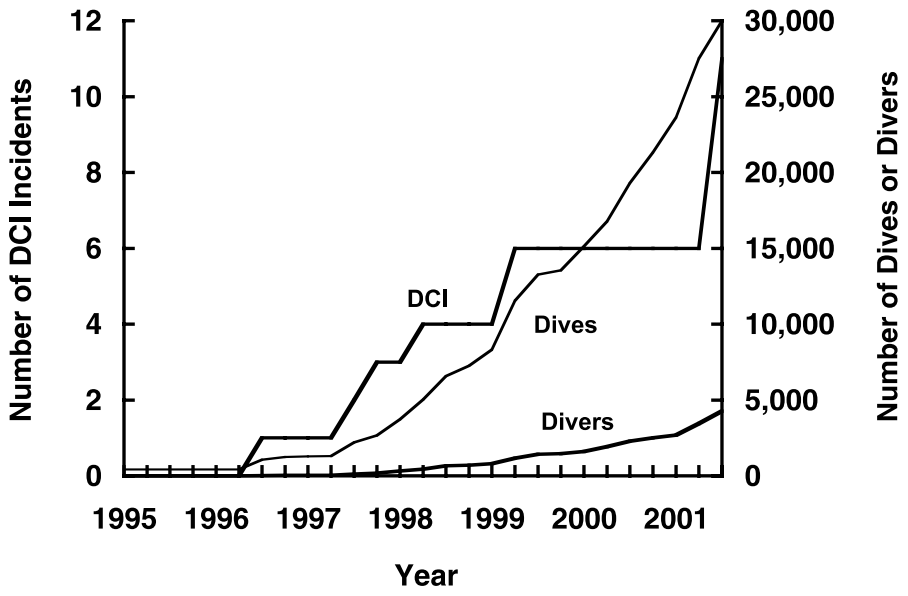


Fig 4
Project Dive Exploration progress.

2. Dive Injuries

This section describes injured divers diagnosed by a diving physician as having decompression illness (DCI) (decompression sickness, DCS or arterial gas embolism, AGE) and treated by recompression in a hyperbaric chamber.

2.1 Characteristics of Injured Divers

Figure 5 shows the distribution of age by gender for divers who were injured in 2000. Seventy percent of injured divers were male, which was consistent with recent years. The average age of injured divers was nearly 36, with females slightly younger than males. The youngest person was 13 and the oldest 73.

Fig 5
Distribution of age by gender for injured divers (n=573).

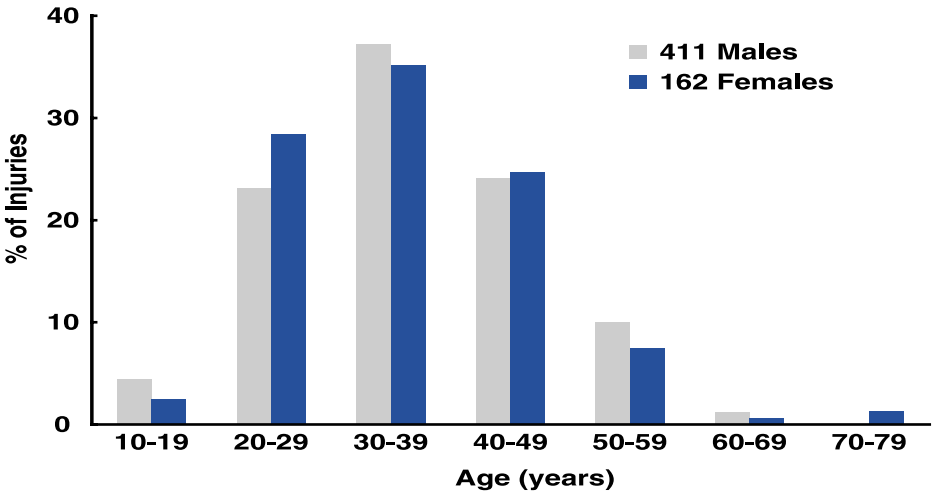


Figure 6 on page 23 shows the chronic health conditions reported by injured divers. (HBP / HD refers to high blood pressure or heart disease. CNS refers to seizures, migraine, or central nervous system injury.) Seventeen percent reported tobacco use, slightly less than the general population. Allergy was reported by 12 percent of injured divers, with women having nearly twice the frequency (18 percent) as men (10 percent). Hypertension or heart disease was reported by 6 percent of injured divers. A previous episode of decompression illness was reported by 5.7 percent. About 5 percent of injured divers reported having or having had asthma. Psychiatric problems had an incidence of 3.6 percent and were three times as common in women (7.1 percent) than in men (2.2 percent). Arthritis was infrequent, with a reported incidence of 1.24 percent. There were self-reported CNS problems in only three divers (0.41 percent), and only four injured divers reported having diabetes.

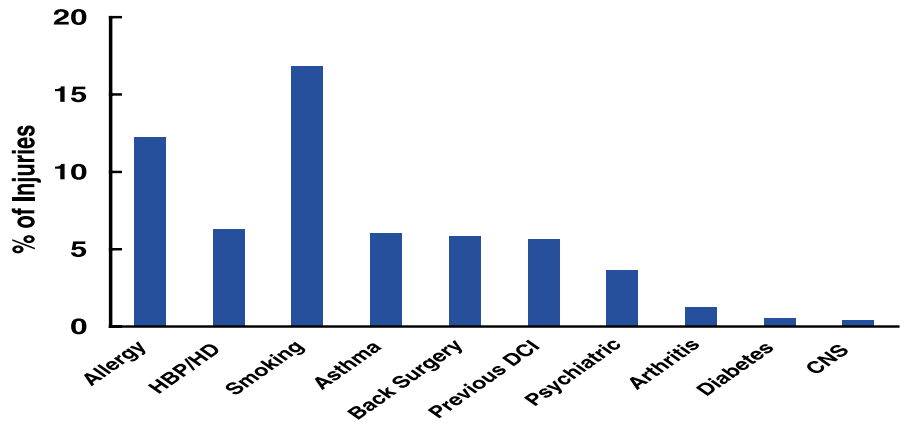


Fig 6
Chronic health conditions of injured divers (n=724).

Figure 7 shows the acute health conditions present at the time of injury. (Orthopedic refers to sprain, muscle pain, or fracture. URI refers to upper respiratory infection. GI refers to gastrointestinal. Birth control medication and estrogen replacement apply only to females.) At almost 15 percent, orthopedic problems were the most common health condition reported by injured divers. Symptoms of motion sickness were present in 6 percent of injured divers prior to injury. Women reported seasickness more often (10.3 percent) than did men (4.3 percent). Gastrointestinal symptoms were reported by about 4 percent of injured divers. Infection of any kind prior to the last dive was uncommon, with a reported incidence of only 1.66 percent. Only three divers (0.41 percent) admitted to upper respiratory symptoms at the time of injury. None of the injured divers reported diving with a hangover. While not strictly health conditions, 26 percent of injured women used oral contraceptives, and 4.25 percent used estrogen replacement therapy.

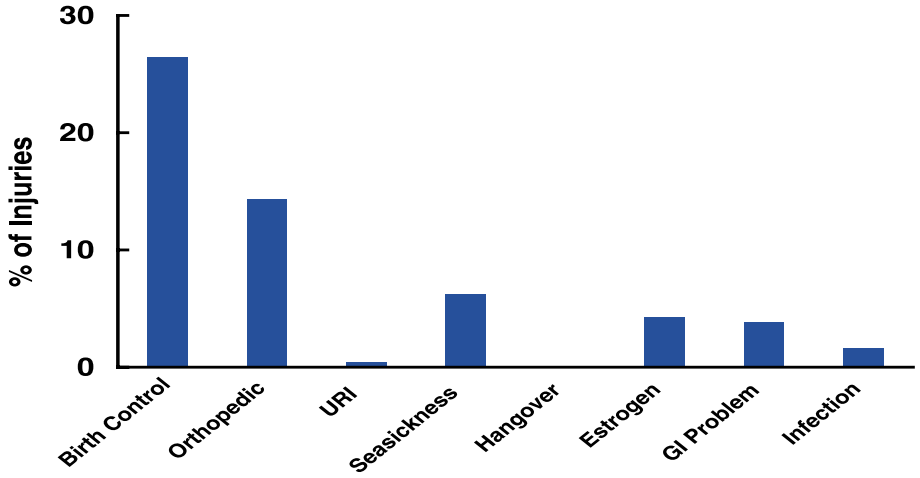


Fig 7
Acute health conditions for injured divers (n=724).

Figure 8 shows that open-water and advanced certification were most common among injured divers. Dive instructors represented slightly more than 10 percent of reported cases. "Specialty" included rescue, scientific, military or commercial divers.

Fig 8
Certification levels of injured divers (n=694).

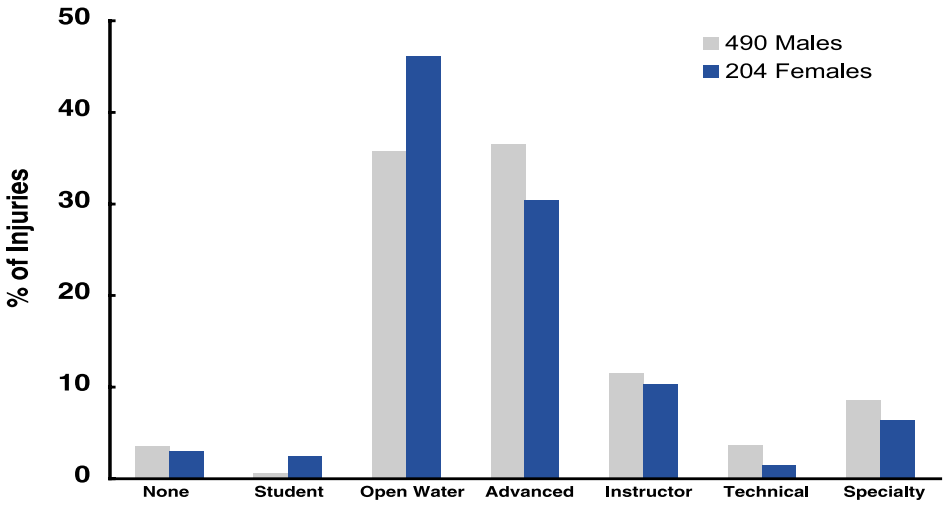


Figure 9 shows the years since initial certification for injured divers. Women, on average, had been diving for one year less than men. The longest reported interval since certification was 41 years, and the shortest was zero. Most divers had been diving for five years or less, although about a quarter had been certified for 10 years or more.

Fig 9
Years since initial certification for injured divers (n=669).

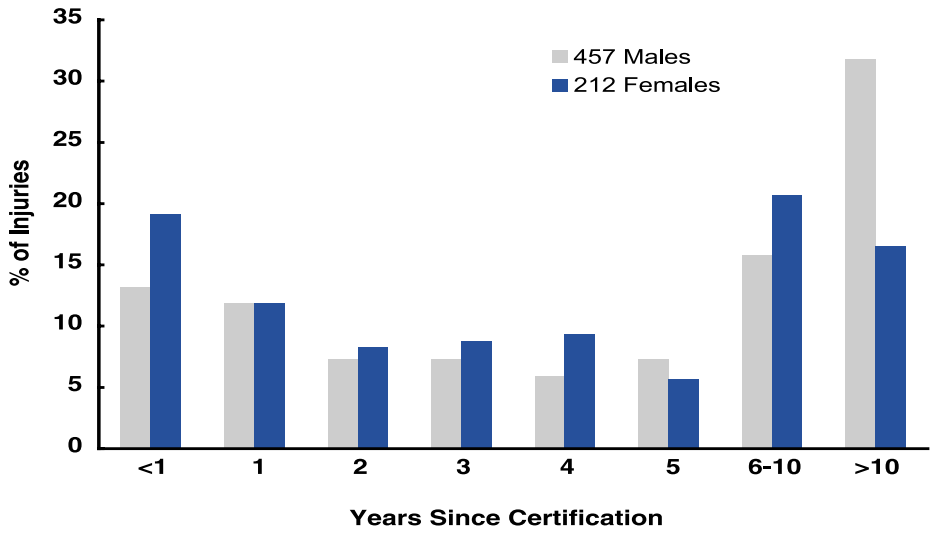


Figure 10 shows the self-reported number of dives in the past 12 months for injured divers. Over half the injured women and nearly 40 percent of the injured men had made fewer than 20 dives in the past year. As in previous years, men had made about 10 more dives per year than did women.

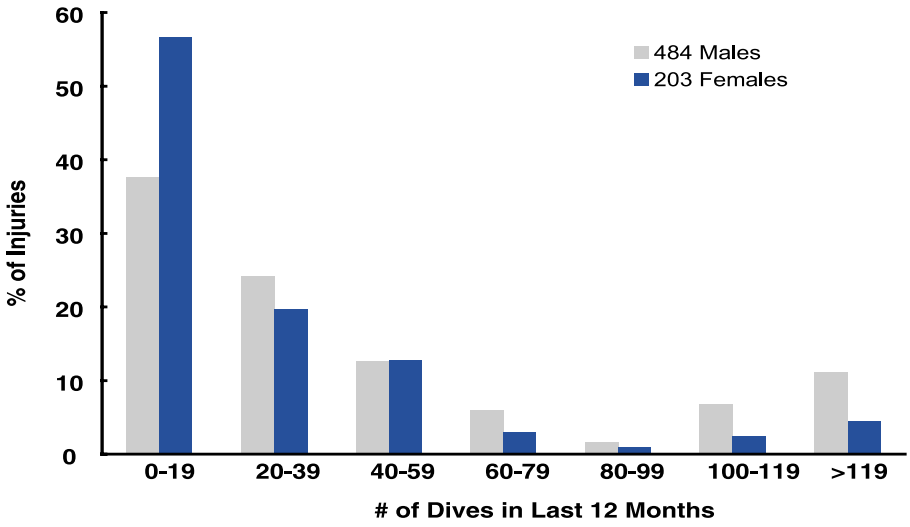


Fig 10
Number of dives in the past 12 months by injured divers (n=687).

2.2 Characteristics of Dives by Injured Divers

Figure 11 shows the months in which diving injuries occurred. The summer months of June, July and August were the most frequent months for decompression illness, while the fewest injuries occurred in December through February.

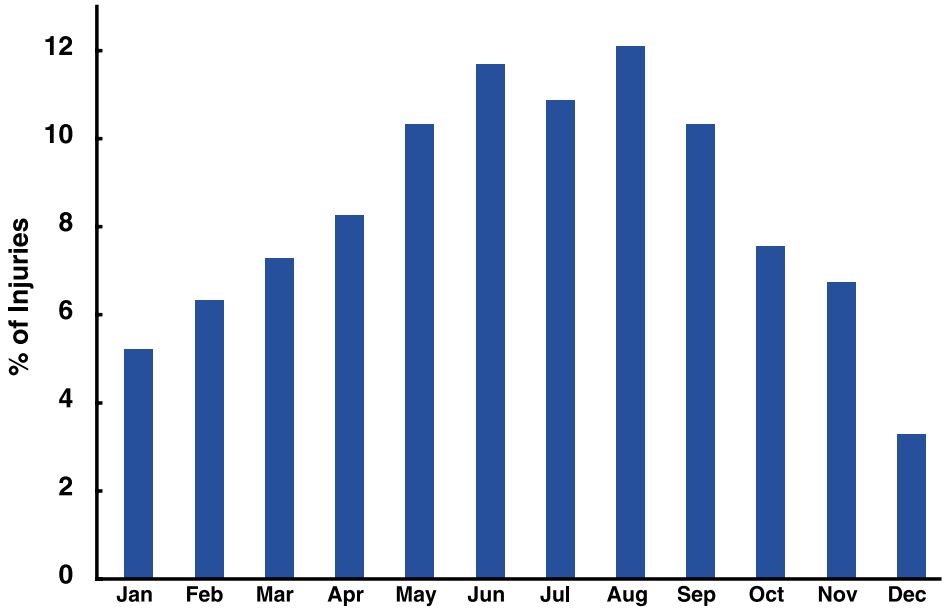
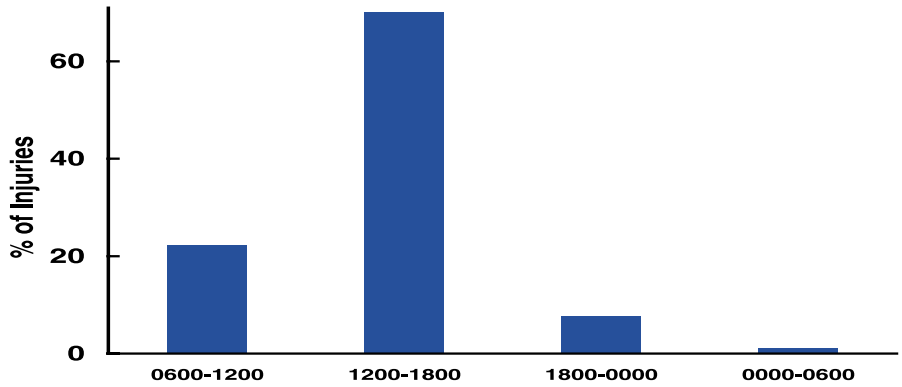


Fig 11
Months in which diving injuries occurred (n=727).

Figure 12 shows the time of day at which diving injuries occurred. Almost 90 percent of the dives took place during the daylight hours of 6 a.m. to 6 p.m. The remainder occurred mostly during the late evening hours.

Fig 12
Time of day at which diving injuries occurred (n=662).



Figures 13 and 14 show the U.S. and international locations at which the reported injuries occurred. Most injuries were reported from either the Southeast U.S. or a limited number of sites in the vicinity of Mexico. Designated "Yucatan" in Figure 14, these sites included Cozumel, Cancun, Baja, the Galapagos and several small islands.

Fig 13
U.S. location of diving injuries (n=298).

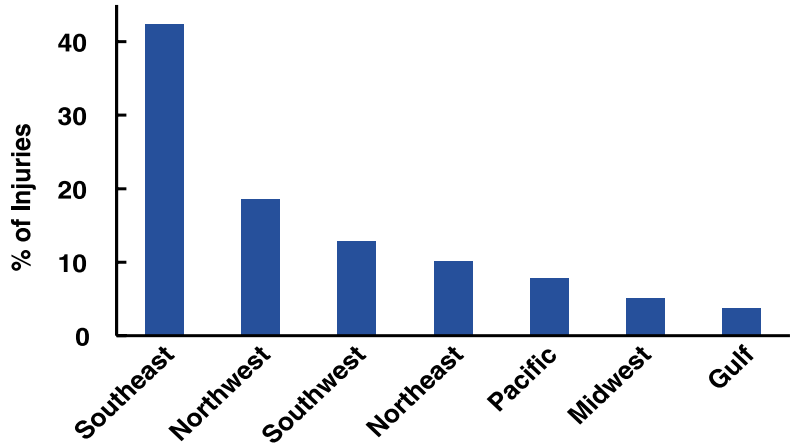


Fig 14
International location of diving injuries (n=231).

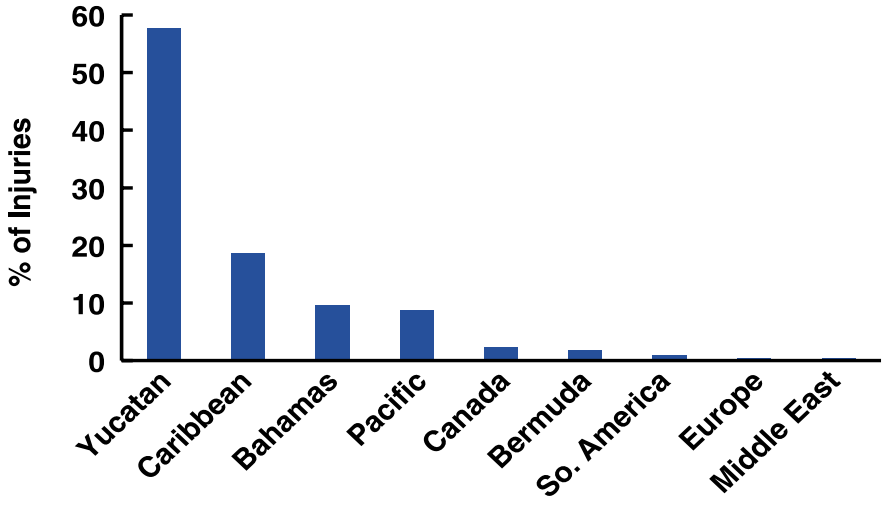


Figure 15 shows the environment in which the diving injuries occurred. The majority of dives (90 percent) took place in salt water. About 7 percent took place in a freshwater lake or quarry, while only 1.7 percent happened in a cave.

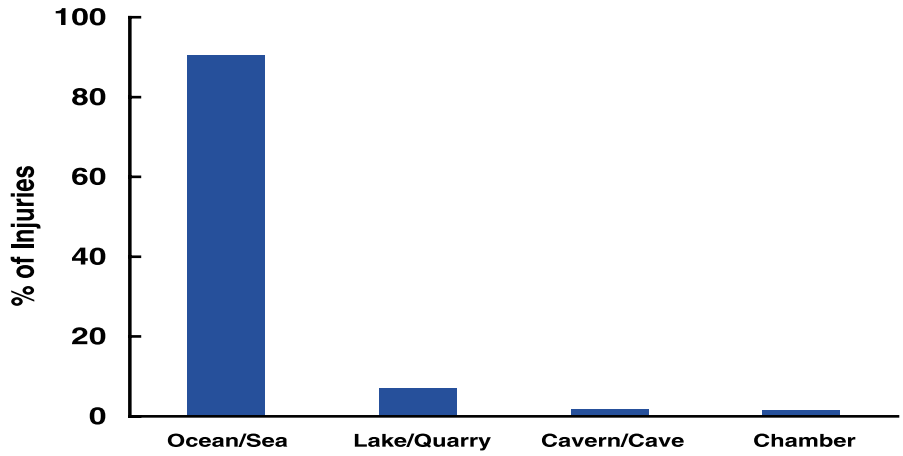


Fig 15
Environment in which diving injuries occurred (n=718).

Figure 16 shows the purpose for diving reported by injured divers. At 76 percent, recreation was the most commonly cited purpose. Learning to dive (student at 9 percent) and teaching diving (instructor at 5 percent) were the next most common reasons for diving. Injuries occurred during 39 technical dives (3.3 percent). The category "Other" included military, commercial, law enforcement and scientific diving.

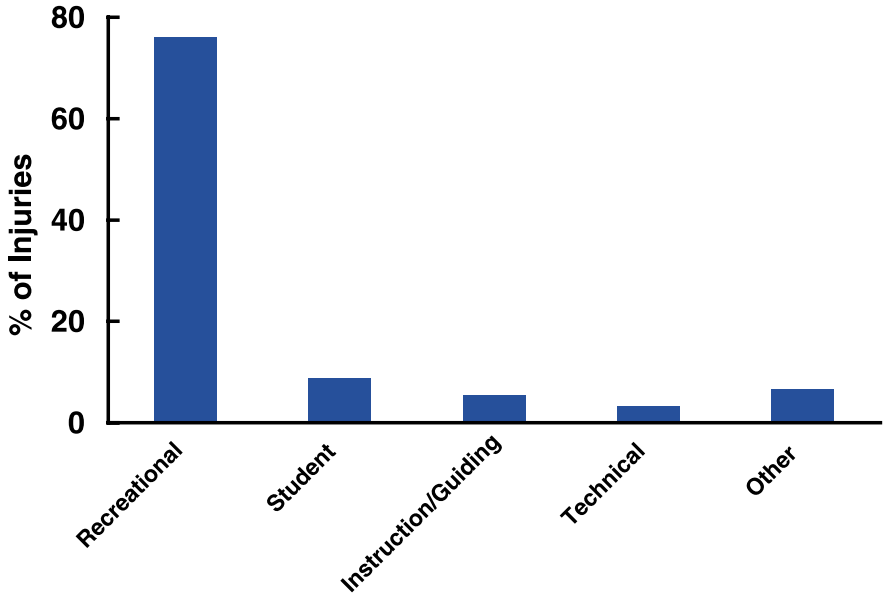


Fig 16
Purpose for which injured divers were diving (n=726).

Figure 17 shows that most injured divers wore some sort of thermal protection. Over 70 percent of all injured divers wore wetsuits. Drysuits were used in 12.6 percent of the injuries, while swimsuits and dive skins were the choice for 15 percent.

Fig 17
Thermal protection used by injured divers (n=638).

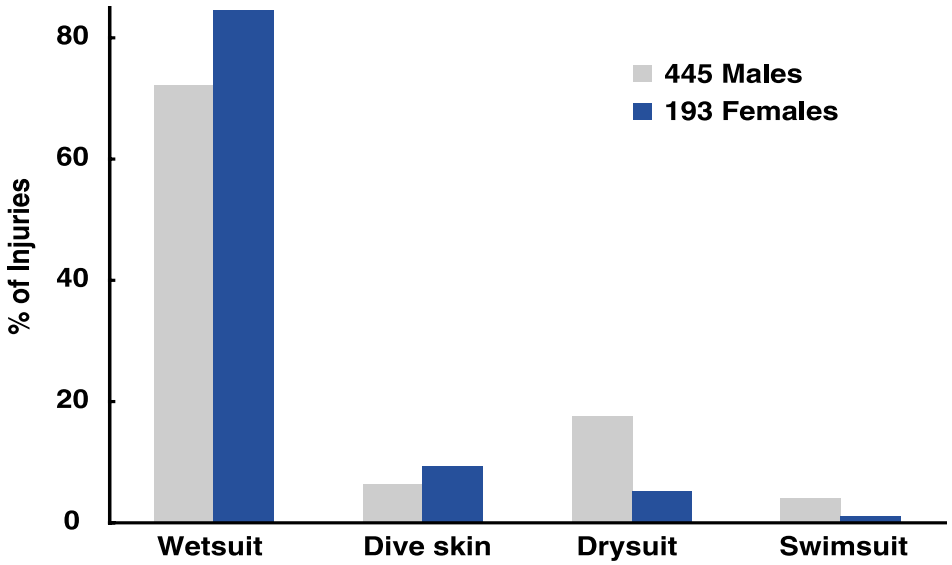


Figure 18 shows the breathing apparatus used by injured divers. At 97.5 percent, the dominant apparatus was open-circuit scuba. Surface-supplied breathing apparatus represented 2 percent, and semi-closed rebreathers represented 0.3 percent.

Fig 18
Breathing apparatus used by injured divers (n=671).

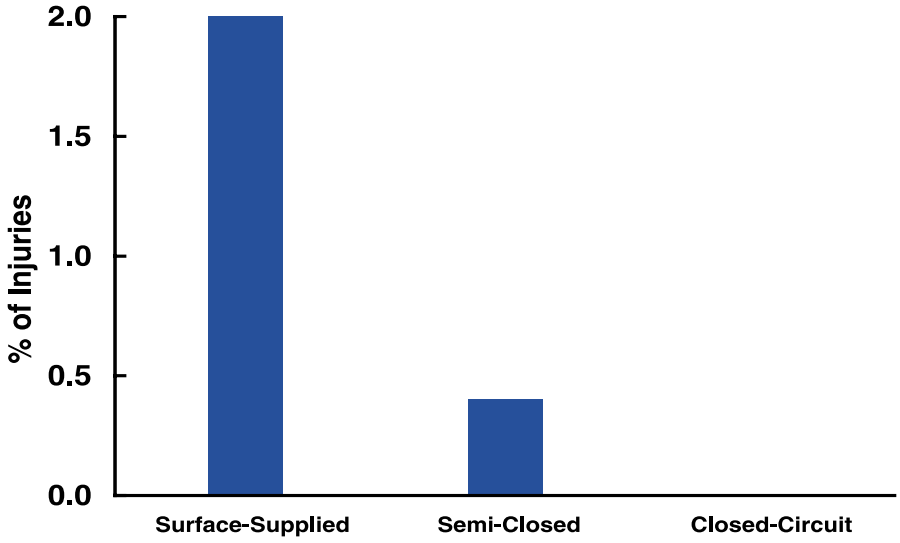


Figure 19 shows the breathing gas used by injured divers. Ninety percent used air, while nitrox (EAN or Enriched Air Nitrox) was used by about 8 percent of injured divers. Heliox (helium-oxygen) or trimix (helium-nitrogen-oxygen) was used by about 1 percent.

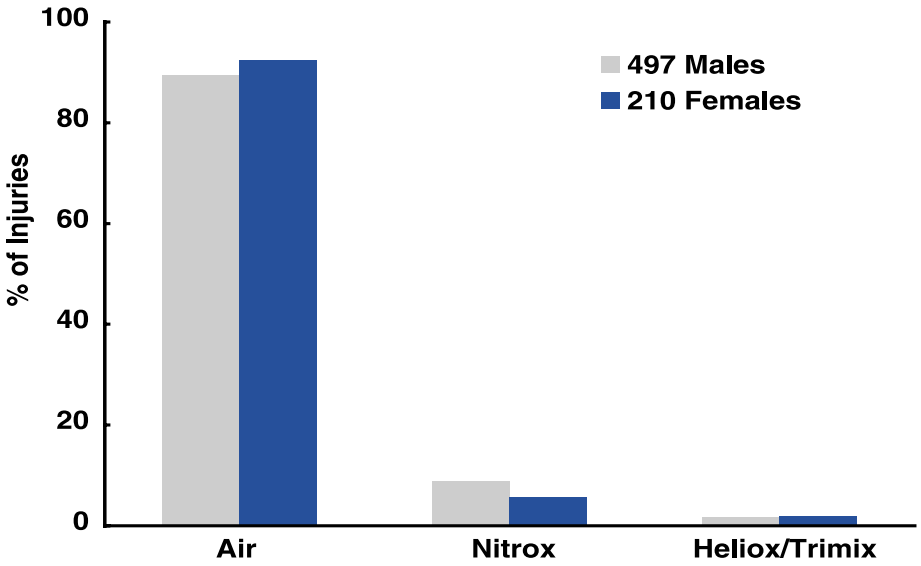


Fig 19
Breathing gas used by injured divers (n=707).

Figure 20 shows the dive planning methods used by injured divers. At 73 percent, the proportion of injured divers using dive computers continues to increase over previous years, although this may reflect the continued growth in popularity of dive computers rather than increased risk over dive tables. Dive tables were used in about 20 percent of the cases. Seven percent of injured divers followed a dive guide or instructor.

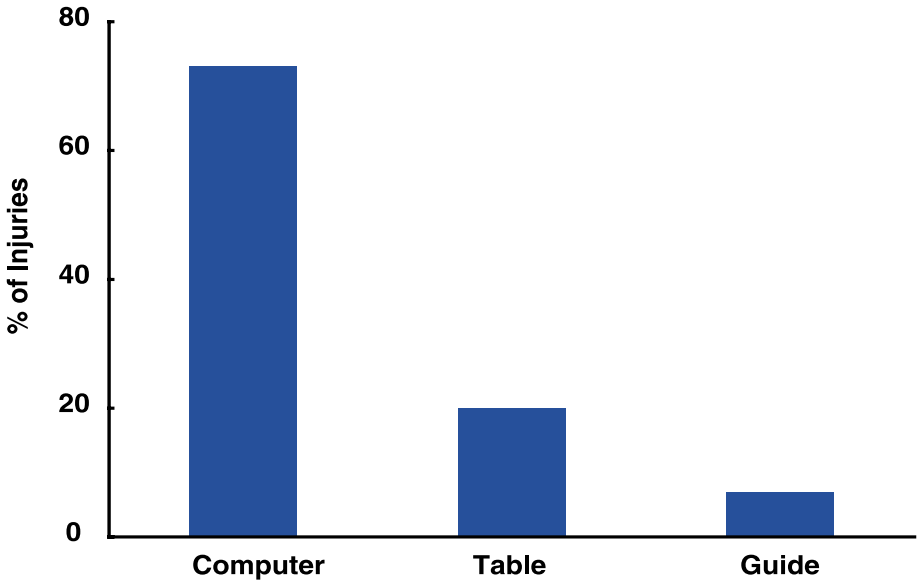


Fig 20
Dive planning methods used by injured divers (n=603).

