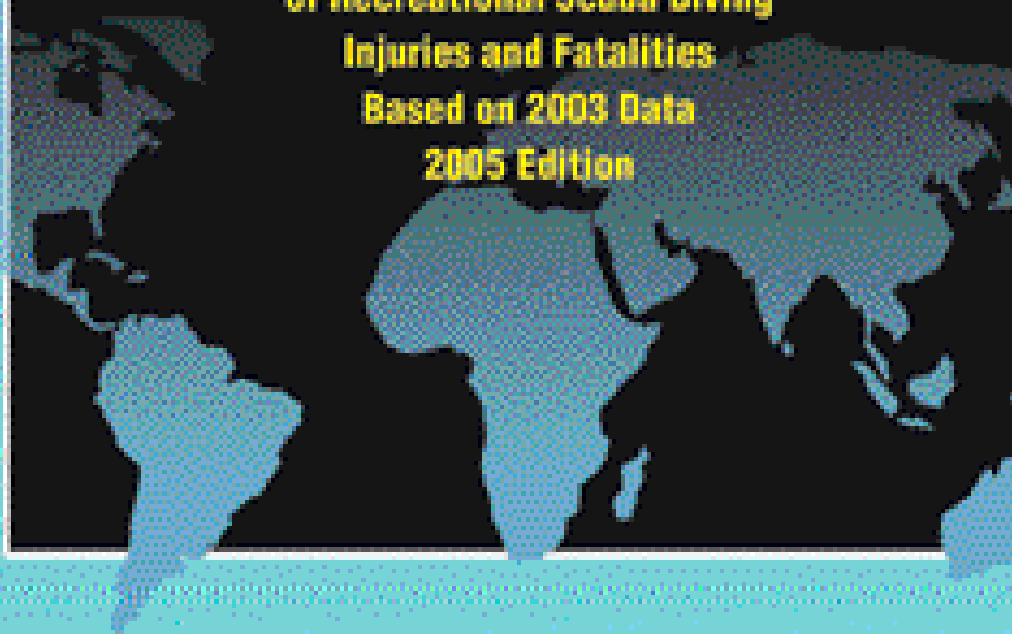




# **Report on Decompression Illness, Diving Fatalities and Project Dive Exploration**

**DAN's Annual Review  
of Recreational Scuba Diving  
Injuries and Fatalities  
Based on 2003 Data  
2005 Edition**



# Report on Decompression Illness, Diving Fatalities and Project Dive Exploration

The DAN Annual Review of Recreational Scuba Diving Injuries and Fatalities.  
Based on 2003 Data. 2005 Edition by Divers Alert Network.

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DAN Report on Decompression Illness, Diving Fatalities and Project Dive Exploration: 2005 Edition  
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The DAN Annual Review of Recreational Scuba Diving Injuries and Fatalities  
Based on 2003 Data. 2005 Edition by Divers Alert Network

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## Project Dive Exploration Dive Profile Collection for 2003 (collectors and number of dives)

### DATA COLLECTION CENTERS

Nekton Rorqual (Caribbean) 6,303  
Nekton Pilot 6,492

### DAN INTERNS (Summer 2003)

Ross Davenport 976  
Lindsay Fair 545  
Matthew Hall 1,293  
Matthew Holzmann 269  
Alecia Kozbial 1,097  
Kathleen Murray 293  
Sally Slaughter 1,425  
Alexander Tanz 769

### RECREATIONAL DIVE PROFESSIONALS PROJECT COZUMEL, MEXICO

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### CAYMAN ISLANDS

Participating Dive Retailers:  
Brac Reef Divers  
Cayman Diving Lodge  
Dive Tech & Cobalt Coast  
Don Foster  
Eden Rock  
Fisheye  
Little Cayman Beach Resort / Reef Divers  
Tortuga Divers

### Brazil

Atlantis Divers 1,865

### INDEPENDENT FRCS

Total Dives Collected: 2,456  
Dave McKay Brian Basura  
Jurgen Galicia Robert Eichholtz, Jr.  
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# DAN Regions and Regional Coordinators for Hyperbaric Treatment

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

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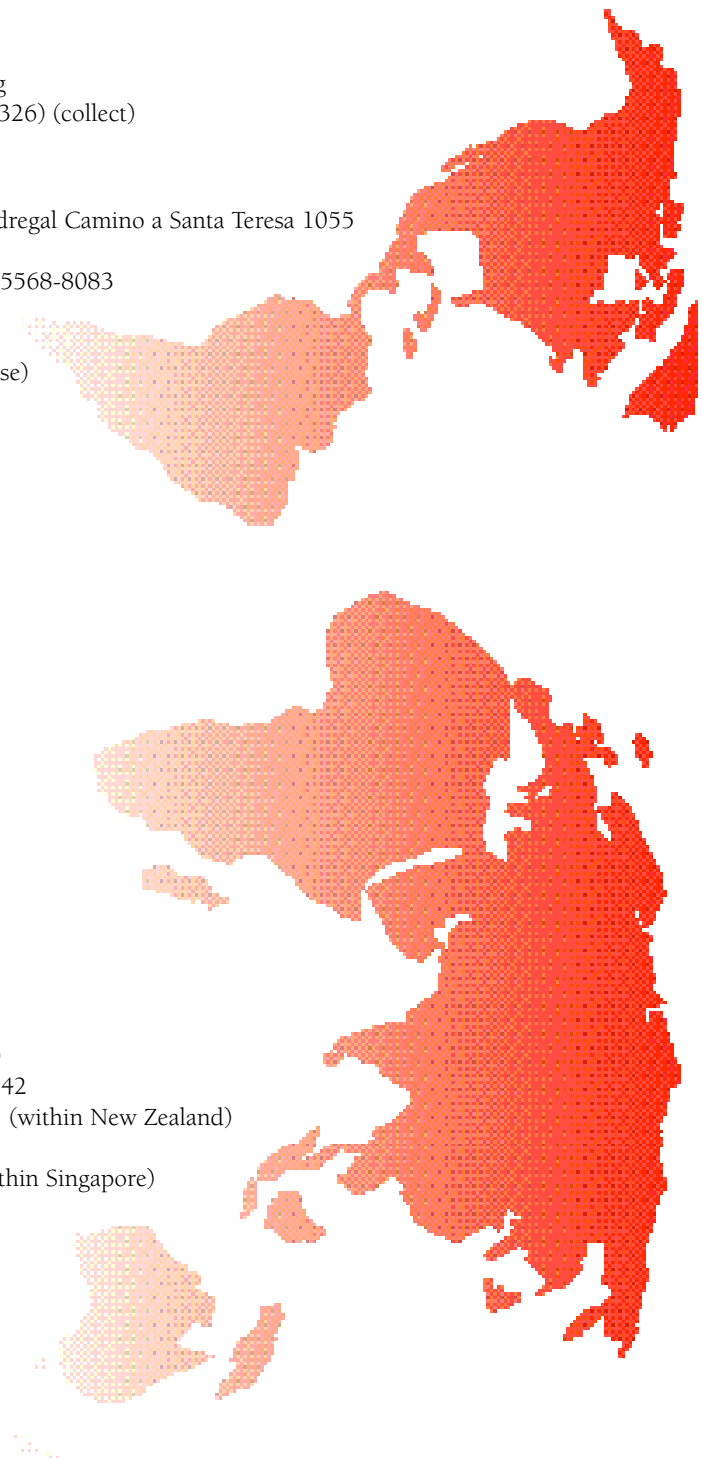
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# DAN - Your Dive Safety Association

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 Systems in Durham, N.C., and is supported by the world's largest membership association of divers.

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

## DAN America's Services to the Recreational Diving Community

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

The 24-Hour Diving Emergency Hotline is DAN's premier service. DAN medics and physicians offer emergency consultation and referral services to injured divers worldwide. In 2004, DAN answered 2,988 calls for assistance on its Diving Emergency Hotline.

DAN's Medical Information Line at +1-919-684-2948 (or 1-800-446-2671 toll-free in the United States and Canada) is available weekdays from 9 a.m. to 5 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](http://www.DiversAlertNetwork.org) — where they can find answers to general questions on dive fitness and health.

## DAN – Your Dive Safety Association

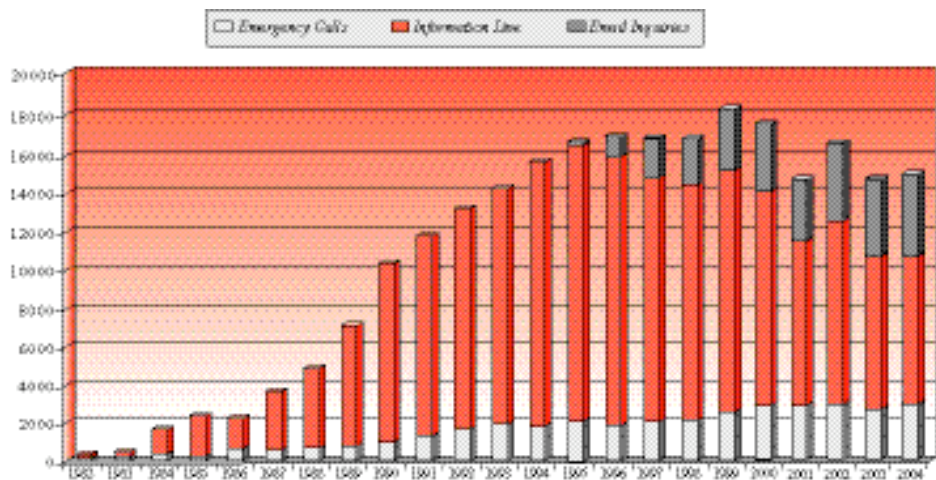
When divers have questions about their health in relation to diving, if they need to find a dive physician in their area, or if they have questions on medicines and diving, diving after surgery or other dive-related issues, DAN's medical information specialists are there to help.

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

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

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. As of September 2004, DAN Medicine received more than 10,000 information inquiries, including 6,755 information calls, 2,988 emergency line calls and 3,258 emails. Since its beginning in 1980, DAN has helped 213,961 callers through these services. Combined with calls to the 24-Hour Diving Emergency Hotline, the number climbs to 253,067.



### **DAN 24-Hour Diving Emergency Hotline with Immediate Insurance Verification**

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

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



## DAN Diver Health and Safety Research

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

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

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

## The Annual Diving Report

The annual diving report is based on data from diving injuries, fatalities and Project Dive Exploration (PDE) dive data. DAN Medicine and Research have published the annual diving report since 1987. Initially, it was a report on injuries and fatalities only. It now includes the dive profiles from PDE, in which injuries are rare. The report has shifted focus over the last few years to include more comparison between the three different populations of injury, fatality and PDE divers. As more data become available from all three sources, a comparative analysis will investigate risk factors for diving injuries and fatalities.

The original purpose of the report — describing the demographics of the cases and providing case summaries — will continue to be important. The report has also grown to include nitrox and mixed-gas diving injuries and deaths, because these gases have increased in use in the recreational population over the past few years. Copies of current fatality, injury and dive incident reports are available through DAN Research at 1-800-446-2671 or +1-919-684-2948 ext. 260. Diving Reports from 2001-2004 are available on the DAN website ([www.DiversAlertNetwork.org](http://www.DiversAlertNetwork.org)) at no cost to DAN members and have been downloaded by more than 150,000 visitors to the site. Printed copies are available for purchase to both members and non-members.

## Diabetes and Diving Project

DAN's project to determine the relative safety of divers with insulin-requiring diabetes was completed in 2001, and a scientific paper was published in the Undersea Hyperbaric Medical Journal (see references). In 2005, Research will also publish the results in an Alert Diver article. On June 19, 2005, DAN and the Undersea and Hyperbaric Medical Society (UHMS) will hold a joint workshop on diabetes and diving during the annual UHMS scientific meeting. Interested parties from the diabetes and diving field will be invited to present their research and participate in a discussion about the future of diabetes and diving.

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



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

## **Flying After Diving (FAD) Study**

In 1999, DAN completed the first phase of a study of flying after scuba diving. This was part of an effort to investigate what surface intervals after diving were safe prior to flying aboard a commercial airliner. In May 2002, DAN hosted the FAD workshop, which included representatives from the recreational diving industry and government diving agencies. The workshop reviewed all available data on flying after diving and agreed upon revised flying after diving guidelines for recreational diving that were first published in the November / December 2002 issue of Alert Diver. The full workshop proceedings were published in 2004 as a DAN Report and are available for purchase from DAN (ISBN # 0-9673066-4-7).

A second flying after diving study, funded by the U.S. Navy, began in May 2002. This study is investigating shorter and longer dive profiles that had not previously been tested.

## **2002 Consensus Guidelines for Flying After Recreational Diving**

The following guidelines are the consensus of attendees at the 2002 Flying After Diving Workshop. They apply to air dives followed by flights at cabin altitudes of 2,000 to 8,000 feet (610 to 2,438 meters) for divers who do not have symptoms of decompression sickness (DCS). The recommended preflight surface intervals do not guarantee avoidance of DCS. Longer surface intervals will reduce DCS risk further.

For a single no-decompression dive, a minimum preflight surface interval of 12 hours is suggested.

For multiple dives per day or multiple days of diving, a minimum preflight surface interval of 18 hours is suggested.

For dives requiring decompression stops, there is little evidence on which to base a recommendation, and a preflight surface interval substantially longer than 18 hours appears prudent.

## **Project Dive Exploration**

Project Dive Exploration (PDE) uses recording dive computers to collect information about the depth-time profiles of volunteer recreational divers. As of December 2004, PDE had collected more than 101,983 dive profiles since beginning data collection in 1995. This report is based on data collected during the 2003 calendar year (26,767 dives).

The goals of PDE include creating a database of both safe dives and dives that result in injuries. This will help provide insight into the behavior, dive profiles and characteristics of recreational divers and their risks of decompression illness (DCI). Since its beginning, PDE has shared goals and methodology with Dive Safety Lab (DSL), a similar program developed and conducted by DAN Europe.

With the encouragement of International DAN, both programs now share the same Information Technology (IT) platform that allows data to be merged. Joining the efforts and data will accelerate the research and provide more power to our analysis. Dive computer manufacturers Cochran, Suunto, Uwatec / Scubapro, DiveRite and dive recorder manufacturer ReefNet have strongly supported PDE. In 2004, two new dive computer manufacturers joined the project – both Oceanic and the VR-3 dive computers are now compatible with PDE.

Cochran, DiveRite and Uwatec have dive log software that allows divers to email their PDE data directly to DAN. Suunto and ReefNet are working on this capability within their software. Volunteer Field Research Coordinators (FRCs) and Data Collection Centers (DCCs) are responsible for gathering PDE data. (See Page 2 for a list of FRCs and DCCs from 2003 and 2004.)

Since 1998, DAN and Nekton Diving Cruises have been working closely together on PDE.

Divers who wish to participate in PDE aboard the liveaboard vessels Nekton Pilot and Nekton Rorqual should contact:

- Nekton Diving Cruises: call 1-800-899-6753 or visit [www.nektoncruises.com](http://www.nektoncruises.com)

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

## DAN Research Internship Program

The DAN Research Internship Program began in 1999 with three objectives:

- expand Project Dive Exploration data collection;
- provide experiences that might motivate young people towards careers in diving science or diving-related fields; and
- educate the diving public about DAN and PDE.

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

In 1999 the first DAN Research Intern collected more than 900 PDE dives at Discovery Diving in Beaufort, N.C. Since 2000, DAN has trained a total of 30 interns who have collected PDE data on the U.S. east and west coasts plus the Gulf of Mexico, Caribbean and South Pacific.

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

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

In 2003 DAN trained seven interns from the United States and placed them in popular diving locations in the U.S., Caribbean and the South Pacific. These interns collected 6,667 dives in three months. For the 2005 summer program, DAN will plan on six to eight interns in various locations around the diving world. Also in 2005, DAN America will work with our international partners in South Africa to build an internship program in their areas. This will add to the ever-growing PDE database and begin to offer varied diving practices and environments.

Many DAN Business Members have volunteered to be Host Diving Facility for the summer Interns. A host facility allows the intern access to their divers, a space to work and helps DAN promote the PDE and internship program. For application procedures or to learn more about being a host dive facility, contact the DAN Research department at 1-800-446-2671 or +1-919- 684-2948 ext. 627, or visit the DAN website at [www.DiversAlertNetwork.org/research](http://www.DiversAlertNetwork.org/research).

### **Recreational Dive Professionals Study**

The Recreational Dive Professionals Project (RDP), a subset of Project Dive Exploration, began in 2003. It is designed to learn more about the diving style and dive profiles of dive professionals. For purposes of the study, a dive professional is defined as a recreational scuba diver who is currently working professionally in the diving industry as a dive instructor, dive-master, dive guide, videographer or photographer.

The RDP Project was initiated because of data collected in 2001 by three dive guides in Cozumel who were serving as PDE Field Research Coordinators. These data suggested that the DCS incidence among dive guides was high compared to other dive groups. The objective of the RDP is to determine if this preliminary observation was valid and, if so, what the cause might be. The RDP will include dive professionals from Mexico, the Cayman Islands and Fernando de Noronha, Brazil.

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

### **Dive Computer Recognition Program**

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

The purpose of the Dive Computer Recognition Program is to augment participation in PDE by increasing awareness of all dive computer users. To date, the seven participating manufacturers (Cochran, DiveRite,

Suunto, Uwatec / Scubapro, Oceanic, Aeris, and the VR-3) are distributing their products worldwide with an announcement that their dive computers are compatible with PDE. The Sensus depth-time data logger manufactured by ReefNet and the Cochran DDR data recorder are also PDE-compatible.

## Rebreather Presentation

Self-contained recirculating underwater breathing apparatus, better known to sport divers as rebreathers, have been in use for more than 120 years, principally by the military, but increasingly during the past 50 years by recreational divers. A PowerPoint presentation on the principals, history, and operating characteristics of rebreathers was made available to DAN members at no cost on the DAN website in 2004.

## DAN's Support to the Dive Medical Community

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

In 1996, DAN broke ground in the field of dive injury treatment and insurance, by creating a Diving Preferred Provider Network (DPPN) of hyperbaric chambers to help manage the costs of recompression treatment and to make it easier for hyperbaric facilities to receive payment for services. In 2002, DAN Services Inc. teamed with Med-Care Plus to offer DAN Members and their families access to a medical savings plan that offers up to 25 percent savings at physicians' locations, hospitals and medical facilities nationwide. The plan is neither insurance nor intended to replace insurance, but it does have access for more than 500,000 physician locations, 75,000 medical facilities and more than 70 percent of the hospitals in the United States.

## DAN TRAINING PROGRAMS

### Oxygen First Aid for Scuba Diving Injuries

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

DAN and all major diving instructional agencies recommend that all divers be qualified to provide 100 percent oxygen in the field to injured divers.

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

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

## First Aid for Hazardous Marine Life Injuries

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

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

## Automated External Defibrillators (AEDs) for Scuba Diving

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

## Advanced Oxygen First Aid for Scuba Diving Injuries

This advanced-level program provides additional training for those individuals who have successfully completed the DAN Oxygen First Aid for Scuba Diving Injuries course within the past 12 months. It is designed to train DAN Oxygen Providers to use the MTV-100 or a Bag Valve Mask (BVM) while providing care for a non-breathing injured diver and activating the local emergency medical services (EMS) and / or arranging for evacuation to the nearest available medical facility.

This is not a stand-alone program. It is intended to train current DAN Oxygen Providers to provide oxygen using advanced-level skills.

## Dive Emergency Management Provider (DEMP)

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

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

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

### **Remote Emergency Medical Oxygen (REMO2)**

The DAN Remote Emergency Medical Oxygen (REMO2) system module supplements the DAN Oxygen First Aid in Scuba Diving Injuries course. Based on medical closed-circuit oxygen rebreather technology, the REMO2 device provides injured divers with high concentrations of emergency oxygen for extended periods. This training course instructs the Oxygen Provider in the use of the new DAN REMO2 system introduced in 2003.

### **Basic Life Support for Dive Professionals (BLSPRO)**

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

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

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

### **On-Site Neurological Assessment for Divers**

Approximately two-thirds of divers with decompression illness have evidence of damage to the nervous system. These signs are often vague and can go unrecognized by the diver. This can cause them to be dismissed as insignificant or not dive-related.

The DAN On-Site Neurological Assessment for Divers Provider ("DAN Neuro Provider") program refreshes the knowledge of the signs and symptoms of a dive emergency, identify when it is appropriate to conduct an on-site neurological assessment and train providers to conduct that assessment.

### **Diving Emergency Specialist (DES)**

DAN America has a new recognition program for trained divers called Diving Emergency Specialist (DES). The DES designation is a way to commend divers who have sought out the training they need to be prepared buddies and safer divers.

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



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

To earn this provider recognition, divers must hold current certifications in the following DAN Training courses (or their equivalents): Oxygen First Aid for Scuba Diving Injuries; Advanced Oxygen First Aid for Scuba Diving Injuries; First Aid for Hazardous Marine Life Injuries; and Automated External Defibrillators (AEDs) for Scuba Diving.

Divers wanting the DES designation must also hold a rescue-level certification or higher with a scuba training agency and current CPR and first aid certifications.

The DES rating also includes an Instructor rating for DAN Instructors and an Instructor Trainer rating for DAN Trainers. These two levels require holding DAN Instructor and/or Trainer credentials while demonstrating additional support of the DAN Training mission by conducting a minimum number of DAN courses in each of the required DES components.

### **DAN Online — [www.DiversAlertNetwork.org](http://www.DiversAlertNetwork.org)**

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

In 2004, DAN Research, along with the Information Technology and Communications departments, developed a new section of the website for research. The new section is separated into several different subtopics, including current projects; past projects with some results; news and events about what Research is currently doing and where we will be in the field; and downloads for individuals who want to participate in our research projects, particularly Project Dive Exploration and Flying After Diving. Another useful feature of the new section is the searchable database of Research papers and abstracts. This annual report can be downloaded free of charge from the DAN website by DAN Members. Please visit the research section of the DAN website at [www.DiversAlertNetwork.org/research](http://www.DiversAlertNetwork.org/research).

Another way to get current information about DAN Research is to subscribe to our quarterly electronic newsletter. It contains all the latest updates to research plus information on our field and chamber activities and much more. To subscribe, please email Jeanette Moore at [jmoore@dan.duke.edu](mailto:jmoore@dan.duke.edu).

### **DAN America Membership Services**

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



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

As of January 2005, more than 218,638 members belong to DAN in the United States, the Caribbean, Canada and Mexico, and the International DAN affiliates. DAN America members receive the following dive and travel benefits:

### **DAN TravelAssist**

One of the automatic benefits of membership with Divers Alert Network is DAN *TravelAssist*. This service provides up to \$100,000 emergency medical evacuation assistance for any injury or illness — dive-related or not — incurred at least 50 miles (80 km) from home by a DAN member or a DAN family member.

### **Alert Diver Magazine**

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

### **DAN Dive and Travel Medical Guide**

New DAN members receive a copy of the DAN Dive and Travel Medical Guide, a valuable reference on treating common diving and travel injuries and illnesses. The guide is also available through the DAN website or by calling DAN Membership Services at 1-800-446-2671 or +1-919-684-2948.

### **DAN Dive Accident Insurance**

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

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

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

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

## **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 items, is available in every issue of Alert Diver magazine. DAN products are also available for review and purchase on the DAN website at [www.DiversAlertNetwork.org](http://www.DiversAlertNetwork.org).

## **DAN Tags**

In 1995, DAN introduced the first medical ID tag created exclusively for divers: the DAN Tag™. Each clip-on tag is personalized with vital membership, medical and contact information in the unlikely event of a diving emergency. Only DAN Members can purchase the DAN Tag. A portion of DAN Tag sales goes directly to support DAN's Diving Emergency Hotline and DAN dive research. As of January 2005, more than 66,000 DAN Tags were in use.

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

## **DAN Business Membership Program**

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

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

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

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

## **DAN Diver Identification System (DIDS)**

With DAN's Diver Identification System (DIDS), dive leaders will always know that all divers have returned safely from their dives.

The Diver Identification System, supported by DAN Donors and DAN Corporate Sponsors, with Disney / The Living Seas as the principal supporter, evolved from DAN's popular Charter Boat Identification System. The revolutionary system now helps dive leaders track their divers at all open-water sites and on charter boats.

The system consists of one or two DAN Tag Boards each in red or white with 12 numbered DIDS Tags capable of tracking up to 24 divers at the same time.

The system works like this: at the beginning of each dive trip, the dive-master assigns each diver an individually numbered DIDS Tag. Before diving, the diver removes the tag and clips it to his or her buoyancy compensation device. After the dive, the diver unclips the tag and returns it to the board for crosschecking by the dive leader. The DIDS System in conjunction with another diver roll call procedure will help ensure that no diver is left in the water.

The DIDS is free of charge. To start using the DAN Diver Identification System, call the Business Membership Team at 1-877-532-6776 or email [bizmember@DiversAlertNetwork.org](mailto:bizmember@DiversAlertNetwork.org). To contribute to this program, call DAN Development at 1-800-446-2671 ext. 446 or email [Development@Divers.Alert.Network.org](mailto:Development@Divers.Alert.Network.org)

## 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](http://www.DiversAlertNetwork.org) — download the new roster and print it whenever you need it, or use the new online roster and email the student information directly to DAN. Either way, Instructors can provide their students with essential dive insurance that all open-water students should have.

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

Instructors who don't have access to a computer can call the DAN Business Membership team at 1-877-532-6776 or email [bizmember@DiversAlertNetwork.org](mailto:bizmember@DiversAlertNetwork.org) and request a free Student Membership Kit (product code 821-0300). For every student who signs up as a regular DAN member within six months of enrolling as a DAN Student Member, instructors or dive retailers receive a point they can use to purchase DAN safety products.

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

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

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

## **International DAN**

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

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

To help reach the increasing diving community in Latin America, DAN's International Department provides promotional, membership and training material in Spanish and Portuguese. Also, in 2001, DAN created a dedicated Spanish / Portuguese language emergency hotline (+1-919-684-9111) and a network of chambers and dive physicians to serve all of Central and South America. DAN also has sections on the DAN website in Spanish ([www.DiversAlertNetwork.org/s](http://www.DiversAlertNetwork.org/s)) and Portuguese ([www.DiversAlertNetwork.org/p](http://www.DiversAlertNetwork.org/p)).

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

## **DAN Development**

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

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

If you would like more information or assistance, please contact us at 1-800-446-2671 or +1-919-684-2948 ext. 446 or email [Development@DiversAlertNetwork.org](mailto:Development@DiversAlertNetwork.org). We can help you meet your philanthropic goals, while ensuring that divers continue to receive the best DAN can offer.

# 1. INTRODUCTION

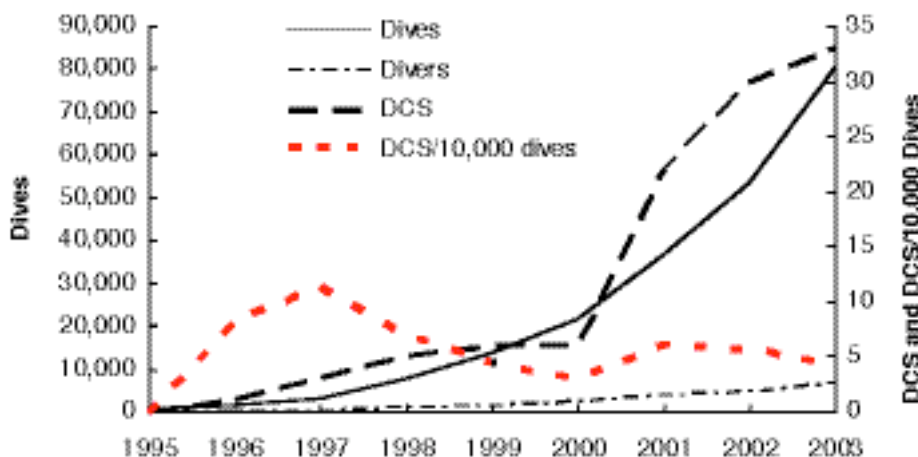
Divers Alert Network (DAN) collected data during calendar year 2003 about divers who were injured, divers who died, and divers in Project Dive Exploration for whom injury was rare. These populations are described below. Figure captions give the number of divers on which each figure was based as applicable.

## 1.1 Project Dive Exploration

Project Dive Exploration (PDE) is a prospective investigation of the medical history, depth-time exposure, and medical outcome of a sample of the diving population. PDE seeks to estimate the incidence of decompression illness (DCI) in this population and to investigate the relationship of DCS (see glossary for definitions of DCS, AGE and DCI) probability to the depth-time profile and diver characteristics. PDE also provides an injury-free control population that can be compared with the injury and fatality populations.

The PDE is funded by Divers Alert Network membership and donors. It was made possible by the development of the downloadable dive computer and depth-time recorders. PDE became practical with the support of the manufacturers Cochran, DiveRite, Suunto, Scubapro / Uwatec, ReefNet, Oceanic and VR3 who made their dive computers and recorders PDE-compatible.

Figure 1 shows the number of dives since data collection began in 1995 through 2003. To date, there have been more than 80,490 dives by 6,659 divers and 33 cases of DCI.