Figure 21 shows the number of days in the dive series by injured divers. Most of the injuries occurred on the first day. The longest number of days of diving reported was 40.

Fig 21
Number of days in dive series by injured divers (n=676).

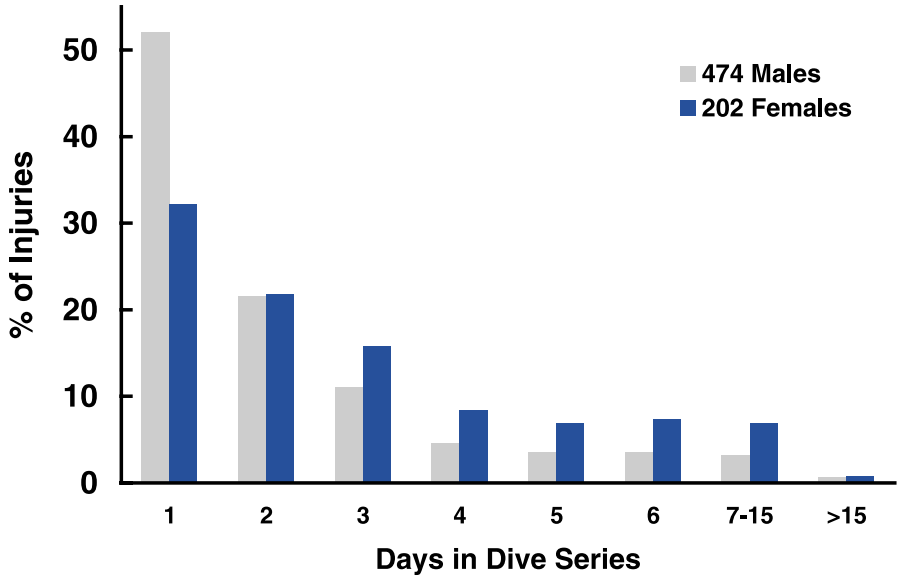


Figure 22 shows the number of dives in the series where the injury occurred. Injuries were most frequent after two dives or after 6-10 dives. Injured women made fewer dives than did injured men. The largest number of reported dives was 80.

Fig 22
Number of dives in series where injury occurred (n=673).

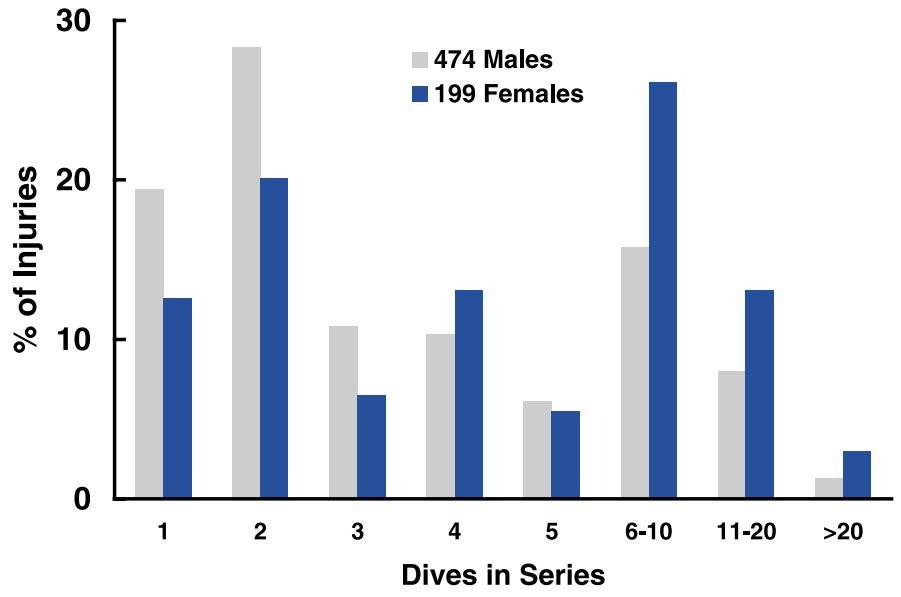


Figure 23 shows the maximum depth in the dive series by injured divers. The average depth was about 90 fsw / 27 msw. For 15 percent of injured divers, the maximum reported depth was 130 fsw / 39 msw or greater. The deepest maximum depth was 322 fsw / 97 msw. The deepest dive was not necessarily the one that resulted in injury.

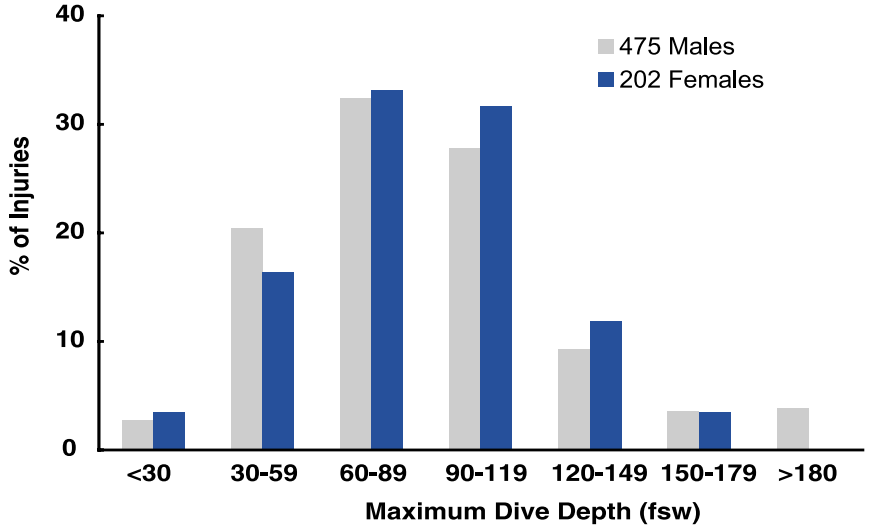


Fig 23
Maximum depth in the dive series by injured divers (n=677).

Figure 24 shows the depth of the last dive made by injured divers. The average depth was 75 fsw / 23 msw. Ten percent of the last dives had depths of 120 fsw / 36 msw or more. The deepest depth reported for the last dive was 302 fsw / 91 msw. The last dive was not necessarily the dive on which the injury occurred. The last dive was about 15 fsw / 14.5 msw shallower than the deepest dive (Figure 23).

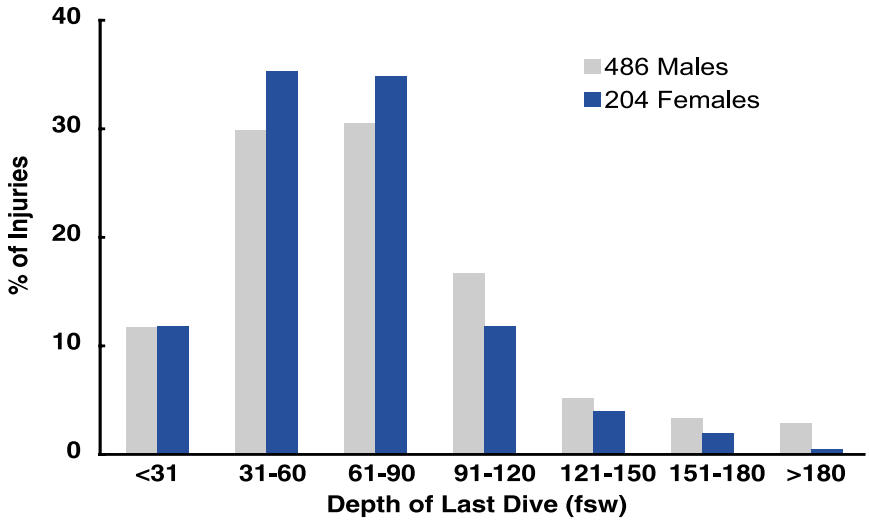


Fig 24
Depth of the last dive for injured divers (n=690).

About one fifth, or 138 injured divers, reported some form of altitude exposure after diving. Figure 25 shows the types of altitude exposure reported by the 138 injured divers. Nearly half of these involved commercial air flight, 19.3 percent unpressurized aircraft, and 5.8 percent mountain travel.

Fig 25
Type of altitude exposure by injured divers (n=138).

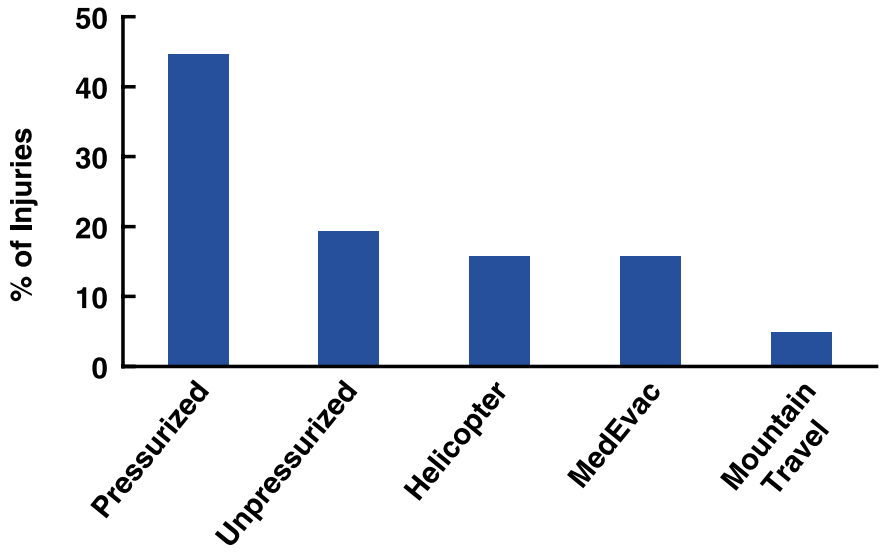


Figure 26 shows the surface interval before flying for 67 injured divers who were exposed to altitude. (This excludes medical evacuations.) The shortest surface interval before flying was less than 30 minutes, and the longest was three days. Divers who had symptoms before flight waited about two hours longer before flying than did divers who developed symptoms during or after flight. "Sx" in Fig. 26 stands for "symptoms."

Fig 26
Surface interval before flying for injured divers (n=67).

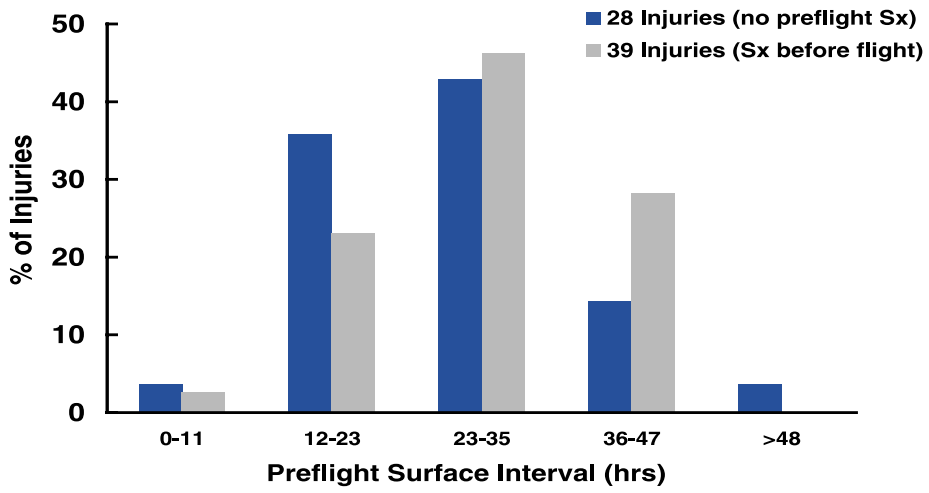


Figure 27 shows the problems during diving that were reported by injured divers. Over 40 percent reported difficulty in maintaining buoyancy. Almost a quarter reported rapid ascent. Only 8 percent of injured divers reported omitted decompression. Five percent reported an equipment problem during the dive resulting in injury, and 4 percent ran out of breathing gas. Men (10 percent) were more likely to report heavy work than were women (6 percent). Six percent of both men and women who were injured reported being cold or experiencing nausea / vertigo. Shortness of breath occurred in less than 4 percent of injured divers and physical injury in fewer than 2 percent, although women reported physical injury four times more often than men.

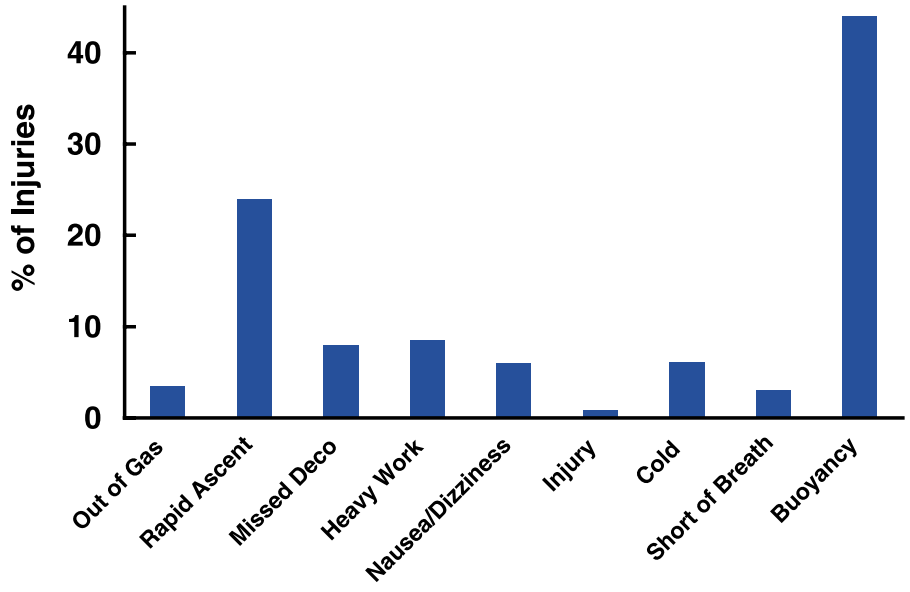
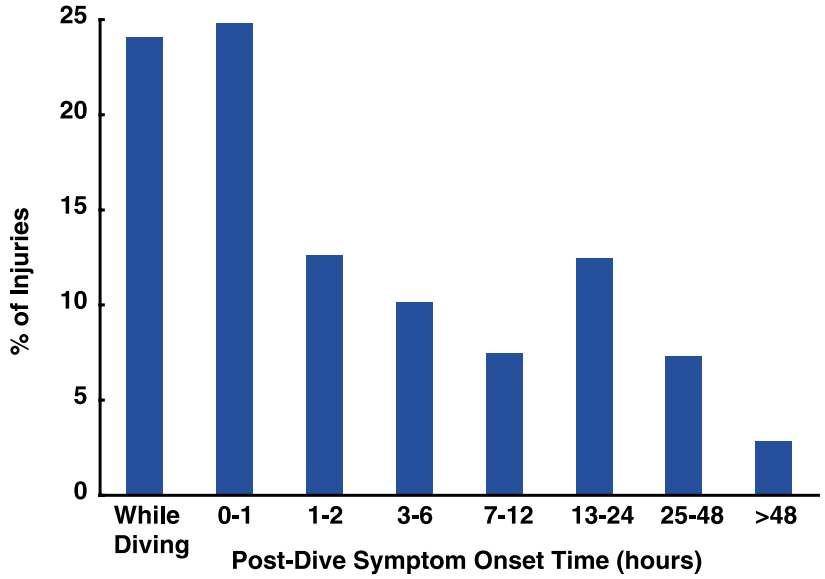


Fig 27
Problems during diving for injured divers (n=717).

2.3 Signs and Symptoms in Injured Divers

Figure 28 shows the onset time during or after diving for the first symptoms reported by injured divers. Nearly a quarter of injured divers reported that their first symptoms occurred while they were in the water, and nearly a quarter reported their first symptoms within one hour of surfacing from the last dive. Almost three-quarters had their first symptoms within 12 hours. About 4 percent reported that their first symptoms occurred more than two days after surfacing from the last dive. The data of Figure 28 apply only to divers who developed symptoms before flying after diving. Of 29 injured divers who reported symptoms during or after flight, two-thirds of these symptoms occurred after longer than 12 hours.

Fig 28
Onset time of first symptom in injured divers (n=573).



Injured divers and chamber physicians reported as few as one sign or symptom per diver and as many as nine for a total of 2,671 signs or symptoms in the 728 injury cases. The mean was three signs or symptoms per diver. Reported signs and symptoms were assigned to one of 17 groups as shown in Table 1. Based on the physician's diagnosis, the signs and symptoms were presumed to be DCI (DCS or AGE). The first column in Table 1 lists six arbitrary categories of symptom severity, ranging from most severe (1. Serious Neuro) to least severe (6. Constitutional/Non-Specific).

Arbitrary Severity Classification	Symptom Group (Alphabetical Order)	Reported Signs or Symptoms
1. Serious Neuro	Bladder or Bowel	bladder or bowel dysfunction
	Coordination	ataxia, coordination, gait
	Consciousness	consciousness
	Hearing	hearing, tinnitus
	Mental Status	dysphasia, memory, mental status, mood, orientation, personality
	Reflexes	reflexes
	Strength	hemiparesis, motor weakness, muscle weakness, paraplegia, paresis
	Vision	vision
2. Cardiopulmonary	Cardiovascular	arrhythmia, cardiovascular, palpitations
	Pulmonary	cough, hemoptysis, pulmonary, respiratory distress, shortness of breath, voice change
3. Mild Neuro	Paresthesia	numbness, numbness & tingling, paresthesia, sensation, tingling, twitching
4. Pain	Pain	ache, cramps, discomfort, joint pain, pain, pressure, sharp pain, spasm, stiffness
5. Lymphatic/Skin	Lymphatic	lymphatic, swelling
	Skin	burning of skin, itching, marbling, skin, rash
6. Constitutional/ Non-Specific	Dizziness	dizziness, dizziness/vertigo
	Fatigue	fatigue
	Headache	headache
	Nausea	nausea, nausea & vomiting, vomiting
	Other	chills, diaphoresis, heaviness, heavy head, lightheadedness, malaise, restlessness
	Vertigo	vertigo

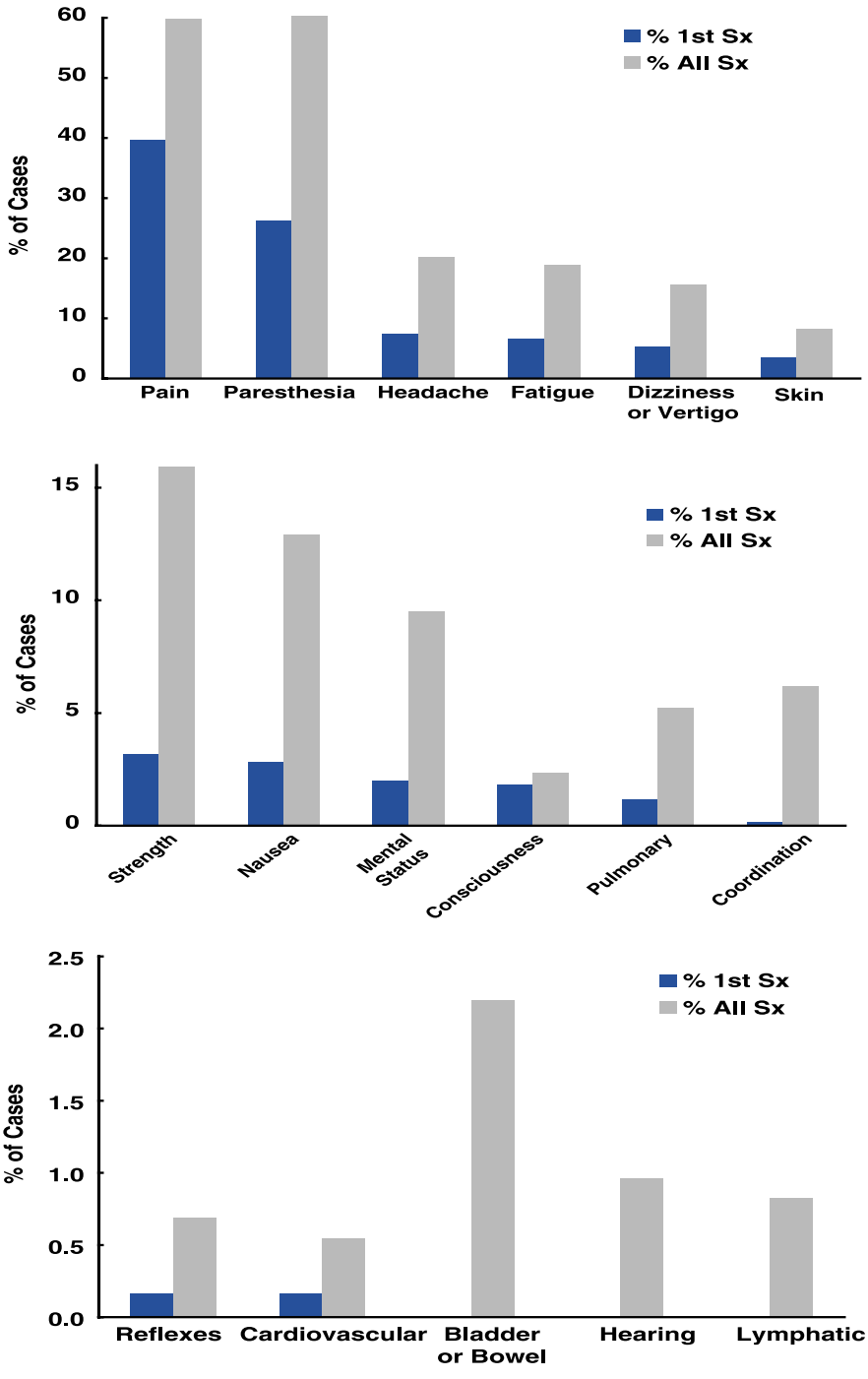
Table 1
Reported signs of symptoms, assigned symptom groups and arbitrary severity classifications.

Figure 29 on page 36 shows the proportions of cases in which each symptom group occurred at least once. The proportions are shown for both initial symptoms and all symptoms that eventually occurred. The proportions of first symptoms sum to 100 percent, as only one symptom could be first, but the proportions of total symptoms sum to greater than 100 percent since individual divers may have had multiple signs or symptoms. Multiple occurrences of a given symptom group in the same diver were not counted.

At 40 percent, pain was the most common first symptom, followed by paresthesia (abnormal skin sensations) at 26 percent, but when all symptoms were considered, 60 percent of the divers reported pain and/or paresthesia. Non-specific symptoms, such as fatigue, nausea and headache, occurred as first symptoms in less than 10 percent of cases but were eventually present in 15-20 percent.

Decreased muscle strength was the first reported symptom in 3 percent of cases, but eventually occurred in 16 percent of cases. Altered mental status occurred as a first symptom in only 2 percent of cases but was eventually present in 10 percent of cases. The most serious symptoms, such as bladder and bowel dysfunction or altered consciousness, were uncommon and were reported in slightly more than 2 percent of cases. Bladder/bowel, hearing and lymphatic symptoms never occurred first. Whenever altered consciousness occurred, it was almost always reported as the first symptom (Sx).

Fig 29 Individual symptoms reported or observed for injured divers (n=573).



Each diving injury case was classified according to the category of its most severe symptom as defined in in Table 1. The distribution of cases by severity is shown in Figure 30. Nearly half the divers met the definition for Mild Neurological decompression illness (Severity Category 3). The most severe DCI category, Serious Neurological (Severity Category 1), was the second most common with almost a quarter of the cases. Pain (Severity Category 4) was third at about 20 percent, followed by cardiopulmonary, constitutional (non-specific), and lymphatic/skin, which were uncommon.

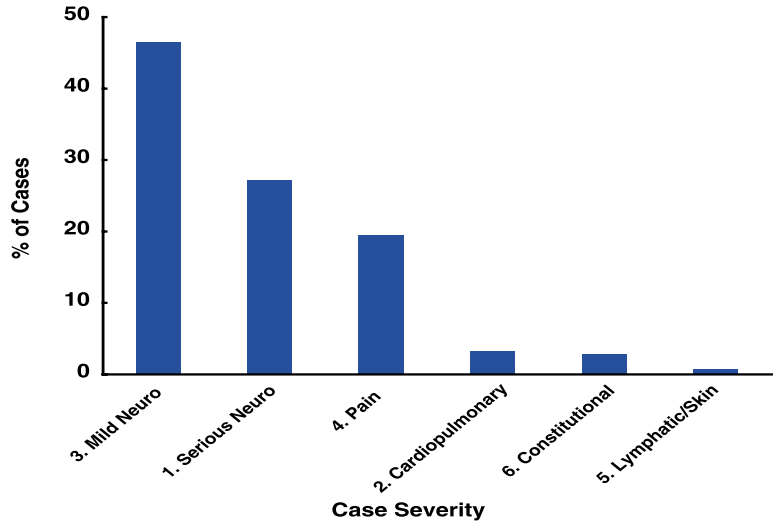


Fig 30
Distribution of case severity classification (n=573).

Figure 31 shows the location of limb pain, limb paresthesia, and muscle pain in injured divers with respect to the arms and legs. The arms were the most common site for either pain or paresthesia at 30-35 percent. The arms and legs were both affected by paresthesias in 10 percent of the cases. Abdominal, trunk, or "girdle" pain was reported in 6 percent of cases. Sensory symptoms, such as tingling in the fingers and/or toes, generally had a peripheral distribution, while sensory changes that followed a classic dermatomal distribution or around the joints were less common.

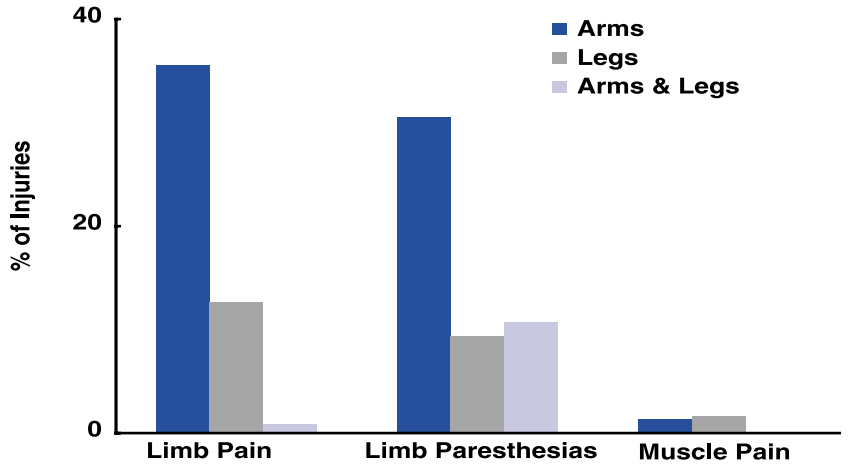


Fig 31
Location of limb pain, limb paresthesia and muscle pain in injured divers (n=690).

Figure 32 shows the final diagnosis of 605 cases. Chamber physicians chose the diagnosis from among Type 1 decompression sickness (DCS-1), Type 2 decompression sickness (DCS-2), arterial gas embolism (AGE), and decompression illness (DCI). At nearly 60 percent, the most common final diagnosis was DCS-2. DCS-1 was next most common at almost one quarter of the cases. The remaining cases were DCI at 8 percent and AGE at 5.4 percent.

Fig 32
Final diagnosis of cases for injured divers (n=605).

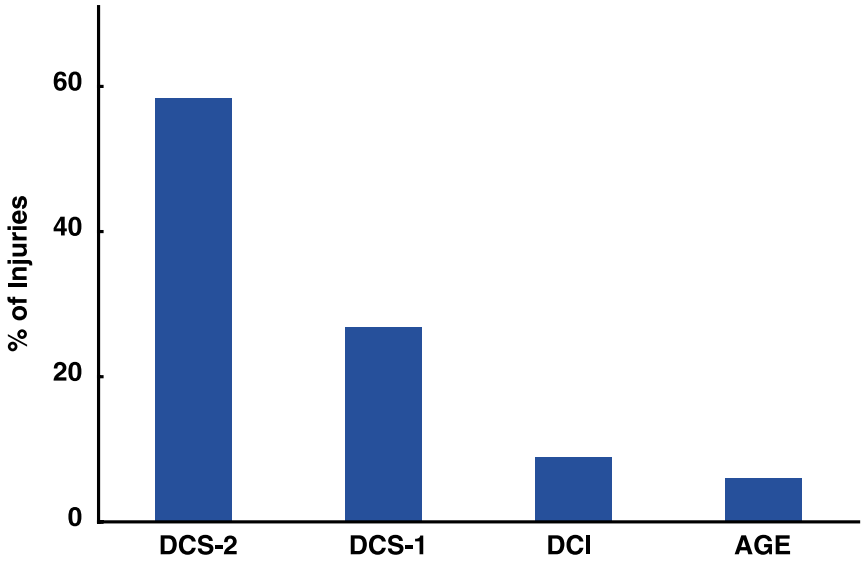
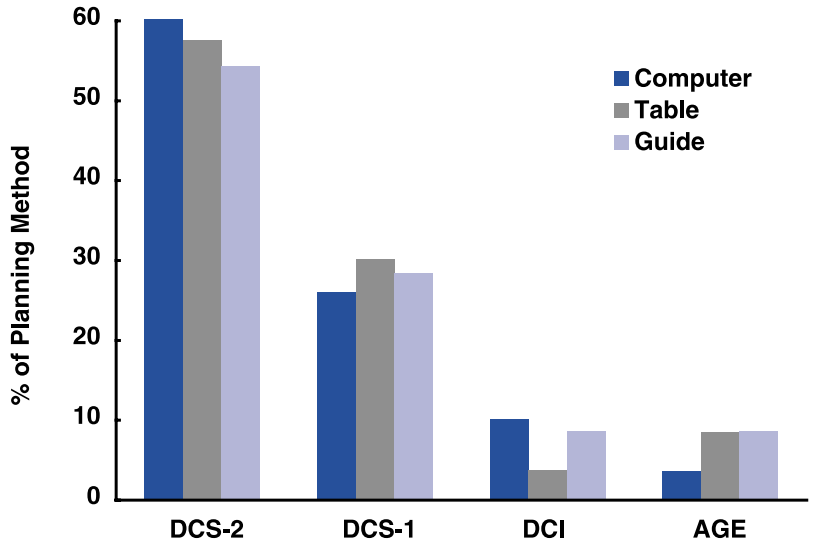


Figure 33 shows the diagnosis according to the dive planning method for injured divers. There was little difference in diagnosis between divers who used computers, tables, or followed a guide.

Fig 33
Dive planning method and diagnosis for injured divers (n=605).



2.4 Therapy for Decompression Illness

Figure 34 shows the method used for delivering surface oxygen to 145 (20 percent) injured divers who reported receiving oxygen prior to recompression therapy. Oxygen was most often delivered (44 percent) by a non-rebreather mask. A demand system was used for 20 percent of divers receiving surface oxygen, a standard face mask was used for 30 percent, and a nasal cannula was used for 7 percent. There were no reports of closed-circuit oxygen rebreathing systems.

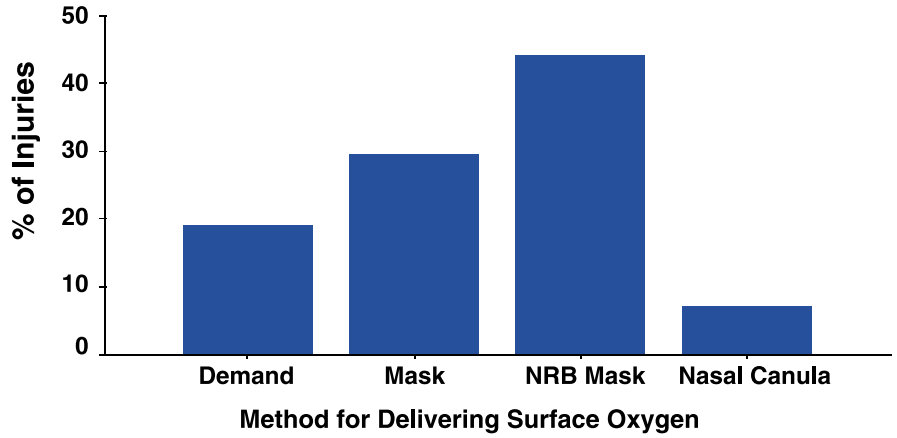


Fig 34
Method for delivering surface oxygen before recompression in injured divers (n=145).

Figure 35 shows the delay to recompression for injured divers from the time of first symptom onset. The median delay to treatment from time of the first symptom was 22 hours, with a range of less than one hour to 746 hours (about 31 days).

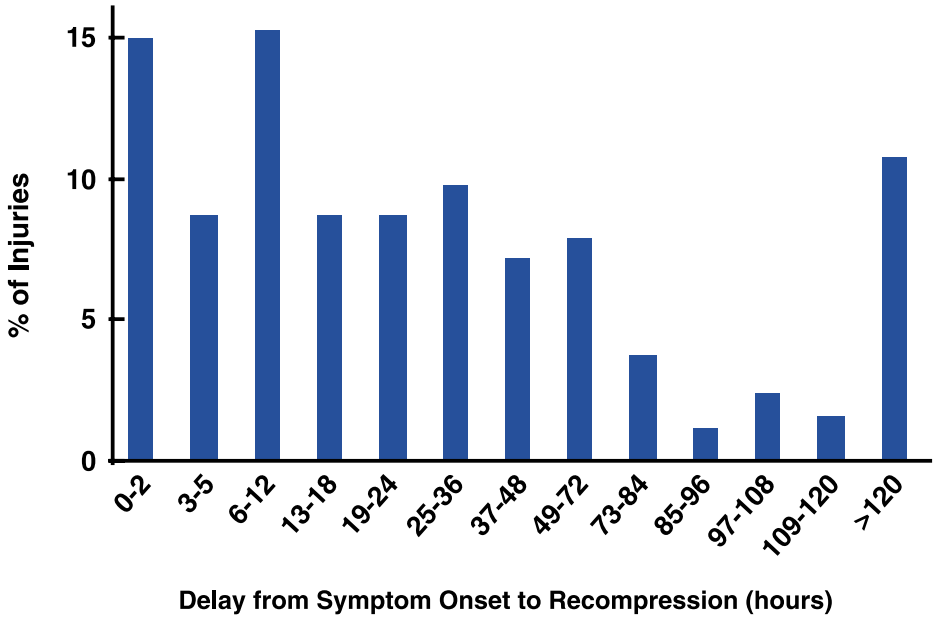


Fig 35
Delay to recompression from the time of first symptom onset for injured divers (n=382).

Figure 36 shows the type of recompression chamber in which injured divers were initially treated. More than three-quarters (77 percent) were first recompressed in a multiplace chamber. Monoplace chambers were used in 19.5 percent of initial treatments, and dual place chambers were used in about 4 percent.

Fig 36
Type of chamber in which injured divers were treated (n=664).

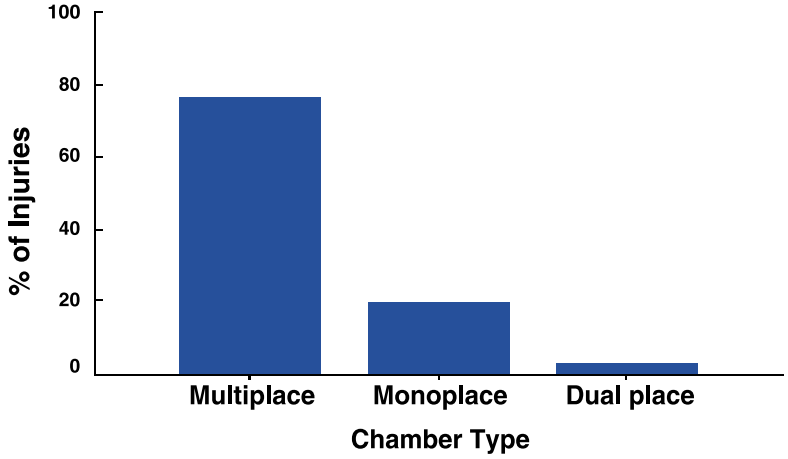


Figure 37 shows the initial treatment table used to recompress injured divers. U.S. Navy Treatment Table 6 was the most common recompression table and was used in 61 percent of initial treatments. Various clinical hyperbaric oxygen therapy protocols were used in 28.6 percent of the initial treatments. Treatment Table 5, intended for pain-only decompression sickness that resolves quickly, was used in 5.5 percent of the cases. Treatment Table 6A, intended for AGE or severe DCS, was used in 4.8 percent of the initial treatments.

Fig 37
Initial treatment table used to recompress injured divers (n=669).

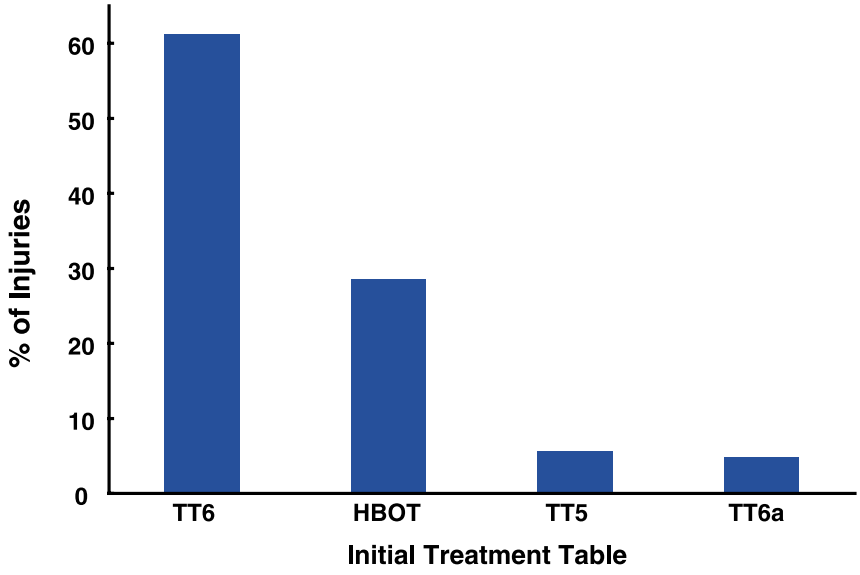


Figure 38 shows the total number of recompressions for injured divers. Over 50 percent received only one hyperbaric treatment. The mean number of treatments received was slightly more than two, and the highest number was 14.

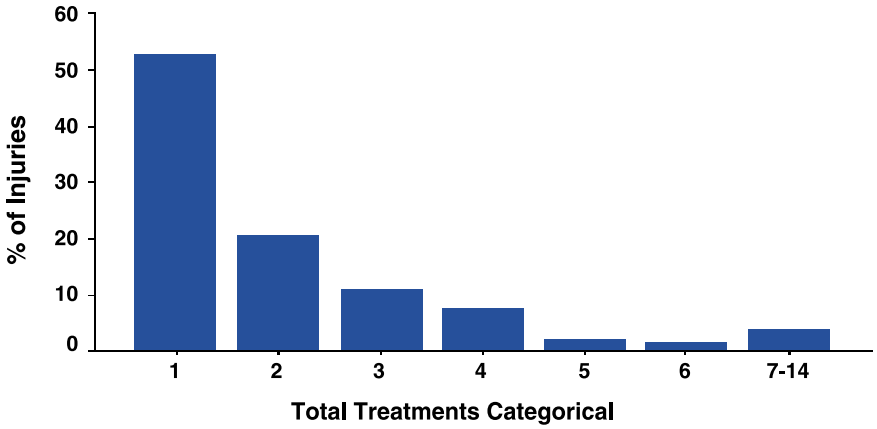


Fig 38
Total number of recompressions for injured divers (n=686).

Figure 39 shows the mean number of recompressions required according to diagnosis for injured divers. Cases classified as undifferentiated decompression illness had the highest number of recompression treatments (mean 2.53), followed by Type 2 DCS (2.34), and AGE (2.14). Type 1 DCS required only 1.55 treatments per injured diver.

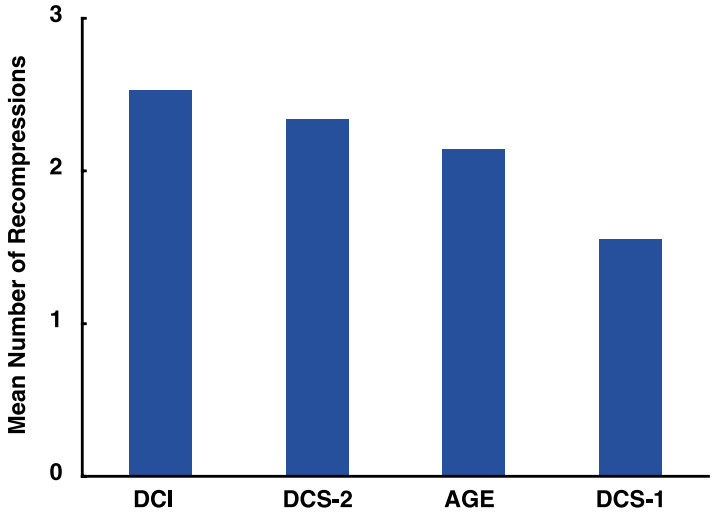


Fig 39
Diagnosis and mean number of recompressions for injured divers (n=650).

2.5 Therapeutic Outcome

Figure 40 shows the response of injured divers to surface oxygen prior to recompression. Of those receiving oxygen prior to recompression, complete relief was achieved in 14 percent of the cases, 57 percent were improved, 24 percent were unchanged, and 5 percent got worse. Injured divers who received surface oxygen were more likely to have complete resolution of symptoms before recompression than were those who did not receive surface oxygen, except for those who received it by nasal cannula.

Fig 40
Response to surface oxygen for injured divers (n=42).

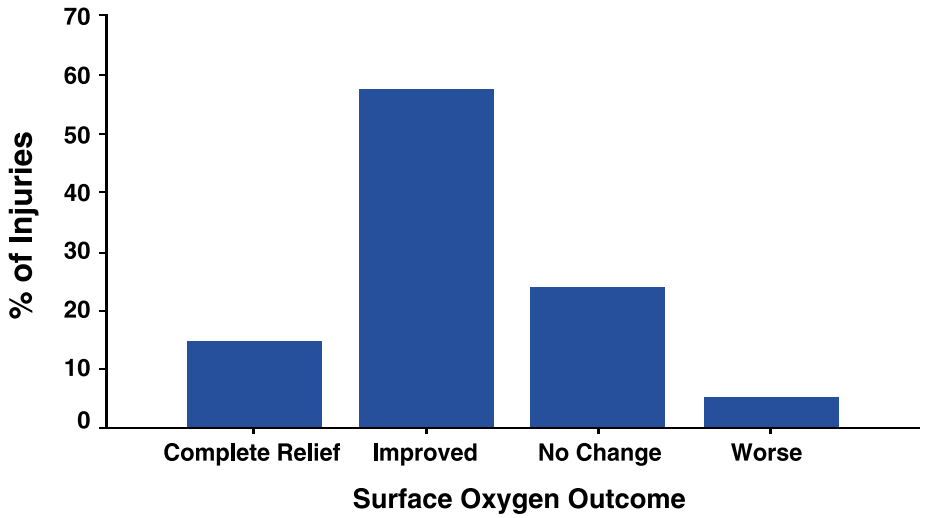


Figure 41 shows the health status of injured divers after the first recompression (313 divers), after all recompressions (727 divers), and at six months (689 divers), nine months (674 divers), and 12 months (674 divers) following completion of all recompressions. Injured divers who had not achieved complete relief of symptoms at discharge following all recompressions were followed up at six, nine, and 12 months.

Half of the injured divers had complete relief after the initial recompression, and 43 percent were improved. Only 6.7 percent had no improvement. Two cases reported that symptoms were worse after the initial treatment.

Seventy-five percent of injured divers had complete relief at the time of discharge following completion of all recompression therapy. Twenty percent were improved at time of discharge but still had symptoms, and 5 percent had no improvement. Only one person was worse after all treatments, and one discontinued treatments against medical advice.

Ninety-six percent of injured divers had resolved by six months, 98 percent by nine months, and 99 percent by 12 months. The remainder reported improvement. "Rx" indicates "recompression therapy."

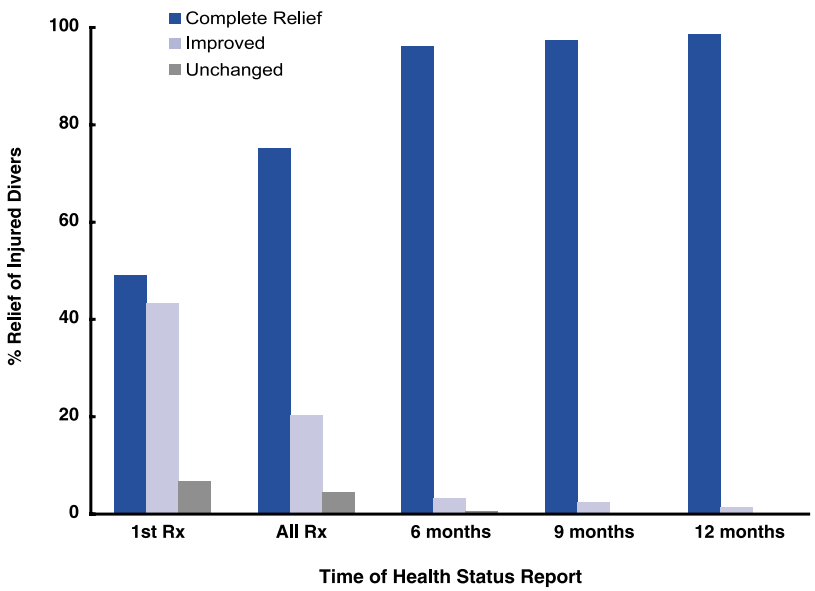


Fig 41
Health status of injured divers after the first recompression, all recompressions and at 6-, 9- and 12-month followups.

2.6 Case Reports

The following reports were taken from the 728 cases DAN received in 2000. These were typical for symptom onset time, type of diving, type of symptoms, and delay to evaluation and treatment. An essential indicator for decompression illness was the onset of symptoms in association with recent scuba diving. Physicians often found objective signs during examination, but more often, divers experienced vague and subjective symptoms leading to a "wait and see" attitude about seeking assistance. As there are a limited number of recompression chambers in the United States, DAN encourages divers to report symptoms and seek evaluation and treatment early. While symptoms can resolve spontaneously, they may also progress and become more severe.

Case 1. Arterial Gas Embolism: AGE After Coughing at Depth and Recurrence of Symptoms on Flight Home

The diver was a 47-year-old female (5′5", 145 lbs.) reported to be in good health. She was certified approximately a year earlier but had not been diving since. She was on a dive vacation and made her first open ocean dive to a depth of 75 fsw / 22.8 msw. She knew her dive buddy, and they planned to follow the divemaster. She had no trouble clearing during descent but had difficulty with buoyancy and returned to the boat for additional weight. She descended without problem, reaching the planned depth of 75 fsw. Shortly thereafter, she coughed twice to clear mucus from her airway.

The remainder of the dive was incident-free, until she began to feel ill on ascent at 60 fsw / 18 msw and was disoriented at her safety stop. Shortly after getting onto the boat, she noted numbness and tingling from left forearm to fingertips, numbness in her left leg, vertigo, and confusion. She also experienced severe left-sided chest pain and was placed on 100 percent oxygen when the boat reached shore. A chest X-ray and EKG showed normal results when she was evaluated at a local hyperbaric facility, and she was placed in a recompression chamber for a U.S. Navy TT6*. Her chest pain resolved soon after compression, and her sensory symptoms were relieved about two hours into the treatment. Her only symptom after treatment was fatigue.

She returned 48 hours after her treatment with decreased sensation in her left face, shoulder, left arm and leg. She was not able to discriminate pinprick in these areas and also had balance problems. She was given 90 minutes of oxygen under recompression at 45 fsw / 13.6 msw with no improvement. The following day she received a third treatment, which was to be a Table 5 but was aborted due to claustrophobia. Her symptoms were only slightly better.

Approximately six days after her last treatment she flew home by commercial airline. During the flight, she had an acute exacerbation of numbness in her left arm, left leg, and left side of her face. She improved somewhat upon landing but experienced an increase in symptoms when traveling home over a mountain pass at 5,000 feet / 1,524 meters elevation.

The following day her symptoms were worse, and she reported to a local medical facility, where she was found to have decreased sharp-to-dull sensation along the left side of her face, motor weakness of the left arm, and balance problems. She also had various cognitive disturbances including short-term memory loss. Her symptoms continued for a year, and she continues to have problems with numbness after sitting for long periods.

**Treatment Table 6*

Case 2. Neurological Decompression Illness: Symptom Onset with Flying After Diving

The diver was a 39-year-old female in good health who took only allergy and motion sickness medications. She had been certified for five years and made about 30 dives per year. She performed eight uneventful dives over a four-day period to 70-95 fsw / 21-28.6 msw without any decompression violations. On her last dive day, she performed a single multilevel dive no deeper than 83 fsw / 25 msw for about 30 minutes with a safety stop at 15 fsw / 4.5 msw. After exiting the water, she suffered nausea that resolved during the evening. She felt better the next morning, and 26 hours after her last dive, she boarded an aircraft for a five-hour flight home.

She was fatigued during the flight but did not recall any in-flight symptoms. That evening, she awoke with right elbow pain and right arm numbness but waited until mid-morning before calling DAN. She was referred to a local physician who found right elbow pain, right hand and finger pain, heaviness in her right hand, and a sensation of tightness in all the fingers of her right hand. She was treated on a U.S. Navy TT6 with resolution by the end of the treatment except for transient elbow pain and tightness in the fingers of her right hand. She was discharged on non-steroidal anti-inflammatory medication and was told to report back if her symptoms did not resolve.

Approximately 48 hours later, she called to note persistent elbow pain and altered sensation in her right hand. She was treated with two and a half hours of hyperbaric oxygen, experienced complete relief, and remained asymptomatic.

Case 3. Neurological Decompression Illness: Followed by a Case of Cerebral Decompression Illness

The diver was a 37-year-old male (6', 185 lbs.) who had been certified for two and a half years. He had made a total of 100 dives, with 50 dives in the past year. He was in good health, a non-smoker with no current or previous medical problems. He made four dives on Saturday to maximum depths of 60-80 fsw / 18-24 msw. The following day he made an 80-fsw dive, followed by two 60-fsw dives. He made a safety stop on the first five dives, while the last two required mandatory decompression according to his dive computer. The diver was cold and slightly nauseated at times on the dive vessel, although his dives were largely uneventful. The exception was a slight sensation of numbness in his right leg between the third and fourth dives: he did not believe this was DCI.

After the end of his last dive, he again noticed numbness in his right leg, that spread to his entire leg over the next two hours. He went to a local hospital, where he was placed on 100 percent oxygen. He was transferred by helicopter to a local hyperbaric facility where he received a U.S. Navy TT6 for five consecutive days. His symptoms resolved after the fifth treatment.

The diver resumed diving three and a half months later at the same location over a two-day weekend. He made two dives with no problems, both to 60 fsw with safety stops. When he awoke the following morning about 12 hours after his last dive, he had a headache, weakness down the right side of his body, slurred speech and altered mental status. During an extended U.S. Navy TT6, he experienced complete resolution. He remained overnight for observation; he did not return to diving.

Case 4. Flying After Diving with Delayed Symptom Onset

The diver was a 53-year-old (5'10", 218 lbs.) male who was certified 30 years ago. He made 12 dives in the last year and 30 dives in the past five years. While a former smoker, he was in good health with no previous major illnesses. On his last day of vacation on a small Caribbean island, he aborted a 25-fsw / 7.5 msw dive after five minutes due to an equipment problem, making a normal ascent. He made a second dive not deeper than 38 feet / 11.5 meters for 35 minutes with no problems. A final dive to between 45-52 fsw / 13.6-15.7 msw lasted approximately 34 minutes.

Approximately 19 hours after his last dive, he returned to the United States in an unpressurized aircraft. He had no symptoms before, during or after this flight. The next morning, he made a second flight to the northern United States and upon landing, had immediate onset of pain in all of the joints of his arms and legs, followed by tingling and numbness in the fingers of both hands and substernal and rib cage pain. He went to a local emergency department, where he was evaluated by a dive-trained physician.

The physician noted a somewhat anxious patient who reported diffuse achey joints, with dull to sharp pains, hearing loss, and possibly an altered mental status. Upon recompression on a U.S. Navy Treatment Table 5 in the local hyperbaric chamber, the diver experienced relief of most symptoms, except for low-grade aches in his hands and legs. He was retreated the following day with 90 minutes of hyperbaric oxygen at 45 fsw / 13.7 msw. The remaining pains resolved, and the treating physician advised the diver he could return to diving in six weeks after re-examination.

Case 5. Flying After Diving with Symptoms During Flight

The diver was a 27-year-old male (5'11", 220 lbs.) in good health. He took regular medication, including antihistamines for mild allergic asthma. He had been a certified open-water diver for three years, with 40 lifetime dives and 20 dives in the past 12 months. During a one-week Caribbean vacation, he performed nine dives shallower than 76 fsw / 23 msw, with no more than two dives per day. All dives were conducted according to a dive computer with safety stops and without incident before the last dive. On this dive, his dive buddy experienced a regulator free-flow at 12 fsw / 3.6 msw, and they made a direct ascent to the surface. Immediately afterward, both divers reported no symptoms.

Approximately 28 hours after the last dive, the diver returned to the United States by commercial aircraft. During ascent to altitude, he felt a Grade 3 (on a scale of 0-10) tightness in his chest. During ascent on a second flight, he experienced itching on his chest and back that continued over the evening but lessened by noon the following day. This was succeeded by moderate mid-back pain that increased in intensity over the afternoon and was accompanied by mild numbness in his right arm. Feeling sluggish and lightheaded as well, he sought medical evaluation for a possible heart attack.

After assessment by a diving physician, he was transferred to a hyperbaric unit and recompressed on a U.S. Navy TT6. His back pain resolved within 15 minutes followed by the numbness in his right arm as well as the generally ill feeling and sluggishness. Only the chest tightness remained at the end of the treatment. He was released with instructions to return should his symptoms recur. At a follow-up evaluation one week after treatment, all symptoms had completely cleared.

Case 6. Symptoms after Diving and Commercial Air Travel

The diver was a 41-year-old male (5'9", 192 lbs.) in good health, whose medical history included allergies for which he took antihistamine medication. He had just finished open-water certification and was on a diving excursion to the Caribbean. In nine dives over four days, he never exceeded 70 fsw / 21 msw, performed safety stops, used a dive computer, and had no decompression violations. His last dive was to 42 fsw / 12.7 msw.

Within 30 minutes after surfacing from his last dive, he experienced mild numbness, or light paresthesia, in his left hand and forearm. He also noted transient numbness around his right index finger that lasted about five minutes. He mentioned this no one, and the numbness subsided after about one and a half hours. He continued his normal activity without recurrence.

About 26 hours after his last dive, he departed for home by commercial airline and noted a return of the left arm paresthesia, with extension to his upper arm and heaviness and aching in the joints. These symptoms remained unchanged during a second flight. The following day, he experienced lightheadedness and elbow pain as well. He went to his personal physician with these complaints and, after ECG and chest X-ray were found to be normal, was referred to a local hyperbaric physician.

Approximately 55 hours after his last dive, he was recompressed on a U.S. Navy TT6 with two extensions. His symptoms gradually resolved, and he was symptom-free at the end the six-hour treatment. He was advised not to dive for a month, pending evaluation by his personal physician.

Case 7. Retreatment of Decompression Illness

The diver was a 30-year-old male (5'9", 190 lbs.) who had been certified for seven years. He had made over 60 ocean dives each year with students and over 500 dives in the past five years. He was in good health, a non-smoker, had no recent illnesses, and no long-term health problems. Over three days while making open-water checkout dives with new divers, he made two uneventful dives per day to 60 fsw / 18 msw for two days. On the second dive of the third day, he made two rapids ascents to assist a student with problems. Within 10 minutes of getting into the boat, he experienced bilateral shoulder pain, left elbow discomfort, and a strange, although not painful, feeling in his left knee. After reaching the dock, a friend drove him to a hospital with a hyperbaric chamber. He showed signs of bilateral shoulder pain, left elbow pain and paresthesia around his left knee. The examination also found motor weakness in both arms and the left leg, with decreased sensation in the leg. All other tests were normal.

The diver was placed in a recompression chamber and treated on a U.S. Navy TT6. He improved gradually, had no problems by the third oxygen period, and was neurologically normal at the end of the treatment. He was discharged with instructions to call if any symptoms returned and advised not to dive for at least 30 days.

Two days after returning home, he noticed altered sensation in both hands and over the next few days, developed numbness and tingling in his left leg and tremors in both hands. These symptoms waxed and waned over the several days until 12 days after initial treatment, he reported to a local hyperbaric facility. He had complete resolution on a U.S. Navy TT6 and was advised to wait for six weeks without further symptoms before returning to diving.

Case 8. Spinal Cord Decompression Illness

The diver was a 55-year-old female (5′2", 135 lbs.) who was certified as a basic open-water diver seven years ago but had not dived for three years and had fewer than 20 lifetime dives. She had a history of pneumonia, lower back surgery, and had just recovered from a relapse of hepatitis C but was very active despite these conditions.

During a week's vacation, she made one uneventful 50-fsw / 15-msw dive for each of three days. On the fourth day, her dive depth was 110-120 fsw / 33-36 msw, and she followed the computer of another diver with a safety stop at 15 fsw / 4.5 msw. During the safety stop, she lost bladder control.

While relaxing on the boat, she had sudden onset of right shoulder pain radiating down her arm, leg, chest, and back with numbness in her legs that progressed to weakness such that she could stand only with assistance. Within minutes, she was unable to walk. Surface oxygen was unavailable. She was taken to a local hospital, where a physician untrained in diving medicine examined and released her after hydration and a multi-vitamin shot.

As she remained weak in her lower extremities and unable to stand or walk, her traveling companion arranged for medical evacuation by pressurized aircraft to the United States. The diver had no memory of these events.

On examination in a diving medical facility, she had paresthesias in her arms and legs, pain in both shoulders and back, could stand only with assistance, and was unable to walk. She had had no bowel or bladder function since the dive. She was treated on a U.S. Navy TT6 about 30 hours after symptom onset with little improvement but had resolution of her joint and muscle pain and a decrease in the paresthesias of her arms and legs after a second Table 6.

Another Table 6 and a Table 5 produced further improvement, and on the fifth day of treatment, she began twice-a-day hyperbaric oxygen therapy at two atmospheres for two hours. After her tenth treatment, her leg strength had returned to about 90 percent, but she still had transient paresthesias and was unable to urinate spontaneously. Due to the severity of her injury and residual symptoms, she was advised to never dive again.

At 12-month follow-up, she continued to have short-term memory loss, bowel and bladder incontinence, balance difficulties, chronic leg pain, paresthesia and general fatigue.

Case 9. Pain-Only DCS Before Flying After Diving

The diver was a 59-year-old overweight male (5′11", 300 lbs.), taking medication for high blood pressure and oral medication for diabetes. In the last 12 months, he had made approximately 12 dives, but had not been diving in the previous five years. While on a one-week cruise ship excursion, he rented dive equipment at one of the daily stops and made a 45-minute multilevel dive with a maximum depth of 82 fsw / 24.7 msw, during which he followed the divemaster. Toward the end of the dive, he became buoyant near the surface and had to work to maintain depth. After a two-hour-and-15-minute surface interval, he made a 40-minute multilevel dive to a maximum depth of 60 fsw / 18 msw. Despite four more pounds of weight, he could not maintain depth at his 20-fsw / 6 msw safety stop and surfaced prematurely.

The remainder of the day was uneventful, and the following day, the cruise ship returned to

Florida. There, he noticed a mild ache in his right shoulder and upper arm that increased in severity from Grade 1 to Grade 4 (on a scale of 0-10) during the course of the day. The following day, at about 48 hours after the last dive, the diver boarded the first of two airline flights during which he had pain in both shoulders. The pain was unchanged during the second flight. Believing he might have decompression sickness at about midnight that evening, he went to the local hospital, where the emergency room physician suspected a possible cardiac event and placed him on 100 percent oxygen. This provided some relief. Shortly thereafter, he was transferred to a recompression chamber and treated with a U.S. Navy Treatment Table 5, during which his symptoms were almost completely relieved. He was released the following day without a second treatment, and his remaining minor aches resolved over the next five days.

Case 10. Pain-Only DCS, Diving with Symptoms, and Prolonged Delay to Treatment

The diver was a 36-year-old male (5'10", 185 lbs.) who exercised regularly, was a non-smoker in good health, and took no medications. He had logged four dives in the six months since he had been certified. On the second day of a four-day dive vacation, he made dives to 80 and 60 fsw / 24 and 18 msw. During the night, he developed mild left shoulder and neck pain that did not change with movement; he ignored the symptoms. On his last day of diving, he made dives to 80 and 50 fsw (15 msw). He made a total of seven multilevel dives, and while he made safety stops, he followed his dive buddy rather than used his own dive tables or computer. He noticed that the pain in his neck and shoulder improved while he was underwater on his last dive day but became worse after his last dive.

Unaware that his symptoms might be decompression sickness, the diver took non-steroidal anti-inflammatory medication for three days before referral to a local dive physician and hyperbaric unit. He was treated on a U.S. Navy TT6, which improved his left shoulder and neck pain. He received two additional two-hour hyperbaric oxygen treatments for residual pain. He was asymptomatic when he was discharged.

3. Dive Fatalities

The collection, interpretation and reporting of dive fatality data is generally more difficult than for dive injuries or Project Dive Exploration. Medical examiners and other state authorities are not required to report dive fatalities to DAN. Most cases are captured through public sources of information such as newspaper articles, local contacts or family members. Information usually gathered in personal interviews is often incomplete, inaccurate or simply not available. Death certificate information often cites drowning as the cause of death even when a precipitating event, such as a heart attack or arterial gas embolism, is the primary cause of the fatality.

Of the 91 dive fatalities in 2000, 13 involved women and 78 involved men. Autopsy reports were available for review in 51 cases and unavailable in 18 cases. Five cases did not include a post-mortem examination. It was not clear if an autopsy had been conducted in seven cases. Bodies were not recovered in 10 cases. One case was sealed due to pending legal action. All cases were from the United States or Canada or involved U.S. citizens diving abroad. It is extremely difficult to collect the required information from other countries. With the expansion and development of international DAN organizations, this may change in the future.

3.1 Characteristics of Divers Who Died

The largest proportion (30.8 percent) of diving fatalities was in the 50- to 59-year-old age group. The combined fatalities from individuals aged 40-59 accounts for over 50 percent of the reported deaths. One percent of the deaths occurred in divers under the age of 19. The average age of divers involved in fatal incidents was 44 for males and 48 for females. The age distributions for males and females are shown in Figure 42.

Fig 42
Age and gender distribution of diving fatalities (n=88).