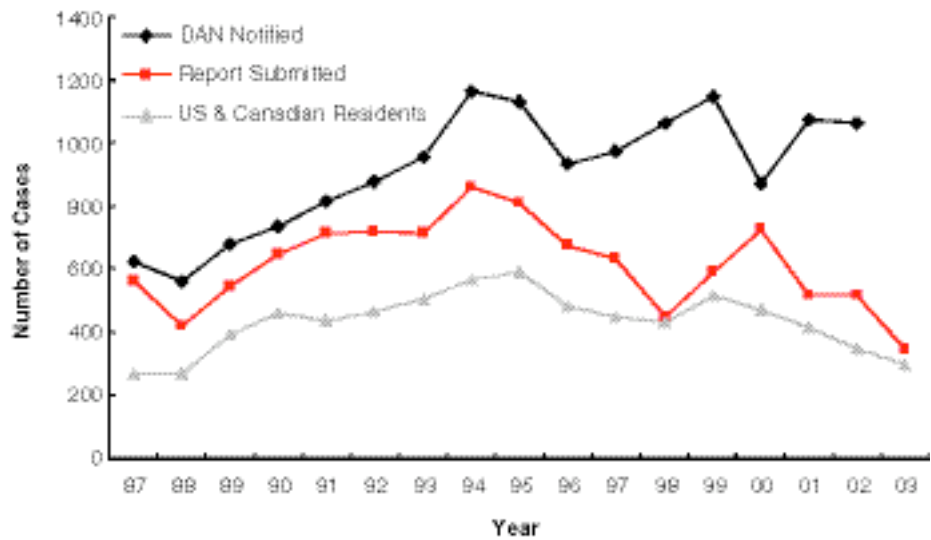
**Figure 1.1-1**  
Project Dive  
Exploration  
progress.

## 1.2 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 of which participating chambers notified DAN. 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 – who are those included in this report.

In 2003, DAN America received 394 reports of treated cases from 78 chambers. Sixty percent of reports pertained to DAN America members. In 297 cases, reports pertained to recreational divers who resided in the U.S. or Canada. These reports are described in subsequent sections. Reports by all chambers of the number of cases treated for 2003 ('DAN Notified') are incomplete and is not shown in Figure 2.

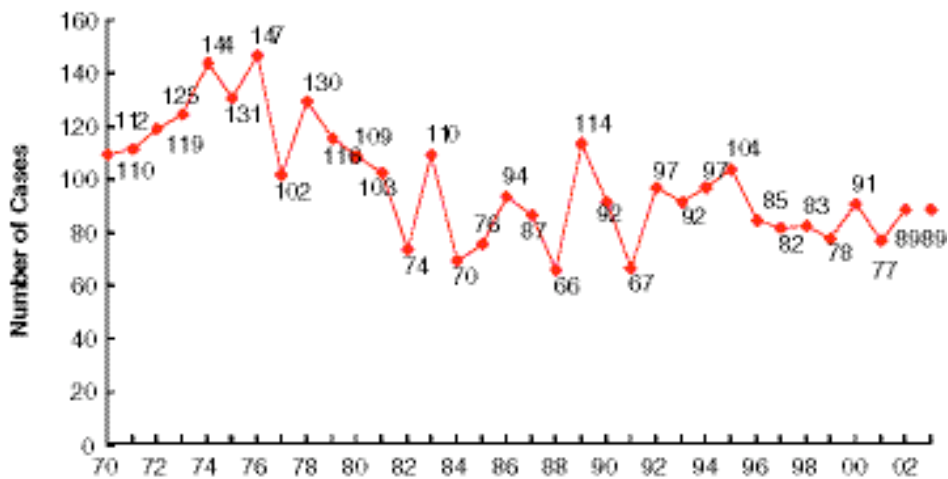
**Figure 1 .2-1**  
Annual record  
of dive injury  
cases.



## 1.3 Diving Fatalities

Figure 3 shows the annual records of U.S. or Canadian residents who died during recreational diving. DAN gathers information about diving fatalities, but as DAN is not an investigating agency, information gathering is restricted to interviews and record reviews. Thus, the collected information is unverified and frequently incomplete.

DAN followed up 108 cases of deaths among recreational USA and Canadian divers. These reports include 89 cases that were completed. Case summaries for all of these are presented in the Appendix.



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



## 2. Project Dive Exploration (PDE)

### 2.1 Introduction

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

DAN Research is continuing to address the scientific need for a database of recreational dives through Project Dive Exploration (PDE). PDE is an observational research study that collects and analyzes electronic pressure-time exposures from data-logging dive computers worn by recreational divers. In 2003, data collection was possible with four dive computers and one data recorder that are PDE-compatible: Cochran, DiveRite, Suunto, Uwaterc and Reefnet Sensus. In 2004, the standard data format was adopted by Oceanic and VR-3, widening the base of potential participants in the project.

Since its inception in 1995, PDE has recorded more than 80,439 dives. Thirty cases of decompression sickness (DCS) and two deaths have been associated with these exposures. The deaths were not felt to be DCS-related. In PDE, the diver's health status before the dive and at 48 hours after diving is linked to the digitally recorded pressure-time exposure. PDE specifically captures:

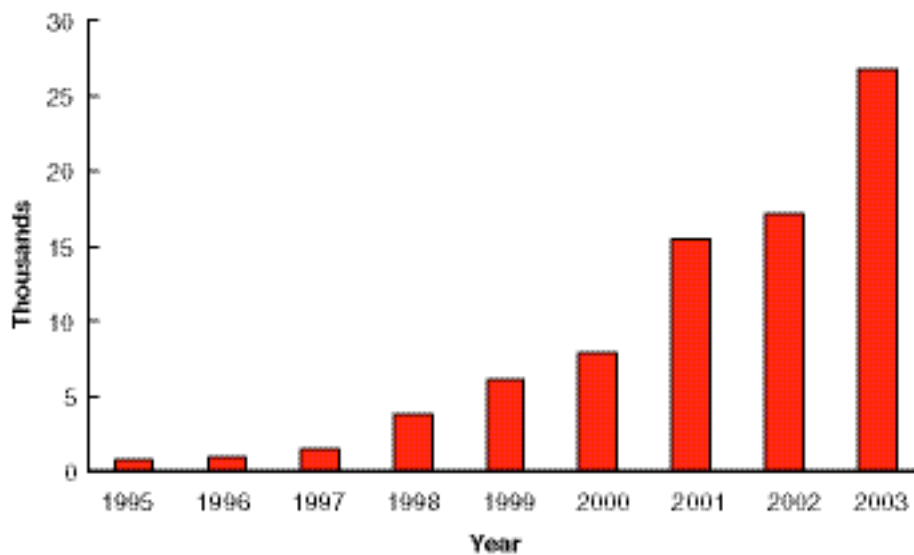
- 1) diver's demographic data;
- 2) diver's pre-existing medical data;
- 3) diver's digital dive pressure-time exposure data; and,
- 4) 48-hour post-exposure report on any medical outcome associated with the pressure exposure.

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

All participants in PDE must be certified recreational divers. If the diver is exposed to altitude during the 48-hour post-dive reporting period, this exposure becomes part of the recorded dive profile. Many divers participate under the guidance of a Field Research Coordinator (FRC), who coordinates the data collection and entry and submits the dive profiles to DAN. The FRC is a passive observer instructed not to interfere with the conduct of any dive. FRCs do not screen divers for symptoms of DCS, nor do they play any official medical role in the event of a dive accident. Divers are also encouraged to collect dive profiles on their own without the assistance of an FRC. Dive profiles downloaded from Cochran, DiveRite and Uwaterc computers can be emailed directly to DAN (dasdata@dan.duke.edu). Further information is available at the DAN website at [www.DiversAlertNetwork.org](http://www.DiversAlertNetwork.org).

## 2.2 PDE 2003

This report includes data from 1,903 divers, 2,703 dive series (defined as a group of dives separated temporally by less than 48 hours) and 26,767 dives collected in 2003 (Figure 2.2-1). The number of dives has increased by 57 percent in comparison to previous years. It is still a small sample of only a few segments of recreational diving, and it should not be used to make general statements about all recreational divers and dives in 2003. However, the subsets of collected data (Table 2.2-2, p. 25) seem to show similar characteristics as the same subsets in previous years, and we may be more confident that the data describe liveboard diving or diving in cold waters of Scapa Flow.



**Figure 2.2-1**  
Annual data  
collection  
progress since  
1995.

Decompression illness among participants is a rare event and varies from year to year. In the 2003 sample, only three participants were diagnosed with DCS and treated in hyperbaric chambers. The data collected on an annual basis continues to increase, bringing the total number of dives logged by PDE to 80,439 (Figure 2.2-2).

**Figure 2.2-2**  
**Cumulative**  
**number of PDE**  
**dives collected**  
**(1995-2003)**  
**(n=80,439).**

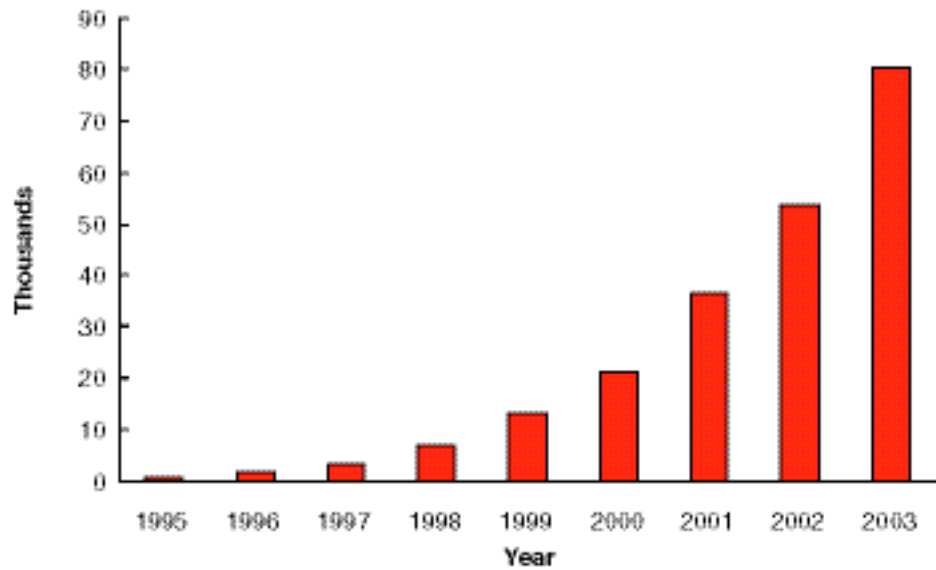


Table 2.2-1 shows an example of the breakdown and subgrouping of dives by providers of data. The contribution of year-round data collection centers established aboard the two Nekton Cruises boats doubled. They provided 49 percent of all PDE dives. The second largest contributors were DAN interns, who collected 24 percent of all PDE dives in 2003, up 32 percent from the previous year. The interns were deployed in areas of special interest that were not well represented in previous years. Data collection among recreational dive professionals increased 87 percent. Among independent FRCs that submit a complete dive log directly to DAN via the internet from their dive log application, data collection increased 59 percent. This feature was available in Cochran and DiveRite computers and their dive log software in 2003. Recently, it has become available in Uwaterc computers. This should significantly increase the contribution of independent divers in the future.

**Table 2.2-1**  
**Providers and**  
**their contribution**  
**of PDE data.**

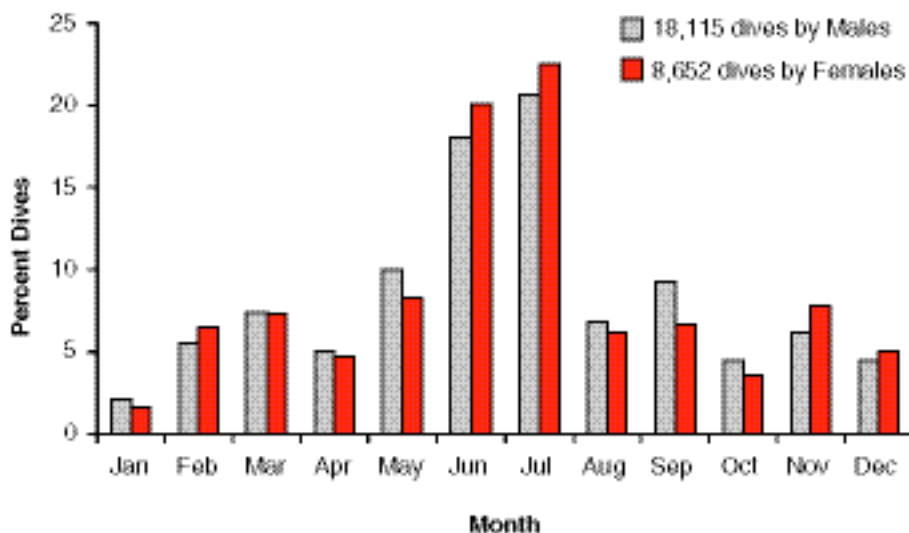
Source	2002	2003	% Dives Collected in 2003	% Increase 2003 / 2002
Liveaboard Collection Centers	6,593	13,046	49	98
DAN Interns	4,878	6,449	24	32
Scapa Flow, Scotland	2,795	2,476	9	-11
Recreational Dive Professionals	1,283	2,396	9	87
Independent FRCs	1,511	2,400	9	59
<b>Total</b>	<b>17,060</b>	<b>26,767</b>	<b>100</b>	<b>57</b>

Table 2.2-2 shows the four main subsets of dives. The subset Liveaboard represents data collected aboard Nekton and includes that collected by individual divers and by two interns working liveboards in the Pacific and in the Gulf of Texas. The latter con-

tribution is beginning to increase the diversity of liveaboard data. The subset Beach and Day Boat include dives collected in dive resorts from divers starting their dives from the beach or from charter boats on a half-day or day trip. Four of the interns were collecting in dive resorts on Cayman, Cozumel and Florida. The subset Cold-water Wreck Diving (CWWD) includes dives exclusively from Scapa Flow in Scotland. Individual divers dived mostly from liveaboards or from dive resorts in the Caribbean, and their data were assigned to groups as appropriate. The subset Recreational Dive Professionals represents dives collected in the beginning stage of the study designed to learn more about dive exposure and outcomes among dive instructors and dive guides. The relatively poor return on 48-hour post-dive reports in the Recreational Dive Professionals group indicates that this element of the effort must be improved.

Region	# Participants	% Participants	# Dives	% Dives	% with 48-Hr Report
Liveaboard	835	43.9	15,285	57.1	80
Beach and Day Boat	793	41.7	6,572	24.6	82
Cold-Water Wreck Diving	235	12.3	2,476	9.3	95
Recreational Dive Professionals	40	2.1	2,396	9.0	51
<b>Total</b>	<b>1,903</b>	<b>100</b>	<b>26,729</b>	<b>100</b>	<b>80</b>

Data collection was relatively constant for most of the year, with a peak in the summer months (Figure 2.2-3). Those peak months correspond to the greatest activity for recreational diving and presence of DAN Interns in the field. This has been a consistent finding over the six-year period from 1998 to 2003.



**Table 2.2-2**  
**Subsets**  
**of 2003 PDE**  
**data.**

**Figure 2.2-3**  
**Percentage**  
**of total dives**  
**recorded by**  
**month.**

## 2.3 Divers

The following information describes both the characteristics of the divers who participated in PDE in 2003 and the frequency of their diving exposure. Most of the volunteers (90 percent) contributed only one series of dives. The maximum number of dive series contributed by any one individual was 57. The median number of dives in each series was eight. Only 3 percent of divers participated with more than four dive series. These were mainly Recreational Dive Professionals or individual FRCs who were using DL7 Level 3-compatible dive computers and sending in all their dives throughout the year. Tables 2.3-1 through 2.3-3 describe the diving frequency of PDE participants

**Table 2.3-1**  
Number  
of series  
per diver.

# Series	Frequency	Percent
1	1,721	90.4
2 - 4	119	6.3
5 - 9	35	1.8
10 - 19	21	1.1
> 20	7	0.4
<b>Total</b>	<b>1,903</b>	<b>100</b>

**Table 2.3-2**  
Number  
of dives  
per diver.

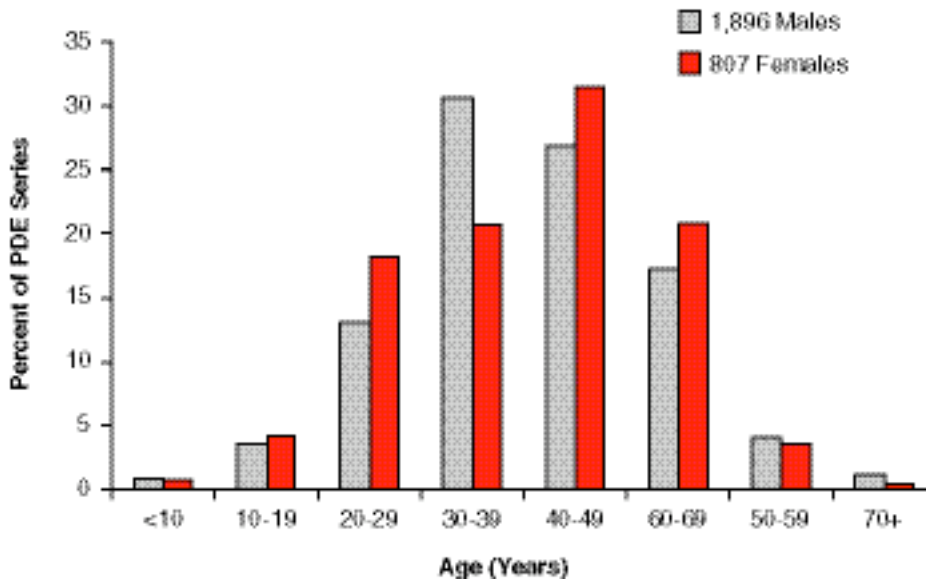
# Dives	Frequency	Percent
1	77	4.0
2 - 4	363	19.1
5 - 9	294	15.4
10 - 19	718	37.7
20 - 29	354	18.6
30 - 99	87	4.6
> 99	10	0.5
<b>Total</b>	<b>1,903</b>	<b>100</b>

**Table 2.3-3**  
Frequency  
of diving.

	Maximum	Mean	Median
# Dives / Day	9	2.6	2
# Days / Series	41	4	4
# Dives / Series	136	10	8

Dive series consisted of five to 29 dives in 72 percent of cases. Twenty-two percent of dives were done in short series of one to four dives, and only 5 percent of dives were completed in series of 30 or more.

The age and gender distribution for the 2003 PDE volunteers is shown in Figure 2.3-1. Most of the participants were between 30 and 50 years of age. Divers over age 50 represented 21.5 percent of the sample, and divers under age 20 represented only 4 percent. The number of teenage divers is shown in Table 2.3-4. Overall, women comprised 31 percent of all PDE divers. That is up from 29 percent in the previous year.



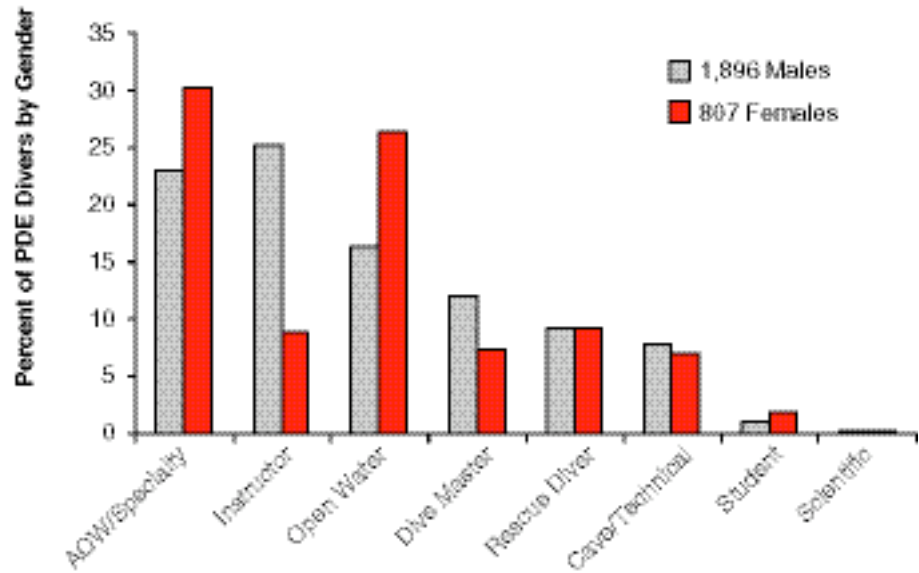
**Figure 2.3-1**  
Age and gender  
of divers for each  
dive series  
(n=2703).

Age	Number of Divers
19	10
18	17
17	13
16	15
15	13
14	7
13	8
12	2
11	2
10	1
<b>Total</b>	<b>88</b>

**Table 2.3-4**  
Age distribution  
of teenage divers  
in 2003 PDE sample  
(n=88).

Figure 2.3-2 illustrates the certification level by gender of divers. The group of advanced and specialty certifications was the largest, with 27 percent of divers. One percent of divers were students, and less than one-half percent of participants earned their certification as scientific, commercial or military divers.

**Figure 2.3-2**  
**Percentage**  
**of 2002 PDE**  
**volunteers**  
**by certification**  
**of divers and**  
**by gender.**



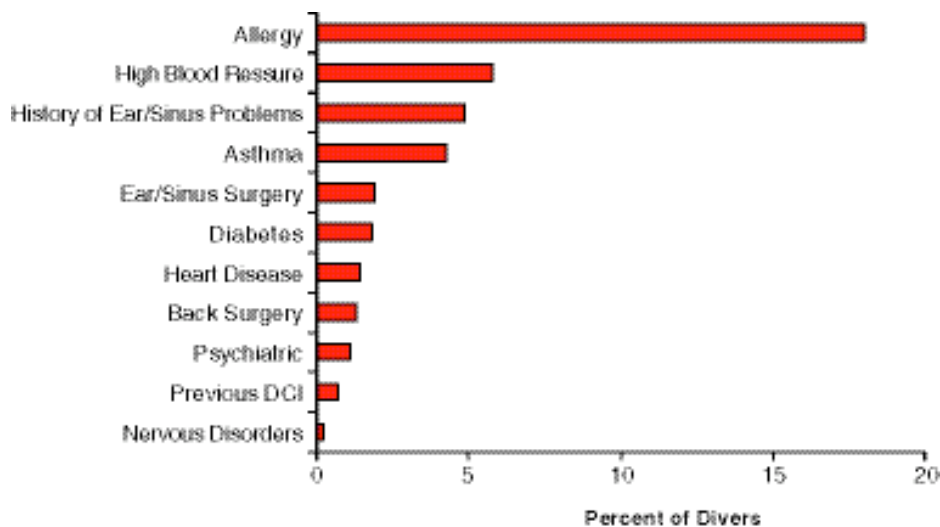
Sixty-one percent of the sampled divers had six or more years since initial certification, and 31 percent had five years or less (Table 2.3-5). PDE participants are mostly experienced divers with decreasing representation from new divers.

**Table 2.3-5**  
**Percentage**  
**of PDE volunteers**  
**by number**  
**of years since**  
**initial certification.**

Years since Certification	1998	1999	2000	2001	2002	2003
1	19.3	16.4	17.9	15.5	15.6	10.7
2	4.8	7.1	9.8	6.4	6.4	8.6
3	7.8	7.9	7.1	10.9	7.1	5.9
4	6.0	7.9	6.3	6.0	6.6	4.4
5	4.4	3.5	5.4	3.8	5.1	6.7
6-10	25.3	23.7	21.0	19.4	18.4	20.5
> 10	26.7	26.2	29.3	26.3	30.1	35.6



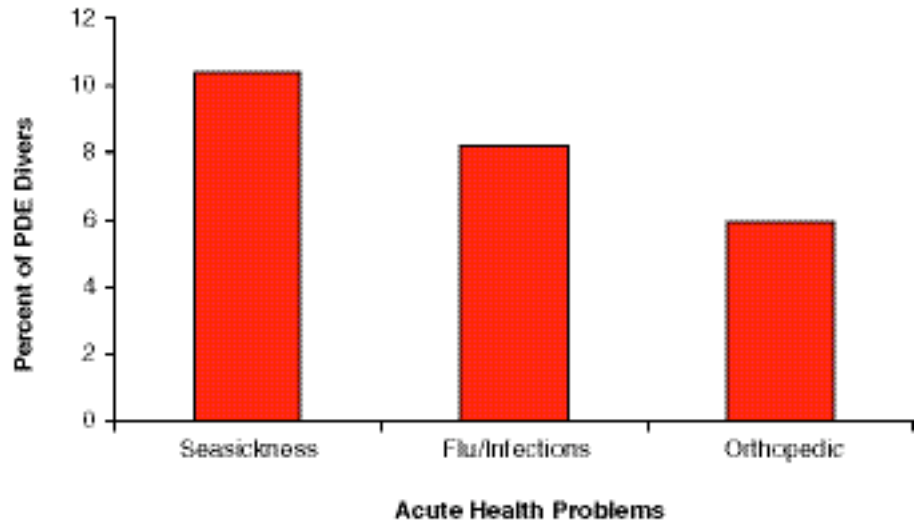
Figure 2.3-3 shows the chronic health conditions reported by the divers providing PDE data in 2003. Some divers reported more than one condition. As in previous years, seasonal allergies were the most frequently reported conditions in our sample (18 percent), followed by history of ear and sinus problems (13 percent). High blood pressure was reported in 7 percent of divers. Four percent of divers (83) reported asthma as a chronic health problem. Sixty-four percent divers with reported asthma used medications. Specifically, 48 divers used inhalers, five used oral drugs and five used both. A total of 1.2 percent of the sampled divers reported having diabetes (Type I or II). Less than 1 percent of participants reported having experienced DCI previously.



**Figure 2.3-3**  
Percentage  
of PDE volunteers  
listing the  
following chronic  
health conditions.

PDE divers were also questioned about acute medical problems they experienced before diving. Figure 2.3-4 shows some of the acute conditions recorded. Ten percent of divers were prone to seasickness, and most of them were taking medication against it. Bone- or joint-related conditions or injury, represented on Figure 2.3-4 as "orthopedic conditions," were reported by nearly 8 percent of divers. Minor complaints such as an upper respiratory infection (URI) were reported by 5 percent of divers.

**Figure 2.3-4**  
**Percentage**  
**of PDE divers**  
**reporting the**  
**following acute**  
**health problems**  
**before a dive.**



## 2.4 Dives

Most PDE data (98 percent) were collected during recreational diving in an ocean (saltwater) environment; 1.3 percent of PDE dive profiles came from freshwater diving. Only 72 dives were recorded in caves or caverns, and 12 dives were done in Antarctica.

Figure 2.4-1 shows the dive platform from which the PDE dives took place. The majority of PDE dive profiles were collected from liveboards (57 percent). This subgroup represents a valuable dataset of repetitive and multiday diving exposures. Thirty-four percent of dives were collected on charter boats that take divers for one day or half-day trips. Only 3 percent of the PDE dives were walk-in beach dives, and 4 percent were dives from small private boats.

**Figure 2.4-1**  
**Percentage**  
**of the PDE**  
**sample by dive**  
**platform**  
**(n=26,767).**

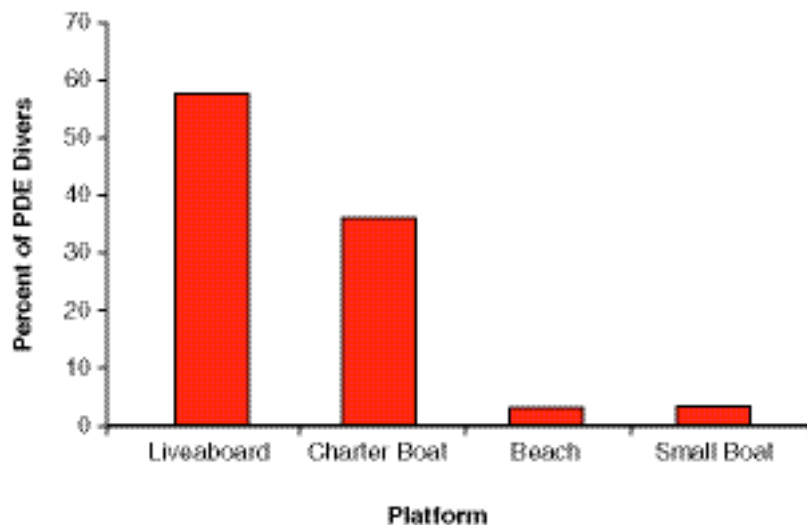
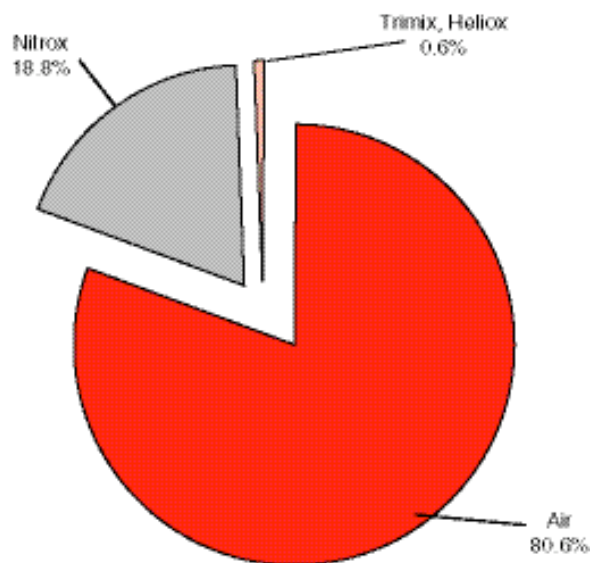
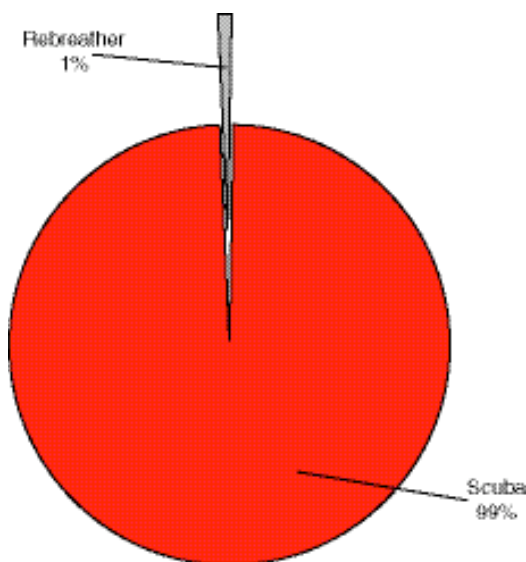


Figure 2.4-2 describes the breathing gas used by PDE volunteers in 2003. Air was used in the majority of dives (81 percent). Nitrox was used in 18 percent, and helium was part of the gas mix in less than 1 percent of the dives sampled. The fraction of captured dives using nitrox was significantly lower than in previous years, although the absolute number of nitrox dives did not decrease. This was due mainly to a large increase in number of liveaboard diving from the boats that did not use nitrox.