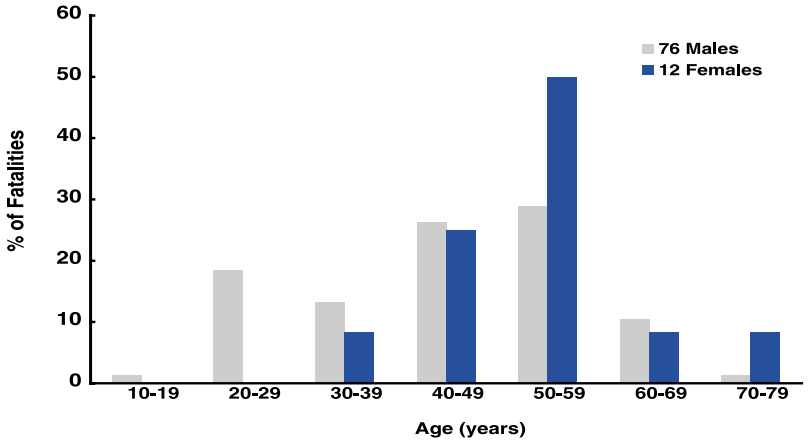


Figure 43 shows the chronic health conditions reported by divers who died. These categories are not mutually exclusive, so each case may have been included in more than one category. ("HBP / HD" refers to high blood pressure or heart disease.) A reported history of smoking and high blood pressure or heart disease were most common among divers who died. Few other chronic conditions were reported in comparison to injured divers or PDE divers.

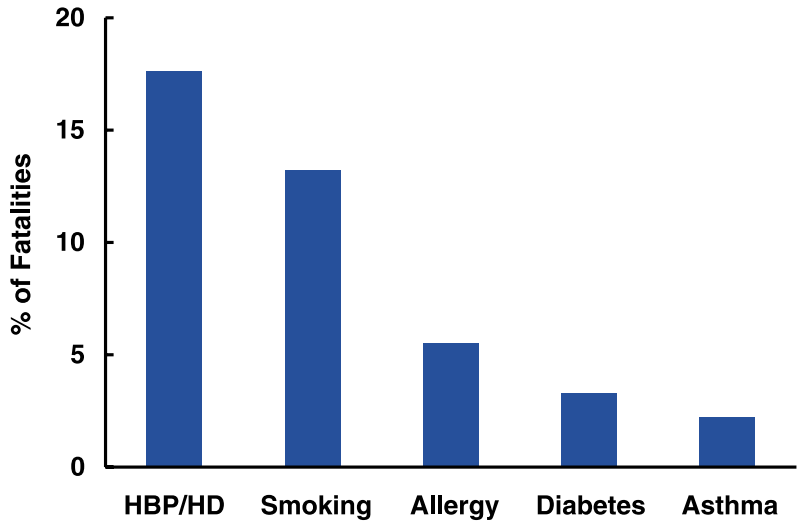


Fig 43
Chronic health conditions of divers who died (n=91).

Figure 44 shows the acute health conditions reported for divers who died. ("Orthopedic" refers to sprain, muscle pain, or fracture; "URI" refers to upper respiratory infection; "GI" refers to gastrointestinal.) Few acute medical conditions were reported. URI and hangover were most common at about 5 percent.

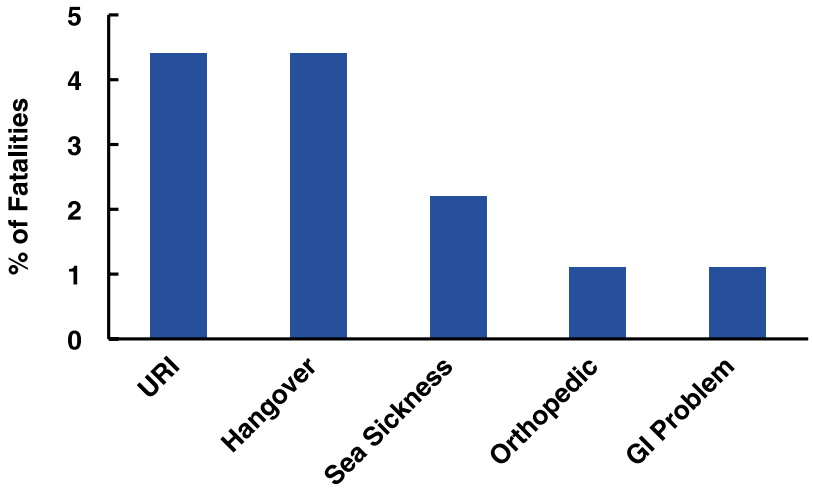
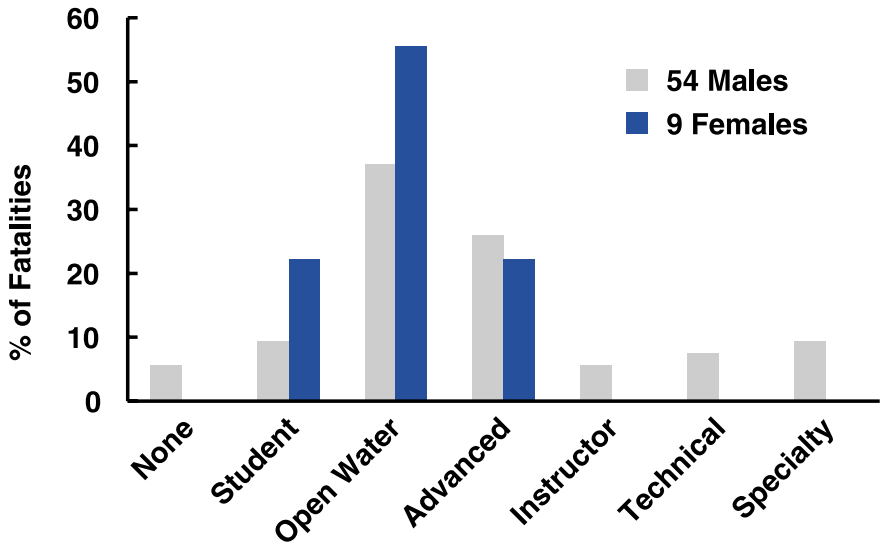


Fig 44
Acute health conditions of divers who died (n=91).

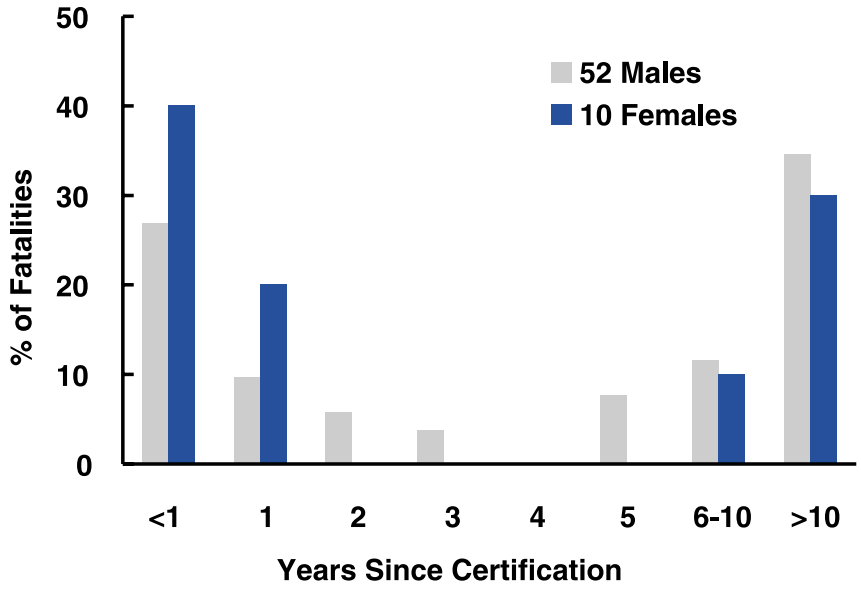
Overall, 31 percent of all reported fatalities had at least one advanced certification in addition to initial dive training. This represents 44 percent of those for whom training information was available. Figure 45 shows that 37 percent of men and nearly 55 percent of women who died in diving accidents had only basic certification or less. "Student" referred to initial diver training. "Specialty" includes categories such as rescue, scientific, military or commercial.

Fig 45
Certification level of diving fatalities (n=63).



The years since initial certification are shown in Figure 46. About 35 percent of both men and women had been certified for more than 10 years. The proportion of fatalities was higher for divers who had either very few or very many years since initial training.

Fig 46
Years since initial certification of diving fatalities by gender (n=62).



The largest proportion of fatalities had made the fewest dives in the preceding 12 months (Figure 47), although this was based on only 19 percent of the reported fatalities. This was similar to previous years and, with Figure 46, may suggest the value of experience after initial certification, regular diving, and refresher training after prolonged absence from the sport.

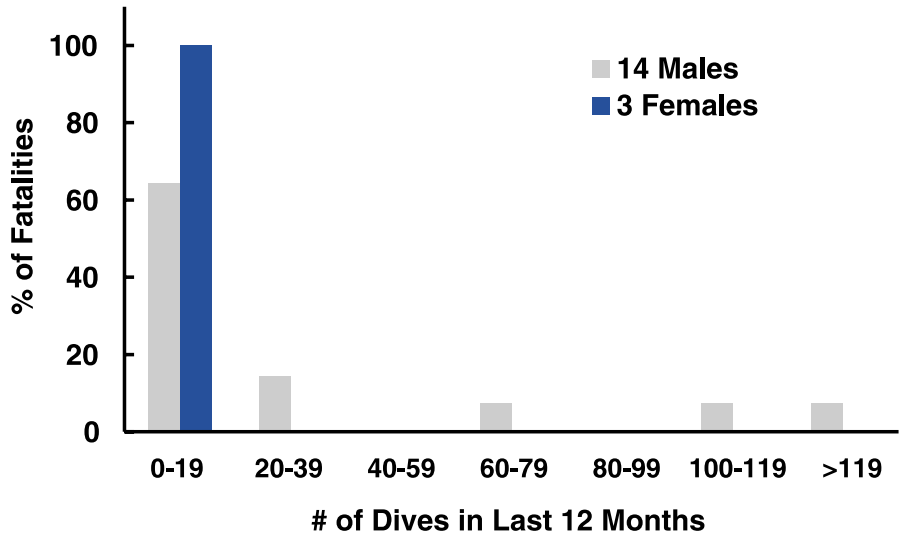


Fig 47
Number of dives in the past 12 months for diving fatalities (n=17).

3.2 Characteristics of Dives by Divers Who Died

The following figures characterize the attributes of a given dive that may relate to the expectation of difficulty or risk. These characteristics are dive purpose, environment, number of dives in series, depth of dive, need for decompression, and problems encountered during the dive. Figure 48 shows the distribution of months in which a dive-related fatality occurred.

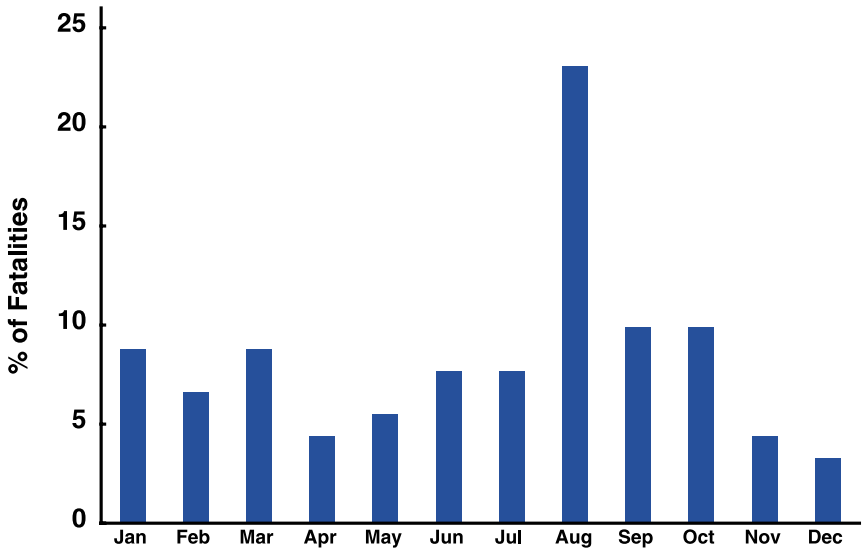
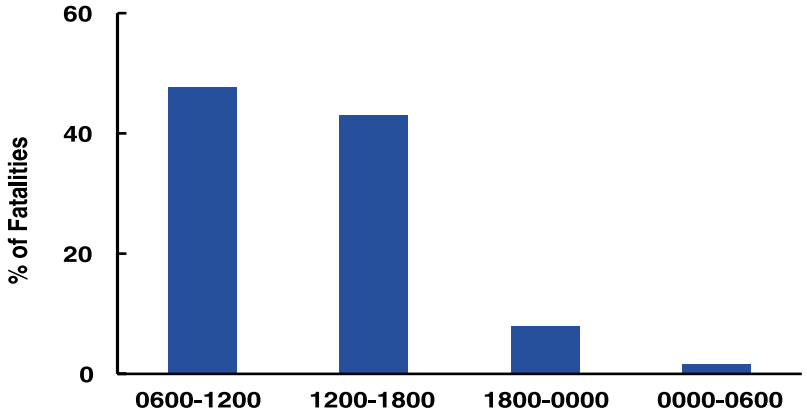


Fig 48
Months in which fatalities occurred (n=91).

Figure 49 shows the time of day in which dive-related fatalities were reported to occur. Over 90 percent of Fatalities occurred during the day.

Fig 49
Time of day in which fatality occurred (n=63).



Figures 50 and 51 show the distribution of fatal dives by U.S. and international regions. Nearly 50 percent of U.S. dive-related fatalities were reported in the southern United States. The Caribbean accounted for over 40 percent of international dive-related fatalities, and another 25 percent were reported from the Yucatan. The designation "Yucatan" in Figure 51 includes Cozumel, Cancun, Baja, the Galapagos, Belize and several small islands.

Fig 50
U.S. sites of diving related fatalities (n=64).

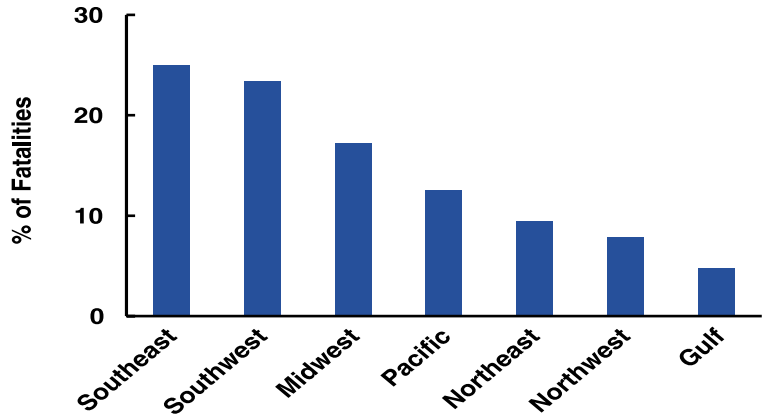


Fig 51
International sites of diving related fatalities (n=27).

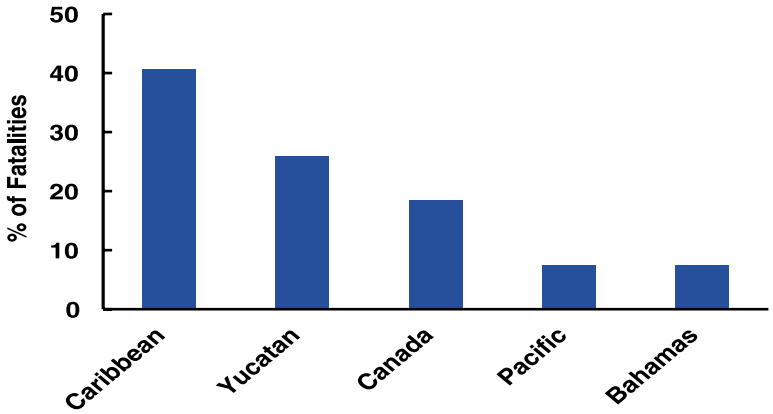


Figure 52 shows the distribution of environment for dives that resulted in fatalities. Seventy-seven percent of fatalities occurred in the ocean, 17 percent in a lake or quarry, and 2 percent in caves or caverns. The "Ocean" category is omitted from Figure 52 for clarity.

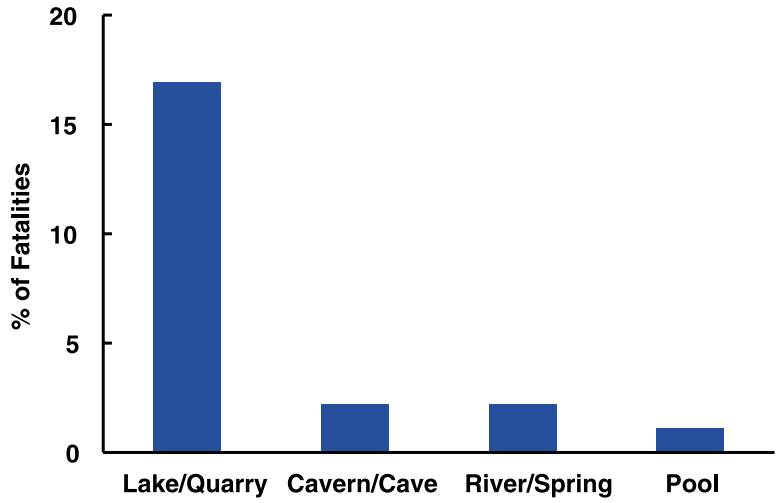


Fig 52
Environment in which fatalities occurred (n=89).

Figure 53 shows the distribution of purpose for dives that resulted in fatalities. Seventy-five percent of dives that resulted in death were reported as recreational dives, 13 percent were characterized as technical dives, and 8.2 percent were reported as student dives. The category "Other" (8 percent) included military, commercial, law enforcement and scientific diving.

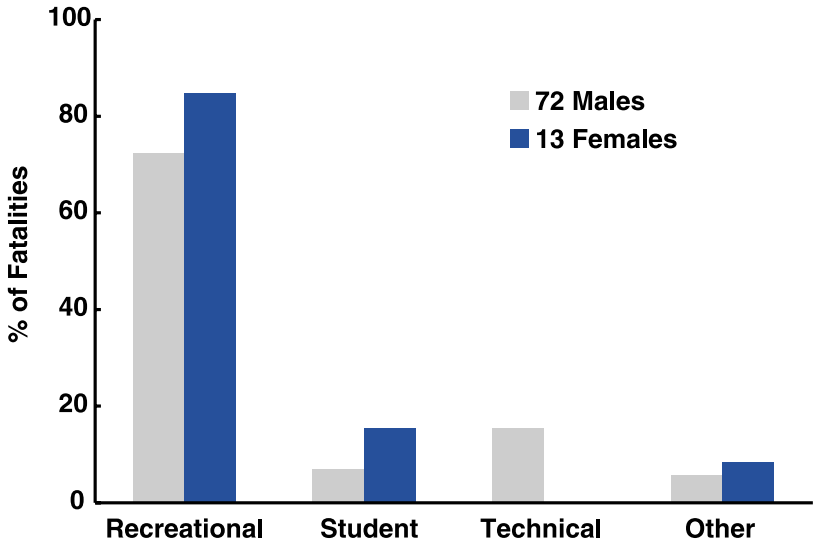


Fig 53
Purpose for dive in which a fatality occurred (n=85).

Figure 54 shows the platform from which diving fatalities began their dives. Of the 83 fatalities for which data were available, 60 percent began their dives from a day boat, 36 percent from the shore, and one diver died while in a pool.

Fig 54
Platform from which diving fatalities began their dives (n=83).

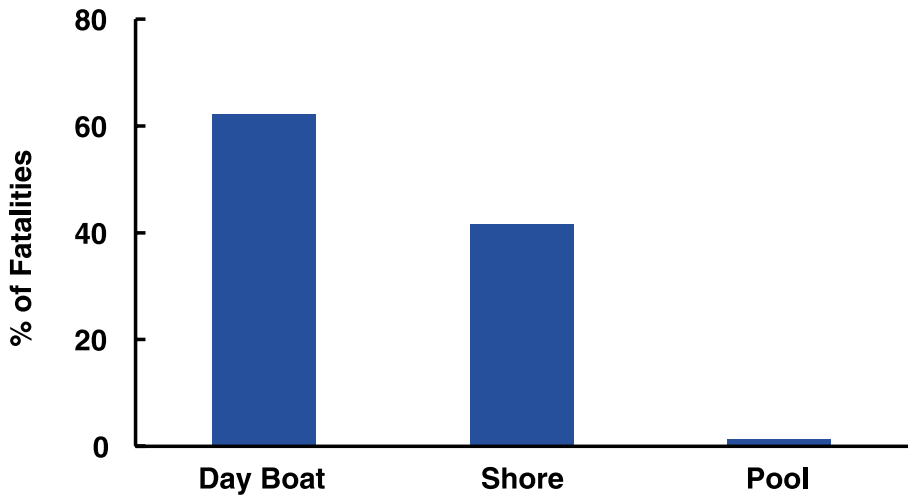
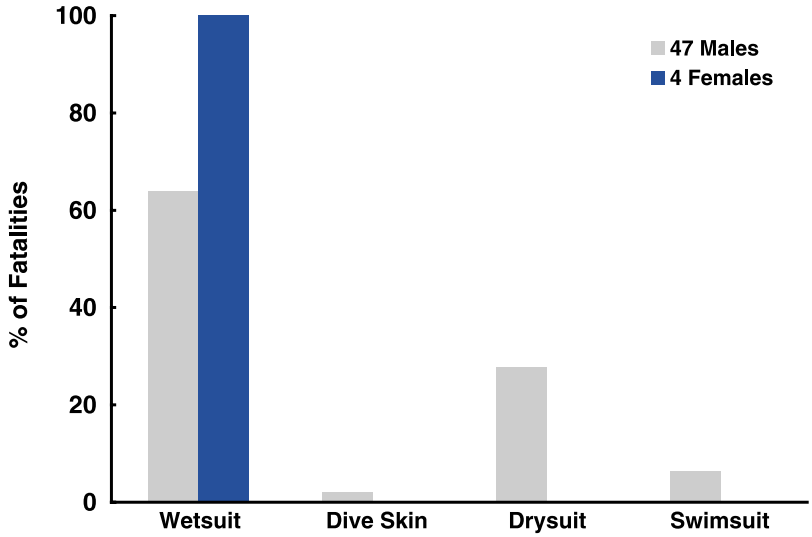


Figure 55 shows the thermal protection worn by divers who died. Sixty percent of the men and the four women for whom data were available wore wetsuits. One quarter of the men wore drysuits, and the remainder wore swimsuits or dive skins.

Fig 55
Thermal protection worn by divers who died (n=57).



Of the 85 divers for whom data were available, one used semi-closed scuba while the 83 used open-circuit scuba. There were three fatalities on nitrox, one on trimix, and two on rebreathers. (One of the rebreathers was homemade.) Information on breathing gas was unavailable in five cases.

While information about the number of days of diving by divers who died was unavailable, most appeared to have died on the first day, and all but eight fatalities died on their first dive. Five made two dives, and three made three dives.

Figure 56 shows the maximum depth reported for dives resulting in death. The average maximum depth for all divers in this category was 78 fsw / 24 msw, and 16 percent of the divers who died went no deeper than 30 fsw / 9 msw.

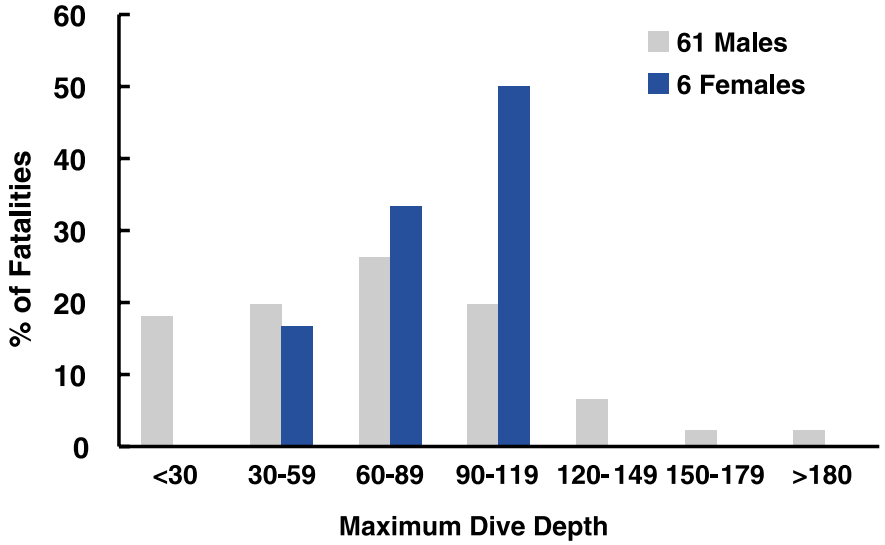


Fig 56
Maximum depth among diving fatalities (n=67).

Figure 57 shows the limited information that was available about problems with diving equipment. The buoyancy compensation device (BCD) was the most common equipment item mentioned in more than 8 percent of fatalities, with breathing apparatus next at 6 percent. It should be noted that a reported equipment problem does not prove that the cited equipment was the proximate, or immediate cause of the fatality or even a secondary cause.

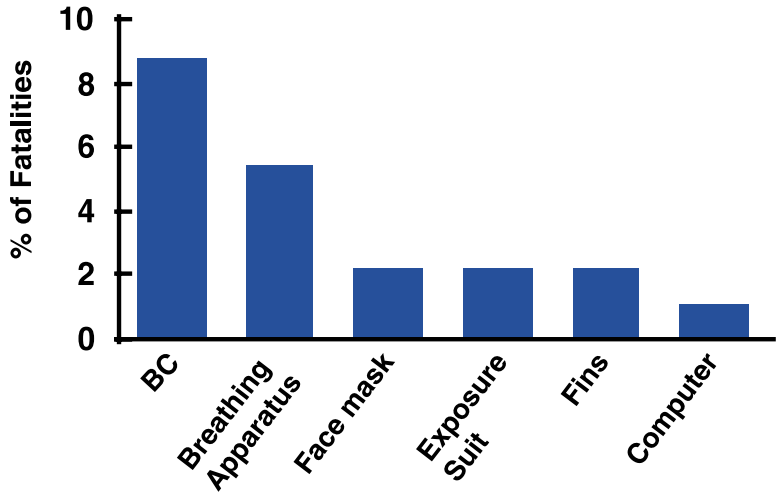
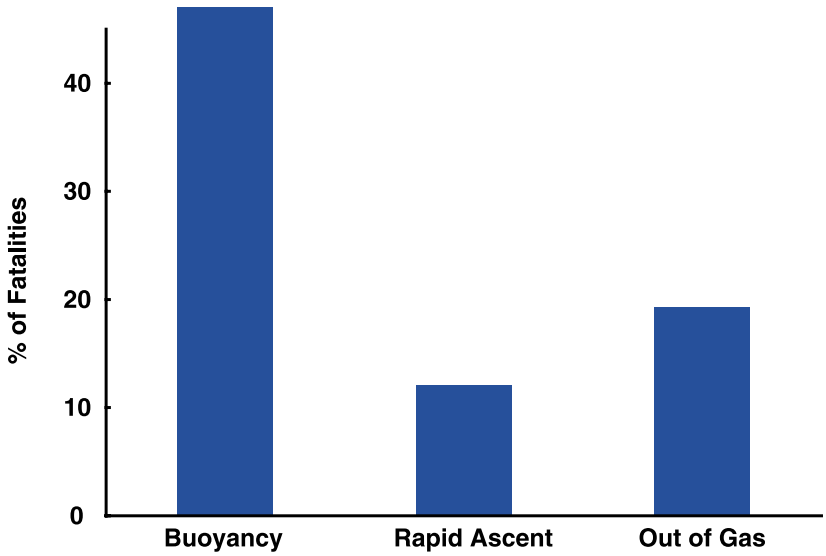


Fig 57
Equipment problems encountered in dives resulting in a fatality (n=91).

Figure 58 shows the distribution of problems that were reported during the dive that may have contributed to the fatality. Buoyancy, rapid ascent, and running out of gas were the most frequently cited problems for divers who died.

Fig 58 Problems encountered on dives resulting in a fatality (n=83).



3.3 Case Reports

Drowning is the most often cited cause of death in dive fatalities, but particular events can be identified in most cases as the cause of drowning. These events are often of greater interest than the cause of death itself, as they may suggest how diving related mortality might be reduced. Figure 59 shows the distribution of cause of death among diving fatalities. Arterial gas embolism and cardiac events were grouped separately if it was determined that death occurred solely or primarily due to these events. Other categories show deaths due to drowning, grouped with the event that most likely led to drowning. The "Drowning / Various" category includes those cases where equipment malfunction, improper configuration or other gear-related problem potentially contributed to the fatality.

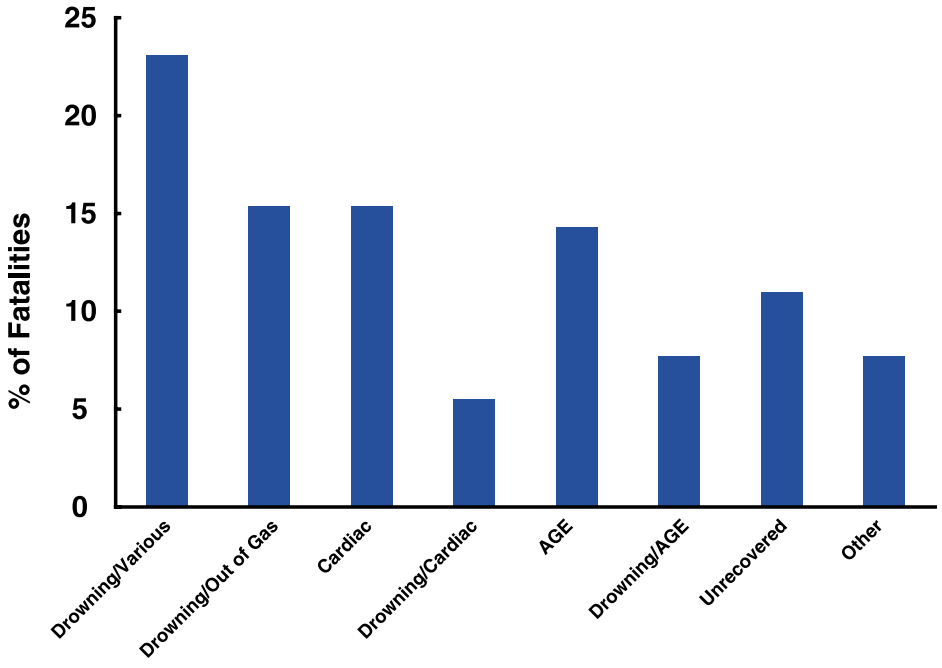


Fig 59
Major causes of death among diving fatalities (n=91).

3.3.1 Proximate Cause: Air Embolism

00-01 Inexperienced diver attempting to share air

This 53-year-old female had made fewer than 10 lifetime dives and had been open-water certified for one year. She was making a drift dive in 65 fsw / 20 msw, and within 10 minutes of descending, she signaled to her buddy that she was out of air. The buddy and the decedent shared an air source to the surface; on topside, the decedent vomited and lost consciousness. The decedent could not be resuscitated. She was a former smoker and was not taking any medications. An equipment evaluation revealed greater than 2,000 psi remaining in the tank. The medical examiner listed drowning as the cause of death, but this case is more appropriately classified as a death due to air embolism.

00-13 Uncertified diver who ran out of air

This 33-year-old male diver had no formal certification. He was making his fifth dive of the day and went to a maximum depth of 110 fsw / 33 msw to collect game. The decedent was diving alone and ran out of air at depth. He was incapacitated upon surfacing and was transferred to a hospital with a recompression facility. There, he received hyperbaric oxygen but subsequently died of multiple organ system failure.