**Figure 2.4-2**  
Percentage  
of the dives by  
breathing gas.

Almost all of the PDE dives (99 percent) used open-circuit scuba breathing apparatus. Rebreathers were used in less than 1 percent and surface-supplied gear in 0.02 percent of the dives.



**Figure 2.4-3**  
Percentage  
of the dives by  
breathing gear.

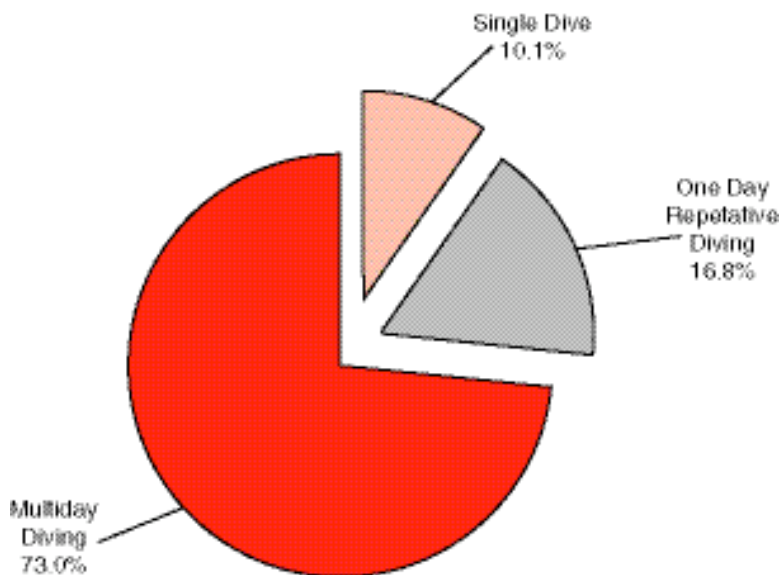
Thermal protection employed by divers in the sample depended on the geographic area where the dive was made. On a liveboard that operates in the Caribbean, 87 percent of divers wore wetsuits or lesser thermal protection suits. In Scapa Flow, nearly all divers (99 percent) wore drysuits. Of the Beach and Day Boats dives, 5 percent were done in dry or heated suits.

The reported purpose of the dive in our sample was overwhelmingly sightseeing (99 percent), with teaching / learning, photography, proficiency, spearfishing, or non-professional work declared in less than 1 percent.

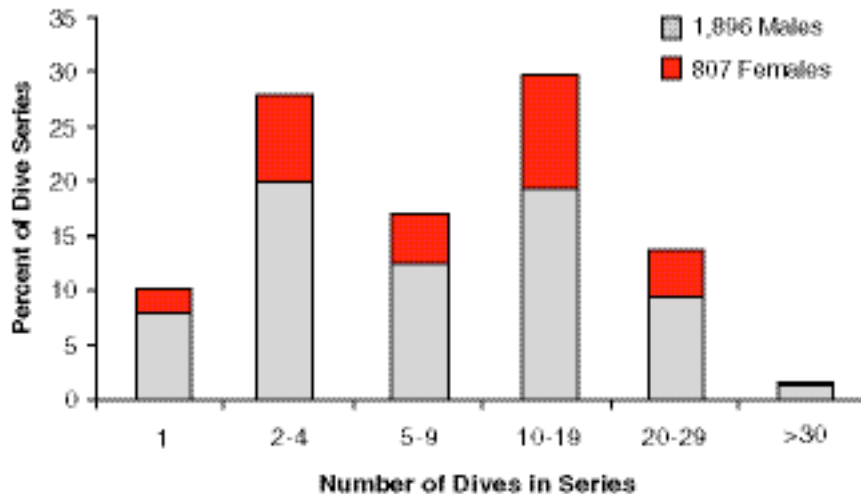
## 2.5 Dive Series

PDE recorded 2,686 dive series in 2003. Figure 2.5-1 breaks down those series by the number of days of diving. Dive series comprised multiday diving in 73 percent of the cases, single-day repetitive diving in 17 percent of the cases and single dives in 10 percent of the cases. This pattern was similar to that evident in the data collected from 1998 through 2002.

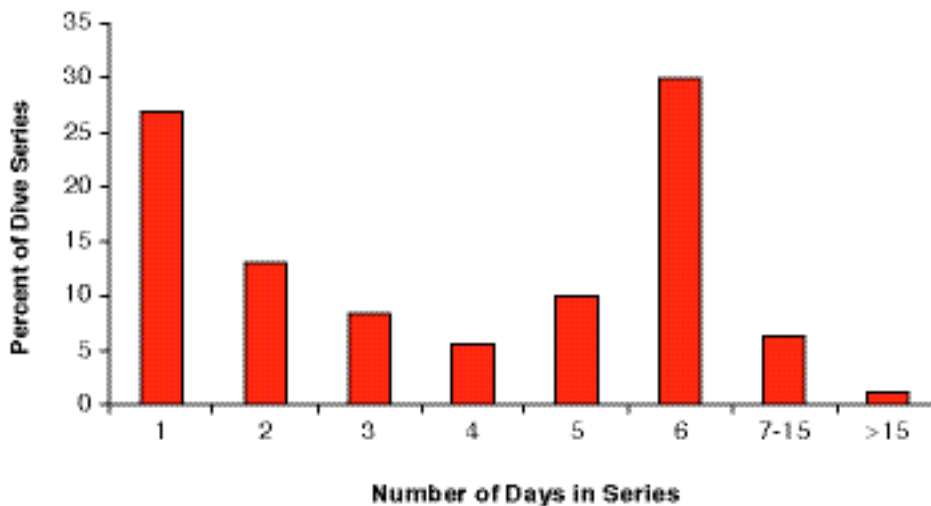
**Figure 2.5-1**  
**Percentage**  
**of the PDE**  
**sample by type**  
**of dive series**  
**for 2003**  
**(n = 2,703).**



Figures 2.5-2 and 2.5-3 indicate that the most frequent dive series pattern in our 2003 sample was 10 to 19 dives over six days. This reflects the fact that more than 50 percent of dives were collected from divers on liveboards. Series with two to four dives made up more than one quarter of all dives and were collected mainly from beach and day-boat divers. Series with more than 30 dives over seven or more days diving were, for the most part, contributed by the dive professionals participating in the Recreational Dive Professional study.



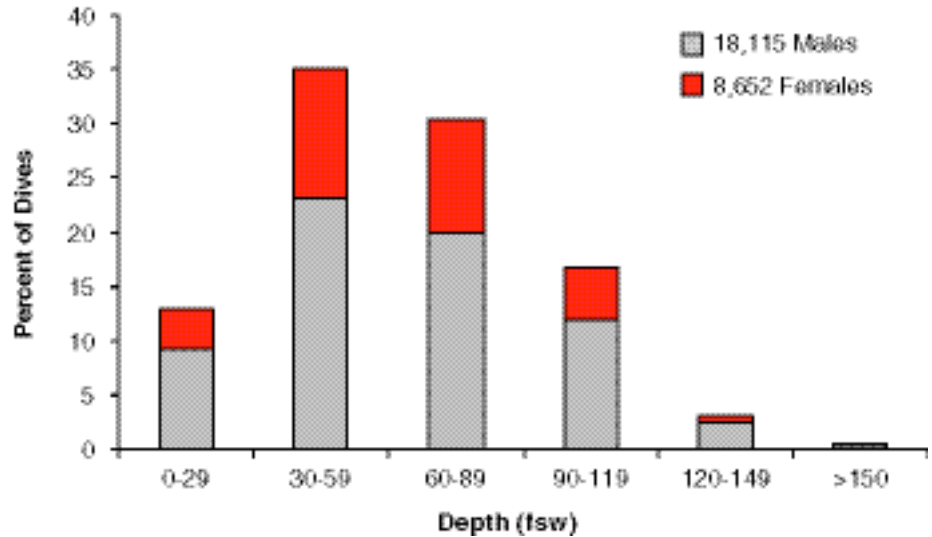
**Figure 2.5-2**  
Percentage of the PDE sample with the indicated number of dives in the dive series (n=2,703).



**Figure 2.5-3**  
Percentage of the PDE sample with the indicated number of days in dive series (n=2,703).

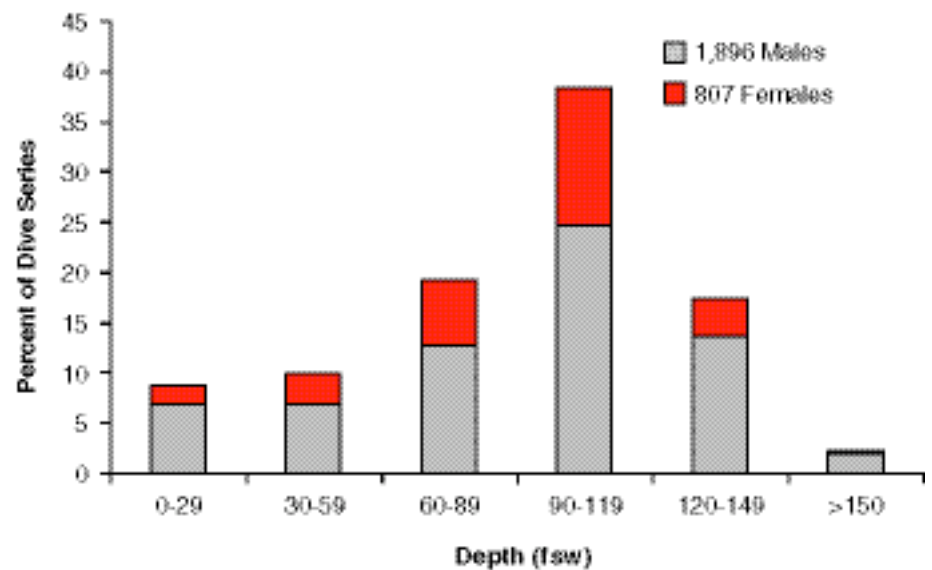
The maximum depth distribution for all dives sampled in 2003 is shown in Figure 2.5-4. The maximum depth was less than 90 feet of seawater (fsw) / 27 meters of seawater (msw) in 77 percent of the sampled dives. Dives with a maximum depth greater than 90 feet made up 20 percent, and dives with a maximum depth greater than 120 fsw / 37 msw was only 3.5 percent.

**Figure 2.5-4**  
**Percentage**  
**of the PDE dives**  
**that reached the**  
**indicated**  
**maximum**  
**depths.**

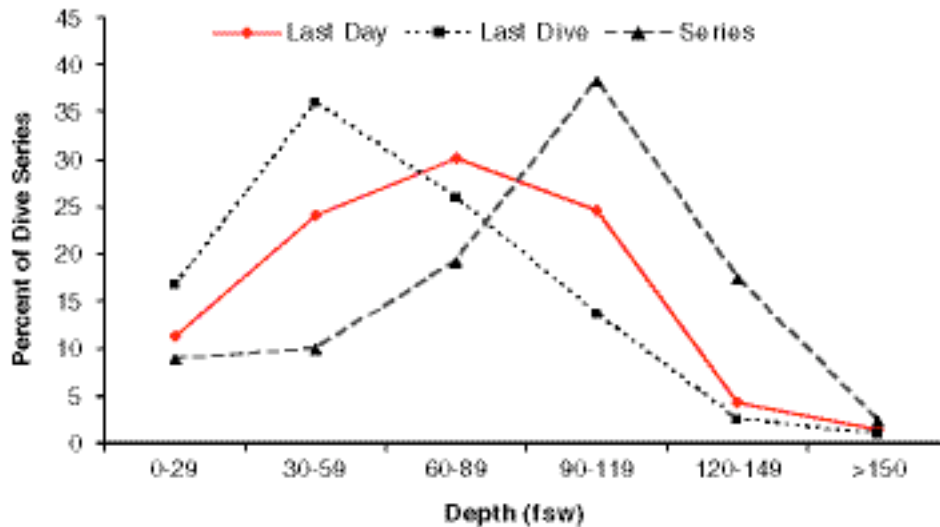


The maximum depth of the dive series (Figures 2.5-5, 2.5-6) indicates that 58 percent of PDE divers made dives deeper than 90 fsw at least once during their dive series.

**Figure 2.5-5**  
**Percentage**  
**of the PDE**  
**dive series**  
**that reached**  
**the indicated**  
**maximum**  
**depth.**

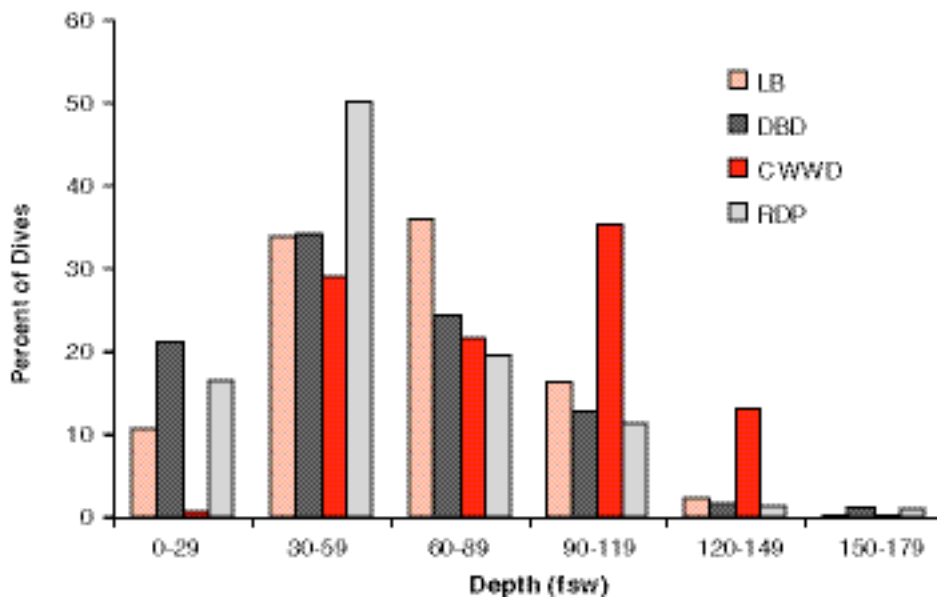


Towards the end of the series, PDE divers dived to shallower depths. This is indicated by Figure 2.5-6, which compares the maximum depth of the dive series to the maximum depth on the last day of diving and of the last dive.



**Figure 2.5-6**  
Comparison of maximum depth in series to maximum depth of last day and last dive in series.

The differences among four PDE subgroups regarding the maximum depth of diving are represented in Figure 2.5-7. While Liveaboard, Beach and Day Boat and Recreational Dive Professionals dives exhibit similar patterns of maximum depth distribution, more than 35 percent of dives in the CWWD had maximum depths in the range of 90-120 fsw (27-37 msw).



**Figure 2.5-7**  
Frequency of diving to indicated depth among four PDE subgroups.



## 2.6 Dive Planning

Table 2.6-1 and Figure 2.6-1 illustrates the use of dive planning methods. Most divers in our sample used dive computers to plan their dives and determine the dive time and the ascent. In 2003, only 1 percent reported relying completely on others for their decompression planning. This is much less than in previous years. Divers reported relying on dive tables in only 2 percent of the dives.

Interestingly, in the Beach and Day Boat subgroup, relying on another person was highest in comparison to other subgroups (Table 2.6-1). The Beach and Day Boat subgroup varies most within the subgroups in terms of diver experience and probably the level of organization of the diving. Nearly 10 percent of recreational dive professionals (dive guides) relied on dive tables.

**Table 2.6-1**  
Dive planning method among four PDE subgroups.

Dive Plan	Subgroup			
	Liveaboard	Beach and Day Boat	Cold-Water Wreck Diving	Recreational Dive Professionals
Dive Computer	81.5	82.4	97.9	88.1
Table	0.3	4.4	2.1	9.5
Another Diver	0.2	1.8	0.0	0.0
Not Reported	18.0	11.5	0.0	2.4

**Figure 2.6-1**  
Use of dive planning and decompression planning by dive.

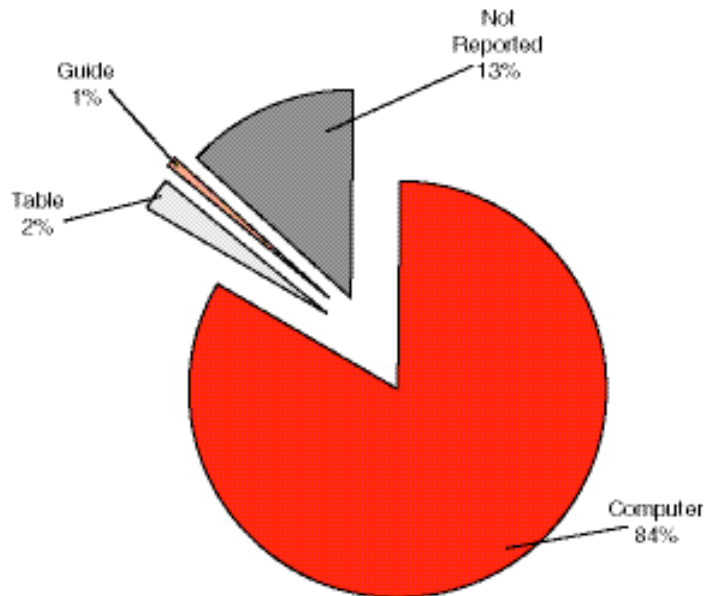


Figure 2.6-2 shows the percentage of dives in the 2003 PDE dataset with reported decompression or safety stops. A safety stop was reported for 72 percent of all dives collected in 2003. This was an increase compared with the five-year sample. Liveaboard divers reported the highest percentage (87 percent) of dives with a safety stop and the lowest percentage of dives with required decompression stop (less than 1 percent) (Table 2.6-2). Divers at Scapa Flow (CWWD subgroup) reported that 37 percent of the dives required decompression stops. Some of them have used oxygen rich gas mix for decompression.

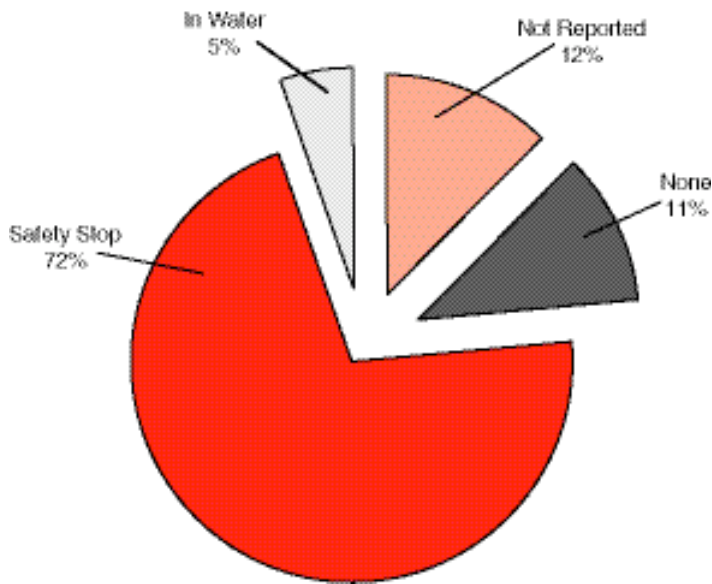


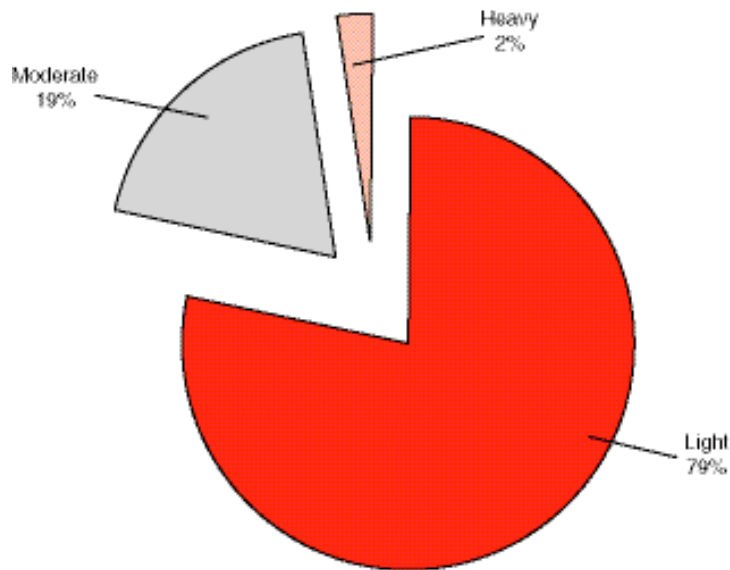
Figure 2.6-2 Decompression procedures.

Decompression	Subgroup			
	Liveaboard	Beach and Day Boat	Cold-Water and Wreck Diving	Recreational Dive Professionals
Safety Stop	86.4	59.5	52.6	25.3
In Water	0.7	5.9	36.5	2.8
None	5.5	24.7	9.8	8.2
Not Reported	7.3	10.0	1.1	63.6

Table 2.6-2 Percent of dives with decompression or safety stop in four PDE subgroups.

The subjective work rate in the majority of dives was light. Only in 2 percent of all dives did the diver report a heavy work rate. The CWWD divers reported on average the highest work rate with 36 percent of dives being in the moderate category (Table 2.6-3).

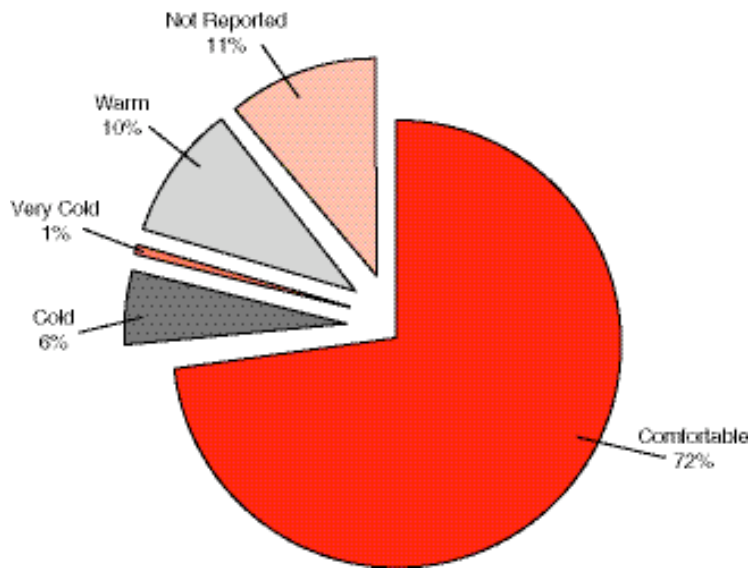
**Figure 2.6-3**  
Percentage of the PDE sample reporting the indicated dive work rate.



**Table 2.6-3**  
Reported work rate in four PDE subgroups (percent of dives)

Work Rate	Subgroup			
	Liveaboard	Beach and Day Boat	Cold-Water and Wreck Diving	Recreational Dive Professionals
Light	74.7	75.3	60.2	24.6
Moderate	15.8	15.3	35.7	10.7
Heavy	2.1	1.8	2.8	0.8
Not Reported	7.4	7.6	1.3	63.9

Figure 2.6-4 illustrates the reported thermal comfort of the divers in our sample. Most divers indicated they were comfortable. Reports of being outside of thermal comfort zone came most frequently from CWWD divers dressed in drysuits. These divers reported being cold on 15 percent of dives and warm on 19 percent of dives. The cold was frequently caused by leaking drysuits. Thermal status was most commonly not reported by the Recreational Dive Professionals group.



**Figure 2.6-4**  
Subjective thermal status of divers during dive.

Thermal Comfort	Subgroup			
	Liveaboard	Beach and Day Boat	Cold-Water and Wreck Diving	Recreational Dive Professionals
Comfortable	78.8	74.3	64.8	37.5
Cold	4.2	9.2	14.5	5.3
Very Cold	0.2	2.0	0.9	0.0
Warm	9.9	7.1	18.5	4.7
Not Reported	7.0	7.4	1.3	52.4

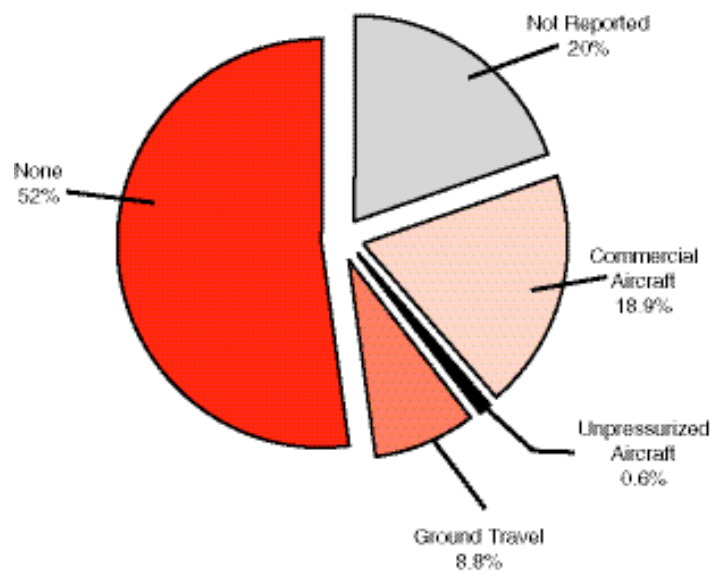
**Table 2.6-4**  
Reported thermal comfort in four PDE subgroups (percent of dives).

## 2.7 Altitude Exposure After Diving

Exposure to altitude higher than 700 feet (210 meters) soon after diving is considered an additional decompression that may provoke DCS in some divers who otherwise would not be affected. At the time when the PDE study was designed there were few data regarding the post-dive time that a diver should wait before safely ascending to an altitude. That was the reason that PDE requests divers to report altitude exposure within 48 hours post-dive.

In the 2003 PDE dataset, 766 (29 percent) divers reported exposure to altitude within 48 hours post-dive (Figure 2.7-1). Most exposures occurred in commercial airliners that are required by law to maintain a cabin pressure equivalent to not more than 8,000 feet above sea level (2,439m; approximately three-quarters of the atmospheric pressure at sea level). Flying in non-pressurized fixed-wing aircraft or helicopters after diving was uncommon. Of the divers who flew on commercial airlines within 48 hours post-dive, 21 percent waited less than 24 hours, and less than 1 percent (eight divers) flew less than 12 hours post-dive.