00-16 Experienced diver separated from group

This 77-year-old female certified diver was very experienced. She made a dive from a boat to 73 fsw / 22 msw for 35 minutes. Her buddy and the other divers descended first, and the decedent apparently never joined the group. Her body was found the next day. The decedent's computer showed that she had made a rapid ascent. The investigative report made a point of noting that the computer also showed "a lot of residual nitrogen." It should be noted that the computer will continue adding bottom time, even when the diver has died, as long as it is at depth.

00-18 Out of air, breathing off wrong regulator

This 53-year-old male had been certified for two years and had advanced open-water qualifications. He was making a dive to 50 fsw / 15 msw but first began to descend without his regulator in his mouth. After returning to the surface, the decedent again descended. This time he made the ascent with the regulator from his pony bottle in his mouth. Other divers attempted to get his attention in the water, but they were unsuccessful in urging him to switch regulators. After 10 minutes, the decedent was low on air and panicked. He made a rapid ascent and became unconscious shortly after reaching the surface. Resuscitation procedures were unsuccessful. An equipment evaluation revealed that the diver had entered the water with his computer turned off. The scuba tank that was connected to his primary regulator was full. The autopsy disclosed evidence of cardiac disease, but the dive profile and response of the diver were classic for air embolism.

00-29 Alcohol, substance abuse prior to diving

This 33-year-old male, an experienced, certified diver, entered the water alone to gather lobsters. He used a tank that had been filled a year earlier and assembled his dive gear incorrectly. The dive was to 35 fsw / 11 msw for five minutes. The decedent seemed to carry the equipment to depth rather than wear the BCD jacket. He panicked during ascent and lost consciousness upon reaching the surface. Resuscitation efforts were unsuccessful. The autopsy revealed pulmonary barotrauma and evidence of ischemic heart disease. Toxicology was positive for cocaine and its metabolites. The decedent also had a blood alcohol level that indicated he had consumed alcohol within the previous 12 hours. An inspection of the equipment revealed the tank was mounted upside down on the BCD and the primary regulator was attached to go over the left shoulder.

00-31 Loss of buoyancy control in poorly conditioned diver

This 52-year-old male received his open-water certification four months earlier and had approximately 20 lifetime dives. He was morbidly obese and had a history of respiratory problems, including asthma. The decedent made a shore entry dive to 60 fsw / 18 msw for 20 minutes using a drysuit. He was witnessed making a rapid ascent and quickly became incapacitated on the surface. The diver was pronounced dead at a nearby hospital. One member of the dive group reported that the decedent had used inhalers just prior to entering the water.

00-48 Type III DCS in an experienced diver

There is minimal information on this dive fatality, but it appears to be one of those fortunately rare cases of combined decompression sickness and air embolism, sometime referred to as Type III decompression sickness. A 36-year-old male had advanced open-water certification and significant diving experience. He reported some nausea prior to beginning the dive. After making a seemingly uneventful

dive to 71 fsw / 21 msw for 42 minutes, he made a controlled ascent to the surface. The diver almost immediately lost consciousness on the surface and was brought to the boat. He was taken to a recompression chamber and initially responded favorably to hyperbaric oxygen treatment. During the middle portion of the treatment the decedent had a seizure, likely secondary to central nervous system oxygen toxicity. During the ascent portion of the treatment, the diver went into cardiopulmonary arrest and could not be resuscitated. There is minimal autopsy information available, and a paradoxical air embolism cannot be excluded.

00-54 Out of air, rapid ascent while sharing, then left alone

This 52-year-old male received initial open-water certification two years earlier and had made 27 lifetime dives. He made a wreck dive, possibly with a planned decompression stop, to 130 fsw / 39 msw. There were loose buddy teams but mostly one large group of divers on this dive. Approximately 17 minutes into the dive the decedent ran out of air and shared air with another diver. They made a rapid ascent (92 fsw / 28 msw to the surface in less than one minute), where the decedent dropped his weight belt but had insufficient air to inflate his BCD. While the other divers returned to depth for decompression, the decedent spent a long time on the surface. The boat lost sight of him, and by the time the diver was pulled from the water, he had lost consciousness and was hypothermic. The decedent was taken to a recompression chamber, where he died during treatment. The autopsy showed mild coronary atherosclerosis, but the cause of death was air embolism.

00-55 Solo wreck diver unconscious at surface after aborting dive

This 56-year-old male was a very experienced technical diver who had made numerous deep, mixed-gas dives. He made a solo dive to 122 fsw / 37 msw using a homemade configuration of seven different tanks and regulators. The gear weighed in excess of 200 pounds / 90 kilograms. The decedent unexpectedly surfaced 15 minutes into the dive and rapidly lost consciousness. Resuscitation efforts were unsuccessful. The autopsy report was not made available, but a natural cause of death was excluded. The decedent's equipment was found adjacent to and within the wreck. It is not known whether the diver experienced an equipment malfunction or if he simply became entrapped in the wreck and removed the gear to escape.

00-60 Drysuit buoyancy problem, followed by rapid ascent with buddy

This 45-year-old male was a certified technical diver with extensive experience. He made a wreck dive to 120 fsw / 36 msw using nitrox with planned decompression stops. The decedent had problems with his drysuit on the bottom and also seemed to have an altered level of consciousness at that time. He refused assistance by his dive buddy, and when the dive buddy decided that the decedent was incapacitated, he decided to bring the injured diver to the surface. The decedent ascended at over 120 feet / 36 meters per minute, based on his dive computer. The autopsy disclosed convincing evidence of an air embolism, but the initial problem that occurred on the bottom and resulted in the rapid ascent was never determined.

00-71 Inexperienced diver with rapid ascent from a drift dive

This 53-year-old male had been open-water-certified for only one month and had made four lifetime dives. He made a drift dive to 60 fsw / 18 msw for 30 minutes and required frequent assistance by the divemaster. The decedent became separated from the divemaster and his buddy; he was last seen making a

rapid ascent to the surface. His body was found an hour later. The decedent had a history of depression and elevated serum cholesterol. The death was attributed to an air embolism.

00-75 Dive instructor becomes entangled on bottom

This 49-year-old certified dive instructor made an ocean dive to 135 fsw / 41 msw, without a buddy, to recover a lift bag. He became entangled on the bottom and his regulator and buoyancy compensator surfaced while he remained below. He was brought to the surface and transferred to a local recompression chamber where he was pronounced dead. The autopsy showed massive amounts of intracardiac and intravascular gas as well as mediastinal and subcutaneous emphysema.

00-80 Diver becomes entangled, panics, during rescue exercise

This 28-year-old male was involved in a search and rescue training exercise. He was a certified diver with advanced open-water qualifications. A group of four divers made a shore entry dive into a quarry using a search pattern and lines. All four divers became separated, and two became entangled in the lines. One of the divers was found on the bottom entangled in line; he panicked when another diver attempted to assist him. He was pulled rapidly to the surface using one of the lines he had become entangled in. The autopsy disclosed subcutaneous emphysema, evidence of pulmonary barotrauma and large amounts of intravascular gas.

3.3.2 Proximate Cause: Drowning / Air Embolism

00-14 Inexperienced diver and rapid ascent

This 27-year-old male was certified two months previously and had made five lifetime dives. He was a student in an advanced open-water class and made a shore entry dive to 118 fsw / 36 msw with a group of other students. He and his dive buddy became separated from the group and likely made ascents and descents in an attempt to find the instructor. (During the previous day's dive the decedent was admonished by his instructor for making a rapid ascent.) The decedent was found unconscious on the bottom; his buddy surfaced with classic symptoms for an air embolism. The dive buddy was treated in a recompression chamber and made a full recovery.

00-20 Divemaster with insufficient air, rapid ascent

This 57-year-old male was a very experienced divemaster. He had a recent history of headaches, night coughs and pedal edema. He made his second dive of the day to 50 fsw / 15 msw but ran out of air five minutes into the dive. The decedent and his dive buddy became separated, and he was seen unconscious on the surface shortly thereafter. Organ harvesting limited the findings at autopsy, but the medical examiner determined the cause of death to be drowning due to running out of air.

00-36 First dive after prolonged inactivity, in overhead environment with unfamiliar equipment

This 33-year-old male had advanced open-water certification and was a very experienced diver. He had not made any recent dives, however, and had little drysuit diving experience. He made a wreck penetration dive with a group of divers to 103 fsw / 31 msw for 47 minutes before running out of air. The diver also had buoyancy problems due to his unfamiliarity with his drysuit. As the divers exited the wreck, the decedent became separated from his buddy and was not successful in switching to an alternate air source. He was quickly brought to the surface, where he lost consciousness and resuscitation efforts failed.

The autopsy showed changes consistent with drowning; toxicology was positive for diphenhydramine.

00-48 First dive after prolonged inactivity with poorly defined supervision

This 26-year-old male had been initially certified five years previously but had made only 15 lifetime dives; none of those dives were made in the past year. He entered the water with a large group but without a designated dive buddy. After a 40-minute dive to 50 fsw / 15 msw, he ascended to a safety stop at 15 fsw / 4.5 msw. From there, witnesses saw him make a rapid ascent to the surface. Shortly after reaching the surface, the decedent was seen with his mask off and regulator out of his mouth. The diver was unconscious, and resuscitation efforts were unsuccessful. The autopsy disclosed evidence of pulmonary barotrauma as well as changes consistent with drowning.

00-62 Rapid ascent during advanced open-water course

This 45-year-old male was a student in an advanced open-water course. Witnesses say he made a rapid ascent from 90 feet / 27 meters in a freshwater lake. On the surface, the decedent did not have the regulator in his mouth, and attempts to replace it were unsuccessful. He lost consciousness, and resuscitation efforts failed. The medical examiner ruled the case a simple drowning. While there was no corroborating evidence of air embolism noted at autopsy, the events of the dive are fairly convincing. Toxicology was positive for hydrocodone.

00-91 Rapid ascent, possible head injury in diver with history of seizures

This 32-year-old male lost consciousness immediately after surfacing from a dive and screaming in pain. His body drifted off and was recovered two hours later. The decedent had a history of epilepsy, though toxicology was negative for any anti-seizure medication. The medical examiner signed the case out as a simple drowning, but the details of the accident are classic for an air embolism that likely resulted in drowning.

3.3.3 Proximate Cause: Cardiac

00-79 Deep dive for poorly conditioned PDE diver with medical problems

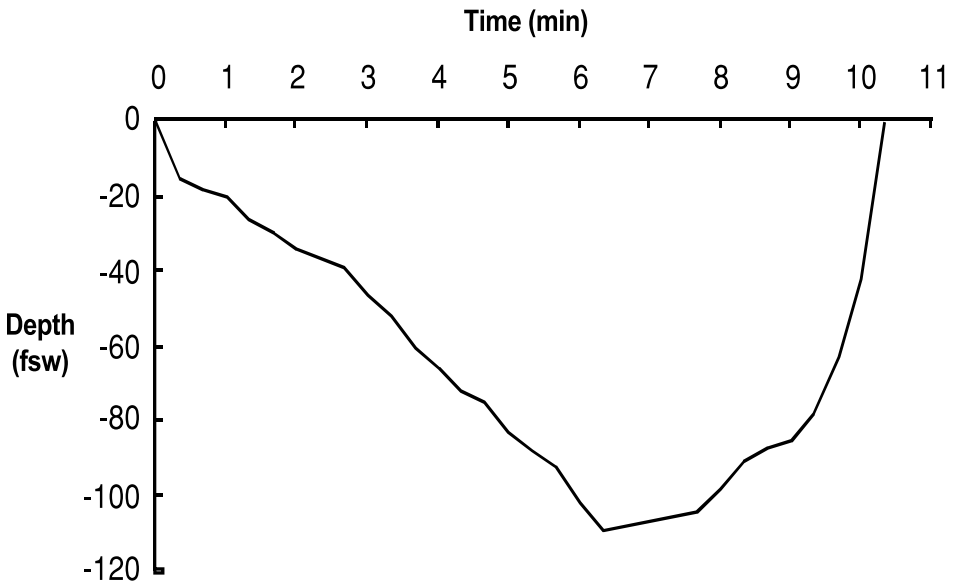
This 42-year-old male had numerous medical problems, including morbid obesity, hypertension, gout and possible elevated blood sugars. He was a student in an advanced open-water course. His depth-time profile was available (Figure 60 on page 64) as he was a participant in Project Dive Exploration. Upon reaching the bottom at 105 fsw / 32 msw, the divers stood in a circle comparing gauges and signaling "OK" to each other. One student noted the decedent seemed to have trouble breathing and motioned the instructor to come over. The instructor checked the decedent's pressure gauge, found air in his tank, and no apparent reason for difficulty. As the decedent's eyes appeared large, the instructor motioned the divemaster to take him to the surface. The decedent became unconscious as they swam to the anchor line at a depth of about 80 fsw / 24 msw. The divemaster inflated the decedent's buoyancy compensator at the anchor line, ascended rapidly, and began CPR on the boat; his efforts were ineffective. It is possible that the decedent suffered an air embolism during the rapid ascent, but the problem on the bottom may have been cardiac-related. The autopsy did not disclose significant coronary artery disease.

See dive chart on following page.

00-03 Solo diver after prolonged inactivity with significant heart disease

This 63-year-old male was an experienced, but infrequent, certified diver. A smoker, he took medications for both hypertension and depression. The decedent was making his first

Fig 6o
Depth time profile for PDE diving fatality in 2000 (Case 00-79).
See account on previous page



dive in over three years, without a buddy, to spearfish. Witnesses at the scene reported that the diver descended to 10 fsw / 3 msw, experienced some buoyancy problems, temporarily became entangled in line, and then set his spear gun down before losing consciousness. Resuscitation attempts were unsuccessful. The autopsy disclosed significant cardiac disease consistent with long-standing hypertension. Toxicology was positive for antidepressant medications.

00-09 Cardiac arrest while diving far from medical assistance

There is very little information about the death of this 64-year-old male who was diving 110 miles / 176 kilometers offshore. He reportedly had a history of heart disease, and his death was attributed to a heart attack.

00-10 Poorly conditioned, undertrained solo diver with significant heart disease

This 52-year-old male diver was certified, but his experience level was not well documented. He was morbidly obese and had a past medical history of hypertension. The diver went to 106 fsw / 32 msw to make a wreck dive, and he had no designated dive buddy. His deep diving experience was limited. He was anxious prior to the dive and became separated from the other divers after descent. When the decedent was unaccounted for at the end of the dive, a search found him on the bottom and unconscious. The medical examiner concluded the cause of death to be an air embolism, but there was no evidence that the diver ever ascended. This was most likely a cardiac-related death.

00-28 Cardiac arrest in uncertified diver with significant heart disease and alcohol use prior to familiarization dive

This 58-year-old female was enrolled in a scuba familiarization class and was not a certified diver. She entered the water, but prior to descending, she was observed having difficulty breathing and was assisted back into the boat. The decedent collapsed and could not be resuscitated. The diver had denied any medical problems on the pre-dive screening form, even though she had previously undergone coronary angioplasty and also had a history of hypertension. Additionally, her postmortem blood alcohol level was over twice the legal limit for driving (183 mg/dl).

00-42 Under-trained, inexperienced diver with severe coronary disease

This 62-year-old male received initial certification two years earlier and possessed advanced open-water and rescue diver certification, despite having made only 17 lifetime dives. He made a wreck dive to 70 fsw / 21 msw for 15 minutes and signaled that he needed to ascend because he was low on air (he had used over 2,500 psi in 15 minutes). He was assisted to the surface and lost consciousness while hanging on a surface line. Resuscitation efforts were unsuccessful. The autopsy disclosed evidence of severe coronary artery disease and also adenocarcinoma of the colon with metastases to the liver. The death was attributed to cardiac disease.

00-45 Cardiac arrest after moderate, uneventful dives

This 55-year-old male, experienced, certified diver made two uneventful dives to 75 fsw / 23 msw. He surfaced from the second dive and appeared to struggle in the water for a short time before losing consciousness. Resuscitation efforts were unsuccessful. The decedent had a history of atrial fibrillation and was on a systemic anticoagulant. While an air embolism was a possibility in this case, witnesses report a controlled ascent and the experience level of the diver makes a cardiac event more likely. The medical examiner felt that the manner of death was natural and due to a cardiac dysrhythmia.

00-51 Heart disease in a poorly conditioned diver

This 48-year-old male was a student in an initial open-water certification class. The diver was obese and in a poor state of physical conditioning. He made a dive to 40 fsw / 12 msw for 10 minutes before developing a problem on the bottom. He signaled to another diver that he was not feeling well and needed to surface. Upon reaching the surface, the decedent was motionless and was assisted into the boat. Resuscitation efforts resulted in some improvement, but the diver died a few hours later at a local hospital. The autopsy disclosed significant cardiovascular disease, including evidence of previous small myocardial infarctions. While an air embolism is difficult to completely exclude in this case, the history and autopsy findings are most consistent with death due to cardiovascular disease.

00-57 Re-trained diver after prolonged absence without updated medical evaluation

This 45-year-old male had considerable past diving experience but had a layoff of several years from diving. He had recently completed a refresher course and then enrolled in an advanced open-water certification program. The instructor stated that the diver looked fatigued prior to the dive but had denied any medical problems. The decedent denied any past medical problems on the pre-dive questionnaire as well. The group of students descended to 70 fsw / 21 msw of a planned 100-fsw / 30-msw dive. The decedent immediately had some difficulty and lost consciousness at depth. He was brought to the surface but could not be resuscitated. The autopsy disclosed significant coronary artery disease as well as an old cerebral contusion. The decedent had a past medical history that included hypertension and alcohol dependence.

00-65 62-year-old new diver with severe cardiovascular disease

This 62-year-old male was a student in an initial open-water certification class making his first open-water dive. He attempted to descend but immediately surfaced after only making it to 5 fsw / 1.5 msw. The diver was assisted by his instructor and lost consciousness on the surface. Resuscitation efforts were unsuccessful. The decedent's medical problems included myasthenia gravis and depression. The autopsy disclosed severe cardiovas-

cular disease as well as chronic obstructive pulmonary disease. The cause of death was determined to be a cardiac event.

00-77 Cardiac event after long diving day

The certification level and experience level of this 54-year-old-male is unknown. He made his fourth dive of the day and struggled on the surface after completing the dive. The decedent lost consciousness and was assisted into the boat before being transferred to a recompression chamber. He could not be stabilized at the chamber and was pronounced dead at a local hospital. The autopsy disclosed significant coronary atherosclerosis and chronic obstructive pulmonary disease. The cause of death was determined to be a cardiac event.

00-78 Separated from buddy during night dive

This 51-year-old male was an experienced diver with open-water certification. He made a shore entry dive at night to collect lobsters. The decedent swam out on the surface with his buddy but signaled that he wanted to return to shore for an unknown problem. The two divers became separated, and the decedent was found unconscious on the surface with his buoyancy compensation device inflated. Resuscitation efforts were unsuccessful. The medical examiner determined this death to have been due to a cardiac event.

00-88 Cardiac arrest in 56-year-old male with diabetes

A 56-year-old male, experienced, certified diver made an uneventful dive to 80 fsw / 24 msw. He stated he did not feel well after the dive and then collapsed. The autopsy revealed evidence of heart disease and no other significant natural disease processes.

00-89 Experienced diver with history of abnormal heart rhythms

This 66-year-old male, experienced, certified diver had a history of atrial fibrillation for which he had taken medication in the past. He made a dive with two other divers into a lake but became separated from both buddies. After reaching the surface when the dive was completed, the decedent called for assistance, but the only two people in the boat were physically unable to remove the diver from the water. When the diver was finally brought into the boat, cardiopulmonary resuscitation attempts were unsuccessful. An autopsy was not performed.

00-90 Cardiac event while attempting a dive in unfavorable conditions

This 50-year-old female was a longtime certified diver. She and her husband made a shore entry in a rough sea state and strong current. The two divers never descended, and the husband was having significant difficulty maintaining control on the surface. The decedent came to her husband's aid but ran into difficulty herself. The two divers were pulled from the water, but the wife had already lost consciousness. She was transported to a local hospital, where she died 12 hours later. The medical examiner concluded the cause of death to be a cardiac event. In light of the fact that the two divers had inflated their buoyancy compensation devices and never went below the surface, this is likely correct.

3.3.4 Proximate Cause: Drowning / Cardiac

00-04 Inexperienced rescue diver with severe coronary disease

This 37-year-old male had been certified for one year and had made 18 lifetime dives. He was drilling with his firefighter diving team and was performing training maneuvers in a drysuit. Near the completion of the third dive of the day, all of the divers ascended together from the bottom except the decedent. He was found unconscious on the bottom with his

regulator out of his mouth. The diver was pronounced dead at a local hospital. The autopsy disclosed severe coronary atherosclerosis; the most likely cause of death in this case was drowning due to a cardiac event.

00-07 Medically unfit trainee has cardiac arrest on second dive

This 64-year-old male was in an initial open-water certification course and had made two lifetime dives. He had numerous medical problems, including hypertension, gout and elevated cholesterol. The diver was also obese and had a poor level of physical conditioning. The decedent made a 35-fsw / 10.5-msw dive for 10 minutes and became short of breath after surfacing. He was brought to the boat for cardiopulmonary resuscitation and transferred to a local hospital where he was pronounced dead. The other possible cause of death in this case is air embolism, but the medical examiner's determination that a cardiac event occurred is most likely the correct conclusion.

00-37 Uncertified diver with undisclosed heart disease

This 57-year-old male was not a certified diver, but was in an introductory class that used SNUBA; this is surface-supplied air delivered through second-stage regulators with very long hoses that allow the individual to go to depth. This individual had a history of a myocardial infarction eight years earlier, though he denied any health problems on his pre-participation questionnaire. He began his descent with the instructor and one other individual, but almost immediately began to shake and then lost consciousness. Resuscitation efforts were unsuccessful. The autopsy disclosed myocardial fibrosis involving the conduction system of the heart in addition to changes associated with drowning.

00-57 Medically unfit search and rescue diver has cardiac arrest while searching for a drowned swimmer

This 52-year-old, experienced certified male diver was making his second dive of the day in 60 fsw / 18 msw without a dive buddy. He was using a dive board and was being towed by a jet ski in search of the body of a drowned teenager. A topside observer noticed the decedent's body on the surface, and resuscitation efforts were unsuccessful. The diver's equipment was in poor repair, and he had significant evidence of natural disease, including severe coronary artery disease, previous myocardial infarctions, left ventricular hypertrophy, and atherosclerosis of the abdominal and thoracic aorta. He was also obese and in a poor state of physical conditioning.

00-74 Inexperienced diver with previously undiagnosed heart disease

This 47-year-old female had been certified five months earlier and had six lifetime dives. She had not made a dive since her initial certification period. The decedent made a dive to 90 fsw / 27 msw for 30 minutes with her husband as a dive buddy. She and her husband decided to ascend to the safety stop, but the husband noted her absence when he arrived at the stop. The divemaster found the decedent on the bottom, unconscious and without the regulator in her mouth. She was brought to the boat and given oxygen and cardiopulmonary resuscitation, but she was pronounced dead at a local hospital. The decedent's equipment and air were tested, and no problems were noted. The autopsy revealed moderate to severe coronary artery disease, left ventricular hypertrophy, and moderate obesity. The death was ruled a drowning secondary to a heart attack.

3.3.5 Proximate Cause: Drowning / Insufficient Air

00-05 Experienced diver loses consciousness after 20 minutes on surface

This 58-year-old male was a certified rescue diver who had considerable past diving experience but had not made any dives in over a year. He made an uneventful dive to 90 fsw / 27 msw with a normal ascent and safety stop. The decedent and his dive buddy spent over 20 minutes on the surface in rough waters, and he apparently lost consciousness during that time. The two divers became separated while waiting to be picked up by the boat. The cause of death was listed as drowning. An autopsy report was not made available.

00-12 Divemaster drowns with improper equipment configuration

This 41-year-old male was an experienced divemaster who made a shore-entry lake dive in a large group. He was assisting with an open-water instruction class at 70 feet / 21 meters when he became separated from the other divers. His body was recovered two hours later at 117 feet / 35 meters. When the decedent's equipment was evaluated, it was noted that that the tank valve was barely open, and the air gauge moved up significantly when the valve was opened appropriately. The decedent's medical problems included diabetes and obesity.

00-15 Diver runs out of air, drowns while attempting to rescue buddy

This 52-year-old male was the dive buddy of the other diver (00-53) involved in a double fatality that occurred during a wreck penetration dive. The other diver was entrapped in a narrow compartment of the wreck, and this diver apparently stayed to the end in an effort to get his buddy out of the wreck. Both divers exhausted their breathing gas, which was nitrox.

00-53 Experienced technical diver dies, along with buddy, during wreck penetration

This 57-year-old male was a very experienced technical diver. He and another diver made a wreck penetration dive to 80 feet / 24 meters in a freshwater lake. The divers used nitrox as a breathing gas, and visibility was minimal. This diver became entrapped in the forward portion of the wreck, and his dive buddy (00-15), who did not appear to be entrapped, stayed to render assistance. Both divers perished in this dive after exhausting their breathing gas. This diver's body was recovered later the same day, and the dive buddy's body was pulled from a nearby compartment of the ship the next morning.

00-17 Tech diver loses consciousness while buddy breathing at 165 feet

This 37-year-old male was an instructor and technical diver. He made a wreck dive in fresh water to 165 feet / 50 meters for 30 minutes. Four divers were together in a group. Two of the divers ran low on air and surfaced. The decedent was the third diver to run low on air and also had some other problem on the bottom. He buddy breathed on the bottom and then began an ascent. The decedent was unconscious by the time he reached 130 feet / 39 meters, and resuscitation efforts on the surface were unsuccessful. The medical examiner ruled the cause of death as an air embolism, but the dive profile and lack of any corroborating evidence argue against that. A deep dive profile like this will cause intravascular gas to be present at autopsy, and the diver lost consciousness while still at a significant depth.

00-19 Solo diver dies inside wreck at 200 feet on third dive

This 39-year-old male was advanced open water qualified and very experienced. He was making wreck penetration dives to 110-200 fsw / 33-60 msw without a buddy. On the third dive of the series, the decedent did not

return at the expected time, and a search was conducted. His body was not recovered until the next day. The diver was known to dive alone, even when performing deep decompression dives. He was apparently taking numerous medications, including Ritalin, codeine, antihistamines and benzodiazepines. The autopsy was performed by a general surgeon who erroneously attributed the cause of death to an air embolism. Since the decedent never made it out of the wreck, an embolism would be very unlikely. The long, deep dives would cause numerous postmortem bubbles in both arteries and veins, which probably lead to the erroneous conclusion made regarding the cause of death.

00-21 Multi-drug use and separation from group

This 52-year-old male was a certified diver who was hunting lobsters in a group of three divers. The decedent became separated from his buddies 30 minutes into a dive to 85 fsw / 26 msw. His buddies surfaced from the dive and went back to depth to search for the missing diver. The decedent was found unconscious on the bottom. The autopsy showed changes consistent with drowning. Toxicology was positive for propoxyphene, benzodiazepine, diphenhydramine, promethazine and cannabinoids.

00-30 Solo diving while intoxicated

This 48-year-old male had no formal diving certification. He made a shore entry without a dive buddy and descended to 9 fsw / 2.7 msw. His body was found four hours later. The decedent's equipment was in poor repair and was configured so that his reserve could not be employed. The autopsy disclosed significant natural disease processes, including coronary artery disease, previous myocardial infarctions, and cirrhosis. A postmortem blood alcohol level showed the diver at over three times the legal limit for driving (259 mg/dl).

00-46 Underqualified, disoriented cave diver runs out of air 2,000 feet from entrance after silt-out

This 27-year-old male diver had introductory cave diving certification but did not possess the experience he and his dive buddy claimed to have prior to entering a deep cave system. The two divers used scooters to explore the caves, and they became separated during a silt-out. One diver made it out of the cave; the decedent's body was recovered several hours later, more than 2,000 feet / 603 meters from the entrance of the cave.

00-66 Solo diver runs out of air at 104 fsw

This 45-year-old male was a certified diver with an unknown amount of diving experience. He was scheduled to meet a dive buddy at a predetermined location in the water. The decedent entered the water alone, from shore, and went to 104 fsw / 31 msw. His body was found six days later, and his tank was empty. The diver had a history of chronic lower back pain and had undergone two prior back surgeries. Toxicology was positive for hydrocodone, diazepam and meprobamate. In addition to changes consistent with drowning, diffuse myocardial fibrosis was also noted at autopsy.

00-67 Novice diver runs out of air after being separated from group in unfavorable bottom conditions

This 47-year-old male had been certified for five months and had made 15 lifetime dives. He made a shore-entry dive with two other divers as part of an advanced open-water certification course. The dive was planned to go to 100 feet / 30 meters; the water was cold and dark with almost no visibility. The water depth was 121 feet / 36 meters with a muddy bottom that contained trees and abundant debris. The three divers made a seemingly uneventful dive, except for some buoyancy problems by the decedent. Toward the end of

the dive, the decedent became separated from the other two divers and ran out of air. His body was recovered 12 days later. Significant health problems included obesity and left ventricular hypertrophy.

00-73 Inexperienced diver panics in strong current, found to be unconscious upon reaching shore

This 27-year-old male was a certified diver but had fewer than five lifetime dives. He and his dive buddy made a dive to an unknown depth that was apparently uneventful until they surfaced. The decedent struggled in a strong surface current with his regulator out of his mouth; he was assisted to shore by his dive buddy. He was unconscious upon reaching the beach and could not be resuscitated. An autopsy was not performed.

00-76 Uncertified novice runs out of air in industrial pond looking for world-record catfish

This 27-year-old uncertified diver with fewer than five lifetime dives entered an industrial lock system and retention pond to search for "world-record catfish." It was a night dive in an unauthorized area, and visibility was minimal. The decedent and his dive buddy brought spear guns with them and used a rope to stay together as they went down as far as 60 feet / 18 meters. The divers ended up in a flooded cement tunnel and somehow became separated shortly after the decedent noted that he was low on air. The buddy managed to find a vent to the surface and called for help. A crane was required to pull the grate off the vent and bring the diver up. The decedent's body was not recovered until the next day. The autopsy findings were consistent with drowning.

00-84 Underqualified, underequipped diver runs out of air on a solo cave dive

This 42-year-old male was morbidly obese and smoked more than four packs of cigarettes a day. He also complained of occasional chest pain. The diver was open-water certified but had no formal cave diving certification. He entered a freshwater cave, without a buddy, and descended to 102 feet / 31 meters. The decedent also did not use a safety rope. His body was recovered the next day by a certified cave diver, who was also diving alone. The decedent's tank was empty. The autopsy findings were consistent with drowning.

3.3.6 Proximate Cause: Drowning / Various Causes

00-06 Diving in rough seas, diver loses boat, struggles to shore, arrives unconscious and cannot be resuscitated

This 65-year-old female had advanced open-water certification and significant dive experience. She was diving with a large group in rough waters and a strong current. The decedent and her buddy surfaced away from the boat and became separated from the group. Both divers made it to shore, but the decedent was unconscious and could not be resuscitated. The autopsy disclosed minimal coronary atherosclerosis; the cause of death was determined to be drowning.

00-08 Overweighted diver found dead after solo night dive

The information on this certified male diver is limited, and his experience level is unknown. He made a shore entry night dive without a buddy and was seen floating on the surface by a witness on the beach. The decedent had a history of asthma, and the autopsy disclosed evidence of coronary artery disease. The medical examiner determined the cause of death to be drowning secondary to scuba diving. It is not known how much natural disease processes contributed to this death. The diver was also significantly overweighted.