**Figure 2.7-1**  
Percentage  
of the PDE  
sample reporting  
altitude exposure  
after dive series.

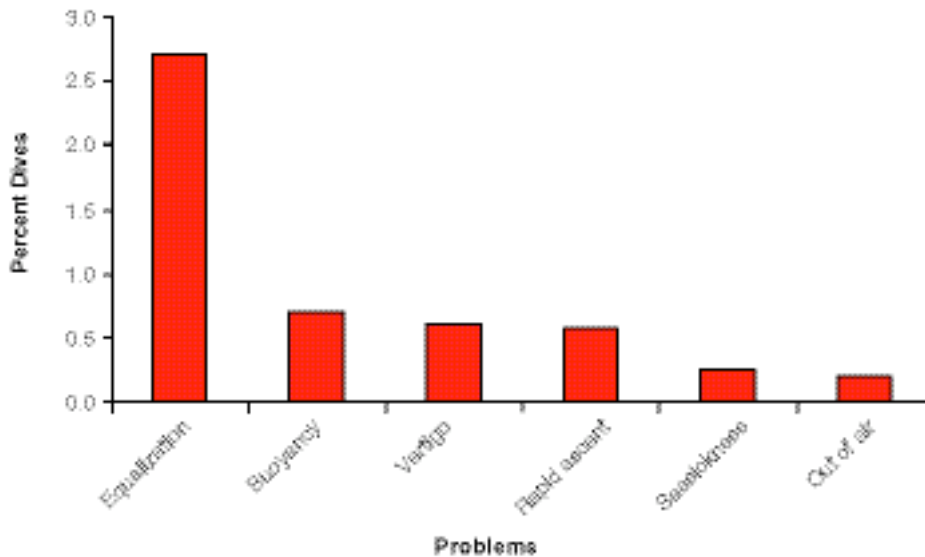


## 2.8 Outcomes

PDE divers were asked to report signs and symptoms after diving before leaving the dive site. They were also asked to submit a 48-hour report form to confirm or deny the presence or absence of signs or symptoms within 48 hours of the last dive. If a diver reported signs or symptoms in the 48-hour report, DAN followed up to gather details necessary to classify the outcome. Four possible medical classifications were employed: (a) uneventful (signs or symptoms denied); (b) an incident (a report of a procedural or an equipment problem that is potentially dangerous event but did not result with an injury); (c) an injury considered unrelated to DCI; and (d) DCI (DCS or AGE).

## 2.8.1 Incidents

Figure 2.8-1 indicates that most PDE divers did not report any problems. Problems were reported in approximately 5 percent of dives. Equalization was the most frequently reported difficulty (2.7 percent of total). Buoyancy problems and rapid ascent were reported in less than 1 percent of dives, often occurring together. It appears that seasickness symptoms during the dive were not common. Out-of-air situation was reported in 67 dives.



**Figure 2.8-1**  
Percentage of the PDE dives with reported problems.

Equipment problems were reported in about 1 percent of our 2003 PDE dives as listed in Table 2.8-1. Problems with masks or fins were reported most frequently.

Equipment Problems	Frequency	Percent
Mask	164	0.70
Fins	147	0.63
BC	71	0.30
Weight Belt	69	0.29
Computer	45	0.19
Thermal Protection	40	0.17
Regulator	34	0.14
Deco Reel Jammed	17	0.07
Pressure Gauge	8	0.03
Depth Gauge	1	0.00

**Table 2.8-1**  
Percentage of the dives with reported equipment problems (n=596)

## Symptoms Not Considered DCI

Most of the reported symptoms were related to ear or sinus barotrauma. Headache was reported by 24 divers, half of them from the CWWD subgroup. Four divers had muscle pain following some kind of trauma. Five other divers reported having pain with-

out an obvious reason. One diver developed vertigo and was diagnosed by a physician as vestibular neuronitis (a nerve disease of the ear unrelated to diving). He was not recompressed and symptoms resolved in a few weeks.

### 2.8.2 DCS cases in 2003

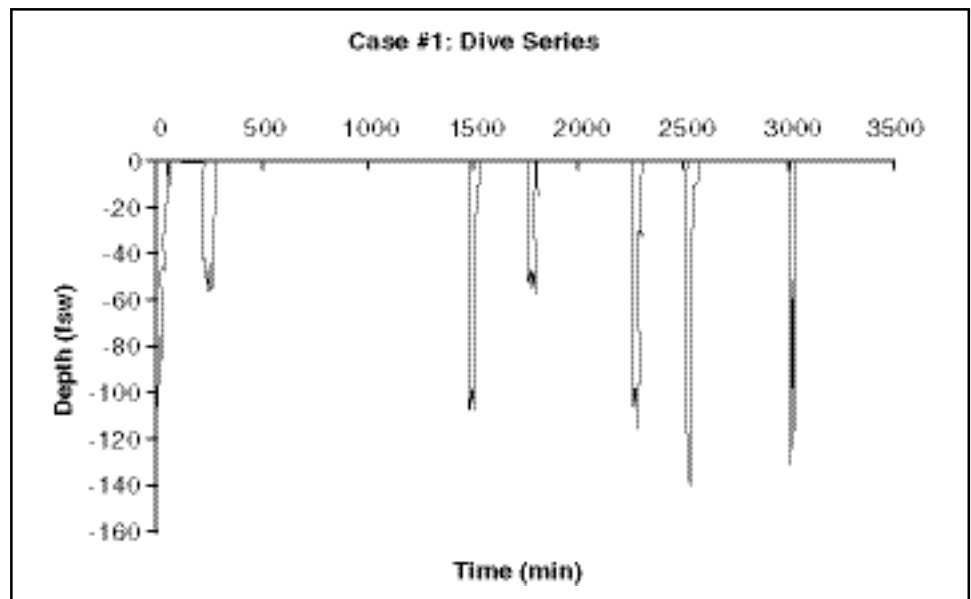
Only three divers underwent recompression therapy for DCS in the 2003 sample. All three were in the CWWD subgroup. The PDE data consistently suggests that there may be a higher DCS incidence in cold-water wreck diving at Scapa Flow, Scotland, than in recreational diving in warm waters. The overall DCS rate in PDE since its inception is 3 cases in 10,000 dives (0.03 percent).

#### Case #1

The diver was a 32-year-old experienced male diver with 150 dives in the past five years and 30 dives in the past 12 months. He had no previous health problems. He completed seven dives over five days in Scapa Flow (Figure 2.8-2). All his dives were on nitrox 32 and decompression gas was nitrox 50. All dives were uneventful and normal.

On his third day and final day of diving, he was tired after the last dive. Within minutes after surfacing, he felt pain in his left shoulder and pins and needles in the fourth and fifth fingers of his left hand. He was recompressed on a USN Treatment Table 6 six hours later with complete resolution of symptoms.

Figure 2.8-2  
Dive Series.

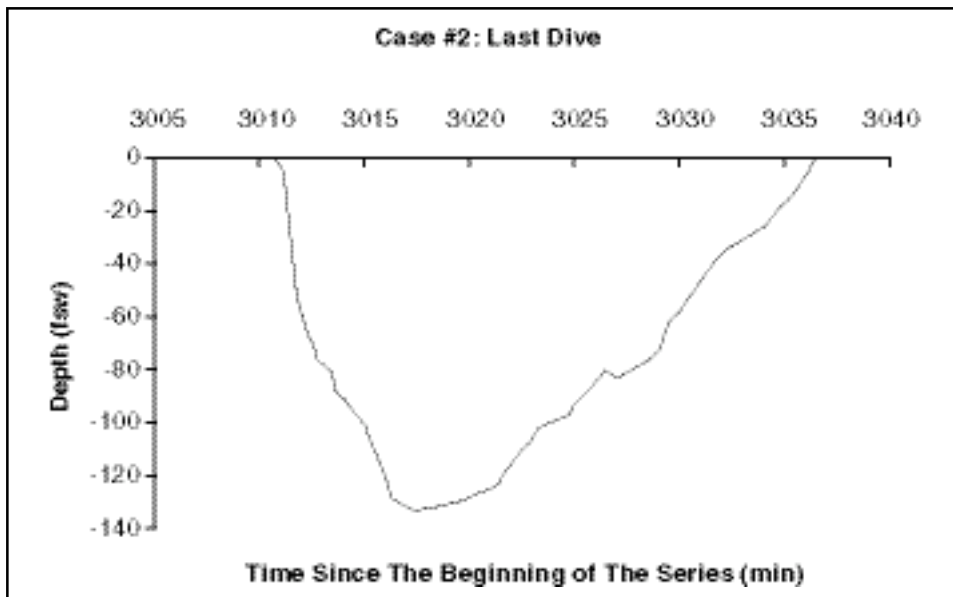




## Case #2

The diver was a 29-year-old male with 44 lifetime dives and a history of previous DCS. He dived as a buddy diver with Case #1. He did seven dives over five days in Scapa Flow, all on nitrox 32, using nitrox 50 for decompression. On the last day he did one dive to 133 fsw (40.5 msw) on air. Five hours post-dive he felt generally ill and started developing numbness in his right foot. The next day he reported to a local chamber and was diagnosed with DCS-II.

He was recompressed the same day, 28 hours post-dive and 24 hours after symptom onset. All symptoms were resolved at the end of recompression treatment on a USN Treatment Table 6. Due to technical problems, his computer could not be downloaded, and his dive profile was lost. During the dive, he maintained a close contact with his buddy diver and did the same dive profile. Figure 2.8-3 shows the detailed profile of the last dive recorded by the dive computer in Case #1.



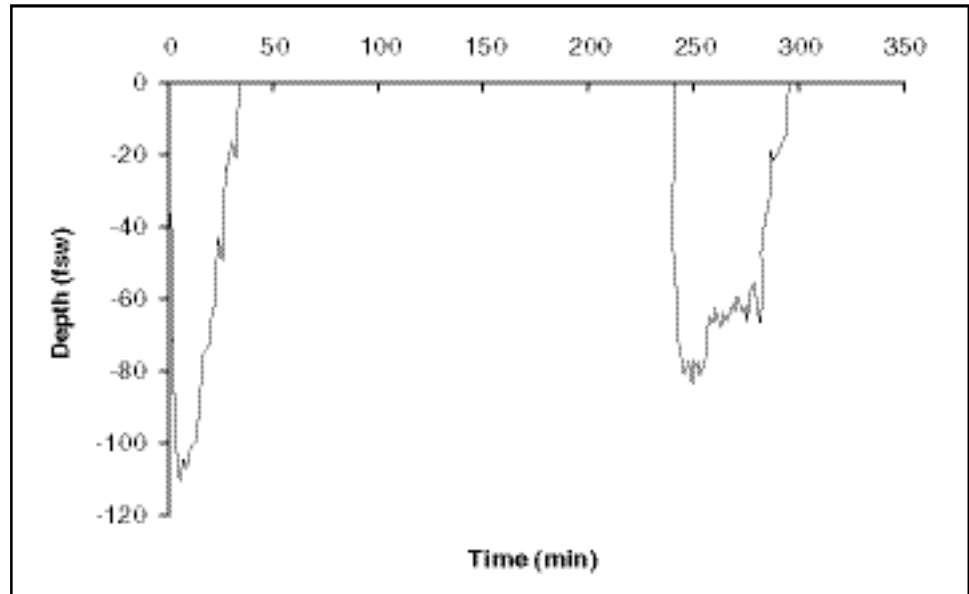
**Figure 2.8-3**  
Profile of the  
last dive.

### Case #3

The diver was a 48-year woman, an experienced diver with more than 200 dives in the last five years and 50 in the last 12 months. She was on medication for high blood pressure and seasickness. She did two dives on air, the first to 110 fsw (33.5 msw) and the second to 83 fsw (25.3 msw) (Figure 2.8-3). She reported having adequate thermal protection.

On her second dive, she had equalization problems. Fifteen minutes post-dive, her right upper arm became painful, and 15 minutes later her left arm was affected, too. The pain was deep and burning. Three hours later she had a shower and noticed at that time a skin rash on her upper arms. The rash was fading slowly during the evening. The next morning she still had pain and was recompressed on a USN Treatment Table 6. All symptoms were resolved after treatment.

**Figure 2.8-4**  
Dive profile.



# 3. Dive Injuries

## 3.1 The Source of the Data

The analysis of recreational diving injuries is an integral part of DAN's mission to improve diving safety. DAN has collected information on recreational scuba diving injuries since 1987. Hyperbaric chambers throughout the United States, the Caribbean and Latin America are requested to send information to DAN on cases treated at their facilities. Seventy-eight chambers sent injury data to DAN in 2003, providing a total of 297 reports.

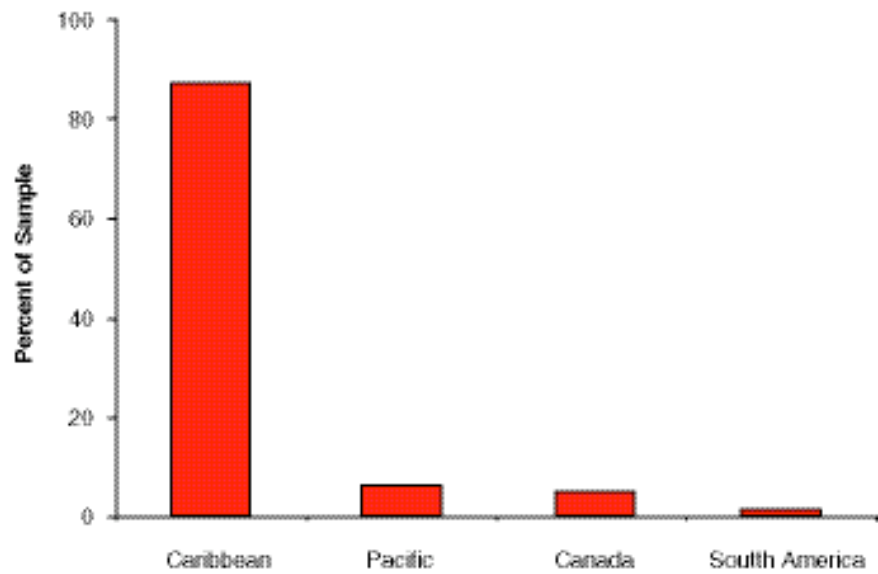
### The Source of the Reports

Figure 3.1-1 shows the percentage of the sample derived from the Caribbean, the Pacific, Canada and South America. This number of cases is less than in previous years both because of increasing concerns of hospitals to protect the privacy of their patients and because DAN is in the process of changing the survey instrument used to collect injury data. 2003 was the last year that DAN used the Diving Injury Reporting Form (DIRF) as the sole survey instrument for injuries.

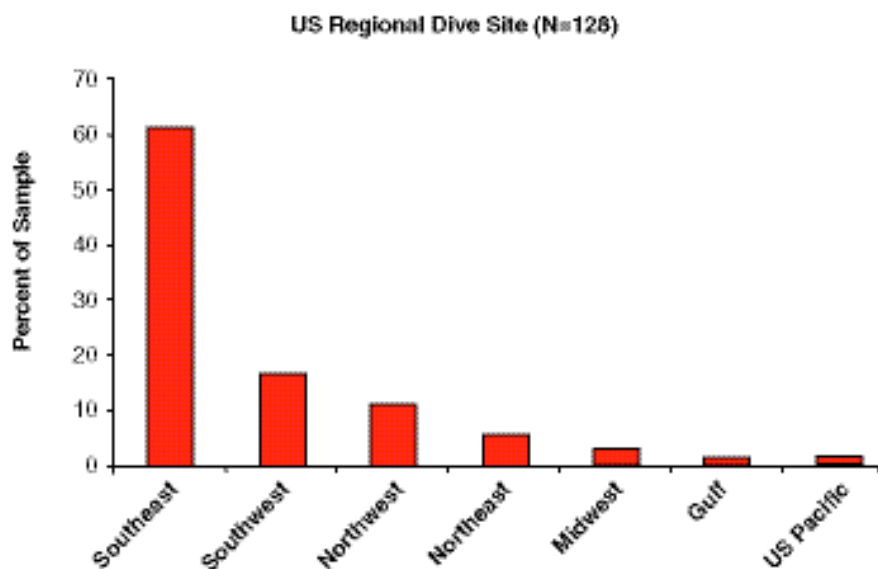
With DAN's new injury collection system, inclusion criteria will be broadened to include exposure and treatment data on commercial and harvest divers as well as recreational divers. This should increase the response rate and improve the scientific validity of the sample not only by increasing the number of observations but also by increasing the potential range of time and depth exposures associated with injuries. A better understanding of the relationship of exposure to injury will eventually decrease the risk of decompression illness for all divers.

Figures 3.1-1 and 3.1-2 show the origin of the reports reaching DAN. Reporting frequency should not be confused with diving risk in a particular region. It should be emphasized that DAN's injury data is based entirely on voluntary notification and that these data should not always be considered a representative sample of the broader diving population.

**Figure 3.1-1**  
**International**  
**source of injury**  
**reports (n=166).**

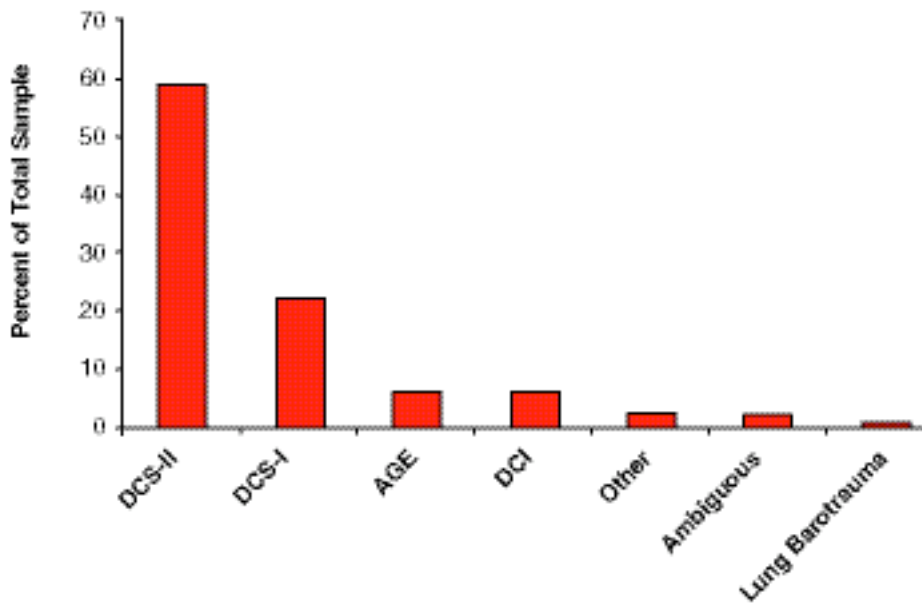


**Figure 3.1-2**  
**Domestic**  
**source of**  
**injury reports**  
**(n=128).**



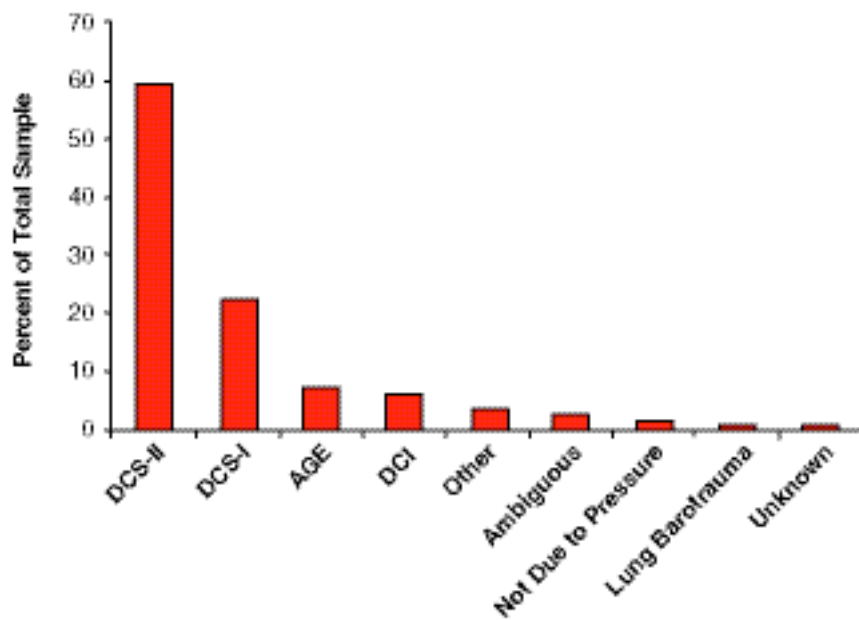
### Case Classification

All diving injury cases reported on the DIRF form are classified by the reporting chambers as either DCS I, DCS II, AGE, DCI or ambiguous when the cases are submitted to DAN. Although redundant, the category of DCI is included to categorize cases that were felt to be pressure-related but not clearly distinguishable as either DCS or AGE. The Ambiguous category refers to cases that may or may not have been pressure-related. Classification criteria are shown in Table 3.8-1 on page XX. The frequency distribution of the classification categories for the 297 cases in the 2003 sample is shown in Figure 3.1-2. As has been seen in previous DAN diving reports, DCS II predominates. DAN staff reviews the original diagnostic assignments for all injury reports for accuracy and internal consistency.



**Figure 3.1-2**  
Distribution of cases  
by reported diagnosis  
(n=297).

As previously stated, all DAN injury cases are reviewed for inconsistencies in their original classification. Reclassification is based on the treating physician's comments and the scheme shown on page 65. The reclassification scheme used is the same as was used in previous years. Figure 3.1-3 shows the distribution of all treated cases by reclassified diagnosis.



**Figure 3.1-3**  
Distribution  
of Cases by  
Reclassified  
Diagnosis (n=297).

## Perceived Severity Index (PSI)

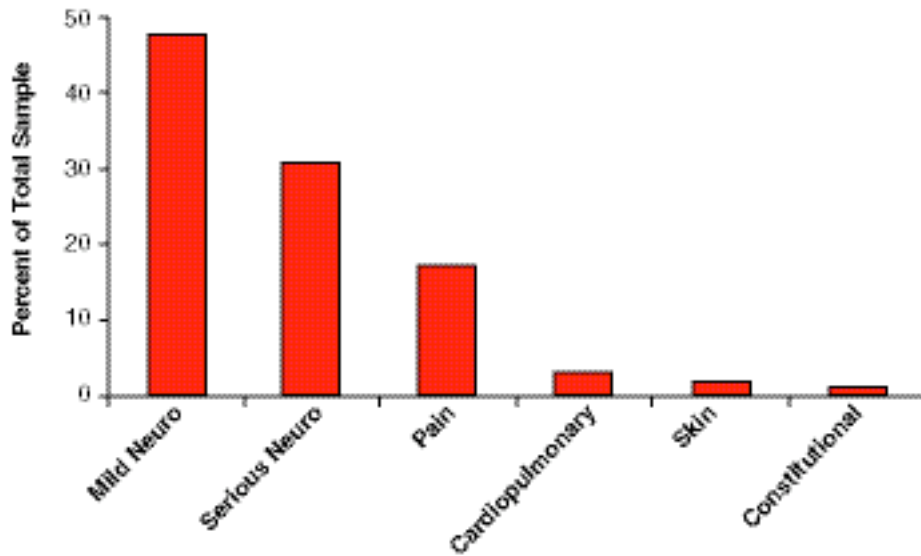
The Perceived Severity Index (PSI) was introduced in the 2002 report and is continued in this year. This classification system is based on the perceived severity of symptoms associated with decompression illness, according to DAN physicians and researchers. The PSI categories are listed in Table 3.1-4 in order of decreasing severity: a) Serious Neurological; b) Cardiopulmonary; c) Mild Neurological; d) Pain; e) Lymphatic or Skin; and d) Constitutional or Nonspecific. The categories are hierarchical in the order listed. This means, for example, that a case categorized for serious neurological symptoms could also have pain, but that a case categorized for pain could not have serious neurological manifestations.

**Table 3.1-4**  
**Perceived Severity**  
**Index (PSI).**

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

The distribution of cases by PSI is shown in Figure 3.1-4. Cases falling into the PSI category of mild neurological were most common in our sample. The next most common category included cases with serious neurological symptoms; however, it should be noted that the definition of serious neurological symptoms is quite broad. Pain-only symptoms represented approximately 20 percent of our sample. Again, it should be remembered the categories are hierarchical, and use of the PSI requires that the case be categorized by the

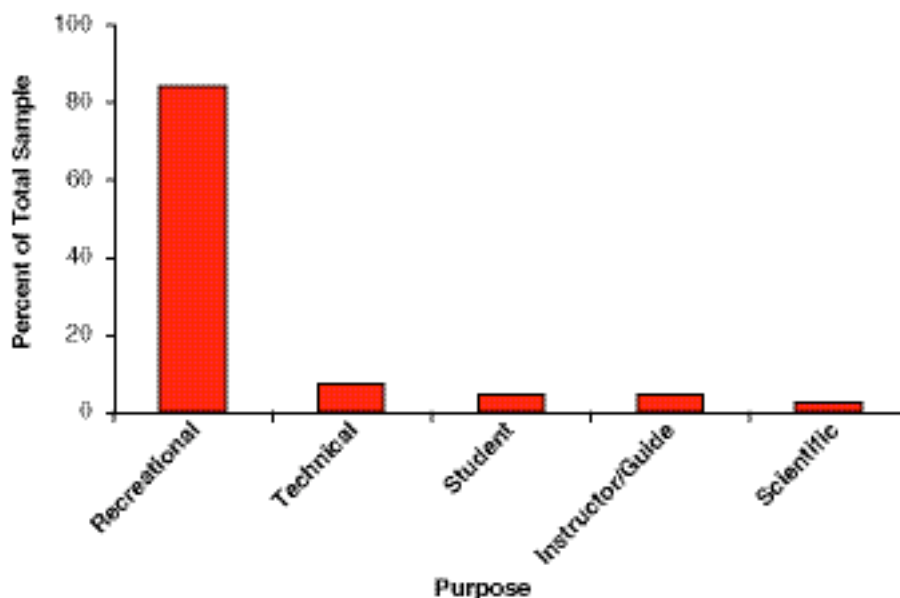
most severe symptom. If a case is classified as serious neurological, it may also have pain as part of its symptom complex.



**Figure 3.1-4**  
Distribution  
of Cases by PSI  
(n=297).

### 3.2 Diving Location Time and Purpose

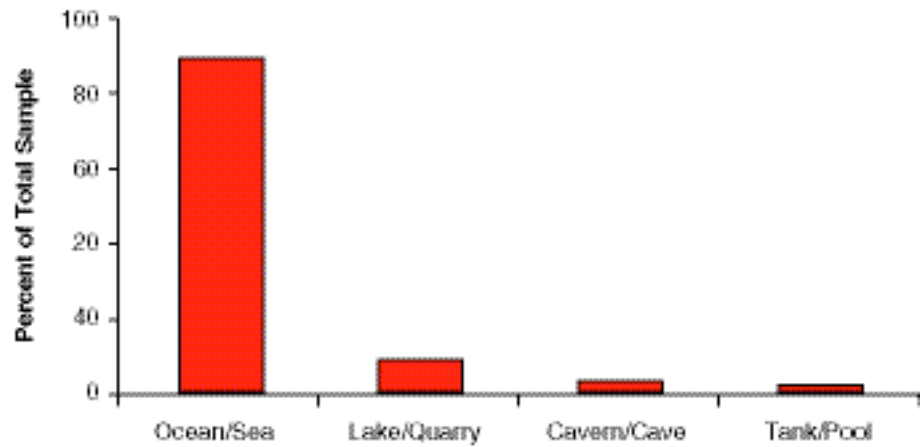
Consistent with previous reports, the majority of recreational injuries currently reported come from divers performing routine, non-technical dives in the ocean environment. Figure 3.2-1 shows the purpose of dives in our sample, and Figure 3.2-2 shows the environment in which the reported diving injuries occurred. The majority of our reported injuries were from the months between May and October, the warmer months during which most northern hemisphere diving is done.



**Figure 3.2-1**  
Purpose of  
dive as reported  
by injured divers  
(n=297).

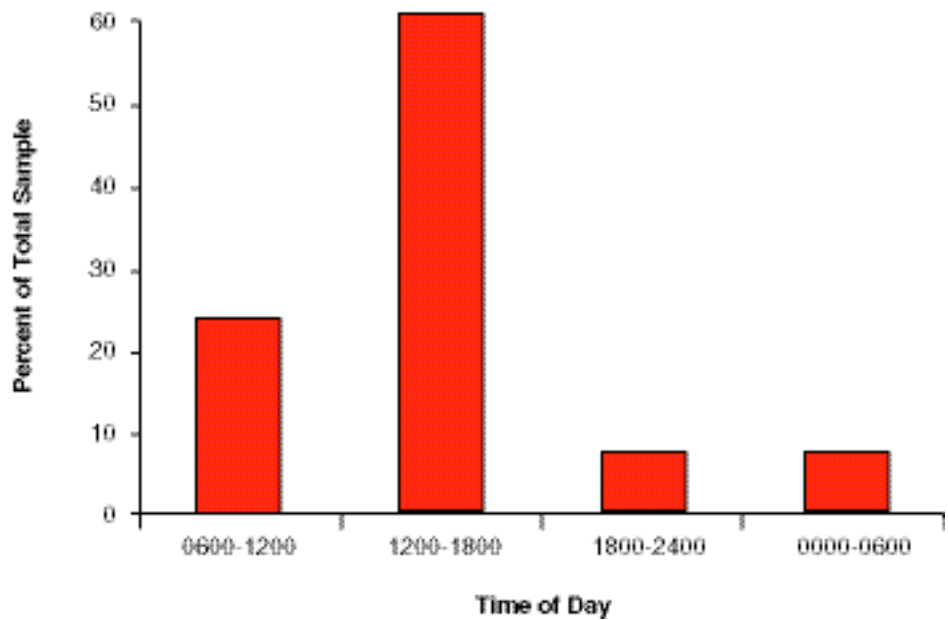


**Figure 3.2-2**  
**Environment**  
**in which diving**  
**injury occurred**  
**(n=290).**



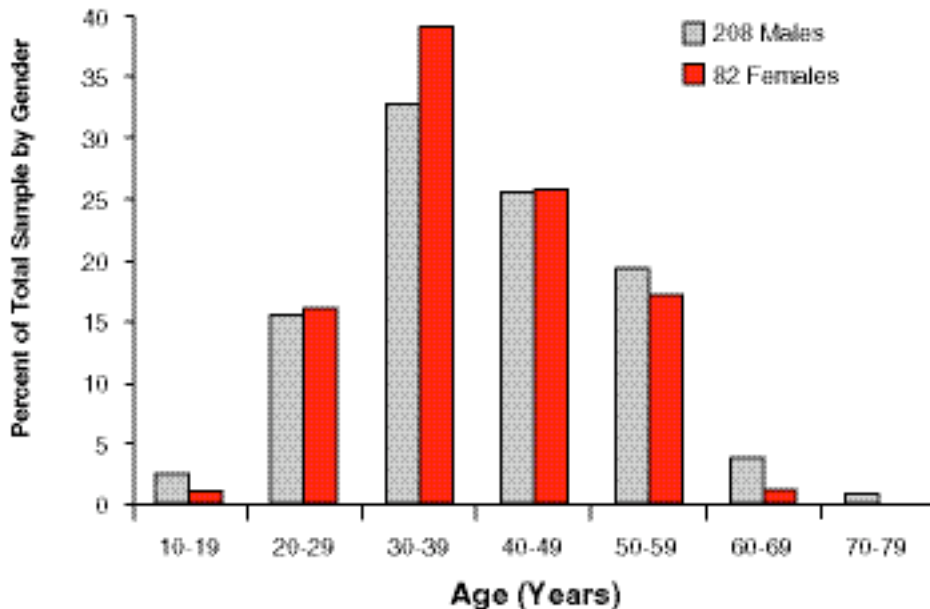
Most of the injuries reported in our sample occurred during routine afternoon dives. Figure 3.2-3 shows the time of day of the last dive made by the divers in our sample.

**Figure 3.2-3**  
**Time of day**  
**of the last dive**  
**(n=175).**



### 3.3 Physical Characteristics of Injured Divers

The majority of the divers in DAN's 2003 sample were between 30 and 60 years of age. Males outnumbered females by approximately two to one. Figure 3.3-1 shows the age distribution of the divers in our sample by gender. The age and gender distribution of the divers is essentially unchanged from the preceding year.



**Figure 3.3-1**  
Age of injured divers by gender (n=290).

DAN collects information on pre-existing medical conditions because they may influence diving injuries. The frequencies of the most common medical conditions are listed in Table 3.3-1. As would be expected from self-reporting, the divers listed for the most part only minor medical conditions. Seasonal allergies occurred in 18 percent of the sample, spine or back problems in 13 percent, musculoskeletal problems in 13 percent and ear or sinus problems in 6 percent. The injured divers in our sample also reported a 5 percent incidence of emotional problems, a 4 percent incidence of cardiac disease, a 3 percent incidence of asthma and a 2 percent incidence of diabetes. It should be noted that these conditions are not overrepresented in our sample of diving injuries as compared to the normal population, and that some divers listed more than one pre-existing medical condition.

**Table 3.3-1**  
**Pre-dive**  
**health**  
**problems.**

Health Problem	Frequency	%
Allergies	53	17.8
Musculoskeletal	49	16.5
Back Problems / Surgery	39	13.1
Seasickness	22	7.4
Ear Nose and Throat	19	6.4
Psychiatric	15	5.1
High Blood Pressure	14	4.7
Central Nervous System	14	4.7
Gastrointestinal	13	4.4
Heart Disease	12	4.0
Circulation / Blood	12	4.0
Asthma	9	3.0
Pulmonary	6	2.0
Diabetes	6	2.0
Eye	5	1.7
Kidney	3	1.0

### Certification Level of Injured Divers

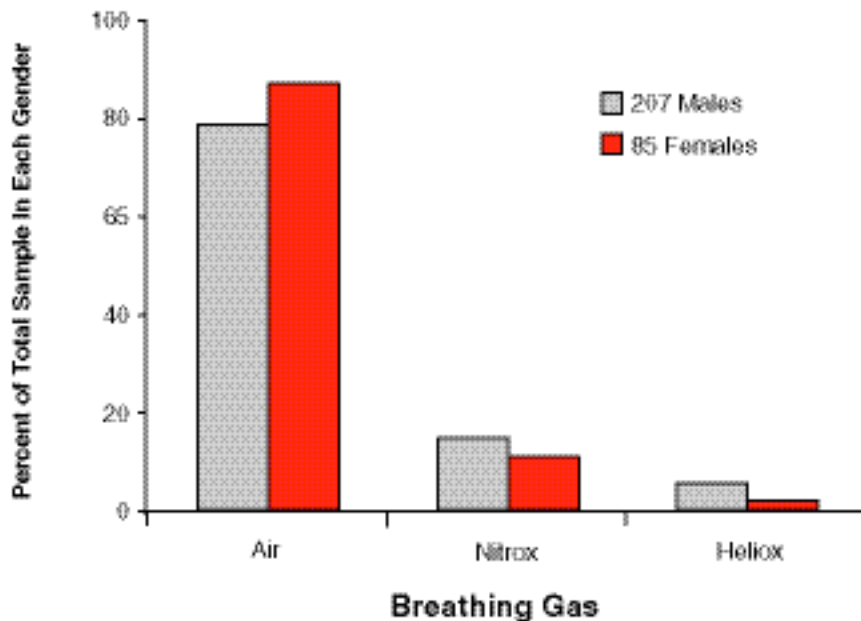
Diving experience does not correlate with the specific type of injury diagnosis in our sample if the highest certification level attained by the injured diver is used as a surrogate for experience. Table 3.3-2 shows the highest certification level obtained by the divers in our sample when stratified by diagnosis. Most of the injuries occurred in entry- or instructor level divers; however, this may be due to the higher representation of these groups in the overall diving population. It should also be noted that because this injury data is entirely self-reported, some certification categories might have either a greater or lesser impact on the injury statistics reported here. There are many instances of self-treatment of decompression illness by divers in the higher certification levels that are not reported to DAN.

Our data show that for most divers, DCS II is most common regardless of certification. However, the student category is the exception to this generalization. If a student is injured, AGE is the type of injury most likely to be involved. Although the 2003 numbers are small, this pattern is consistent with data from previous years.

Diagnosis	#	Highest Certification Level (Percentage)								
		Missing	None	Student	Entry-Level	Advanced	Instructor	Specialty	Technical	Commercial
DCS I	53	38.5	33.3	0.0	10.3	20.4	22.2	22.6	11.1	0.0
AGE	19	7.7	0.0	40.0	13.4	2.2	0.0	3.2	0.0	0.0
DCS II	211	53.8	55.6	40.0	72.2	72.0	72.2	71.0	88.9	100.0
Lung BT	4	0.0	11.1	20.0	1.0	1.1	0.0	0.0	0.0	0.0
Ambiguous	10	0.0	0.0	0.0	3.1	4.3	5.6	3.2	0.0	0.0

### 3.4 Characteristics of Dives Made by Injured Divers

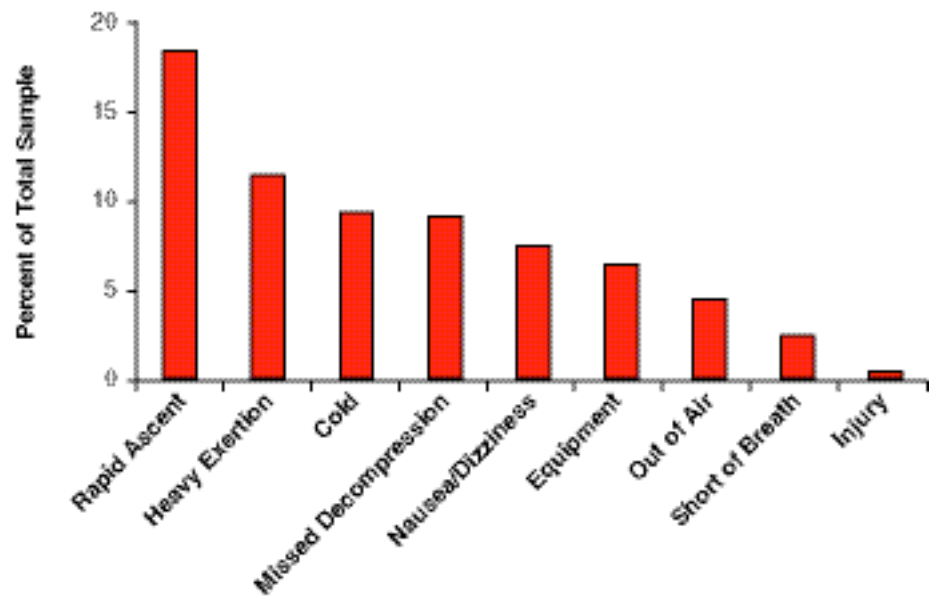
Consistent with previous years, the largest percentage of our reports came from divers using open-circuit scuba who were breathing air. However, there is an apparent increase in the percentage of the injured divers in our sample who were injured while breathing nitrox. This likely reflects an increase in the use of nitrox overall. Figure 3.4-1 describes the breathing gas used by the divers included in our sample.



**Figure 3.4-1**  
Breathing gas  
used in sample  
(n=292).

Some dives resulting in injury were associated with problems during the dives. When problems were reported, a rapid ascent was the most frequent complication. Figure 3.4-2 describes the frequency of reported problems during the dive series immediately prior to the injury in our sample. Computer use was approximately 70 percent of our sample, similar to 2002. Less than 20 percent reported planning their dives using only tables.

**Figure 3.4-2**  
Frequency  
of reported  
problems  
during dive series  
(n=297).

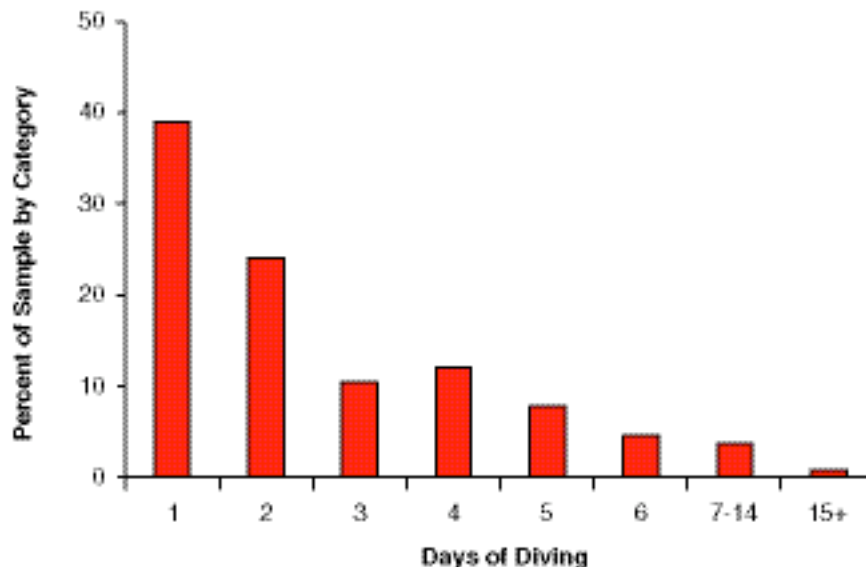


### 3.5 Estimate of Diving Exposure

The DAN diving report concentrates on injuries caused by DCI. Because it is primarily the intensity of a diver's depth-time exposure that dictates total inert gas uptake, exposure has a large influence on DCI risk. The number of dives, number of consecutive days of diving and flying after diving also contribute to exposure related risk. This section of the diving report describes exposure in our sample of the injured divers.

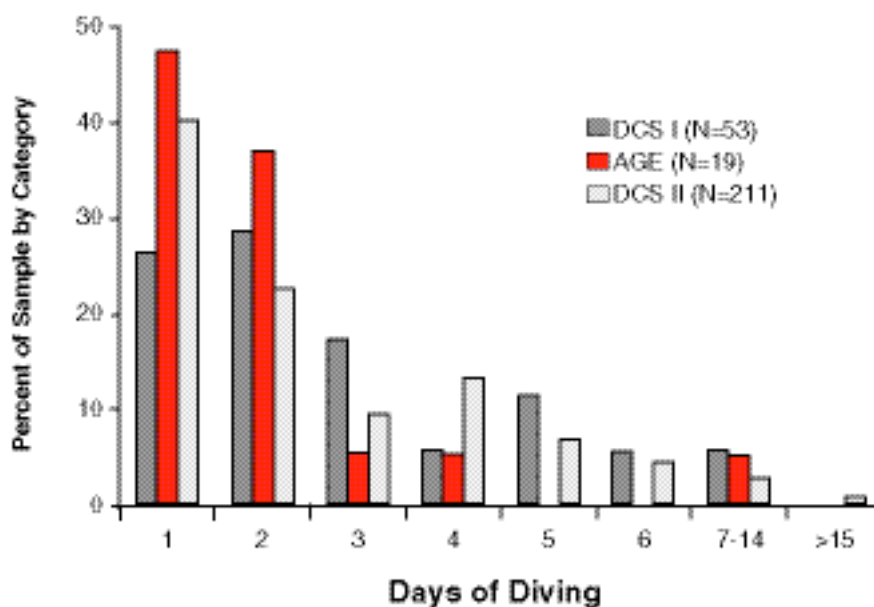
## Days in Dive Series

DAN defines a dive series as all dives temporally separated by less than 48 hours. Therefore, a diver could have a dive series lasting many days even though he or she took several single-day breaks in between. Figure 3.5-1 shows the number of consecutive days of diving preceding injury. The majority of all injuries occurred after the first two days of diving. However, there are some cases of injuries occurring after long series of consecutive dives.



**Figure 3.5-1**  
Days in dive series preceding injury (n=288).

Figure 3.5-2 shows the consecutive days diving preceding the injury when stratified for DCS I, DCS II and AGE. The percentage of injuries appears to decrease as the number of consecutive days in the dive series increases, but this may be in part because divers who were injured did not continue to dive.

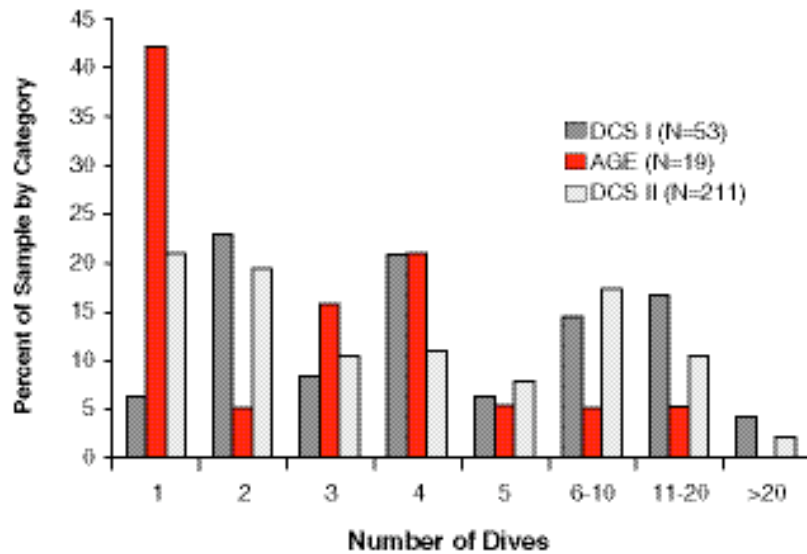


**Figure 3.5-2** Days in dive series preceding the injury by diagnosis (n=297).

## Dives

Figure 3.5-3 shows the total number of dives in the entire dive series when stratified by diagnosis.

**Figure 3.5-3**  
Total number of dives in series by diagnosis (n=297).



## Maximum Depth of Dive Exposure

Inert gas uptake is directly associated with the depth of the dive. The maximum depth of the last dive and the maximum depth of the dive series may be used to partially estimate the intensity of the pressure exposure and consequently the DCS risk. Figure 3.5-4 shows the maximum depth of the last dive, stratified by gender. It can be seen that most divers remain within the 130-foot (40m) recreational limits. There is a small group of injured divers in our sample who recorded the maximum depth of their last dive of greater than 180 feet (55m). This group is made up of mostly male technical divers.

**Figure 3.5-4**  
Maximum depth of last dive by gender (n=292).

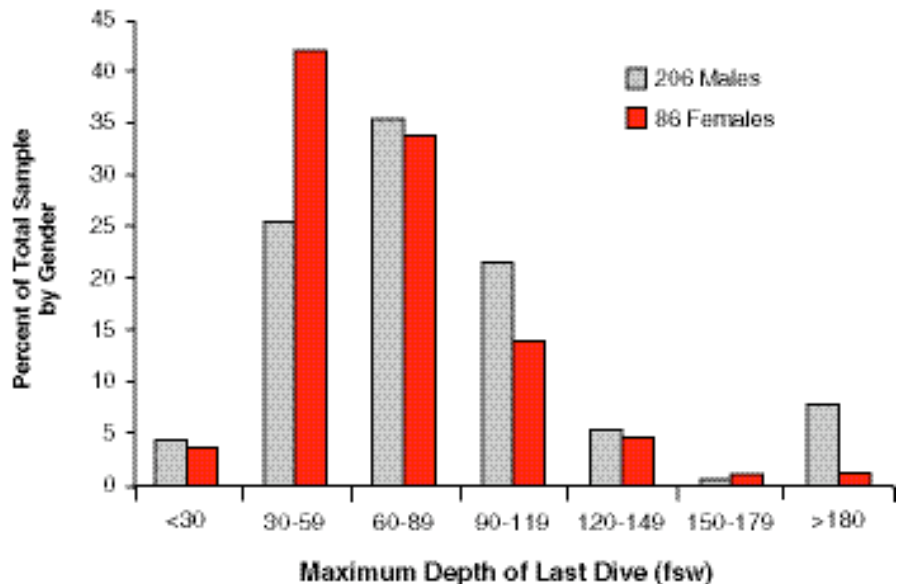




Figure 3.5-5 represents the maximum depth of the last dive stratified by diagnosis. Deeper than 60 fsw (feet of seawater; 18 msw, or meters of seawater), there is little difference between the depths recorded by injured divers for any of the three diagnostic categories.

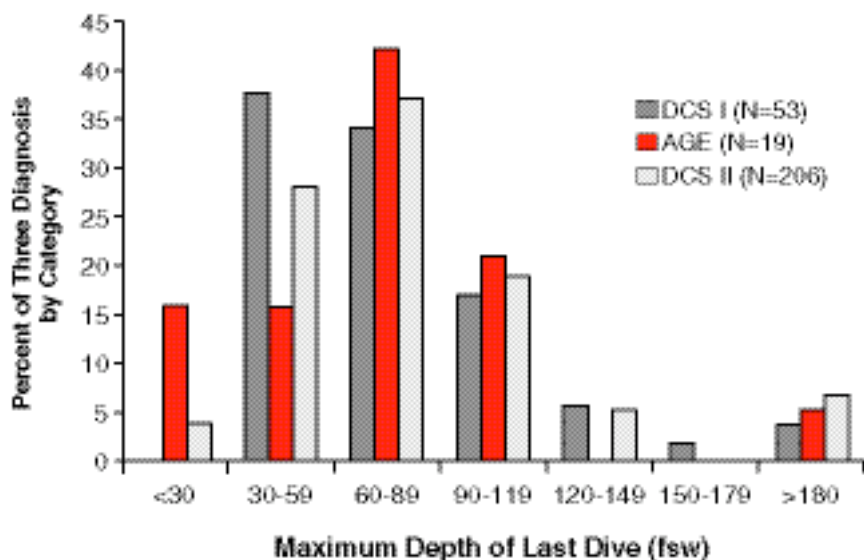


Figure 3.5-5  
Maximum depth of last dive by diagnosis (n=297).

Figures 3.5-6 and 3.5-7 show the maximum depth of the dive series by gender and the maximum depth of the last dive by gender, respectively. When the injury cases in the sample are analyzed by maximum depth of the dive series, there is a tendency for DCS II cases to be associated with deeper depths.

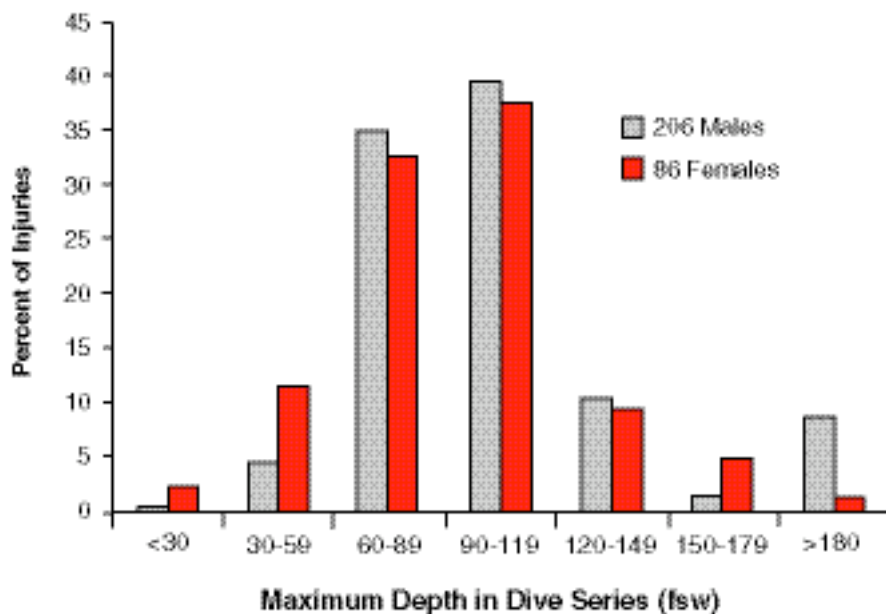
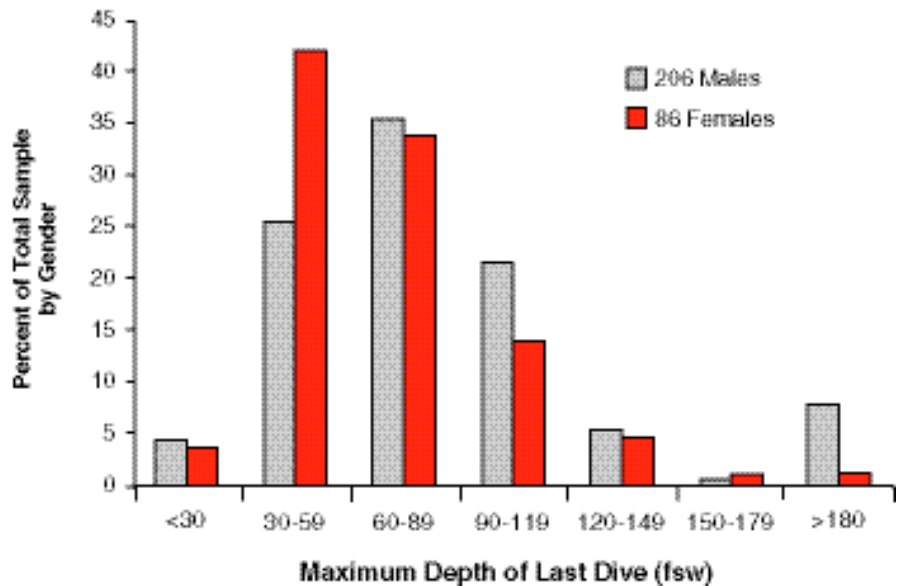


Figure 3.5-6  
Maximum depth of the dive series by gender.

**Figure 3.5-7**  
**Maximum depth of**  
**the dive series by**  
**diagnosis (n=297).**



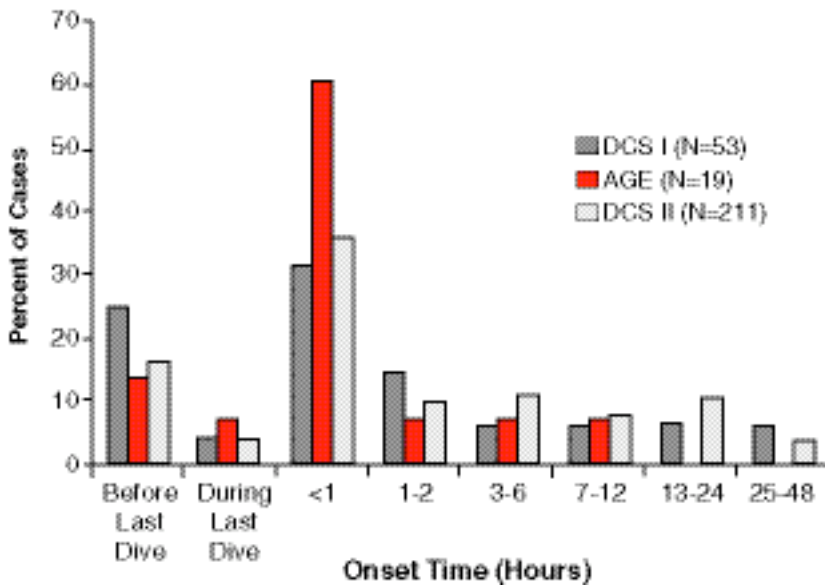
### Flying After Diving (FAD)

A total of 70 divers (14 percent) in our injury sample reported altitude exposure after diving. Approximately 20 percent of these exposures were associated with medical evacuation. DAN does not have information about whether the additional altitude exposure during the evacuation worsened their condition or not. There were 19 "true" FAD cases in our sample. These 19 divers developed their first symptoms in response to the altitude exposure. Sixteen of the 19 flew within 24 hours of diving.

## 3.6 Signs and Symptoms

### Onset Time

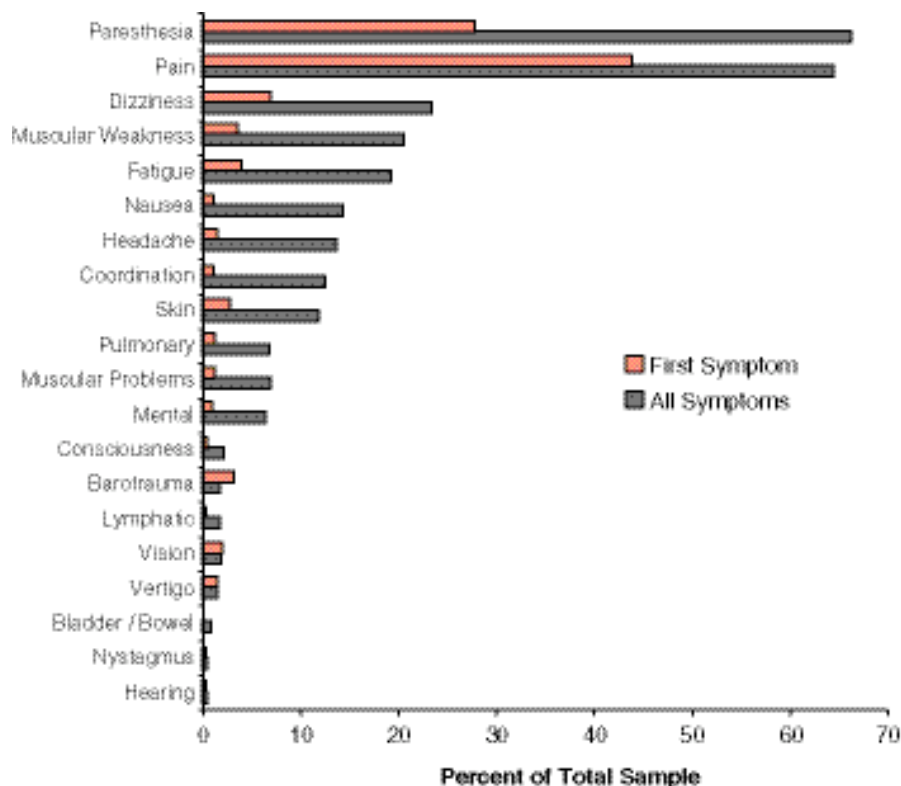
The onset time for signs and symptoms in our sample of the injured divers is shown in Figure 3.6-1. The majority of signs and symptoms of decompression illness occurred within one hour of the termination of the pressure exposure. This was true for all three diagnoses listed. A large number of the injuries were first manifested prior to the last dive as in the past. This may be an education problem that should be addressed. The onset of signs or symptoms more than 24 hours post-dive occurred in very few cases.