00-34 Solo diver drowns while testing homemade rebreather

This 52-year-old male was a very experienced diver, according to his family. He made a shore entry dive in a nearby body of water, alone, to test a rebreather apparatus that he had made from a kit. He had some previous technical difficulties with this rig a few weeks earlier. When the decedent did not return home by evening, a search was conducted. The body was found the next day in 60 feet / 18 meters of water. Toxicology was positive for very high levels of a narcotic analgesic. Otherwise, the autopsy findings were consistent with drowning.

00-35 Diver loses consciousness, drowns shortly after surfacing

Not much information is available regarding the death of this 49-year-old female diver. She was diving with her family off a charter boat, and her certification level and experience are unknown. Diving took place in 100 fsw / 30 msw, but the dive profile is also not known with certainty. The decedent struggled on the surface after ascending from the dive and received cardiopulmonary resuscitation on the boat. The medical examiner signed out the death as consistent with drowning, but the autopsy report was not made available for review.

00-39 Solo diver drowns in pool testing homemade dive rig

This 41-year-old male was alone in a swimming pool testing a prototype of homemade diving equipment. He had a history of depression and was taking antidepressant medication. Another tenant found the decedent on the bottom of the pool at the apartment complex later that night. The autopsy findings were consistent with drowning.

00-41 Poorly conditioned, non-current diver entangled on a wreck

This 45-year-old female certified diver had moderate diving experience but had not made a dive in two years. She was obese and had a history of diabetes. The diver was a student in an advanced open-water course and was making a deep wreck dive, possibly with planned decompression stops. Initially the decedent had to return to the boat to obtain more weight. Later in the dive, her octopus became caught on the wreck, and she removed her mask. The decedent's buddy untangled her and attempted unsuccessfully to replace her mask. She lost consciousness on the bottom and was assisted to the surface. Resuscitation efforts were unsuccessful. The medical examiner determined the cause of death to be drowning, but a cardiac event cannot be excluded. The autopsy revealed coronary atherosclerosis as well as changes consistent with drowning.

00-44 Diver loses buoyancy, drowns with improper tank / BC configuration

This 57-year-old male had been a certified diver for 14 years but had only 42 lifetime dives. He was gathering lobsters with a buddy at 15 fsw / 4.5 msw when the two divers became separated. The divers surfaced separately but the decedent went back below the surface after a visible struggle with surface sea conditions. His body was found two hours later. An equipment evaluation revealed that the buoyancy compensator and tank were improperly configured. The decedent also had multiple medical problems, including coronary atherosclerosis, hypertension and elevated serum cholesterol.

00-49 Overweighted, non-current diver drowns after losing buddy in poor visibility

This 55-year-old male certified diver was experienced but had made no dives in the previous six years. He made a dive to 50 fsw / 18 msw from a boat but not too far from shore. The decedent's buddy was his brother and, due to poor visibility, the two divers quickly decided to abort the dive shortly after reaching bottom. The divers became separated during ascent, and the decedent did not surface. An immediate search was unsuccessful. Fishermen found the body four months later and 75 miles / 120 km offshore. The autopsy was limited to formal identification of the remains, which was achieved with dental records. The equipment was functional but the decedent was overweighted.

00-50 Experienced diver loses buddy, drowns during deep recreational dive

This 29-year-old, experienced, certified male diver made a shore entry dive to 130 fsw / 39 msw for nine minutes. He was using a drysuit, and it appeared to be a planned decompression dive. The decedent became separated from his buddy during ascent and did not surface. The dive buddy returned to depth but could not locate the missing diver. His body was recovered two days later. The autopsy was complicated by numerous artifacts due to decomposition and marine life. An air embolism cannot be excluded.

00-58 Untrained novice diver with borrowed gear drowns in surf zone during shore entry

This 23-year-old male had no formal certification and used equipment borrowed from his dive buddy to make a shore entry dive. He and his dive buddy became separated approximately 10 minutes into the dive when the decedent struggled in the surf zone. The dive buddy found the decedent on the bottom with his regulator out of his mouth. Resuscitation was attempted, but he died at a nearby hospital. The autopsy showed evidence of external trauma, bilateral middle ear hemorrhages, and changes consistent with drowning.

00-59 Novice diver unable to maintain buoyancy on surface

This 41-year-old male had recently received initial open-water certification and had made fewer than eight lifetime dives. His medical problems included an elevated cholesterol level and a seizure disorder. The decedent and his dive buddy became separated on the bottom after 20 minutes at 25 fsw / 7.5 msw. On the surface the decedent struggled and called for assistance before losing consciousness. The autopsy report was not made available, but there was evidence of natural disease processes, including coronary artery disease. The death was ruled a drowning by the medical examiner.

00-63 Experienced diver drowns while using disconnected drysuit / BCD

This 49-year-old male was an experienced, certified diver. He made a shore entry dive into a lake using a drysuit and signaled to his dive buddy that he was going to ascend because of a tear in the suit. He became separated from his buddy at approximately 14 feet / 4.2 meters; the buddy surfaced, but the decedent did not come up. His body was recovered 90 minutes later. In addition to the tear, the drysuit was improperly configured. There was no connection for inflation of either the drysuit or the buoyancy compensation device. An autopsy was not performed, and the death was ruled a drowning.

00-64 Novice diver drowns during night dive due to unknown cause

This 23-year-old male had been certified for one month and had five lifetime dives. He made a shore entry dive into a lake at night and descended to 100 feet / 30 meters. During ascent, the diver and his buddy became separated at approximately 80 feet / 24 meters. His body was not recovered until 16 days later. The autopsy findings were consistent with drowning.

00-68 Untrained diver drowns during intro dive on shallow wreck

This 69-year-old male was enrolled in a non-certification introduction to scuba class. After one hour in the swimming pool he was taken to a wreck in 15 fsw / 4.5 msw. The exact details of what occurred on the bottom are not available, but the medical examiner determined the cause of death as drowning. The autopsy report was not made available.

00-72 Air source problem possibly leads to drowning

There is very little information available about the death of this 46-year-old male. He apparently made a shore entry dive to 20 fsw / 6 msw and was pulled to shore by his buddy. He apparently had some problem with his air source. An autopsy was not performed. The medical examiner concluded that the cause of death was drowning, but a cardiac event or air embolism cannot be excluded.

00-87 Novice diver panics, drowns during shallow dive

This 29-year-old male had been certified six years earlier but had made fewer than 10 lifetime dives. He had a history of an irregular heart rhythm for which he had taken medication in the past. The decedent made a dive to less than 20 fsw / 6 msw with his wife as a dive buddy. He panicked during descent and was brought back to the boat unconscious. Resuscitation efforts were unsuccessful. The autopsy showed a thickened left ventricle but no other evidence of natural disease. The death was ruled to be due to drowning.

00-69 Novice diver in rough surface conditions drowns after head trauma

This 45-year-old male had been certified for only one month and had fewer than five lifetime dives. He made a shore entry dive, at altitude, in a cold freshwater lake. Late in the dive, the decedent was thrown into rocks by rough surface surge. He lost consciousness after hitting his head on a rock and was pulled to shore by other divers. Resuscitation efforts were unsuccessful. The autopsy disclosed evidence of significant cardiac disease, but death was attributed to drowning secondary to head trauma.

00-81 Divemaster struck by boat, drowns while attempting to exit water in rough surface conditions

This 50-year-old female was reported to be an experienced diver with divemaster certification. She was making a search-and-rescue training dive with two other divers in a large lake. The sea was moderate, and surface conditions were rough. At the end of the training evolution at a depth of 35 feet / 10.5 meters, the decedent signaled that she was going to ascend and left her two dive buddies on the bottom. On the surface, witnesses saw the decedent struggle with the rough surface conditions, and the tenders in the boat were unable to pull her out of the water very quickly. She had her regulator out of her mouth, despite several calls by the tenders to replace it. The diver lost consciousness before she was brought onto the boat; resuscitation efforts were unsuccessful. The autopsy findings were consistent with drowning and also disclosed several superficial and deep soft tissue injuries over the face, neck and shoulders. The traumatic injuries were due to contact with the boat during the difficult extraction from the water.

00-83 Young diver drowns after being attacked by large fish that he had speared, then attached to himself, during deep air dive

This 16-year-old male received his initial open-water certification from an organization with no national affiliation one year earlier. He was making his second dive of the day on an oil rig approximately 50 miles / 80 km offshore with his mother and another diver. Both dives went to depths past 200 fsw / 60 msw, and the decedent relied on his mother's computer for a dive profile. After shooting an extremely large fish and attaching it to a stringer on his buoyancy compensation device, the decedent was seen to struggle in the water as the fish made contact with his face and neck. By the time the diver's mother was able to assist him, he was unconscious, and she brought him to the surface. Resuscitation efforts were unsuccessful. The decedent's equipment was evaluated, and the regulator was found to be in marginal operating condition for deep dives. His mother's computer had maxed out for depth and bottom time earlier in the dive. The medical examiner based his diagnosis of an air embolism on gas in the right side of the heart and vena cava, but that is most likely due to postmortem offgassing. There was no evidence of pulmonary barotrauma, and the decedent was unconscious prior to ascent.

00-85 Experienced diver drowns after becoming entangled

This 24-year-old male was a certified diver with 10 years' experience. He made a shore entry dive, alone, into a thick area of kelp to hunt for lobsters. The decedent became entangled in the kelp at approximately 30 fsw / 9 msw, surfaced briefly to call for assistance, then submerged again. A friend on shore saw him surface approximately 50 feet / 15 meters from the beach and called for help. The decedent was unconscious and entangled in kelp when rescuers found him. Resuscitation efforts were unsuccessful. The death was declared a drowning.

00-11 Novice diver unfamiliar with BCD / drysuit buoyancy problems, found unresponsive on bottom

This 41-year-old male was open-water certified but had fewer than five lifetime dives. He made a pair of very shallow dives and had a problem with buoyancy control on descent during the second dive. The decedent could not adequately inflate his buoyancy compensation device or dry suit and became separated from his buddy on the bottom. The decedent's buddy found him unconscious on the bottom 10 minutes later. He was transferred to a local hospital, where he received treatment in a recompression chamber. The diver remained critically ill and died four days later.

3.3.7 Proximate Cause: Unspecified, Body Not Recovered

00-02 Experienced diver unaccounted for, possibly left behind

This 46-year-old male was an experienced diver with advanced open-water certification. He was diving with a large group of divers who were initially put in the water in an incorrect spot. The decedent did not have an assigned buddy. The divers were recalled and put in at another location. It is not clear if the decedent was accounted for when the boat moved to a different dive site. At the end of the dive, the decedent could not be accounted for, and a search was initiated. It was reported that the decedent used his own tank, which was not full at the beginning of the dive. He also had some difficulty with initial descent and buoyancy. The missing diver's body was never recovered.

00-25 Novice solo diver fails to return

This male diver, reportedly in his twenties, was certified one month prior to this final dive. He entered the water alone while his girlfriend, a certified rescue diver, waited back on shore. The decedent did not return, and his body was never recovered.

00-26 Unrecovered diver diving off oil platform

There is little information available on this 27-year-old male. His certification level and experience are unknown. The decedent and two other divers descended to 40 fsw / 12 msw on an oil platform, where the decedent signaled to the others that he felt ill. Witnesses topside reported seeing the decedent break the surface and remove his regulator and mask before descending back to depth. The diver's body was never recovered.

00-37 Experienced diver fails to accompany buddy on aborted dive, does not surface

The certification level of this 50-year-old male diver was unknown, but he reportedly had considerable diving experience. He made a shore entry dive to 160 feet / 48 meters in fresh water with another diver. The dive buddy was having some problems with his gauges and signaled that he wanted to abort the dive. The decedent did not wish to ascend, and the two divers became separated. The dive buddy searched until he ran low on air. A body was never recovered.

00-33 Diver, separated from buddy on deep night dive, does not return

Many facts remain unknown on this fatality, including the certification level and the diving experience of the decedent. He was a 29-year-old male who was making a night dive in the ocean and became separated from his buddy. The dive may have been planned to go to a depth of nearly 200 fsw / 60 msw. The decedent became separated from his buddy, and a body was never recovered.

00-40 Novice divers lost after running low on air

This 50-year-old female was newly certified (still had a temporary C-card), making her second drift dive of the day in a strong current. Her dive buddy (00-61) was equally inexperienced. Both divers ran low on air and were sent up to the safety stop by the divemaster. Neither diver was seen again after that; their bodies were never recovered.

00-61 Unobserved novice divers lost on ascent

This was the dive buddy of the woman (00-40) in the previously listed fatality. Both were newly certified with temporary C-cards. They made a drift dive and ran low on air before ascending to the safety stop. The divemaster was the last person to see these two divers as they ascended. Neither body was ever recovered.

00-52 Experienced diver persists in diving at night after head trauma, under adverse temperature and wind conditions

This 59-year-old male had rescue diver certification and considerable diving experience. He made a shore-entry night dive in frigid water with a group of divers to celebrate the new millennium. The decedent reportedly hit his head just prior to beginning the dive and seemed very agitated. After a dive to 65 fsw / 19.6 msw for 28 minutes, all of the divers were in the process of exiting the water. The decedent was last seen near the exit point on the beach before drifting back out into the channel. Rescue efforts were hindered by winds gusting to 80 mph / 128 kmph, ice formation in the water and a very strong current. A body was never recovered.

00-22 Solo diver with chemical dependence, psychiatric disorder lost after diving under the influence of recreational drugs and alcohol

This 45-year-old male was reported to be an experienced diver with an unknown level of certification. His medical history included cocaine addiction, alcoholism, cirrhosis of the liver, and bipolar disorder (manic-depressive psychiatric disorder). He reportedly used alcohol and recreational drugs the night before the dive and alcohol the morning of the dive. The decedent entered the water with a buddy and made a short dive to 30-40 fsw / 9-12 msw. The dive buddy exited the water, but the decedent continued to make excursions to depth before submerging one last time. His equipment was found in several locations, but a body was never recovered. The tank was empty when it was recovered, and the decedent did not use a buoyancy compensator for this dive.

00-86 Solo diver lost during deep air dive

This 35-year-old male had open-water certification; his level of experience is not known. He made a dive without a buddy on a deep wall. The diver had told his wife that he made a dive to 200 fsw / 60 msw alone one day previously. The decedent's body was never recovered.

3.3.8 Proximate Cause: Other

00-43 Loss of consciousness breathing hypoxic atmosphere in overhead environment

This 38-year-old male was an experienced, certified diver. He entered a horizontal water well (similar to a cave) alone with his brother holding the other end of a rope. When the decedent did not return rope pull signals, the brother went to get help. The body was recovered hours later in an air pocket that branched off the water filled tunnel. Testing of the air in that pocket revealed that it contained only 4.3 percent oxygen. The decedent's tank he was using for the dive was still nearly full. He apparently lost consciousness while breathing the oxygen-depleted air in the enclosed space.

00-32 Dive-related fatality, details unknown

The information on the death of this 59-year-old female is incomplete. Certification and experience level are unknown, as are the details of the dive and subsequent treatment. The decedent spent more than a year on a ventilator before succumbing to multiple organ failure.

00-82 Anoxic brain injury / death in a novice diver, details unknown

This 34-year-old female was a student in an initial open-water certification class with seven other students. The details of the event in the water that resulted in her death are not known, but she was pulled unconscious from the water and transferred to a local hospital. The decedent spent six days on a ventilator before succumbing to multiple organ-system failure and brain death. This case was not put under the jurisdiction of the local medical examiner, though it absolutely should have been.

00-70 Buoyancy problems during moderate dive profile, followed by stroke while on the bottom

This 55-year-old male had advanced open-water certification and a moderate amount of diving experience. He made a dive to 40 fsw / 12 msw for 20 minutes and ran low on air. The diver also apparently had some problems with buoyancy control earlier in the dive and surfaced to get more weight. The decedent signaled to his buddy that he did not feel well on the bottom and was brought to the surface unconscious. Resuscitation efforts failed and the autopsy disclosed a cerebrovascular accident as the cause of death.

00-23 Dive-related fatality, details unknown

There is very little information available on the death of this male diver. The unofficial report said he may have suffered a cardiac event, but there is no official cause of death available.

00-24 Dive-related fatality, details unknown

There is little information available on the death of this 61-year-old male diver. He was making a dive at altitude in fresh water.

00-59 Dive-related fatality, details unknown

No information was available on this fatality. It was reportedly related to recreational diving.

4. Project Dive Exploration

During the year 2000, Project Dive Exploration (PDE) collected data on 7,694 dives by 1,048 divers. Four DAN interns worked with members of the research staff and volunteers to record data from dive charters, liveaboard trips and Continuing Medical Education conferences sponsored by DAN.

No PDE volunteers were treated for decompression illness in 2000, although one PDE diver died during his participation. A detailed description of this fatality, including the dive profile, can be found under Case Report 00-79 in Section 3.3.2.

4.1 Diver Characteristics

The distribution of PDE divers across age and gender is shown in Figure 61. Divers aged 40-49 predominated in the PDE group, but there were many divers well into their fifties, sixties and seventies. DAN makes a particular effort to recruit divers over the age of 50 through the Aging Diver Study to gain a better understanding of the effects of age on diving safety. Although male divers continue to outnumber female divers by a ratio of approximately 3:1, the age distribution for both sexes was similar.

Fig 61
Age and gender of PDE divers (n=1,021).

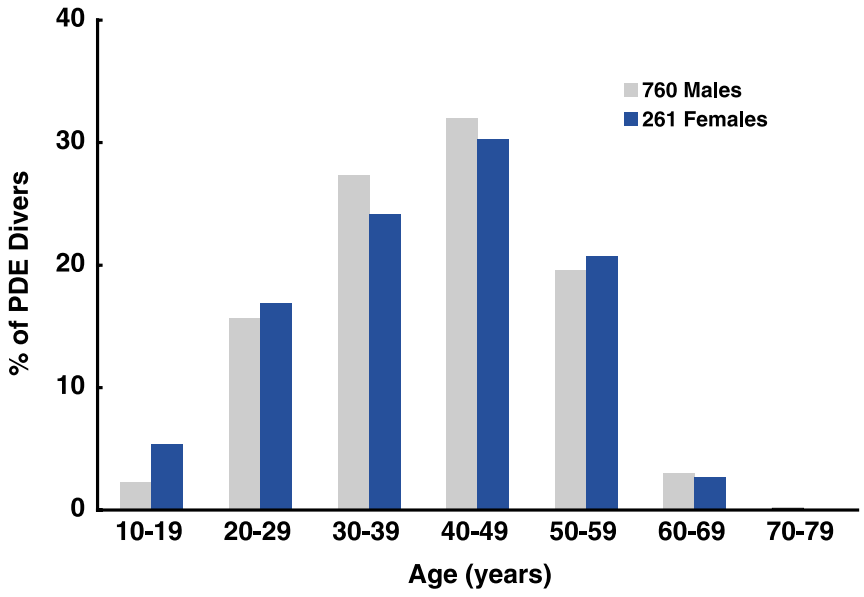


Figure 62 shows the chronic health conditions reported by PDE divers indicating that they were generally healthy. (HBP/ HD refers to high blood pressure or heart disease. CNS refers to seizures, migraine, or CNS injury.) Allergy, smoking and high blood pressure or heart disease were the conditions most frequently reported by PDE divers. Diabetes, arthritis and CNS problems were reported least.

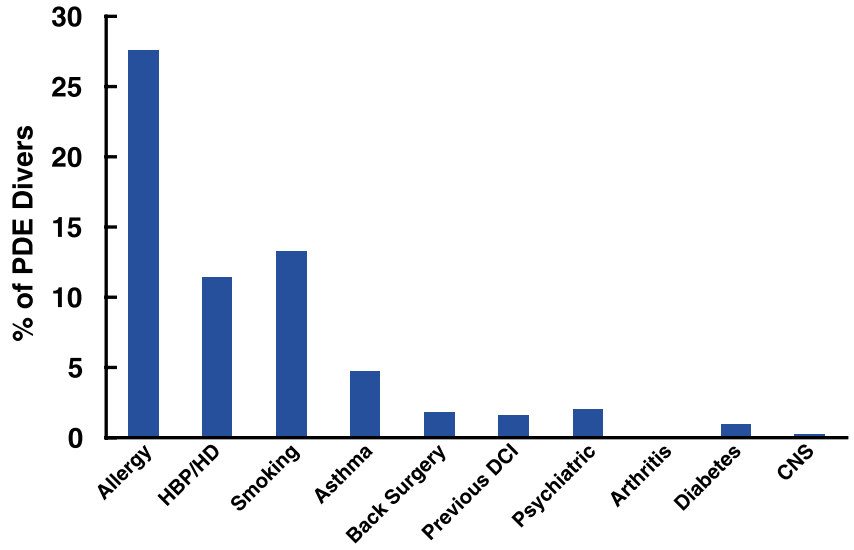


Fig 62
Chronic health conditions of PDE divers (n=1,044).

Figure 63 shows the acute health conditions reported for PDE divers. (Orthopedic refers to sprain, muscle pain, or fracture. URI refers to upper respiratory infection. GI refers to gastrointestinal. Birth control medication and estrogen replacement apply only to females.) Orthopedic, URI, and seasickness were the most common acute medical conditions reported by PDE divers. Twenty percent of female PDE divers reported using birth control, and none reported estrogen use.

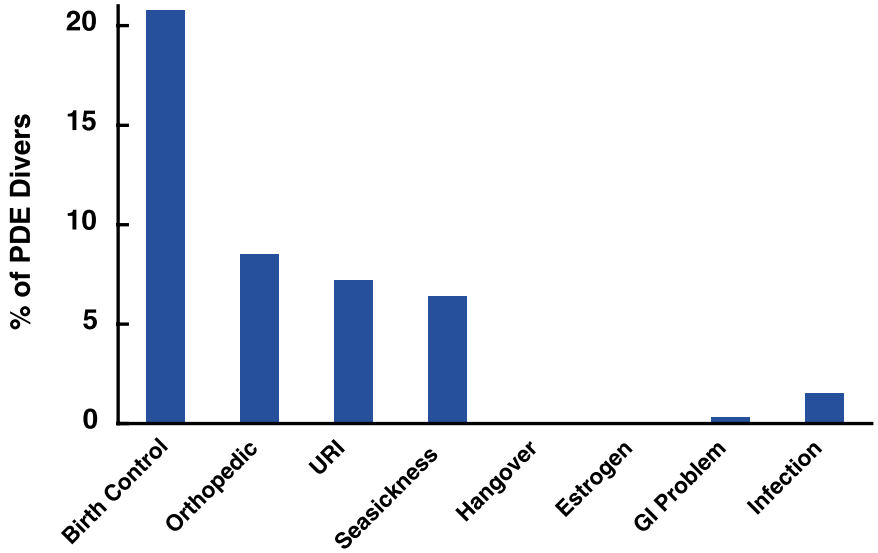
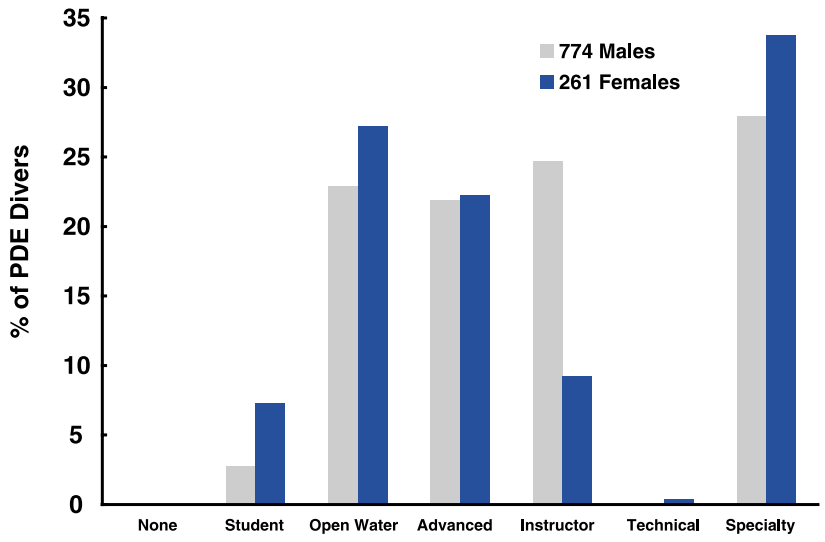


Fig 63
Acute health conditions for PDE divers (n=1,044).

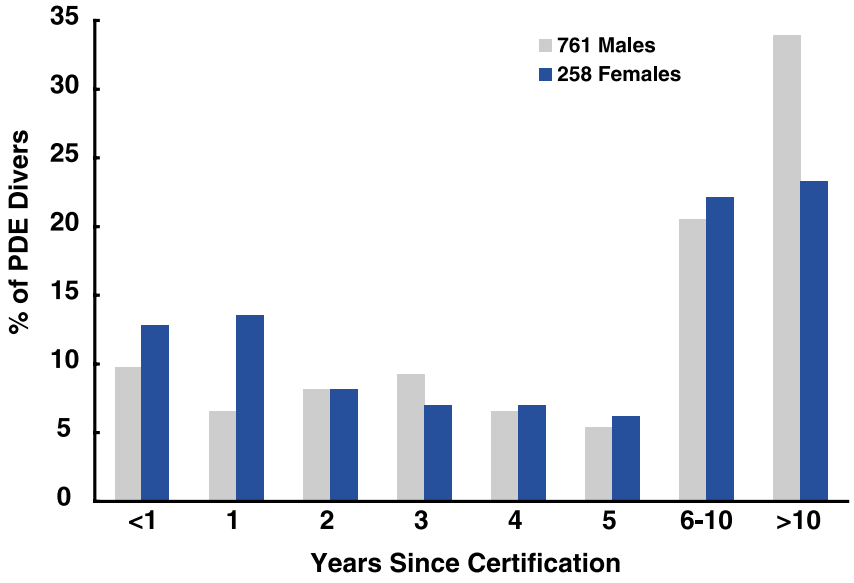
Figure 64 shows that most PDE divers (71 percent) reported having taken training beyond open water certification. "Specialty" included rescue, scientific, military or commercial divers.

Fig 64
Certification level of PDE divers by gender (n=1,035).



Consistent with the additional certification of PDE divers was the finding that 42 percent had been certified for more than six years (Figure 65). This was true for both male and female divers.

Fig 65
Years since initial training of PDE divers by gender (n=1,019).



4.2 Characteristics of PDE Dives

Figure 66 shows how PDE dives were distributed by month. Fifty percent of the PDE dives were collected during June and July, when the DAN Interns were active, while 14 percent were collected during December. Because the time of day during which the dives occurred was not comparable with the time at which diving injuries or deaths occurred, a time of day figure is not shown for PDE.

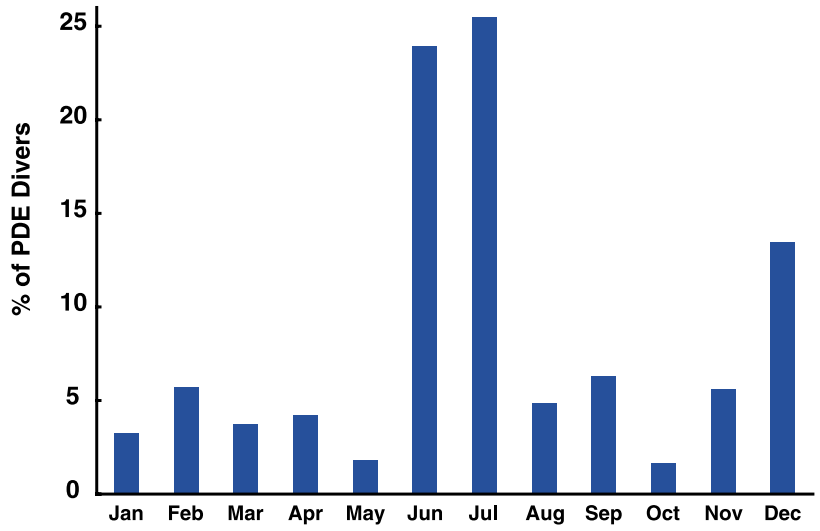


Fig 66
Months in which PDE dives occurred (n=1,048).

Figures 67 and 68 show the geographical locations of PDE dives. Slightly less than half of the dives (49 percent) were collected from U.S. sites, primarily in Florida and the Southeastern states (Figure 67). The majority of international PDE dives were collected in the Caribbean and at a limited number of sites in the vicinity of Mexico. Designated "Yucatan" in Figure 68, these sites included Cozumel, Cancun, Baja, the Galapagos and several small islands.

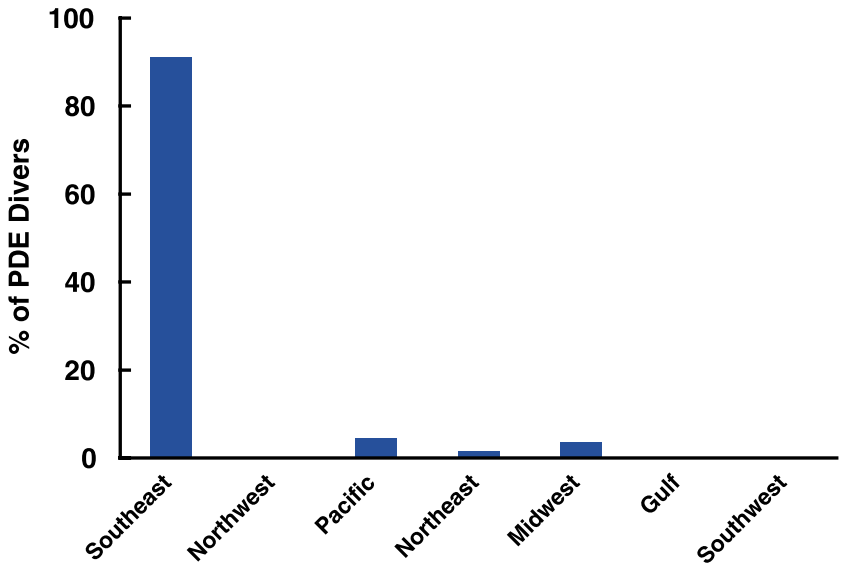


Fig 67
Domestic locations of PDE dives (n=467).

Fig 68
International locations of PDE divers (n=492).

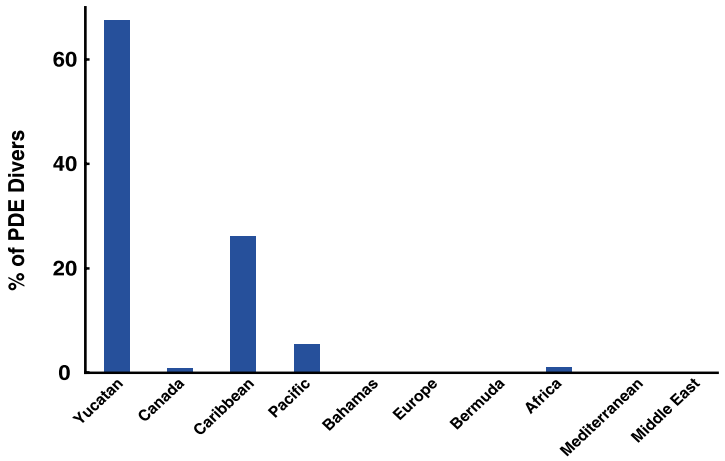


Figure 69 shows the diving environment of PDE dives. The majority was made in salt water.

Fig 69
Diving environment for PDE dives (n=1,047).