**Figure 3.6-1**  
Symptom onset  
time by diagnosis  
(n=297).

## Symptom Types

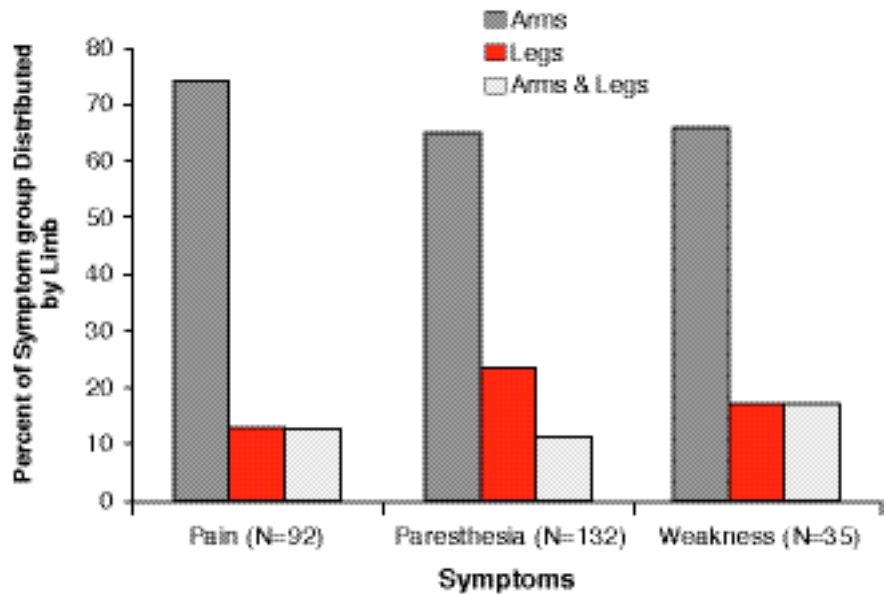
Figure 3.6-2 shows the frequency distribution for the different types of signs and symptoms reported. Paresthesia and pain were present in approximately 70 percent of all divers reporting symptoms of decompression illness. Paresthesia and pain were also the first symptoms reported in most cases. This symptom distribution is consistent with previous diving reports.



**Figure 3.6-2**  
Reported  
symptoms  
(n=297).

**Figure 3.6-3**  
**Distribution**  
**of pain, numbness**  
**and tingling, and**  
**muscular weakness**  
**by limb (n=259).**

The symptoms were more frequently located in the upper extremities, as exhibited in Figure 3.6-3.



### 3.7 Therapies Given

#### Surface Oxygen Treatment

Surface oxygen was delivered to injured divers in 47 percent of our sample. This percentage is unchanged from last year. Figure 3.7-1 shows the pattern of methods used to administer oxygen. The oronasal resuscitation mask accounted for the largest use percentage.

**Figure 3.7-1**  
**Method for**  
**delivering surface**  
**oxygen before**  
**recompression**  
**(n=139).**

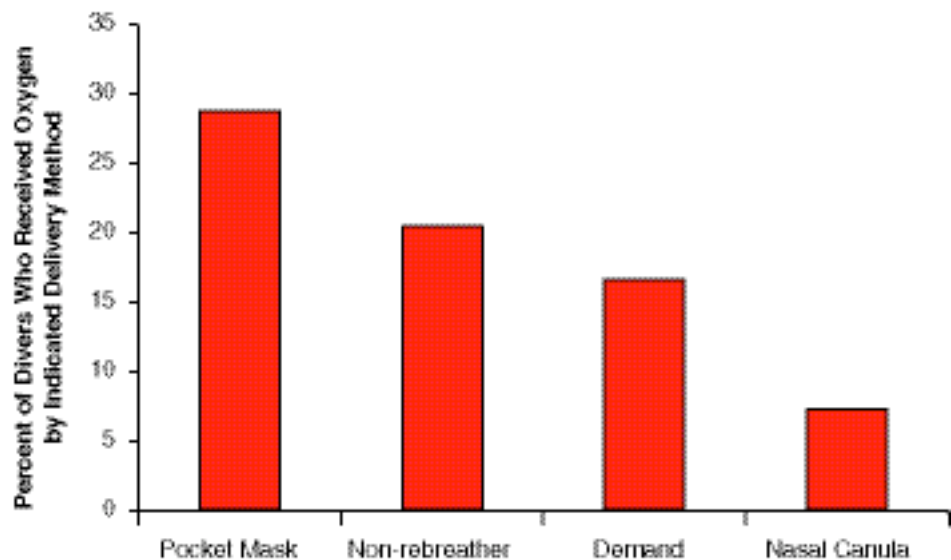
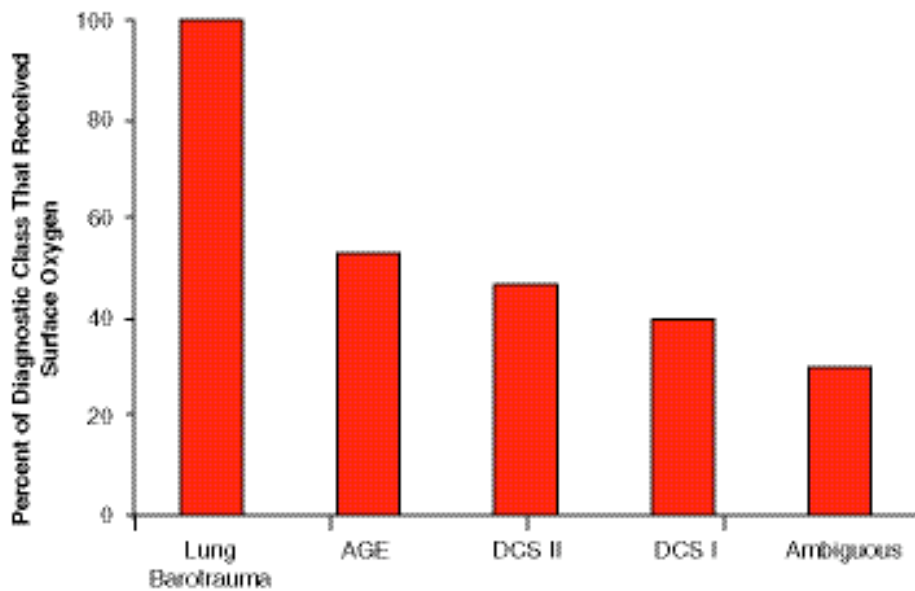


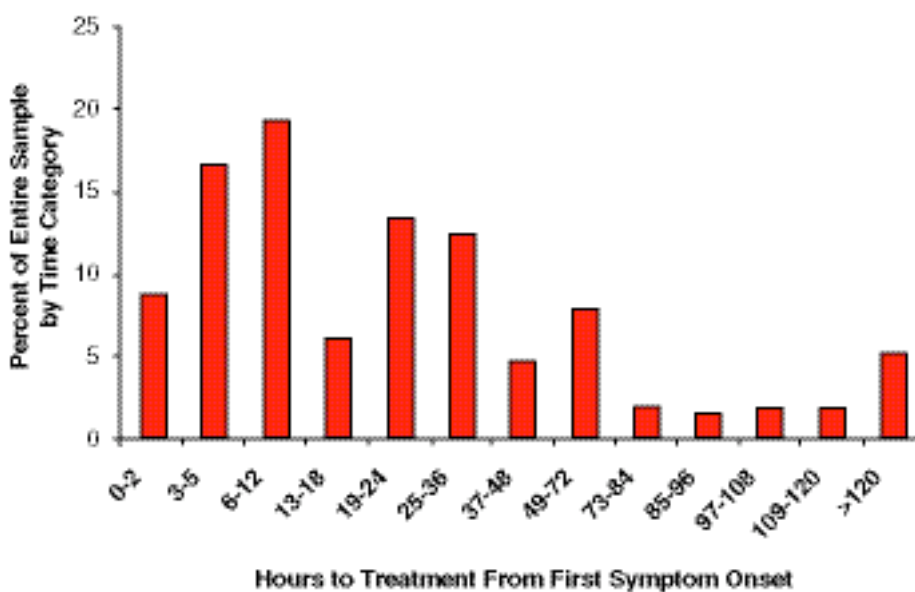
Figure 3.7-2 shows the percentage of each diagnostic category in our injury sample that received oxygen on the surface. The percentage of injured divers that had oxygen available to them is unknown.



**Figure 3.7-2**  
Administration  
of first aid oxygen  
by diagnosis  
(n=138).

## Recompression Treatment

There was a wide range in the times required to obtain recompression treatment for the injured divers in our sample (Figure 3.7-3). The majority of the injured divers received recompression treatment within 36 hours; however, some had delays of more than 120 hours. The median time to recompression treatment was 20 hours.



**Figure 3.7-3**  
Delay to  
recompression  
from the time  
of first symptom  
onset (n=297).

Figure 3.7-4 shows the initial treatment table used to compress injured divers in our sample. The USN Treatment Table 6 was most commonly used. Short tables refer to hyperbaric oxygen delivered at either 90 minutes at 33 fsw (10 msw) or 90 minutes at 45 fsw (14 msw). Other tables include Catalina and USN 6A.

**Figure 3.7-4**  
Initial treatment table used to recompress injured divers (n=297).

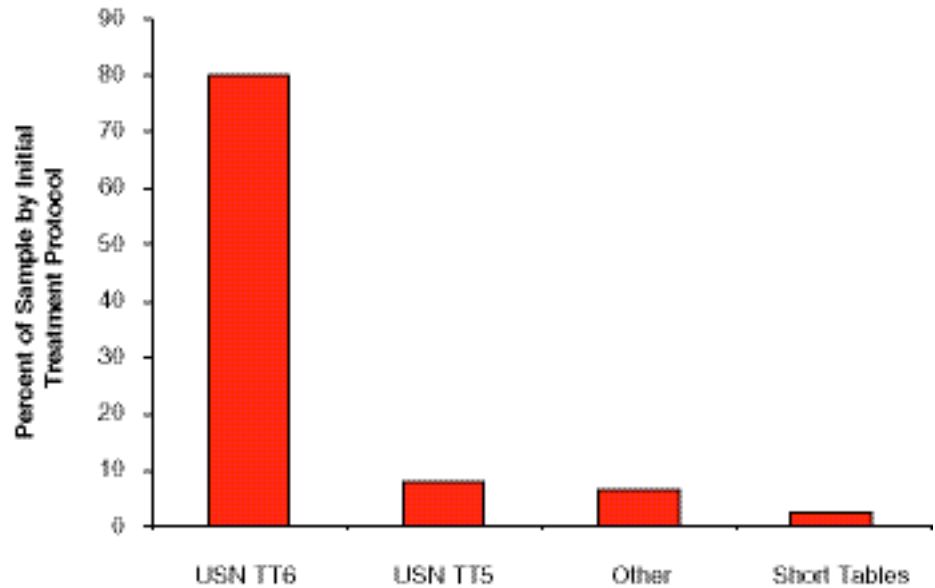


Figure 3.7-5 describes the resolution of symptoms by diagnosis. Approximately one-third of recreational divers had a residual symptom at the end of recompression treatment. It is interesting to note that cases classified as ambiguous had a higher percentage of residual symptoms than those in other diagnostic categories. This is understandable, since symptoms not caused by decompression illness may not respond to recompression treatment. It is possible that the ambiguous category contains cases that were not correctly diagnosed.

**Figure 3.7-5**  
The outcomes at discharge by diagnostic category (n=293).

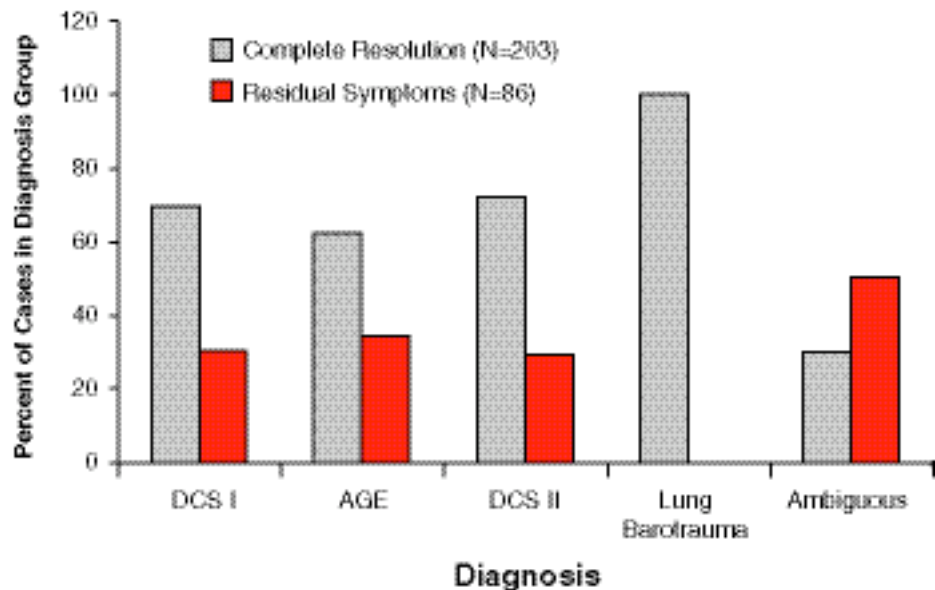
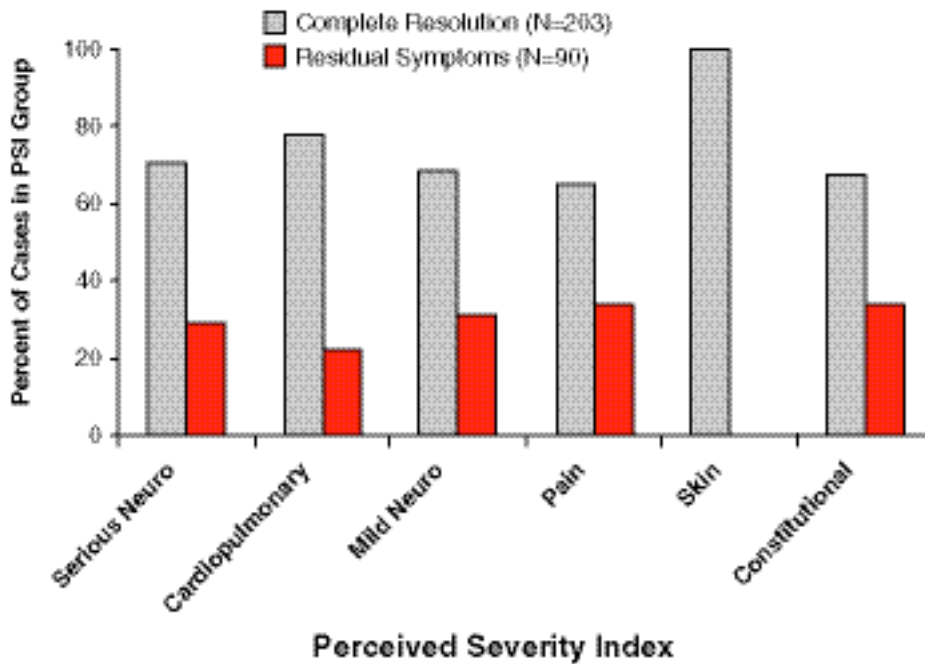
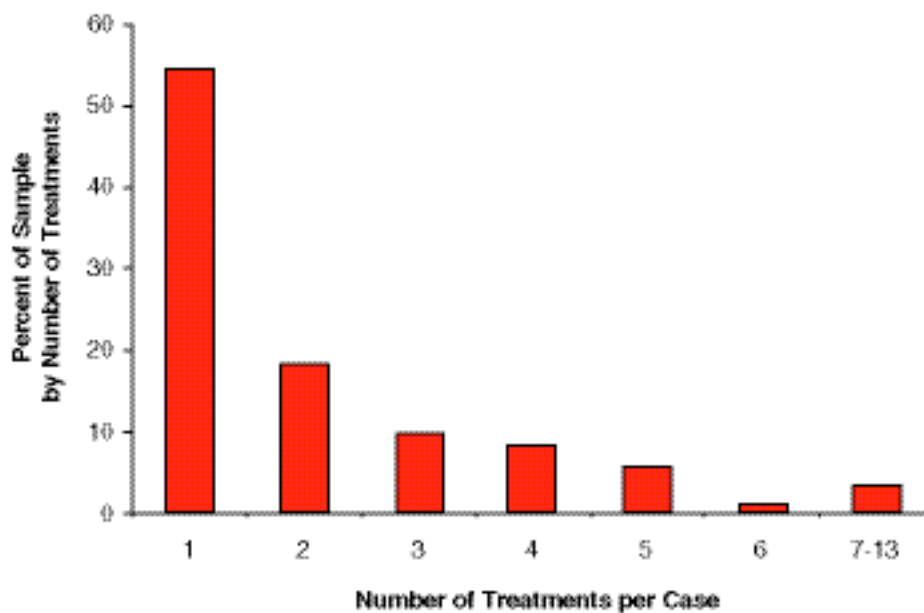


Figure 3.7-6 describes the outcome at discharge when the cases are stratified by DAN's Perceived Severity Index (page 48). There is little difference among the categories in the degree of residual symptoms at discharge, unlike previous years, when persistence of residual symptoms after treatment was related to the severity of symptoms at presentation.



**Figure 3.7-6**  
Outcomes at discharge by Perceived Severity Index (n=293).

The number of recompression treatments given divers varied extensively. The majority of divers (55 percent of our sample) received only one recompression treatment; however, some divers received up to 13 treatments. Figure 3.7-7 shows this distribution.

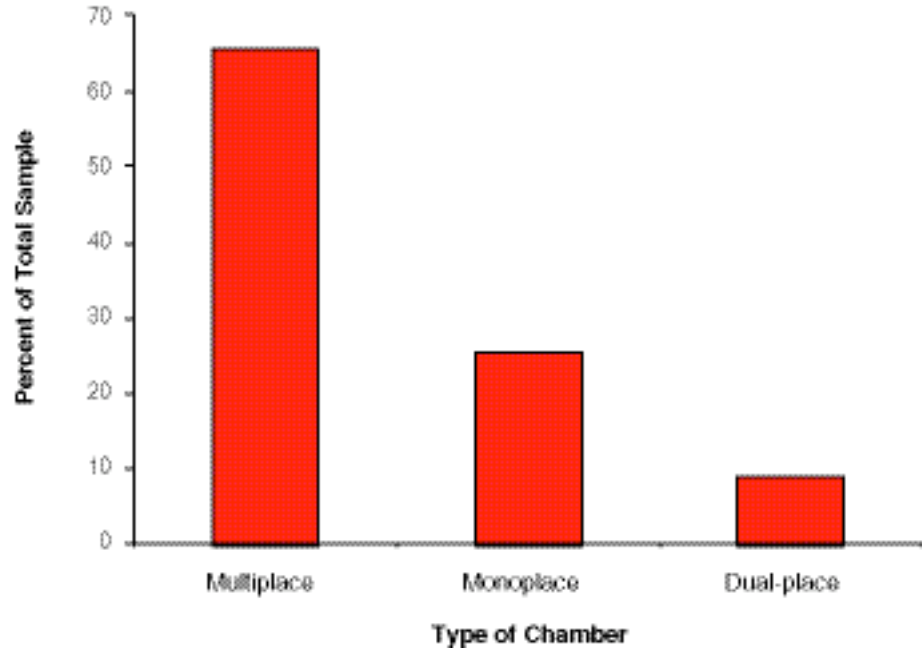


**Figure 3.7-7**  
Total number of recompressions for injured divers (n=294).



**Figure 3.7-8**  
**Type of chamber**  
**in which injured**  
**divers were treated**  
**(n=297).**

The majority of divers were treated in multiplace chambers. Figure 3.7-8 shows this distribution.



### 3.8 Data Collection Issues

This is the last year that DAN's diving report will present data collected using only the DIRF. During the years 2004 and 2005, the transition to the new Scuba Epidemiological Reporting Form (SERF) will occur. Using the SERF should result in an improvement in both the response rate and the quality of the data reported.

The SERF was designed to specifically answer the question of how the severity of an injured diver's symptoms at the time of presentation to a medical facility correlates with the eventual medical outcome. To accomplish this goal, the SERF strictly stratifies all cases by severity at the time of presentation. Since the issue of delayed treatment and the effect of time on long-term outcome are still unknown, the condition and evolution of symptoms at multiple time points is also recorded. Because the issue of diagnostic ambiguity is important, the SERF allows the treating physician to state his or her degree of confidence in the diagnosis.

Finally, the SERF is integrated with PDE technology to facilitate the capture of dive profile information from the injured diver's dive computer. This will allow precise documentation of the pressure-time exposure associated with the specific injury. All of these innovations will be of great assistance in answering questions regarding the risks of decompression illness in recreational diving.

## Case (diagnosis) Reclassification

### Cases reclassified as "Not DCI"

- a) Cases with single dives to less than 30 fsw (9 msw) and symptoms that could not be attributed to AGE
- b) Cases with symptom onset times more than 48 hours after the last dive or altitude exposure
- c) Cases with signs and symptoms likely due to a non-diving cause of injury upon review of medical history
- d) Cases with symptoms that resolved spontaneously without recompression in less than 20 minutes with surface oxygen or in less than 60 minutes without oxygen
- e) Cases with no response to recompression were reviewed extensively before classification as Not DCI

### Cases reclassified as "ambiguous"

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

### Decompression sickness cases

- a) Cases with a dive depth of at least 30 fsw
- b) Headache, dizziness, anxiety, general weakness, fatigue, and subjective numbness and tingling of both hands and feet were not classified as DCS in absence of other symptoms or without objective findings

### Type I DCS (DCS I)

included PSIs of Pain, Skin/Lymphatic, Constitutional / Non-Specific

### Type II DCS (DCS II)

included PSIs of Serious Neurological, Cardiopulmonary, Mild Neurological and simultaneous presence of Pain and Constitutional.

**AGE cases**

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

**Lung Barotrauma cases**

- a) Mediastinal emphysema
- b) Subcutaneous emphysema
- c) Pneumothorax
- d) In the absence of any neurological signs or symptoms

**DCI cases**

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

# 4. Dive Fatalities

Death while diving is most often classified as drowning. Recreational scuba drowning deaths represent a small fraction of the 5,600 drownings per year in the U.S. Scuba fatalities are rare events and do not occur as a significant problem on the national level. For scuba divers who are directly concerned with the possibility of death in diving and for the friends and families of divers, the problem is always there and cannot ever be small enough. To help learn why divers die and how deaths can be prevented, DAN has maintained a recreational diving fatality surveillance system since 1989.

The DAN fatality surveillance system consists of two components: an external voluntary notification system and an active in-house investigation process. Voluntary notification comes from divers who may have witnessed the accident, family members, dive businesses, investigative agencies, and government agencies. DAN also actively monitors newspapers and the Internet for news on fatal accidents. Once the notification has been received, DAN researchers start an inquiry in order to collect all available relevant data. The inquiry is limited to recreational scuba diving fatalities that occur in the United States and Canada or that involve U.S. citizens diving abroad. Despite all investigative efforts, information on fatalities is often incomplete, especially in cases that occurred abroad.

The major purpose of this collection and analysis system is to identify preventable deaths and avoid repetition. Some sudden deaths are not attributable to diving. Some risk factors may be controllable by better understanding of the environment, better dive preparation, safety checks and better training. The data are not always adequate to distinguish between preventable and random deaths, or to evaluate suspected risk factors. As there are more possible causative and contributing factors to explore than there are accidents, a separate review of each accident is useful. In this chapter, we present the fatality surveillance in three ways: a) basic descriptive statistics as in the PDE and Injury chapters; b) an analysis of situations and hazards; and c) a case summary of each fatality.

## 4.1 Fatality Statistics

In 2003, DAN received notification on 153 deaths during diving. Follow-up was completed in 109 of these. Among the 44 cases rejected, there were seven cases involving commercial divers. Twenty of the cases occurred in freediving or snorkel swimming. These cases are described in Chapter 6. The others excluded either involved non-U.S. or non-Canadian citizens or failed to meet the other criteria listed above.

Eighty-nine cases are thus reported in this chapter, 24 women and 65 men. Autopsy reports were available for 47 cases, not available in 21 cases and unknown or not performed in 11 cases. There were 10 cases where the body was not recovered. In 48 percent of the cases, there were no witnesses of the critical event.

A forensic pathologist who is trained in dive medicine has reviewed all the cases. Since drowning is basically a diagnosis of exclusion, it is important to look at all of the circumstances surrounding the death of a diver. The autopsy itself was inconclusive in several cases. By putting the autopsy findings together with the circumstances surrounding the death, it is possible to elucidate the most likely sequence of events that resulted in the death of the diver.

Sixty-three percent (n=56) of these cases occurred in the U.S. and 37 percent (n=33) abroad. Geographic distribution of U.S. fatalities by region is shown in Figure 4.1-1. Thirty-seven percent occurred in the Southeast Region (North Carolina to Florida, including Tennessee and Alabama). DAN regions and the states they represent are listed in the front of this report.

**Figure 4.1-1**  
**Regional**  
**distribution**  
**of fatalities**  
**in the U.S.**

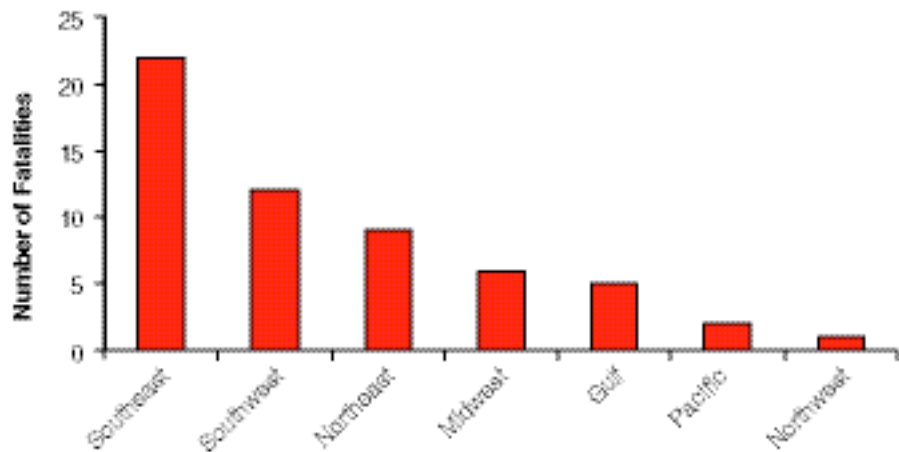
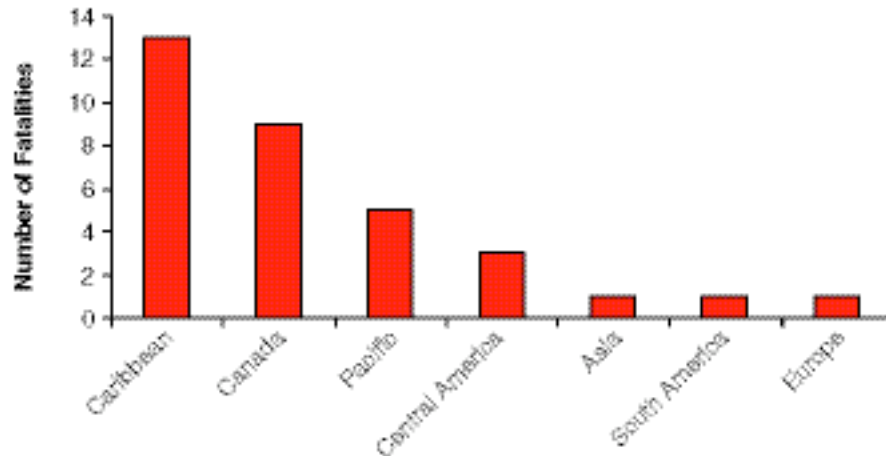


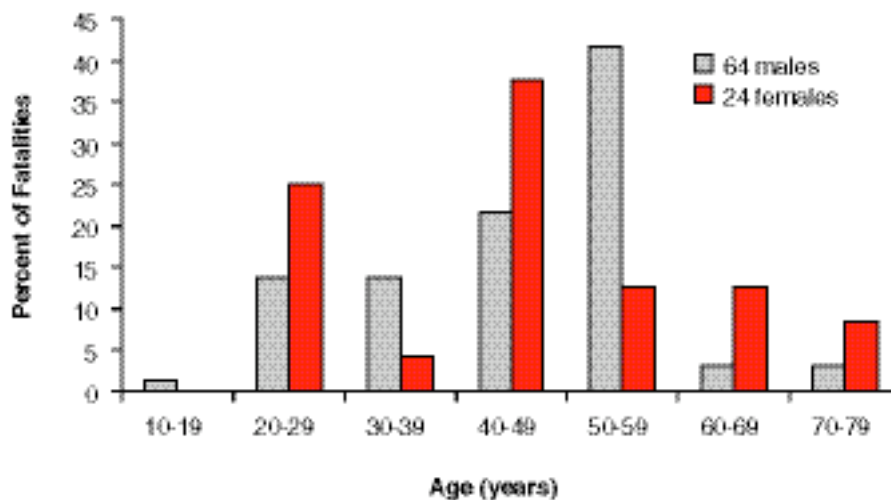
Figure 4.1-2 shows the distribution of cases by international regions. Most fatalities occurred in the Caribbean (15 percent, n=13). However, the number is relatively small in comparison to 144 injuries (49 percent of all injuries in this report) that occurred in the same region.



**Figure 4.1-2**  
Geographic locations where the fatalities occurred.

## 4.2 Characteristics of Divers Who Died

The age distribution for dive fatality victims is shown in Figure 4.2-1. Seventy percent of deceased divers were 40 years or older, both in males and females. The age range for females was from 21 to 75 years of age, with a median of 45 years. The range in males was from 18 to 79 years of age, with a median of 47 years.



**Figure 4.2-1.**  
Distribution of fatalities by age and gender.

Age per se may not be a risk factor for diving accidents but aging is associated with increasing prevalence of chronic and degenerative diseases that may constitute risk factors for death during a dive. The past medical history was available in 57 cases (64 percent). In 51 percent of cases with available data (n=29), there was no indication of any health problem. The most frequently reported medical condition was high blood pressure (16 percent, n=9). Heart disease was implicated by drug history in five (9 percent), diabetes in one and asthma in one case. Among 10 cases with other conditions, four were using antidepressants, two were treated for cancer in the past, one suffered sleep apnea and others had some minor allergy, pain or motion sickness. Smoking history was known for 53 cases. Among them there were three known smokers and seven ex-smokers.

Medical examiners have reported many conditions that the decedent may or may not have been aware of. Some of these conditions may have contributed to their deaths (heart conditions that may cause arrhythmia, lung emphysema, lung blebs).

Figure 4.2-2 shows the level of obesity in the fatality population according to the standard body mass index (BMI). The BMI is a derived value that evaluates the relationship between subject height and weight. As the BMI increases, except in the case of well-conditioned athletes with increased muscle mass, the level of obesity increases. Data were available for 61 fatalities. Twenty-six percent of victims were classified as appropriate or normal weight, and 33 percent were classified as overweight. A total of 41 percent of divers in this sample were considered obese, ranging from a Grade 1 to extreme obesity, according to the U.S. National Heart, Lung and Blood Institute scale (1998).

Obesity is often associated with poor exercise tolerance, heart disease and diabetes.

**Figure 4.2-2.**  
**Classification**  
**of fatalities**  
**according to**  
**US National Heart,**  
**Lung and Blood**  
**Institute Scale.**

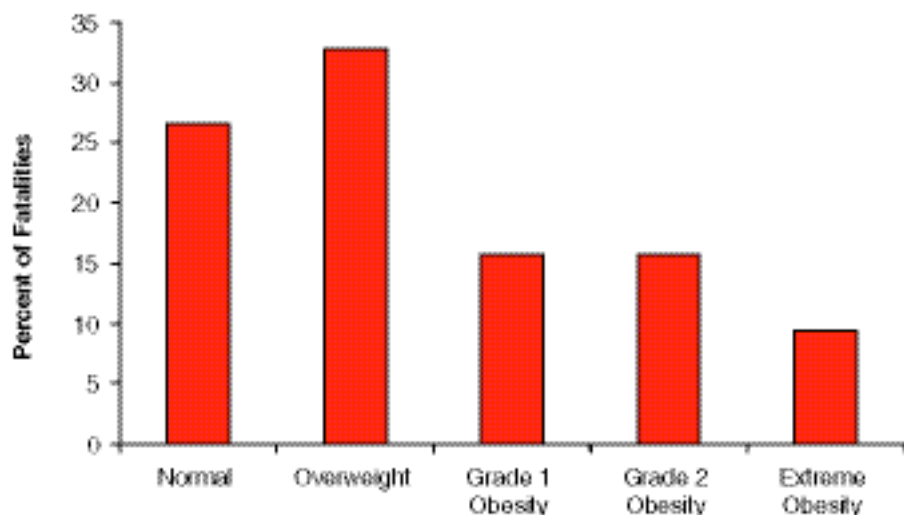
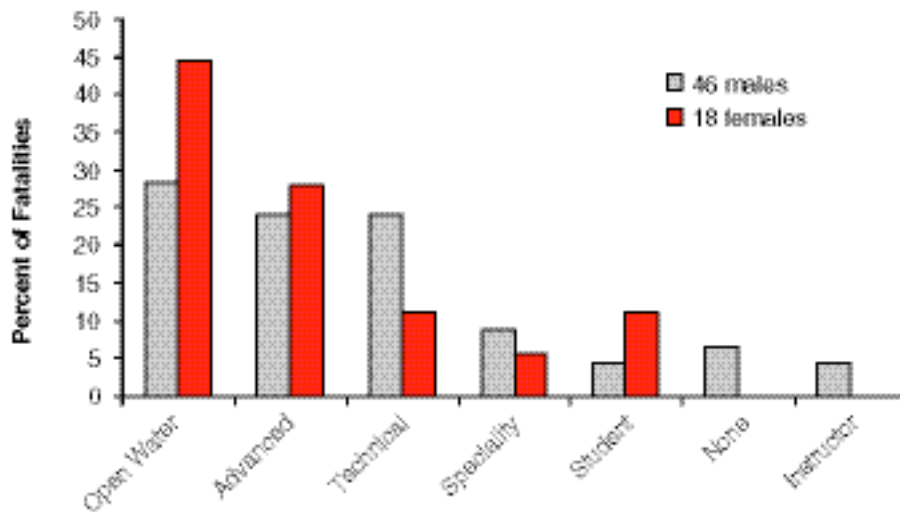


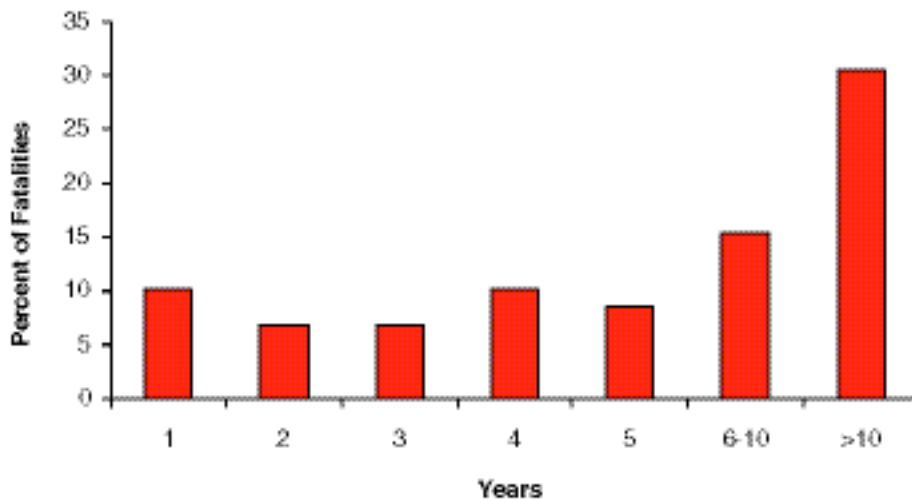


Figure 4.2-3 shows the breakdown of certification levels and gender for 46 male and 18 female victims. The majority of divers had open water or advanced certification. Of four student fatalities, two were males and two females. Three had no formal training.



**Figure 4.2-3**  
Certification of  
divers who died.

Figure 4.2-4 shows the number of years since initial certification of divers who died. Thirty-one percent of divers had 10 or more years of diving, and 10 percent had one year or less. The number of years diving itself does not always reflect the level of experience, since most of the recreational divers are infrequent divers.



**Figure 4.2-4**  
Number of years  
since initial  
certification of  
divers who died.

Figure 4.2-5 shows the number of dives that were performed by the diver in the 12 months prior to the incident. Information was available in 54 cases. Nearly 45 percent of divers had no dives or had not dived in the previous 12 months. The 28 percent of divers had less than 20 dives in the past 12 months. They could be considered infrequent divers. Twenty-eight percent of divers with more than 20 dives in the previous 12 months could be classified as regular divers. There were at least 10 "novice divers" or those with 20 or fewer lifetime dives.

**Figure 4.2-5**  
**Number of dives**  
**that were performed**  
**by the diver in the**  
**previous 12 months**  
**prior to the incident.**

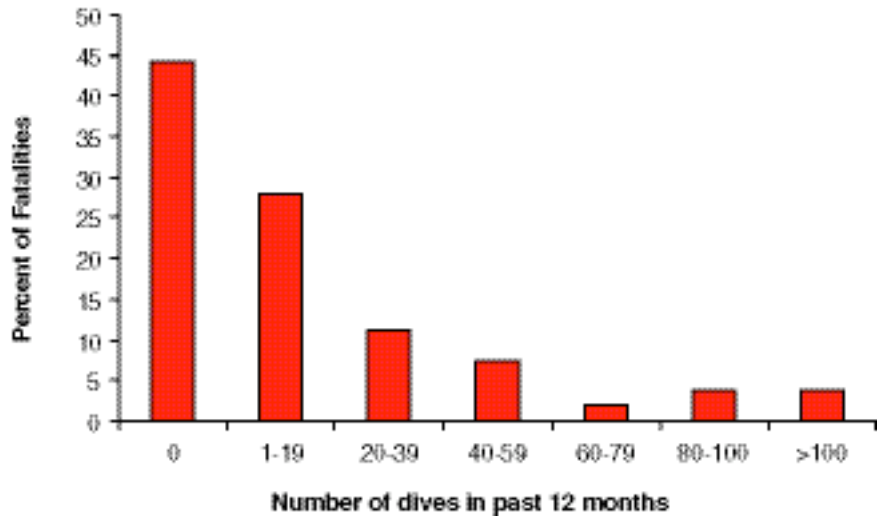
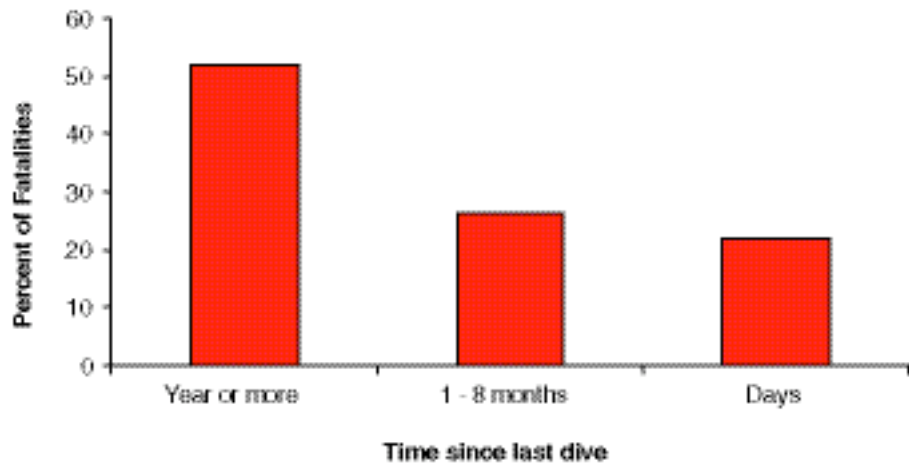


Figure 4.2-6 shows the number of months between the last dive and the accident dive (n=50). Fifty-six percent of divers were returning to dive after one to four years. A one dive trip per year is quite common among PDE divers and thus divers diving once a year may be proportionally represented among the fatalities. However, there were several divers returning to diving after two or more years, and only one had a formal refresher course.

**Figure 4.2-6**  
**Time between**  
**last dive and**  
**day of accident.**

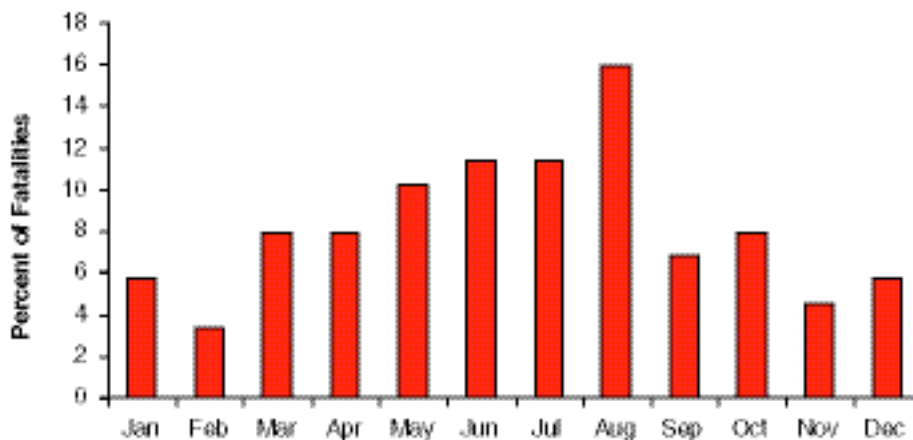


Our data show that divers of any certification level or years of experience may become victims. The number of dives in the previous 12 months was related to the occurrence of death. There were more occasional than regular divers among fatalities.

### 4.3 Characteristics of dives in fatality accidents

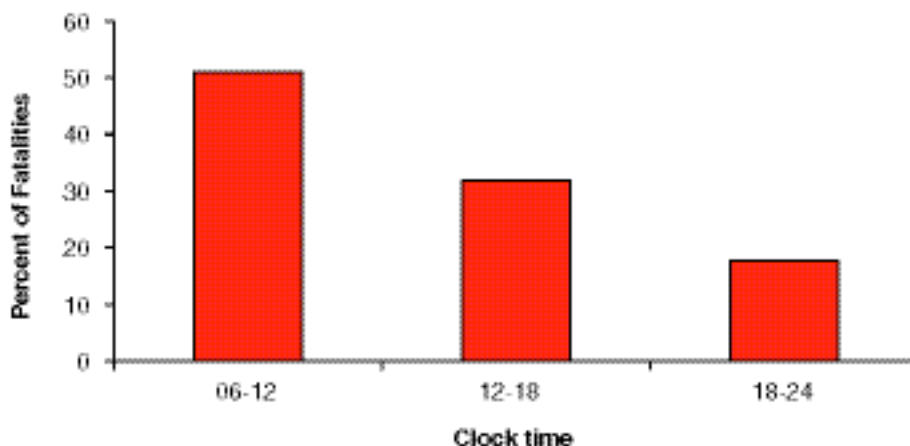
The following figures describe characteristics of the dives that resulted in death. The information about dive exposure in fatal accidents is often limited to the last day of diving and is usually not complete. We have information about the date and time of the dive, environment, equipment, maximum depth and duration of dive and information about organization of diving.

Figure 4.3-1 shows the death by month. Cold may have been a contributing factor in some. Three cases occurred in freezing water in divers who died under the ice.



**Figure 4.3-1**  
The month when diver deaths occurred.

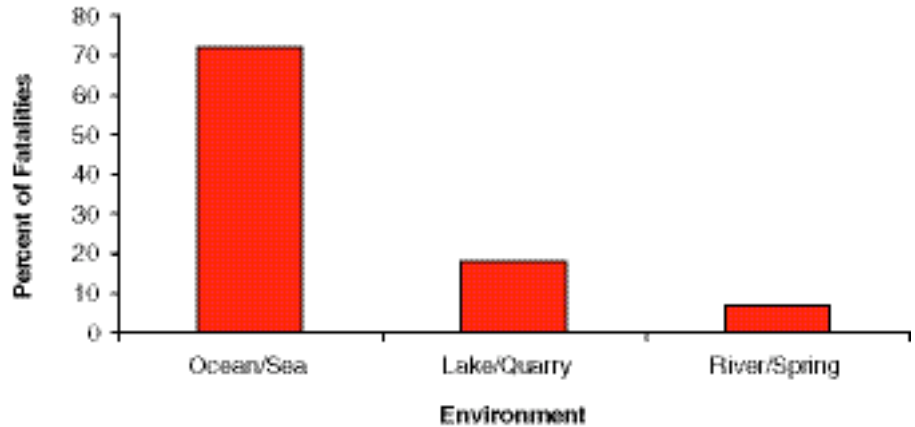
Figure 4.3-2 shows the time of day that most fatalities occur (n=63). Most accidents occurred during daylight hours, as might be expected, since most diving is conducted during daylight hours. Three drownings occurred during night diving. Two of them involved inexperienced divers and failure of the buddy system.



**Figure 4.3-2**  
Time of death.

Figure 4.3-3 shows the water environment for dives that resulted in a fatality. Out of 28 percent (n=25) that occurred in fresh water, 18 percent (n=16) occurred in lakes or quarries, and 7 percent (n=6) occurred in rivers. Six cases occurred while cave diving, most in freshwater but some in the ocean. The category River/Spring suggests moving water. However, many rivers and springs have less current than some ocean dive sites. Out of six fatalities in River/Spring, two occurred in strong current, and in three cases there was no current at all.

**Figure 4.3-3**  
The environment where the fatalities occurred.



Specific reasons for the dive are shown in Figure 4.3-4. Thirty-eight percent of divers (n=33) were involved in a pleasure or sightseeing dive. Fifteen percent of divers (n=13) were fishing or collecting game. Training was the main activity in 10 percent of fatalities (n=9). Wreck and cave diving combined made up 15 percent and personal work 6 percent of cases. Five percent (n=4) occurred during the night and three cases under the ice.

**Figure 4.3-4**  
Diving activity.

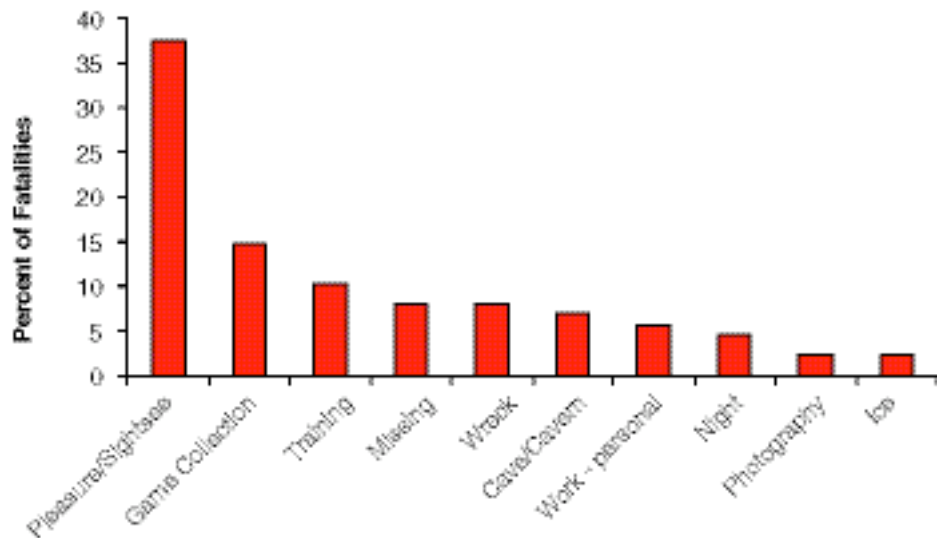
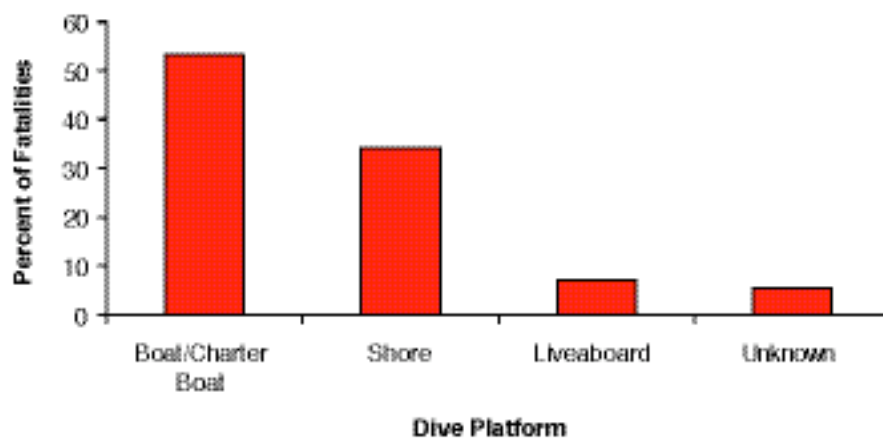


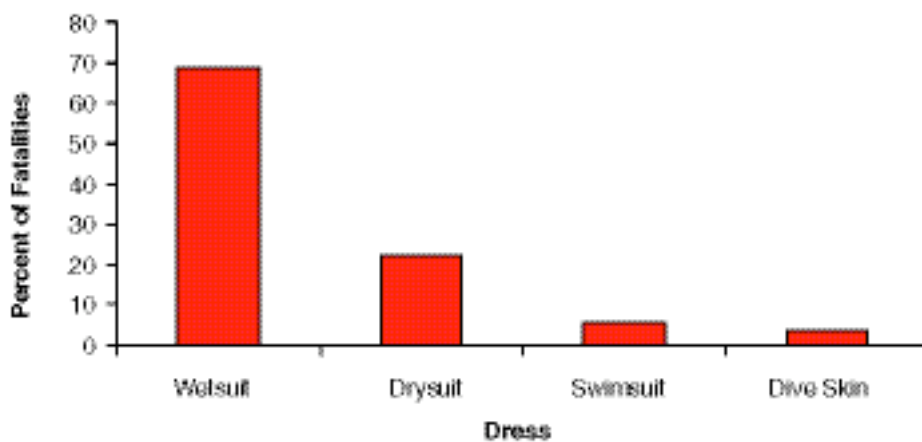
Figure 4.3-5 shows the dive platform from which the fatal dives began. Fifty percent began from a charter or private vessel, which is consistent with previous reports. The differences in absolute numbers of fatalities for various platforms probably reflect different numbers of participating divers. We do not have denominators for incidence rates.

In shore diving, entry and exit may sometimes expose divers to long swims against waves and current and small groups may operate without surface support. Beginner divers are more likely to dive off the beach. In contrast to liveaboard diving, diving from private boats is often done by a single diver or a small group of divers without any formal organization.



**Figure 4.3-5**  
Dive platform.

Figure 4.3-6 shows the type of thermal protection worn by divers who died. The majority used a wetsuit. Drysuits were used in 22 percent, swimsuits in 6 percent and dive skins in 4 percent.



**Figure 4.3-6**  
Thermal protection worn by divers who died.

Figure 4.3-7 shows the range of depths reported for 62 scuba fatalities. Six percent (n=4) occurred on the surface before the dive. Sixty-nine percent (n=42) occurred in depths less than 90 feet (27 meters) and 25 percent (n=16) on deeper dives. Nitrogen narcosis is always a risk in deep dives and may have been an influence here. One death occurred in a dive deeper than 300 feet (92 meters). The diver announced his intention to exceed 400 feet (125 meters) during his air dive. He was seen crossing 300 feet on his way down. He disappeared at depth and was never found.

**Figure 4.3-7  
Maximum  
dive depth.**

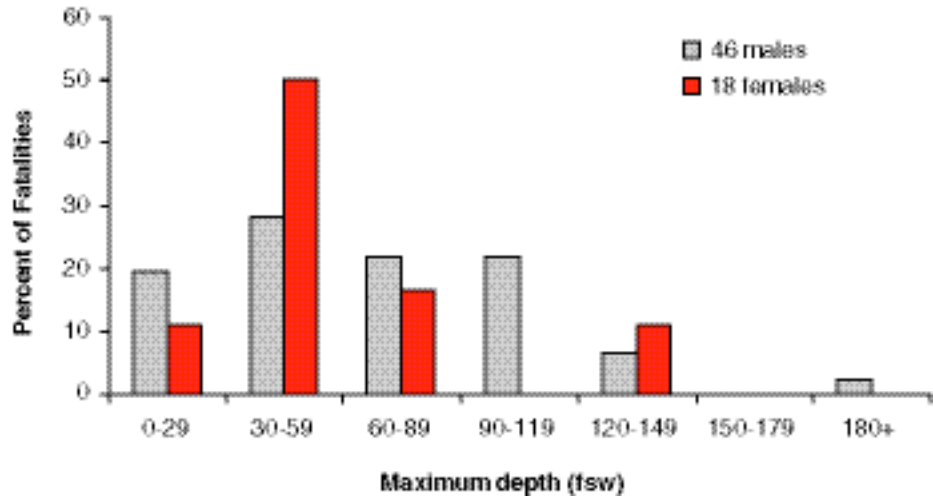


Figure 4.3-8 shows breathing gear and breathing gas. Scuba was used in 94 percent of the cases (n=73), most frequently with air (88 percent). In 6 percent (n=5), the breathing gas was nitrox, and in one case it was trimix. Rebreathers were used in four cases.

**Figure 4.3-8  
Breathing gear  
and gas.**

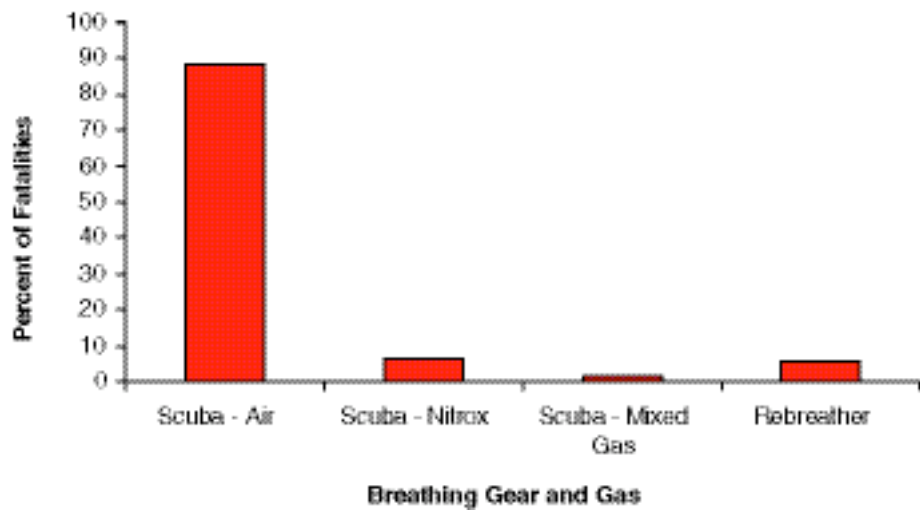


Figure 4.3-9 shows the distribution of cause of death in the judgment of the DAN pathologist who reviewed each case. Forty-six cases (52 percent) were designated as a drowning death. Arterial gas embolism was probably the main cause of death in 16 cases (18 percent). Cardiac dysrhythmia was suspected in 15 cases (17 percent) and myocardial infarction in one case.

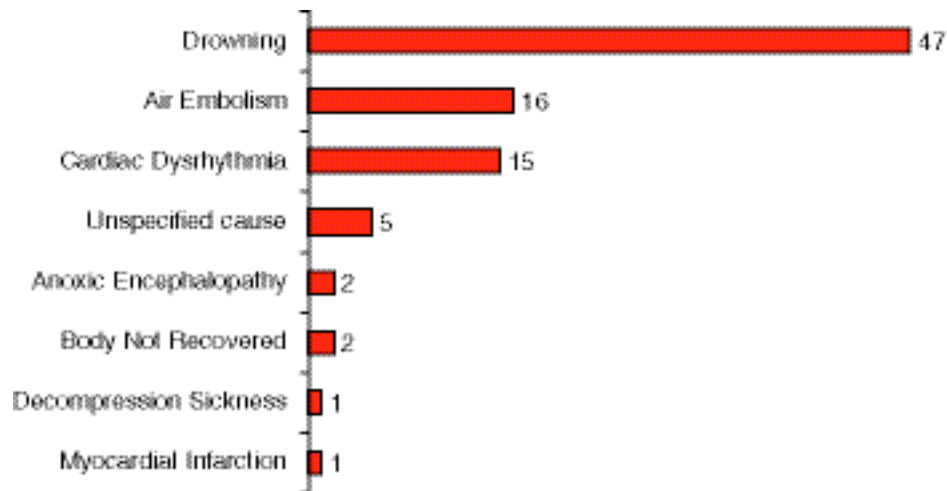


Figure 4.3-9  
Cause of death.

## 4.4 Analysis of situations and hazards

### 4.4.1 Accidents by stage of dive

We will consider each dive in five stages:

- 1) Pre-dive: period from water entry until submersion.
- 2) Descent: period from leaving the surface until reaching the bottom, including events early in the dive.
- 3) Bottom: period from reaching the bottom until ascent.
- 4) Ascent: period from start of ascent until reaching the surface.
- 5) Post-dive: period from reaching the surface until exiting the water.

Figure 4.4-1 shows the frequency of accidents by the stage of the dive. For 35 percent of the cases (n=31), it was not known when and where the accident occurred.

**Pre-dive.** In five cases the accident occurred on the surface before submersion. Rough sea and strong current were explicitly reported in two cases. In one case a diver dropped his regulator because, as later was shown, his gas cylinder was nearly empty.

**Descent.** In five cases the accident happened on descent or at an early stage of the dive. In one case the computer recorded that the gas tank was practically empty on entering the water. The diver signaled his buddy that he was in trouble, but his buddy was not

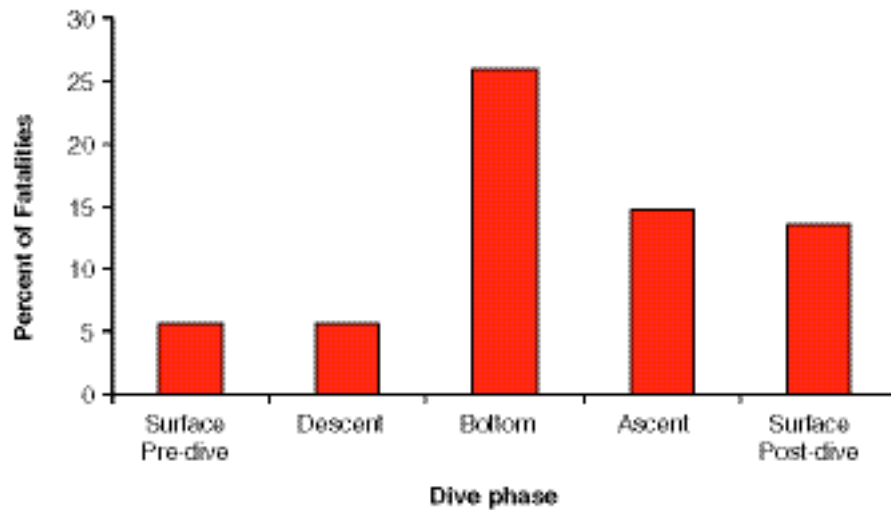


aware of the nature of the problem. They started their ascent together but the diver became unresponsive halfway to the surface. Another inexperienced diver died underwater soon after the descent. The valve on her gas tank was not open enough to supply gas at depth. One diver may have experienced a heart attack underwater and his buddy could not bring him up. In two other cases problems started early in the dive and the divers decided to abort the dive. One diver never made it to the surface, and the second diver died after surfacing.