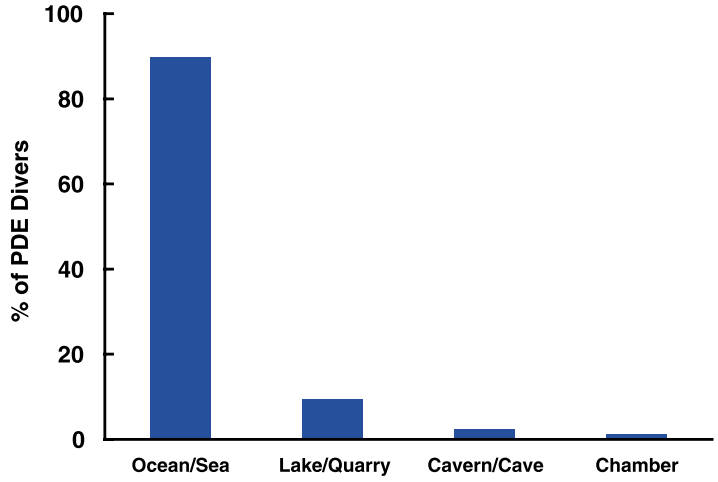


Figure 70 shows the reasons given for dives recorded under PDE. Most PDE dives were collected from the recreational divers. The category "Other" included military, commercial, law enforcement and scientific diving.

Fig 70
Purpose of PDE dives (n=959).

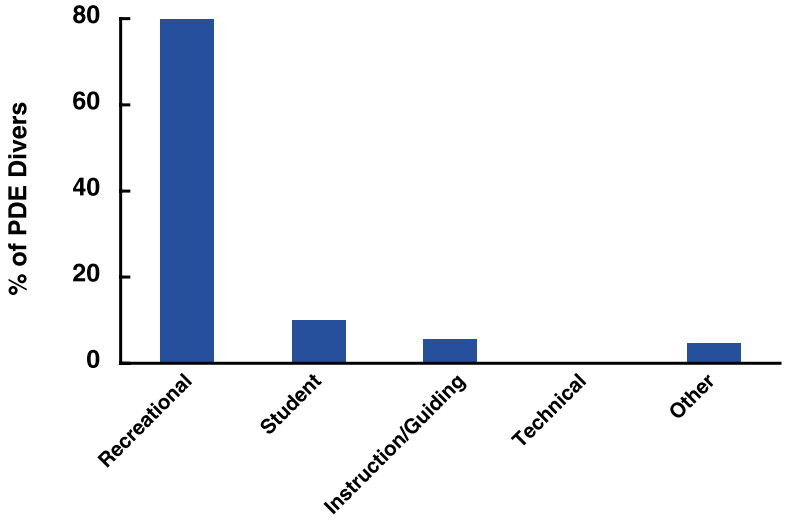


Figure 71 shows the dive platforms used by PDE divers. Nearly 60 percent of PDE dives were made from small boats or charter boats.

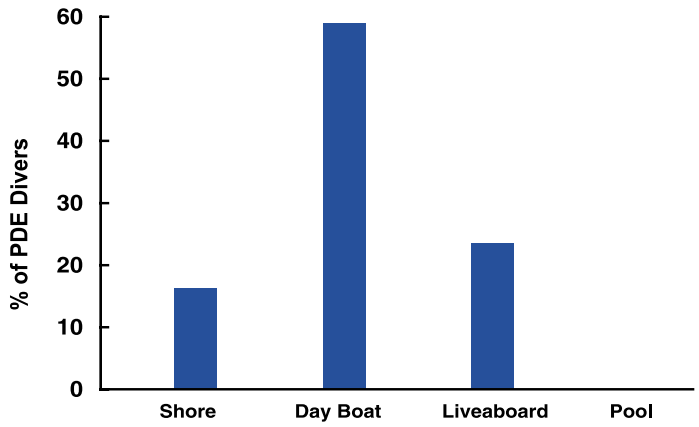


Fig 71
Platform of PDE dives (n=796).

Figure 72 shows the thermal protection used by PDE divers. Nearly 80 percent of PDE divers used wetsuits.

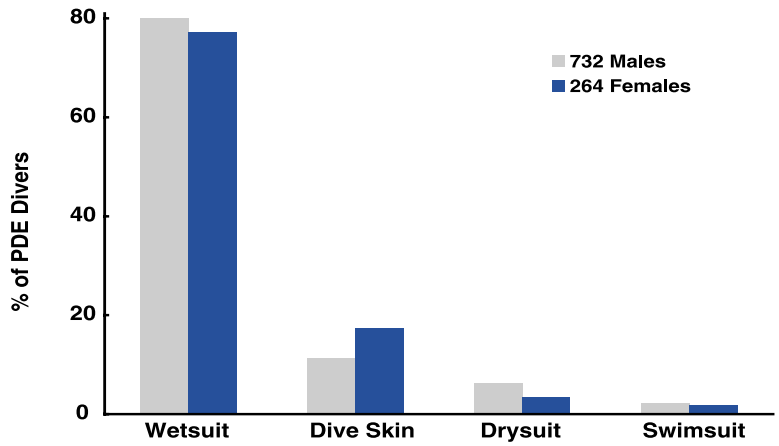


Fig 72
Thermal protection worn by PDE divers (n=996).

Figure 73 shows the distribution of breathing gases used by PDE divers at maximum depth. Over 80 percent of PDE divers breathed air, and nearly 13 percent breathed nitrox, but only five divers used heliox or trimix. All PDE divers used open-circuit scuba.

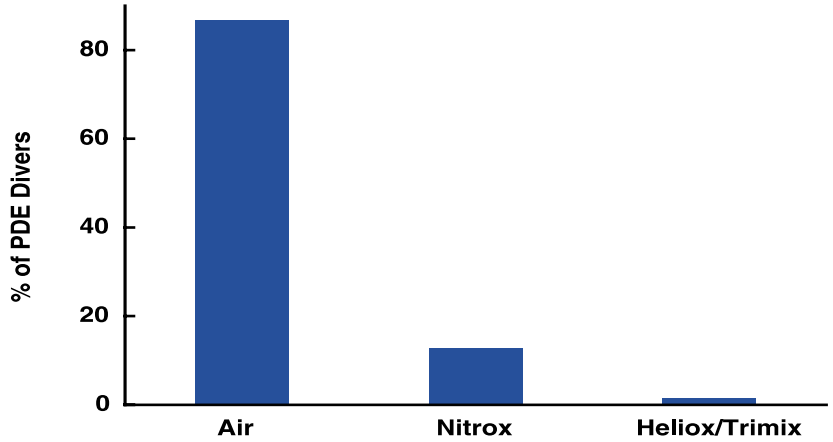


Fig 73
Breathing gas used by PDE divers (n=1,037).

Figure 74 shows the dive computer was used by 90 percent of PDE divers to plan their dives.

Fig 74
Dive planning method used by PDE divers (n=994).

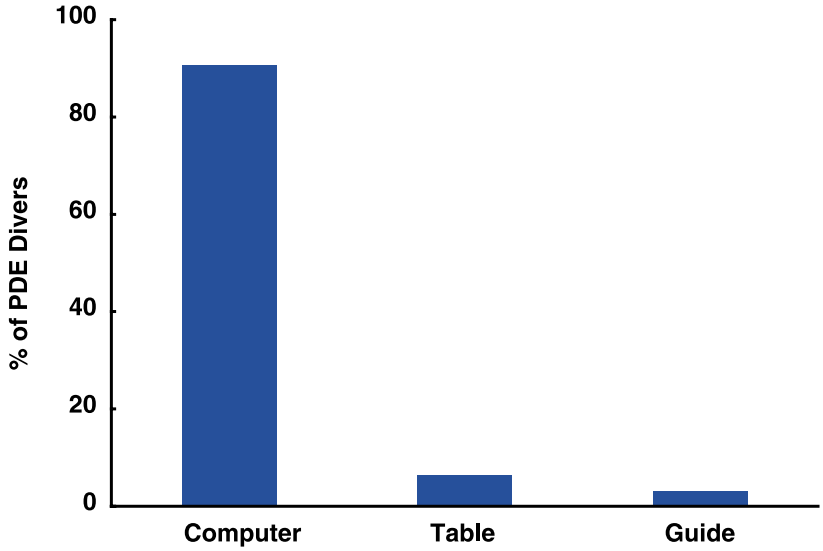


Figure 75 shows the number of days in a dive series by PDE divers. The most common groupings were one and six days, with six days likely representing liveaboard dive trips.

Fig 75
Number of dive days in each dive series by PDE divers (n=1,044).

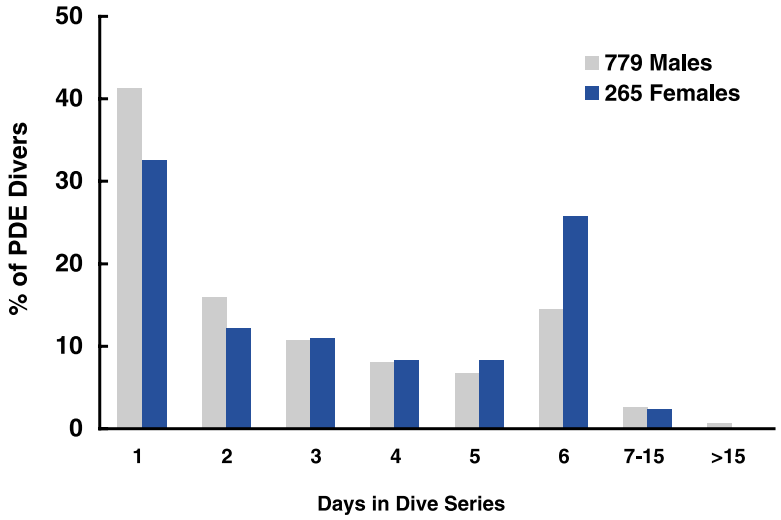


Figure 76 shows the number of dives in each dive series by PDE divers. The most common group was two dives, which probably reflects the single day of diving, while the 6-10 and 11-20 groups may have represented instructors or guides and liveaboard divers.

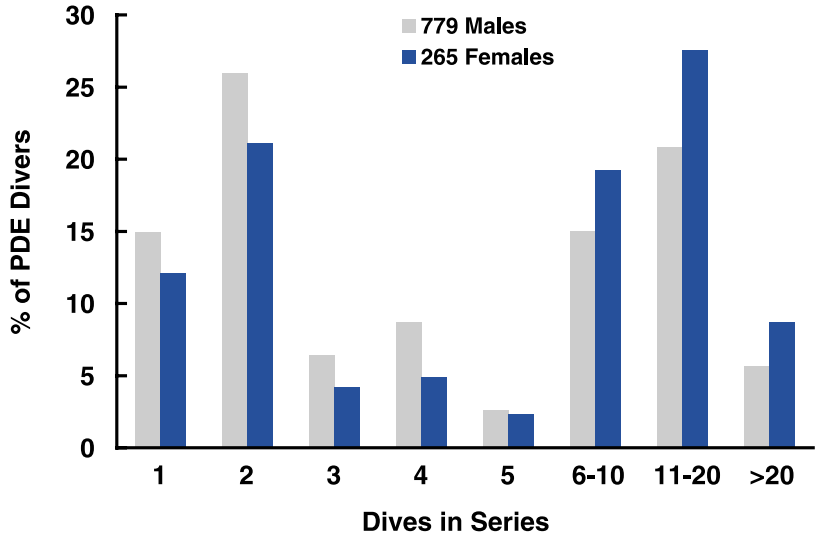


Fig 76
Number of dives in the dive series by PDE divers (n=1,044).

Figure 77 shows the maximum dive depths by PDE divers, and Figure 78 shows the maximum depth on the last day of diving. Most PDE dives had a maximum depth in the 60-120 fsw (18-36 msw) range, while on the last dive day, the maximum depth was in the 30-90 fsw (9-27 msw) range.

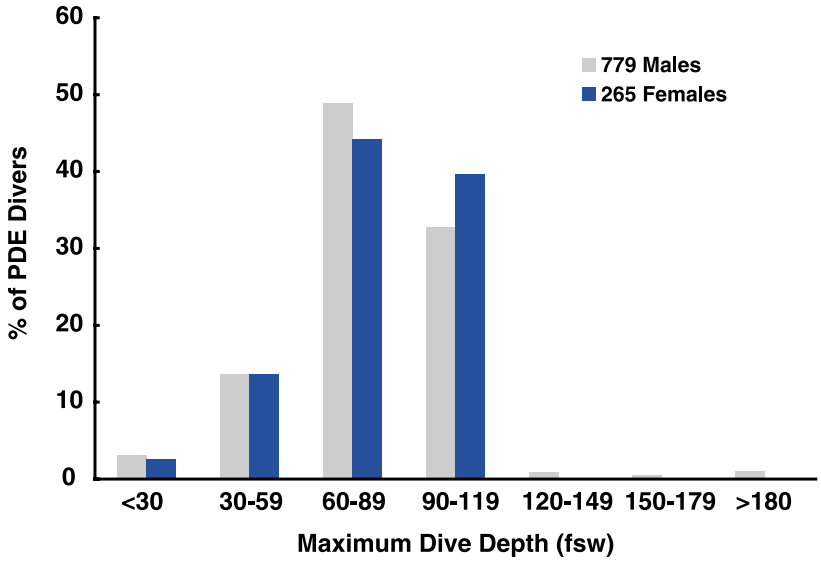


Fig 77
Maximum depth of dives in series for PDE divers (n=1,044).

Fig 78
Maximum depth on last dive day for PDE divers (n=1,044).

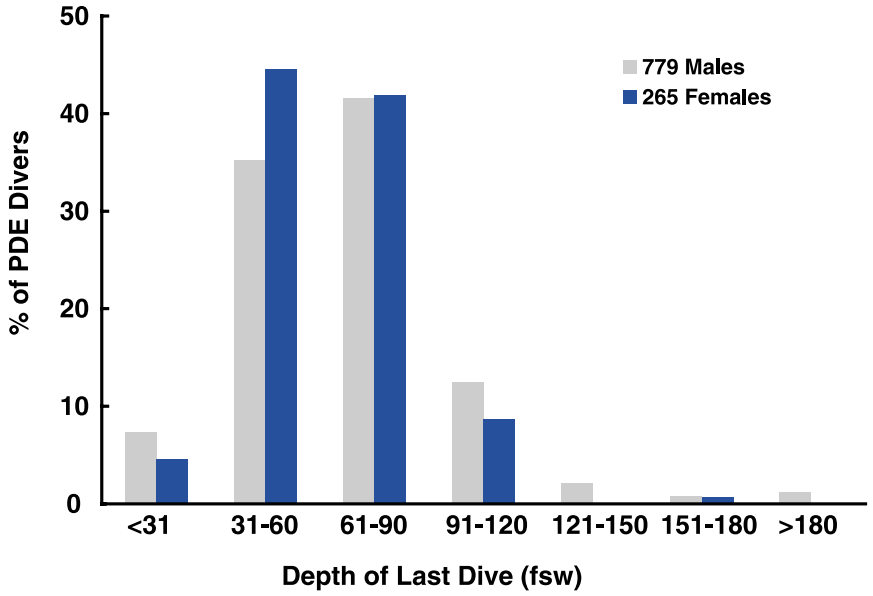


Figure 79 shows the type of altitude exposure for PDE divers that occurred within 48 hours of diving. Of the 35 percent who were exposed to altitude, most flew commercially in pressurized aircraft.

Fig 79
Type of post dive altitude exposure for PDE divers (n=623).

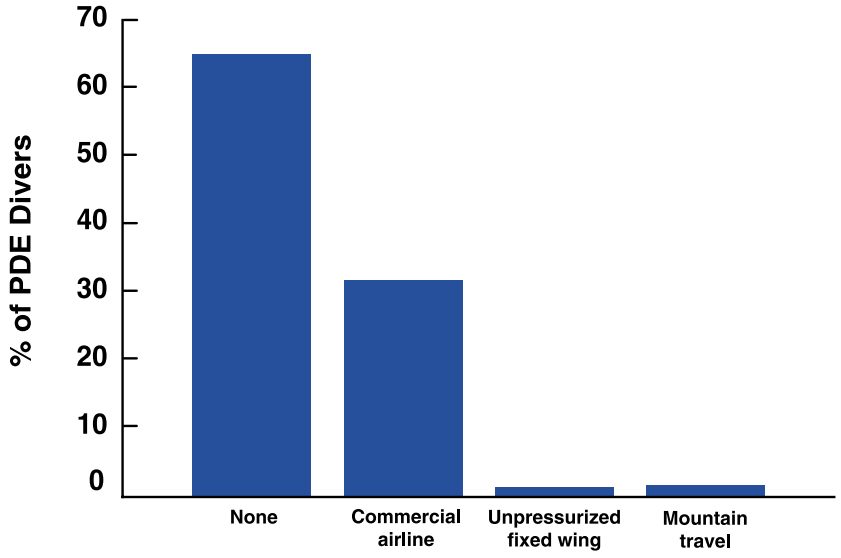


Figure 80 shows the distribution of preflight surface intervals for PDE divers. Of the 194 for whom surface interval data was available, most waited for at least 24 hours before flying, and none waited for less than 12 hours. No PDE diver developed DCI in 2000.

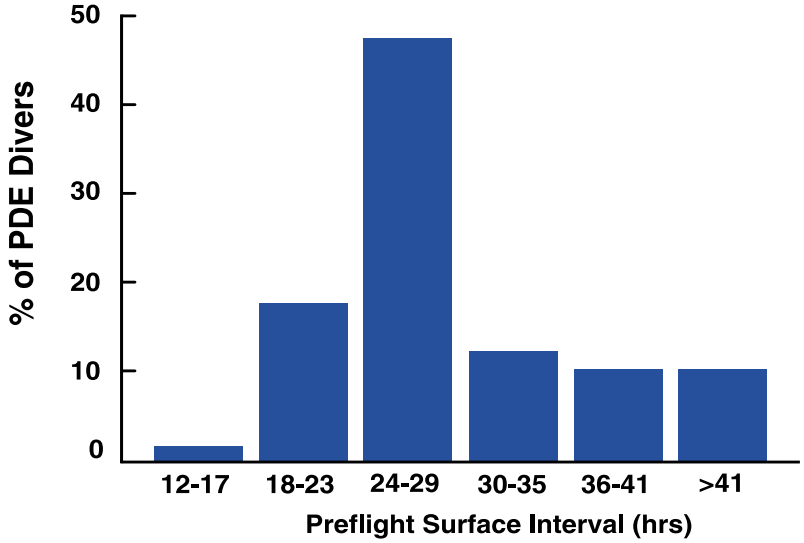


Fig 80
Distribution of pre-flight surface intervals for PDE divers (n=194).

PDE divers reported problems during diving only rarely. Figure 81 shows that less than 1.5 percent reported difficulty with buoyancy, rapid ascent, or running out of gas. The incidence of dive problems was much smaller than for injuries or fatalities.

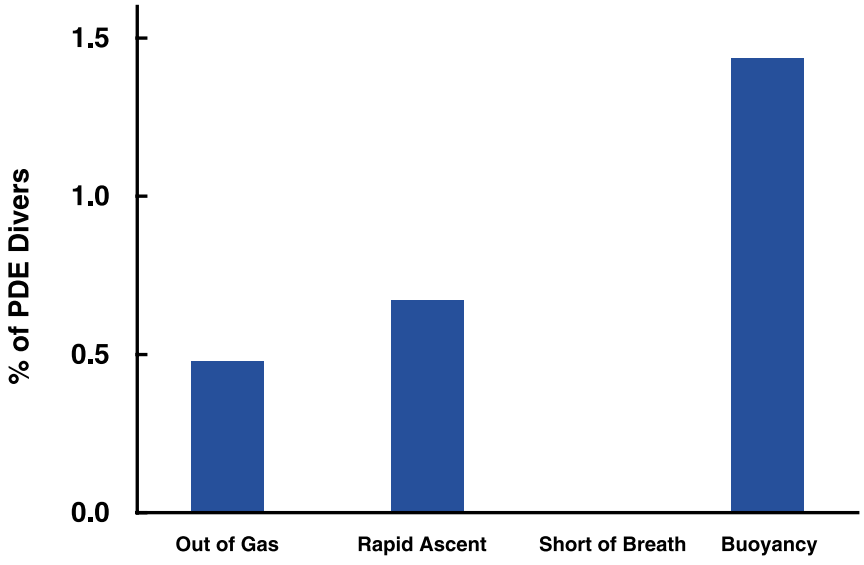


Fig 81
Problems during diving reported by PDE divers (n=1,044).

5. Injury, Fatality and PDE Population Comparisons

One of the objectives of Project Dive Exploration was to develop a database of "normal" dives that could be used as a point of reference for the injury and fatality databases. This year, a number of variables that were common to the databases were analyzed statistically. In this section, we present selected characteristics of divers and dives that were significantly different across the three populations. Such an analysis can claim that a difference exists that is not likely to be due to chance, but no statement can be made as to the cause of the difference. These results can be used, however, to identify areas worthy of further research.

Standard statistical methods were used to determine if the differences between populations had less than one chance in 20 of occurring randomly. Error bars on graphs represent the 95 percent Confidence Intervals, or the intervals that are 95 percent likely to include the true values.

5.1 Diver Characteristics

The average ages of the three populations are shown in Figure 82. The average age of each population was significantly different from the others. There was almost a 10-year difference between the average age of the fatality and injury populations.

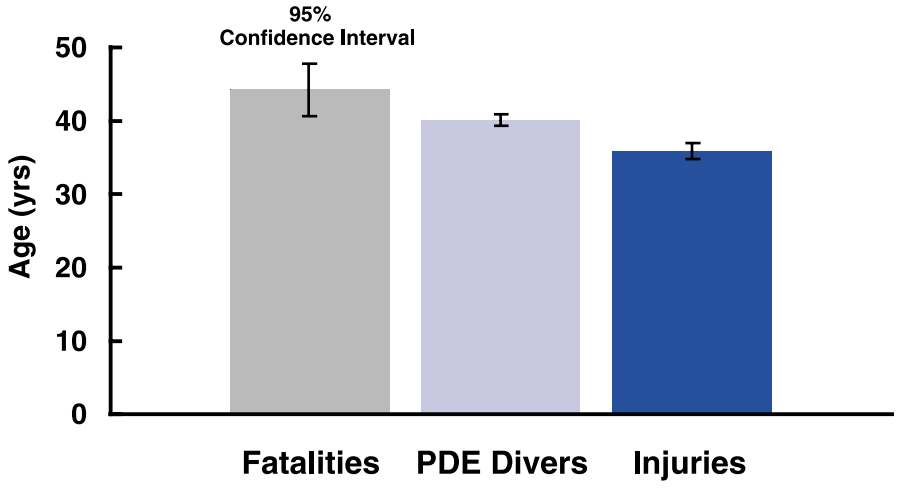


Fig 82
Comparison of average age by population.

The gender distribution between populations was also significantly different. Figure 83 shows the proportion of males and females in each group. While the difference between the injury and PDE databases was not significant, the difference between the injuries and fatalities was significant.

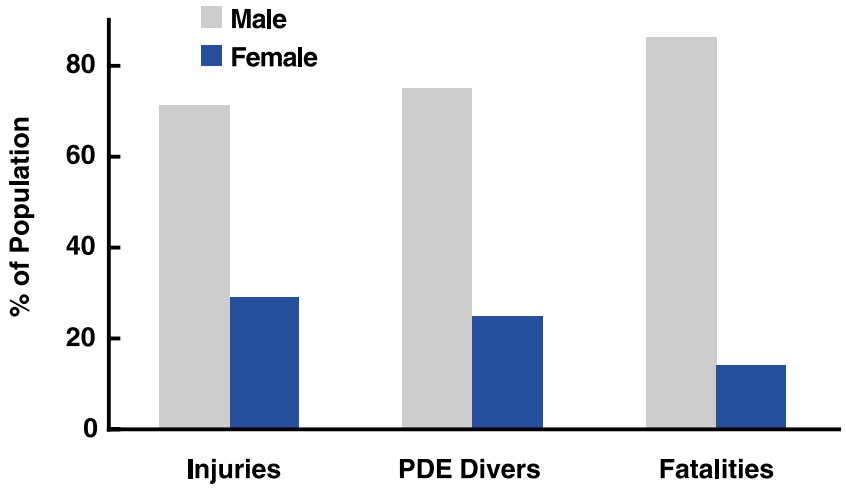


Fig 83
Comparison of gender distribution by population.

Figure 84 shows the level of certification reported in the three populations. The distribution of certification categories was significantly different for all three databases. Individual testing of categories was not performed, but examination of the graph suggests more advanced training in the PDE group.

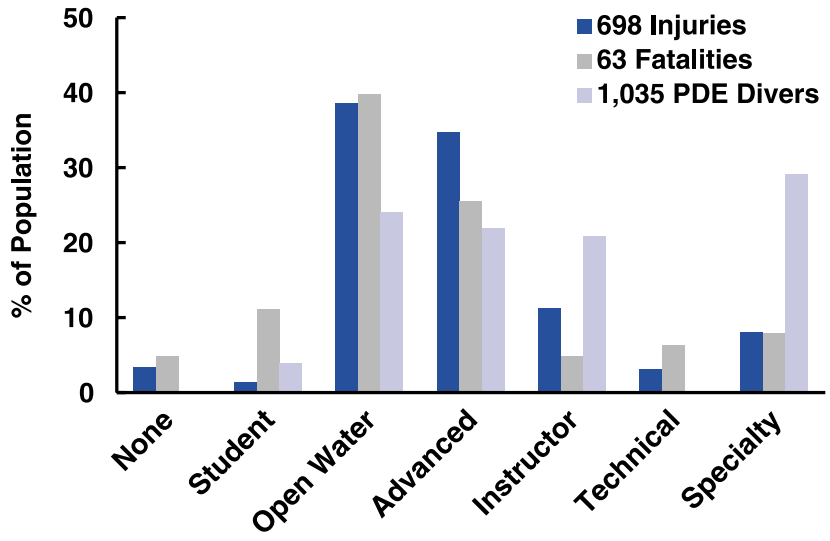
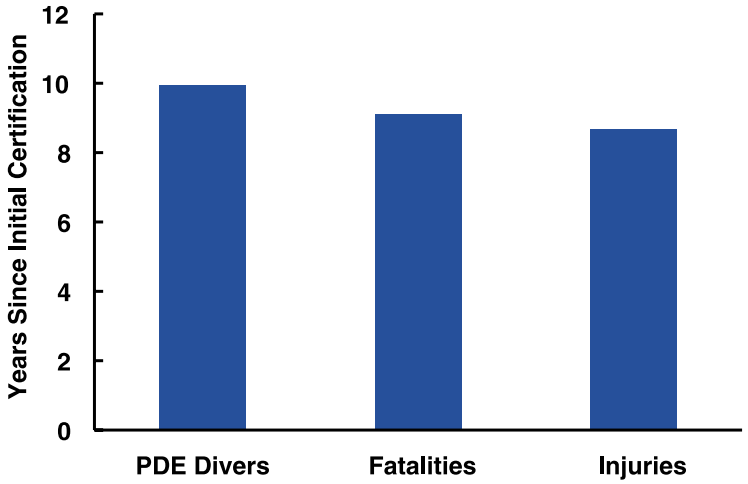


Fig 84
Comparison of certification by population.

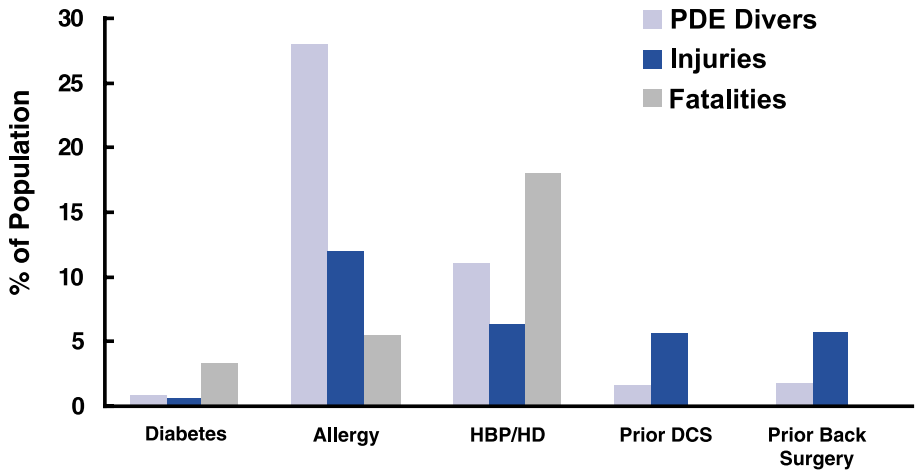
As shown in Figure 85, there were significant differences in all three populations for the average number of years since initial certification.

Fig 85 Comparison of years since certification by population.



Of the 19 health history categories identified in the data, five appeared to differ significantly in their distributions across the three populations as shown in Figure 86. For diabetes, the affected proportion of the fatality population was significantly higher than in either the injury or PDE populations. Diabetes in the injury and PDE groups was distributed similarly. Allergies were significantly higher in the PDE divers. High blood pressure and heart disease (HBP/HD) were over-represented in the fatality and PDE populations, relative to the injury group. Prior DCS or back surgery was not reported in the fatality population, but the proportion of these conditions was greater in the injury population compared to the PDE group.

Fig 86 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 differed significantly across the populations as seen in Figure 87. "Other" included military, commercial, law enforcement and scientific diving.

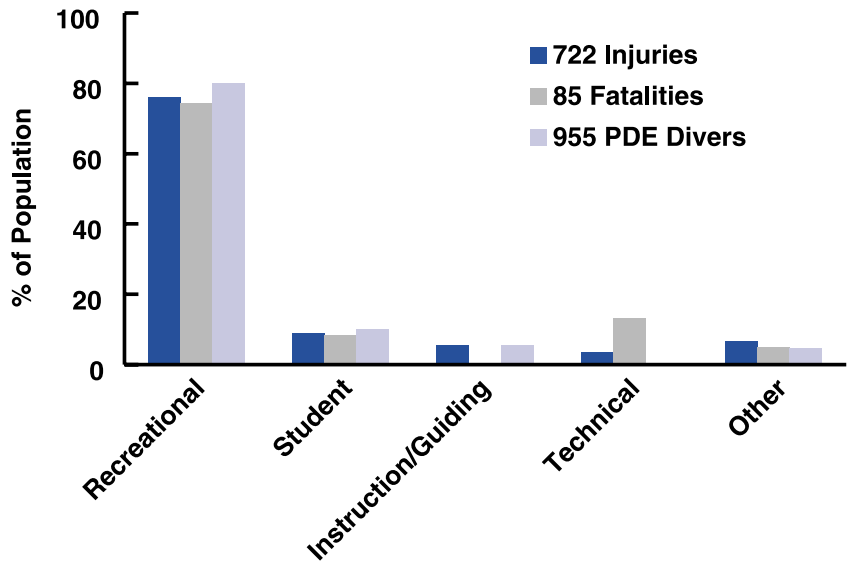


Fig 87
Comparison of dive purpose by population.

As shown in Figure 88, the proportion of dives in different environments varied across the populations. Ocean dives were the greatest proportions of dives reported for each group and were removed for clarity in Figure 88. The second highest environment was lakes / quarries.

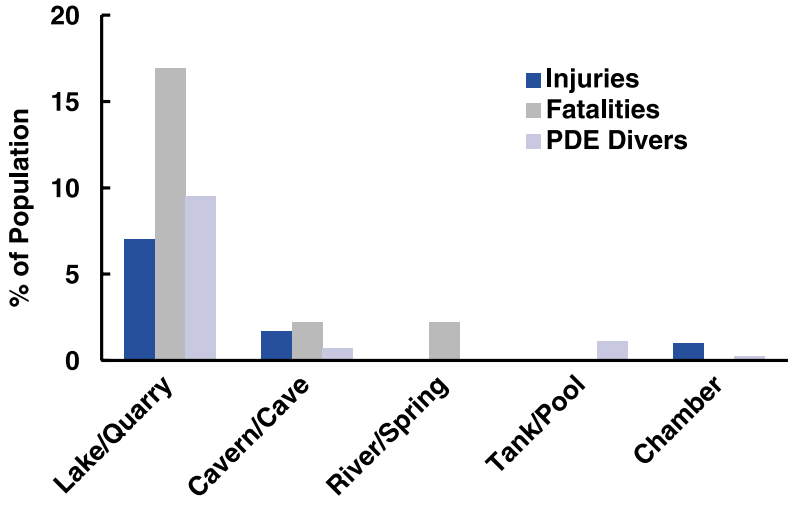


Fig 88
Comparison of dive environment by population.

Figures 89 and 90 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 be reported at shallower depths than injury or PDE dives for both the entire series as well as the last dive reported.

Fig 89
Comparison of mean maximum depth in series by population.

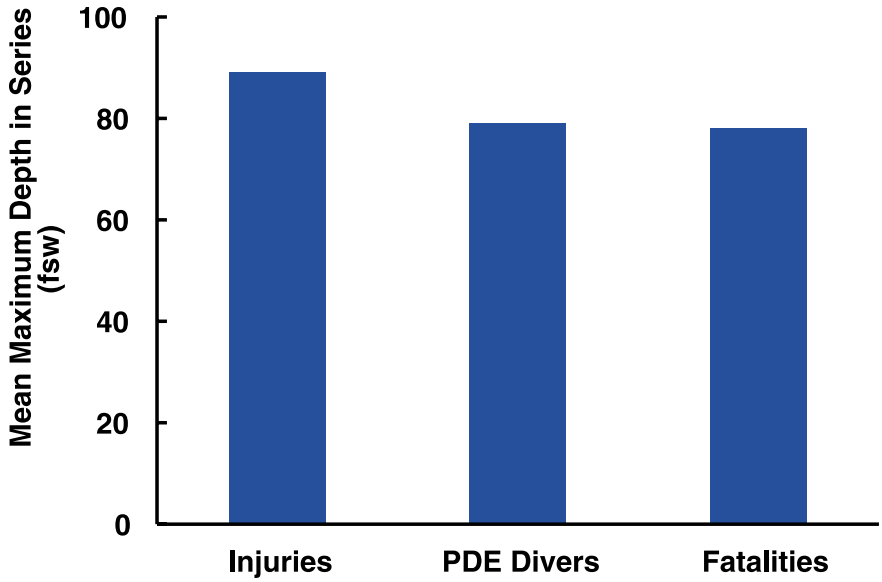
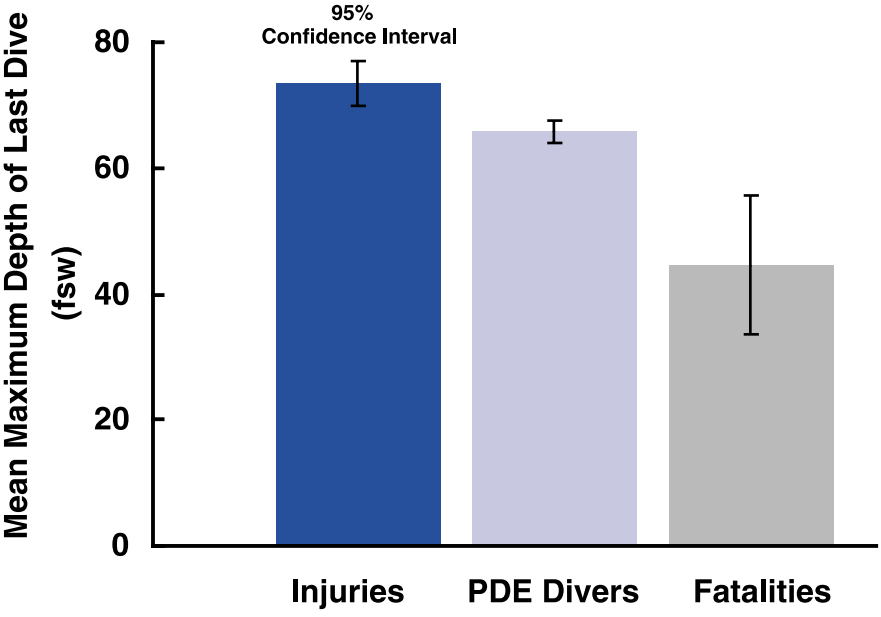


Fig 90
Comparison of mean maximum depth for the last dive by population.



Figures 91 and 92 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 fatality population than for the injury or PDE groups. Average number of dives per day was not available for the fatality population. The PDE population reported three dives per day on average versus two point five (2.5) dives per day for the injury population.

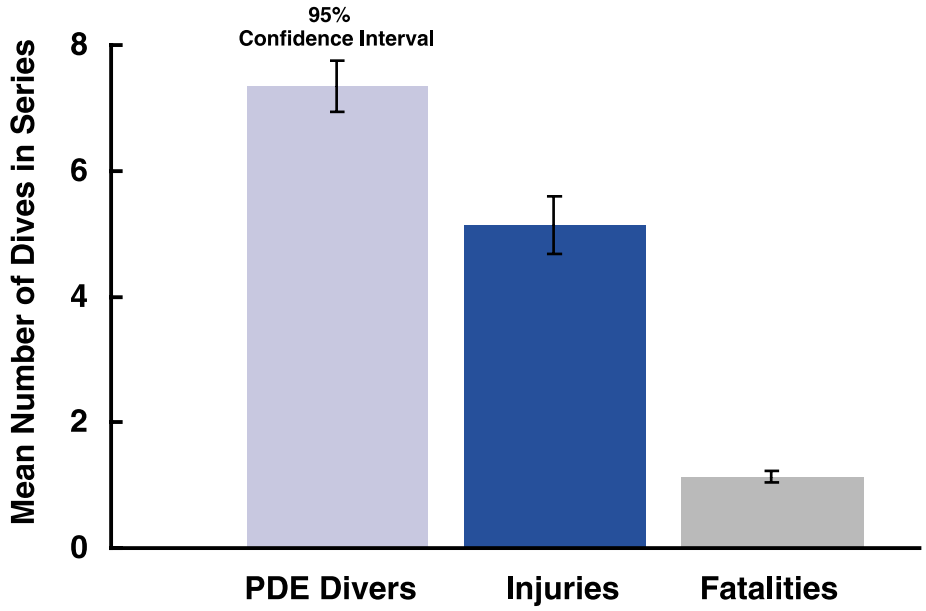


Fig 91
Comparison of total number of dives in series by population.

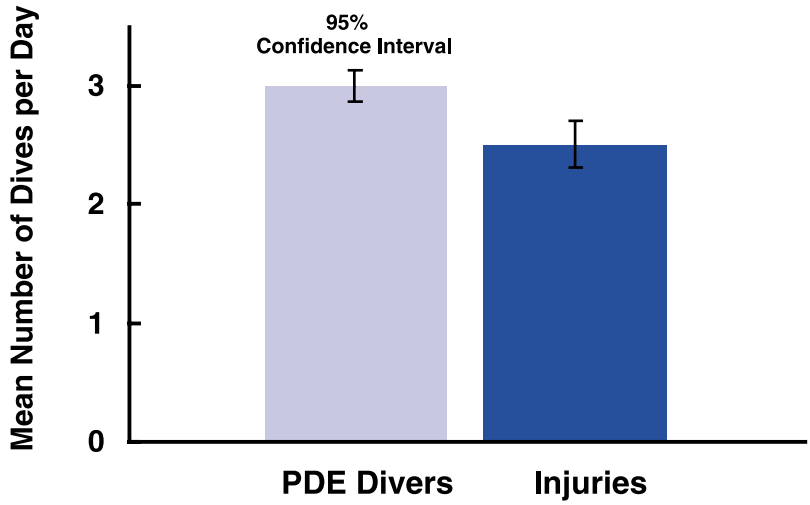


Fig 92
Comparison of number of dives per day by population.

Figure 93 shows a comparison of the distributions of the total number of days in the series for PDE and dive 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 injury populations, most likely due to the large proportion of six-day series in the PDE group. This probably reflects PDE dives collected on liveaboards.

Fig 93
Comparison of the distributions of number of days diving by population.

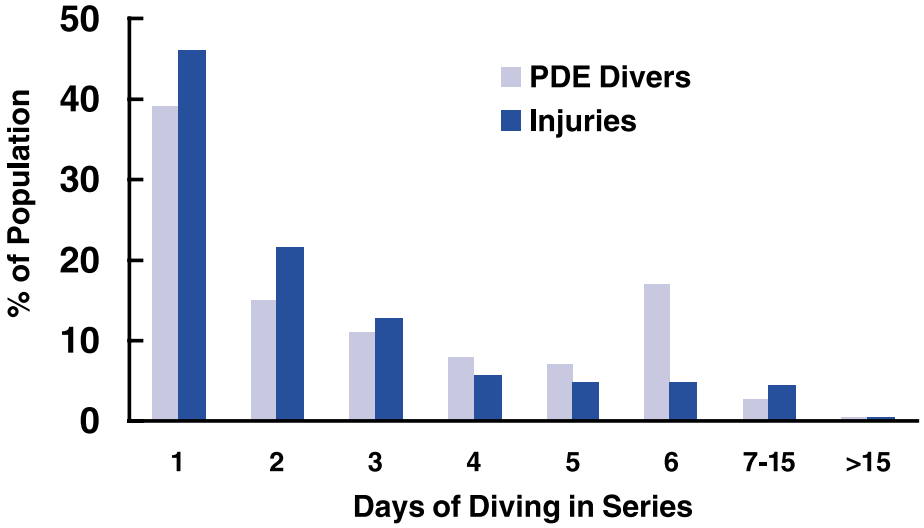
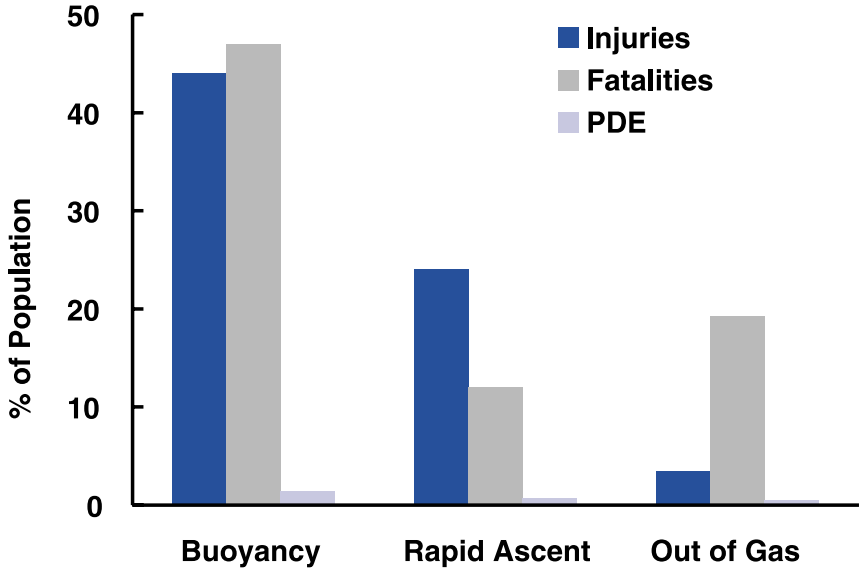


Figure 94 shows that there were large differences between populations with regard to difficulty maintaining buoyancy, rapid ascents, or running out of gas. The incidences of problems in the three populations were significantly different.

Fig 94
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 2000. Figure 95 shows the distribution of diving activity within the three populations and three categories of breathing gas. In more than 80 percent for all populations, air was the most common gas. Thirteen percent of PDE divers used nitrox, while nitrox was used by only 7.9 percent of injuries and 2.4 percent of fatalities.

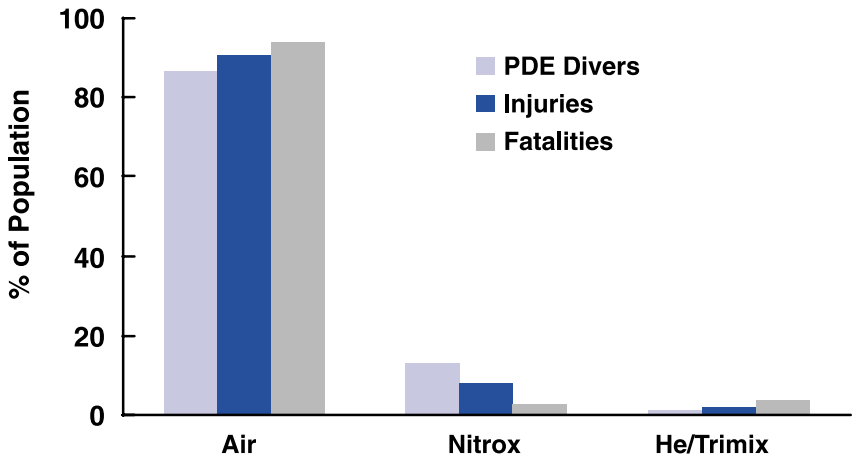


Fig 95
Proportions of air, nitrox and heliox or trimix divers among fatalities, injuries and PDE divers (1,041 PDE Divers, 711 Injuries, 83 Fatalities).

The percentage of female air divers was as great as 30 percent among injured divers and as low as 17 percent among fatalities (Figure 96). No females died while diving and breathing nitrox or heliox/trimix.

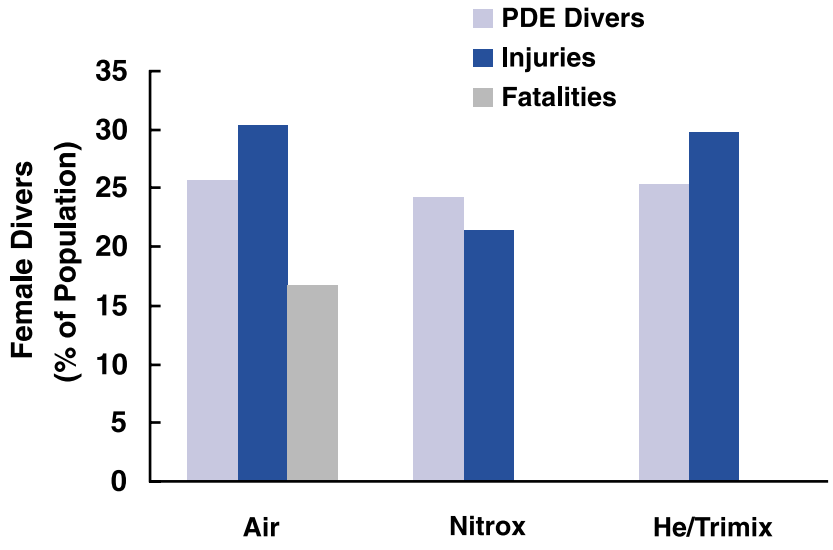


Fig 96
Proportions of female divers (1,037 PDE Divers, 707 Injuries, 83 Fatalities).

Figure 97 shows the mean ages of the population and breathing gas groups. The mean age of divers who died was 7-10 years greater than the mean age of injured divers.

Fig 97
Mean diver age (1,014 PDE Divers, 564 Injuries, 82 Fatalities).

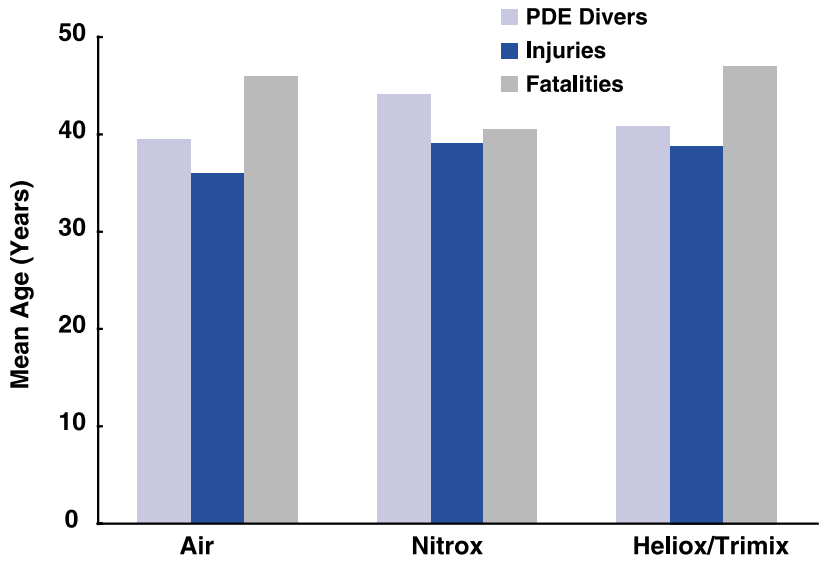


Figure 98 shows the mean years since initial diver certification. PDE divers who used heliox or trimix appeared to have the most experience as measured by their years since initial certification.

Fig 98
Mean years since certification (1,012 PDE Divers, 643 Injuries, 44 Fatalities).

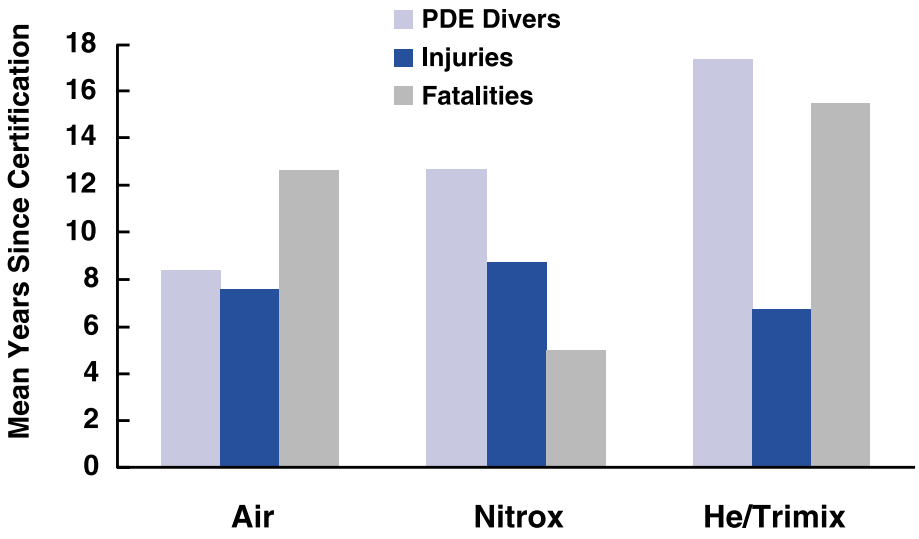


Figure 99 shows the mean number of days diving in the dive series for PDE divers and injured divers. For air and nitrox dives, PDE divers dived about half a day more than did injured divers. While explicit data on days of diving were not available for fatalities, most fatalities appeared to occur on the first day.

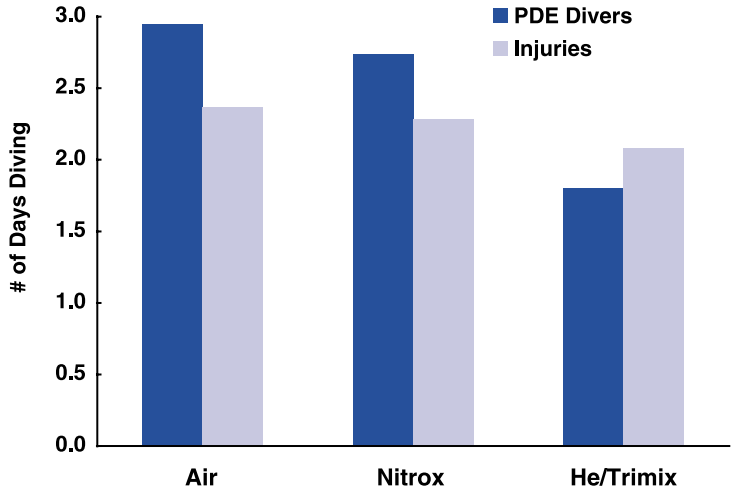


Fig 99
Mean days of diving in the dive series (1,041 PDE Divers, 669 Injuries).

Figure 100 shows the mean number of dives in the dive series. For air and nitrox, injury-free PDE divers made two more dives than did injured divers. Divers who died usually did so on the first dive, suggesting that experience was a relevant factor.

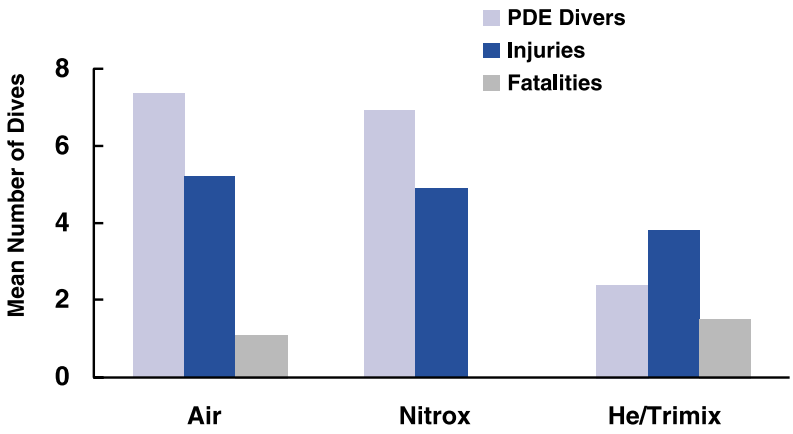


Fig 100
Mean number of dives in the dive series (1,041 PDE Divers, 669 Injuries, 83 Fatalities).

Figure 101 shows that injured divers had deeper maximum depths in their dive series for air and nitrox diving than did PDE divers. Divers who died had shallower maximum depths than did PDE divers or injured divers except for nitrox.

Fig 101
Mean maximum dive depth in the series (1,041 PDE Divers, 669 Injuries, 83 Fatalities).

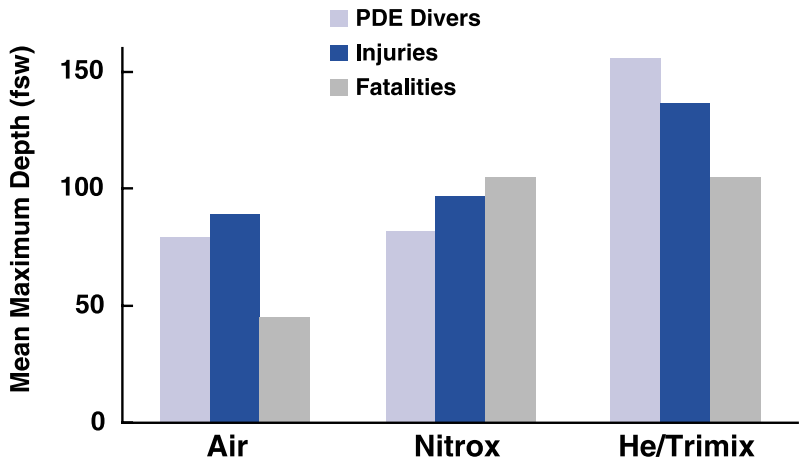


Figure 102 shows the distribution of dive computer use across the diving populations and breathing gases. Over 85 percent of all divers used dive computers.

Fig 102
Dive computer use (987 PDE Divers, 591 Injuries, 27 Fatalities).

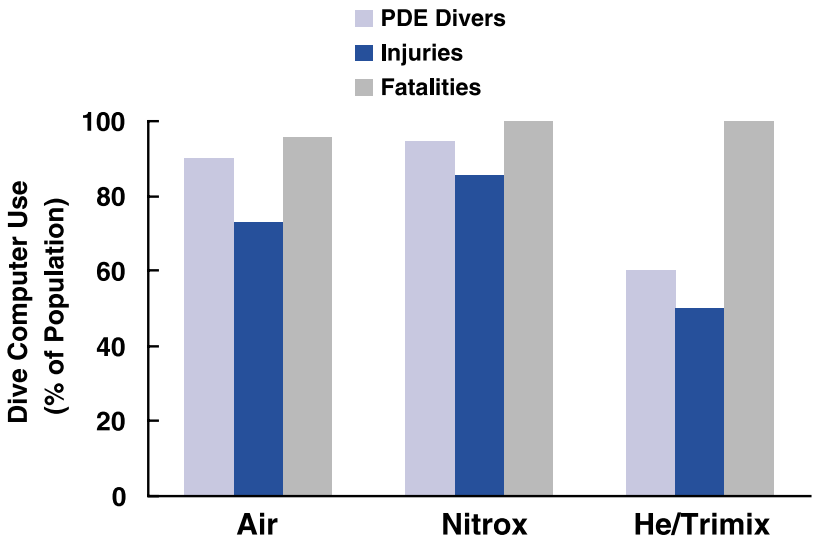


Figure 103 shows the maximum oxygen partial for PDE divers and injured divers who used nitrox breathing gases. No PDE diver had a PO_2 of greater than 1.2 atm, while injured divers had PO_2s as high as 1.9 atm.

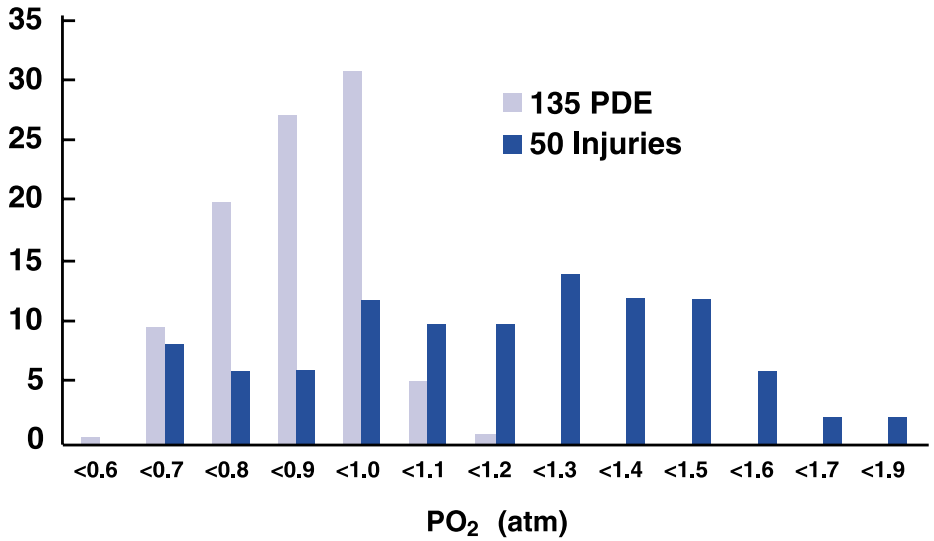
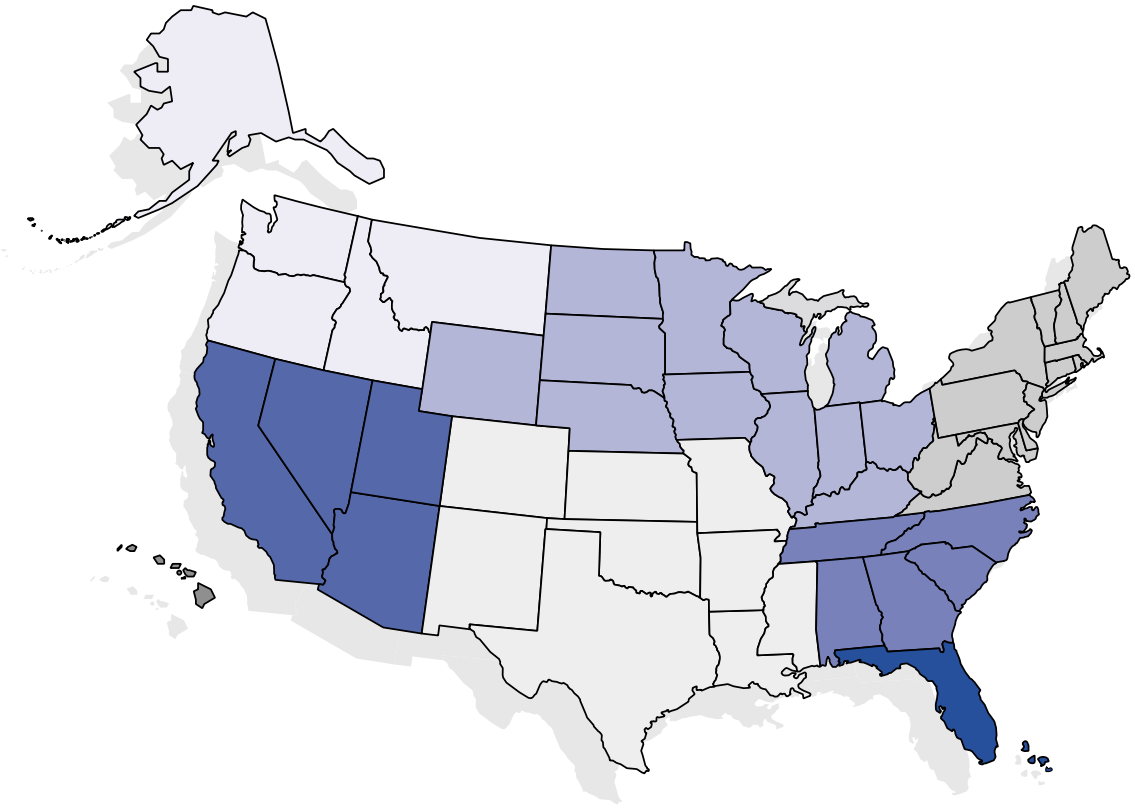


Fig 103
Maximum oxygen partial pressure (PO_2) during nitrox diving for PDE divers (135 PDE Divers, 50 Injuries).

INJURIES & FATALITIES BY REGION & STATE 2000

(Total number used in report analysis)



	Fatality	Injury
Southeast Region	**6**	**13**
Alabama	2	0
Georgia	0	1
North Carolina	3	11
South Carolina	1	1
Tennessee	0	0
Southwest Region	**15**	**38**
Arizona	0	0
California	14	31
Nevada	1	4
Utah	0	3
Northeast Region	**6**	**30**
Connecticut	0	0
Delaware	0	3
Maine	0	0
Maryland	1	1
Massachusetts	2	1
New Hampshire	0	0
New Jersey	1	15
New York	1	3
Pennsylvania	0	1
Rhode Island	1	1
Vermont	0	0
Virginia	0	5
West Virginia	0	0

	Fatality	Injury
Gulf Region	**3**	**11**
Arkansas	0	0
Colorado	0	1
Kansas	0	0
Louisiana	0	1
Mississippi	0	0
Missouri	0	0
New Mexico	1	0
Oklahoma	0	1
Texas	2	8
Midwest Region	**11**	**15**
Illinois	2	1
Indiana	1	0
Iowa	0	2
Kentucky	0	0
Michigan	4	7
Minnesota	1	1
Nebraska	0	0
North Dakota	0	0
Ohio	0	2
South Dakota	0	0
Wisconsin	3	2
Wyoming	0	0

	Fatality	Injury
Northwest Region	**5**	**55**
Alaska	2	0
Idaho	0	0
Montana	0	0
Oregon	1	3
Washington	2	52
Pacific Region	**8**	**23**
Hawaii	8	23
U.S. Territories	0	0
Caribbean Region	**23**	**182**
Florida	11	113
Caribbean	12	69
Mexico/Central America Region	**7**	**133**
Mexico	6	108
Central America	1	25
Other	**7**	**27**
Canada	5	5
Western Pacific	2	20
Middle East	0	1
Europe	0	1

2001 Publications

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PJ Denoble, C Sanchez, A Fostervold, OM Haukenes, A Brubakk, W Gerth. Diving patterns in lobster fisherman of Isla Mujeres, Mexico. Undersea and Hyperbaric Medicine 28(Suppl) 23, 2001.

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M Lang (ed.). DAN Nitrox Workshop Proceedings. Divers Alert Network, Durham, NC; 2001.

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RD Vann, PJ Denoble, DM Uguccioni, JJ Freiberger. Nitrox diving. Undersea and Hyperbaric Medicine 28(Suppl) 73, 2001.

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