**At the bottom.** In 26 percent of the cases (n=23), problems started on the bottom. Three divers were trapped; four may have had heart problems while underwater. In one case, a solo diver died in a cave although he had a plenty of available gas and no obstacle to leave. He had a history of narcolepsy (episodes of suddenly falling asleep in any situation), which was suspected as a main cause of his drowning. One diver was found unconscious by his buddy at 130 feet. The cause of his death was never established. In five cases the initial event was an out of air situation. In four cases buoyancy problems, cold, a new scooter, or lack of fitness contributed to a rapid gas depletion. One diver was separated from his buddies and came back with his regulator in free flow. He never made it to the surface alive. One diver lost consciousness soon after he signaled his buddy that he was low on air. Visibility was poor and his buddy realized that the diver was missing when he reached the surface a few minutes later. Panic was witnessed in three cases. The trigger of panic was not known. Out of 23 divers in this group, 13 did an emergency ascent. Five divers were attended during the ascent by their buddy, and eight were unattended. AGE was confirmed in two of the unattended ascents.

**Ascent.** In 15 percent of the cases (n=13), problems started during the ascent, sometimes even after completion of the 10-foot safety stop. In one case, the diver was lost in shallow water after leaving the safety stop. Inspection of his rebreather has shown major malfunctions due to poor maintenance and assembly.

**Post-dive.** In 12 cases problems became apparent after the ascent. At least two of these cases had a rapid ascent for unknown reasons. One death occurred after the diver exited the water without indicating he had any problem. Nine cases seemed to be in distress on the surface due to exertion while swimming against strong currents and waves, or just trying to stay afloat against buoyancy problems. Unconscious divers were often found floating face down. This is a reminder that BCDs are not designed to keep a diver's head on the surface and that a diver in distress needs assistance all the time while in the water.



#### 4.4-1 Distribution of accidents by stage of dive.

### 4.4.2 Hazards

Some of the hazards that may lead to loss of life in scuba diving are:

- 1) Loss of consciousness, self-control or faculties while in the water, possibly as a result of a health problem like cardiac disease or a seizure disorder.
- 2) Loss of gas supply.
- 3) Errors in ascent procedures causing injury by expanding gas within body tissues (barotrauma) or gas escaping solution in the tissues (decompression sickness).
- 4) Obstacles to the surface from entanglement or overhead environments such as cave diving, wreck penetration and ice.
- 5) Inability of the diver to cope with current, waves, or cold.
- 6) Equipment failure.
- 7) Mechanical injuries not specific to diving such as being struck by a boat, etc.
- 8) General medical conditions such as a heart attack.

While divers must be self-reliant and are responsible for their own safety, use of the buddy system is meant to ensure support by another diver in case of need. DAN always inquires whether diving with a buddy was planned and implemented.

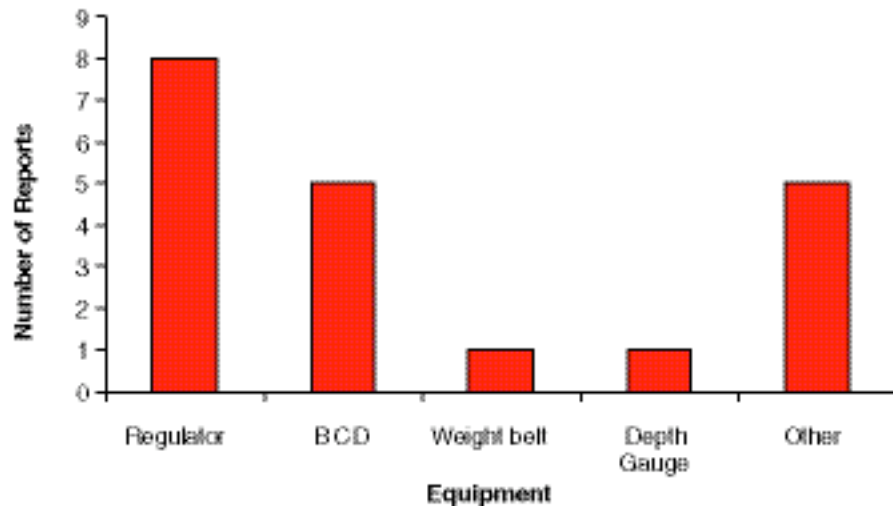
**Loss of gas** supply was a problem in at least 29 cases. Among these were five solo divers who could not get help. In 15 cases, buddies separated intentionally or lost contact before running out of air. In two cases, divers did not check their gas supply before the dive and started diving with nearly empty tanks. In one case, the diver used a rebreather that was poorly maintained such that oxygen was not delivered due to partial obstruction of the supply line. One diver consumed nearly all of his gas on the way into a cave.

**Errors in ascent procedures** that resulted in fatal injury occurred in at least two cases of AGE proved by autopsy. AGE was suspected in a few more cases but was not proved. In one case gas expansion during apparently a normal ascent caused a rupture of pre-existing blebs in the lungs and tension pneumothorax (burst lung) that killed the diver. Rapid ascent was observed or suggested in several other cases but problems that caused death either started before ascent or death was due to some complication later on the surface.

**Loss of consciousness** while underwater was witnessed in two cases, apparently due to cardiac events. A diver with a history of narcolepsy drowned in a cave despite a plentiful gas supply. Loss of self-control underwater, as an initial event, was witnessed in one case. The diver that suffered a panic attack was aware of this condition and had experienced one episode before the fatal dive. An older diver with diagnosed dementia was observed having difficulty with her diving equipment before she drowned.

**Inability of the diver to cope with current, waves and cold** was suspected in 14 cases: four pre-dive, one at the bottom and nine post-dive. The current can be a challenge both at depth and on the surface. There was only one witnessed case where a diver was overwhelmed by strong current at depth and lost his regulator. Swimming against the current and waves on the surface is more demanding on the cardiovascular system than swimming underwater. If the diver has run out of air, this is more tiring. This was the case in at least three accidents in this group. Buoyancy problems during diving that may have contributed to large gas consumption also could have negatively affected their ability to swim on the surface. Six divers who ran into problems post-dive at the surface were over 50 years old, three were obese and four had known heart conditions.

**Equipment failure.** Limited information was available concerning equipment problems in scuba fatalities. Equipment was retrieved in 77 cases. It was tested in 39 cases, not tested in 19 cases and for 22 cases we could not determine the equipment status. Figure 4.4-2 shows the reported findings. The regulator had signs of poor maintenance in eight cases. None apparently contributed to death. "Other" includes one case where combination of poor maintenance and error in assembling the rebreather were considered a direct cause of death. In another case there was a leak on the regulator hose that may have emptied the tank before the dive, and in another there was a free flow of the octopus at depth that caused the diver's death.

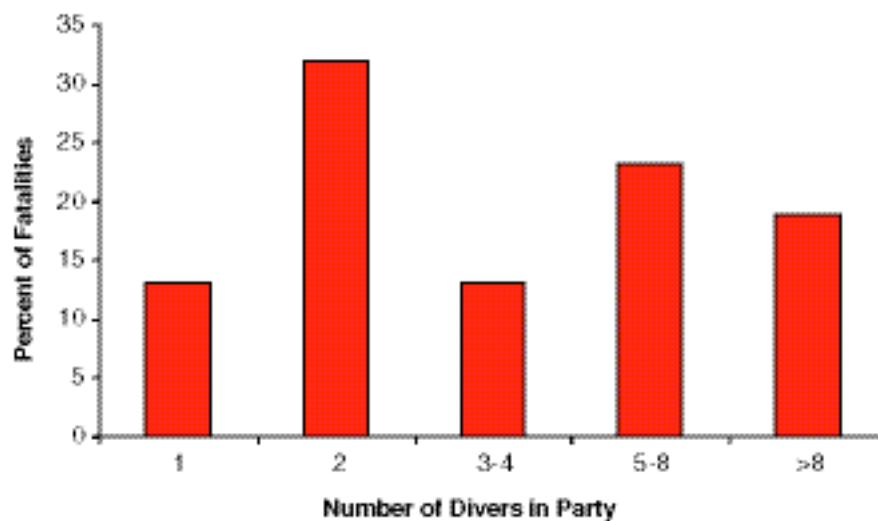


**Figure 4.4-2**  
Reported  
equipment  
problems.

There were several injuries not specific for diving. In one case the diver was struck by a boat. The dive site was not marked by a buoy. Another diver was killed by electric shock when he tried to use an electric tool underwater.

### 4.4.3 Organization of diving

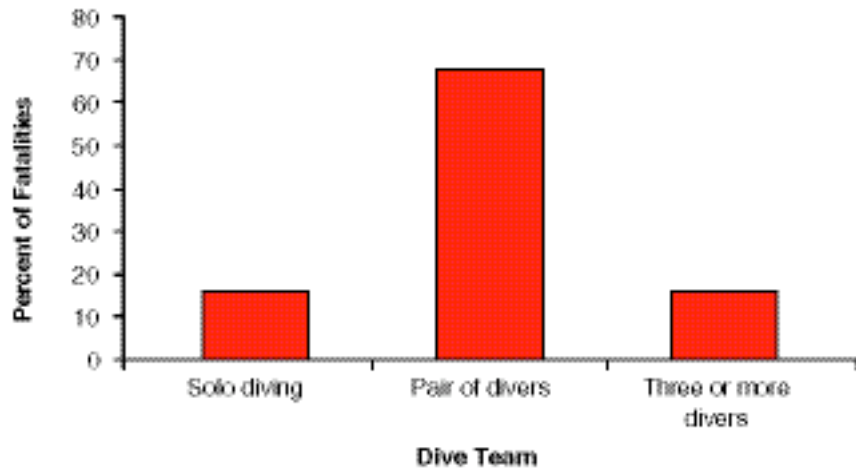
Most diving hazards are well known and good organization may either prevent accidents or increase chances of survival. Figure 4.4-3 shows the number of divers in the dive party or group.



**Figure 4.4-3**  
Number of divers  
in party.

The number of divers in the actual diving team is shown in Figure 4.4-4 (n=81). In 16 percent of accidents (n=13), the diver was diving alone. The buddy system was formally attempted in 84 percent (n=68) of accidents, most frequently with a pair of divers and in 16 percent of cases with three or more divers. In 50 percent (n=34) of cases, the buddy system failed due to separation of divers.

**Figure 4.4-4**  
Number of divers  
in team.



A separation of divers was sometimes a matter of choice and sometimes accidental. In at least three cases, the divers may have panicked after losing contact with their buddy. In many cases, the buddies were separated due to poor visibility. In four of these situations, both divers died. Three of the double fatality cases involved overhead environments, including cave, tunnel, and ice. In one case, a pair of divers disappeared in a strong current.

In the remaining 30 accidents when buddies stayed together, some divers died despite an excellent assistance from their buddies. The buddy system failed due to panic, a lack of communication, or a lack of training in 20 cases. In two cases, for example, an instructor assisted the diver to the surface but could not provide him with breathing gas because he did not have a secondary regulator to share and the diver that needed assistance was not cooperative enough to engage in sharing the same regulator. There were several cases where the divers assisted their buddies in need to the surface and then left them unassisted at the surface. This probably comes from the perception that the surface means safety. The data in this report alone has proved this wrong many times over. In a few cases, despite all efforts of divers to assist their buddies and get them to the surface, they were unable to do so due to a disparity in body size or lack of strength or skills.

## Conclusion

Death in recreational diving is rare but a real risk for any diver in any diving environment. Divers should be aware of their limitations and plan their dive accordingly. Diving experience and physical fitness are equally important; both need to be maintained. Experience and fitness often progress in opposite directions, and even the most experienced divers may not cope if they become ill or unfit.

Equipment must be well maintained and effectively used. Divers have to bear in mind that hazards may be encountered not only underwater but also on the surface. Currents, waves and cold may turn otherwise pleasant recreation into a struggle for life.

Assistance is important both underwater and on the surface. For the buddy system to work, it takes two able divers, preparation in advance, cooperation and visual contact in all phases of the dive. A buddy diver is the first and usually the only one who can intervene, maybe change a direction of an adverse event and eventually prevent the death. Buddies have to extend their assistance until the assisted diver leaves the water.

# 5. Injury, Fatality and PDE Population Comparisons

The purpose of comparing the samples of PDE divers, injured divers, and divers who die is to investigate possible differences among the three groups that may represent risk factors for diving injury and death. While the amount of data collected annually is not large enough for definitive analysis, the annual reviews may suggest hypotheses that can be tested formally when data from a period of several years are combined.

## 5.1 Diver Characteristics

The average ages of the three populations are shown in Figure 5.1-1. On average, divers who died were 5-6 years older than participants in PDE and injured divers. PDE divers and injured divers were similar in age

**Figure 5.1-1**  
**Comparison of**  
**mean age**  
**by population**  
**for 2003.**

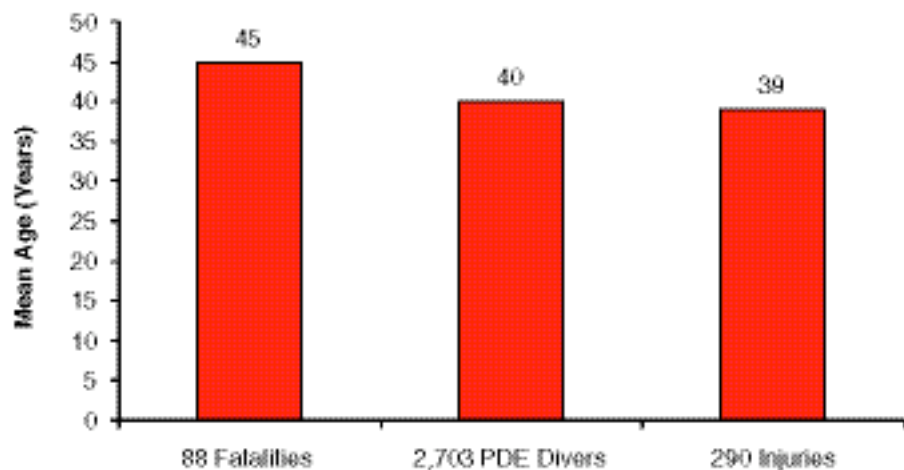




Figure 5.1-2 shows the proportion of males and females in each group. Gender was similarly represented in all groups. As the number of fatalities is relatively small in comparison to the other groups, one year of data should not be interpreted as a trend.

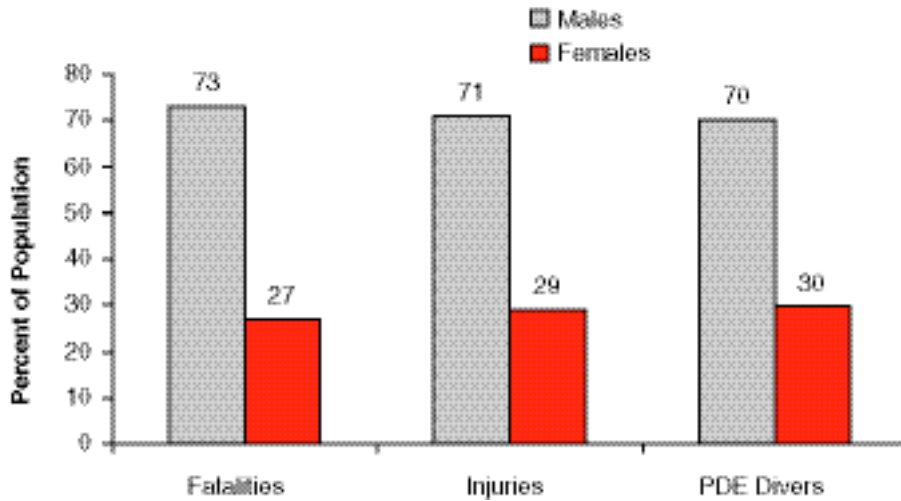


Figure 5.1-2 Comparison of gender distribution by population for 2003.

Figure 5.1-3 shows the certifications reported in the three population samples. Students and technical divers seemed over-represented in fatalities in comparison to PDE and injuries that had more instructors and divers with advanced certification.

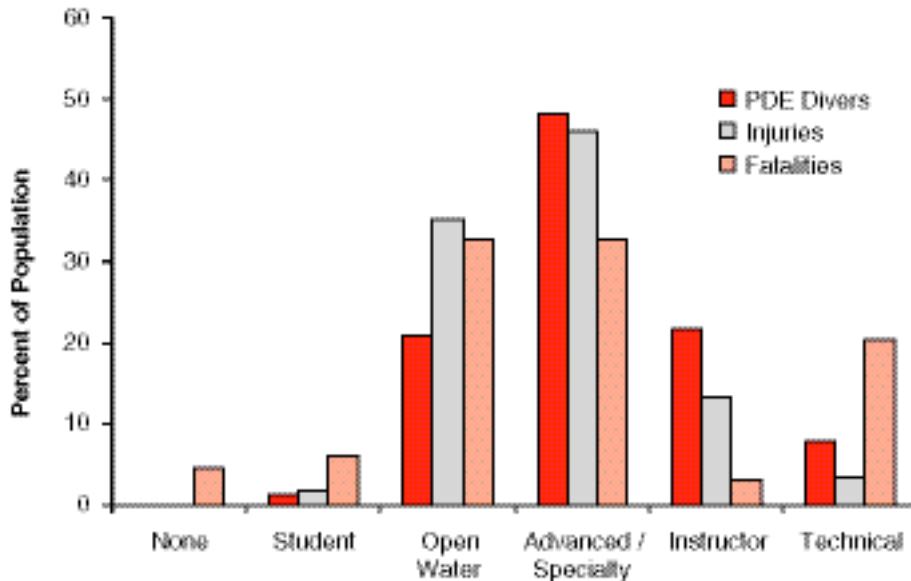


Figure 5.1-3 Comparison of certification by population for 2003.

Figure 5.1-4 shows the average number of years since initial certification. As in the past, PDE participants appear to have been diving for longer than injured divers or fatalities, but this parameter varies from year to year, and caution is advised against over-interpretation.

**Figure 5.1-4  
Comparison  
of years since  
initial certification  
by population  
for 2003.**

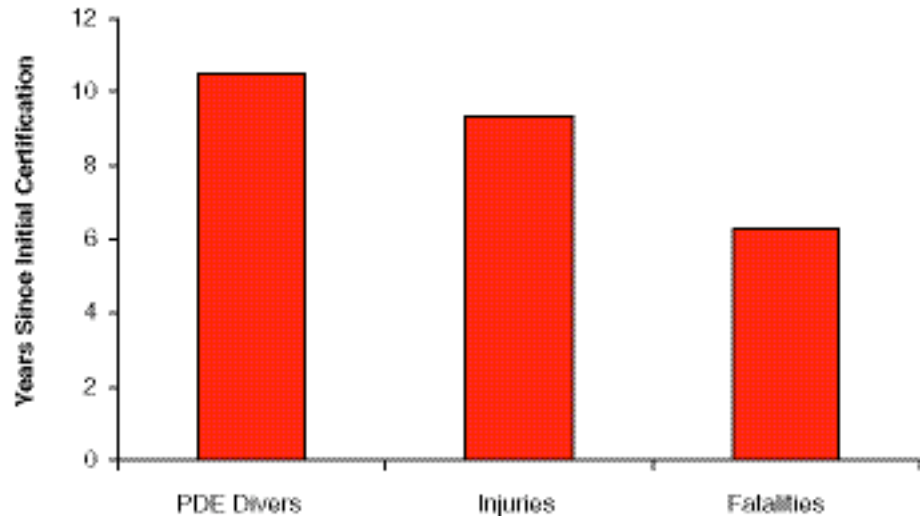


Figure 5.1-5 is similar to the observations from the previous year. The prevalence of high blood pressure and heart disease (HBP / HD) was highest among fatalities. Information about cigarette smoking was not complete and probably exaggerated the annual variation of this habit in the small samples.

**Figure 5.1-5  
Comparison of  
health problems  
by population  
for 2003.**

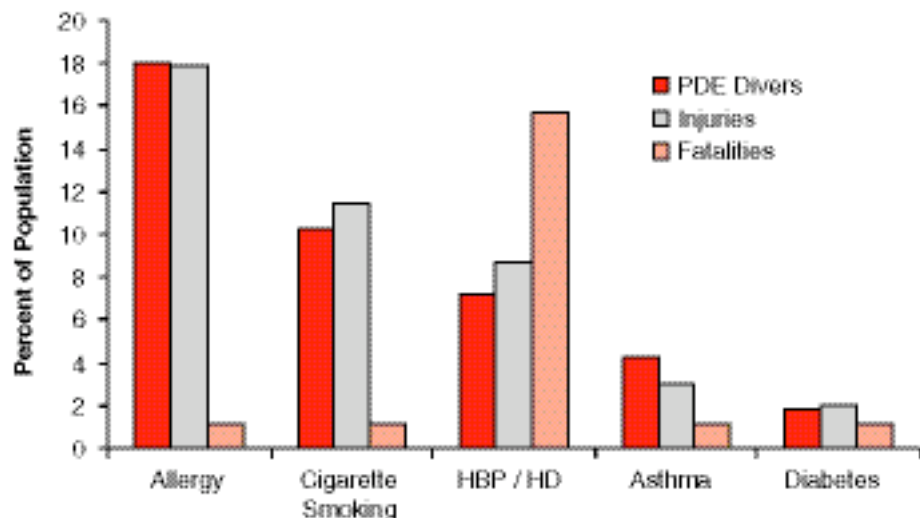
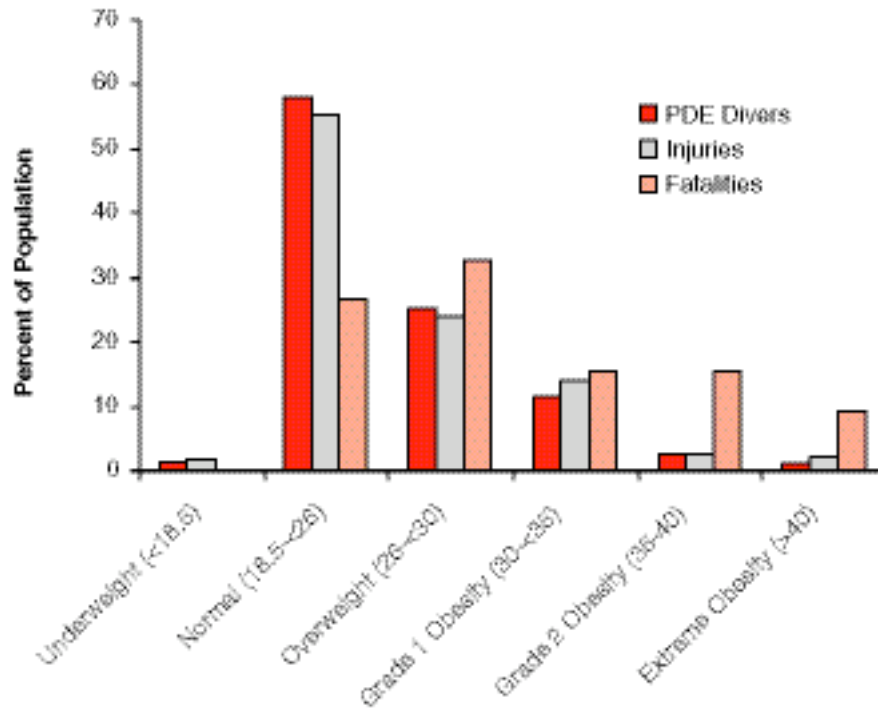


Figure 5.1-6 shows a comparison of obesity based on the body mass index (BMI) classified according the U.S. National Heart, Lung and Blood Institute (1998). As in the previous year, obesity is proportionally more frequent among fatalities than among PDE divers and injured divers.



**Figure 5.1-6  
Comparison  
of body fatness  
estimated from  
BMI for 2003.**

## 5.2 Dive Characteristics

Seawater dives constituted 98 percent, 89 percent and 71 percent of the dives made by PDE participants, injured divers and fatalities, respectively. Figure 5.2-1 shows the distribution of dives in different freshwater environments for the three groups. Fatalities occurred proportionally more frequently in lake/quarries and least in cave/cavern environments. These results are likely to be strongly influenced by the prevalence of dives in each environment, but prevalence data are not available.

**Figure 5.2-1  
Comparison  
of freshwater  
dive environment  
by population  
for 2003.**

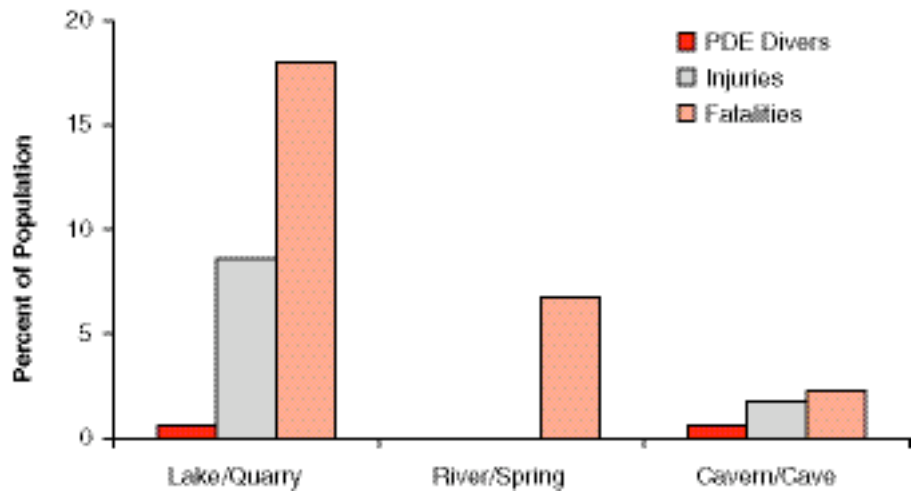
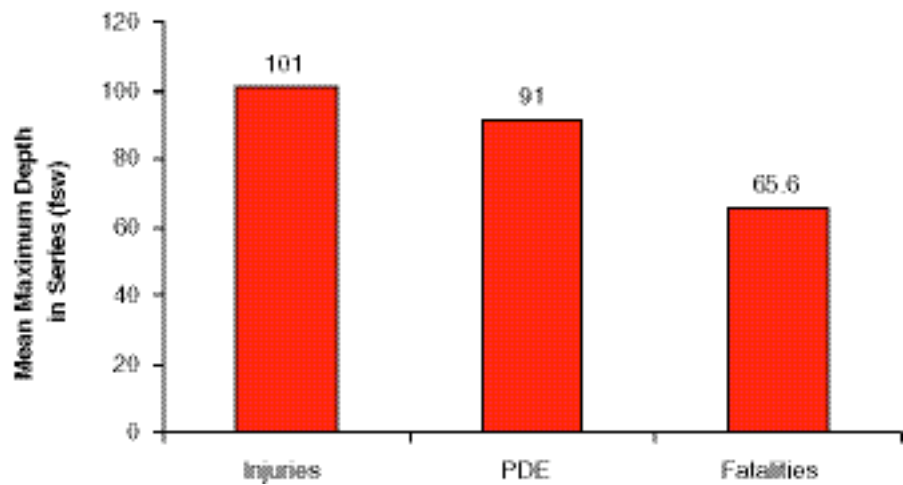
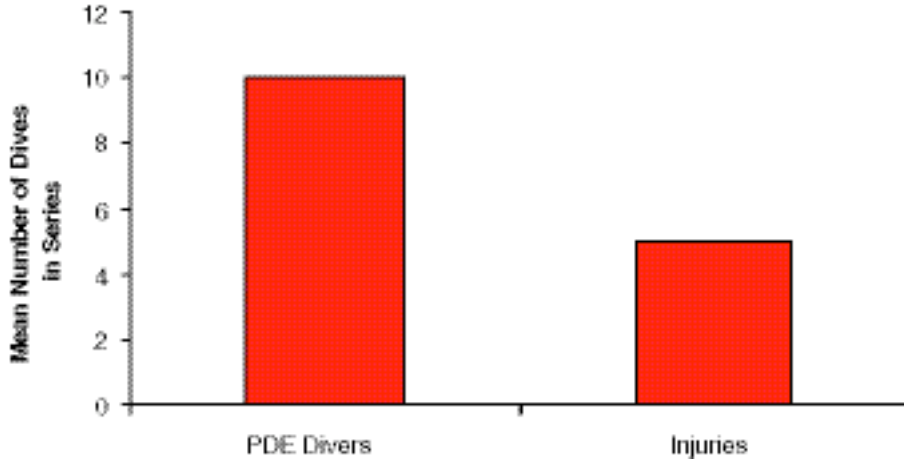


Figure 5.2-2 shows how the populations differed for maximum depth in the dive series. The injured divers had the deepest average maximum depth. Fatal dives occurred at shallower depths than injuries or PDE dives, and some fatalities occurred even before submersion.

**Figure 5.2-2  
Comparison  
of mean maximum  
depth in series  
by population  
for 2003.**

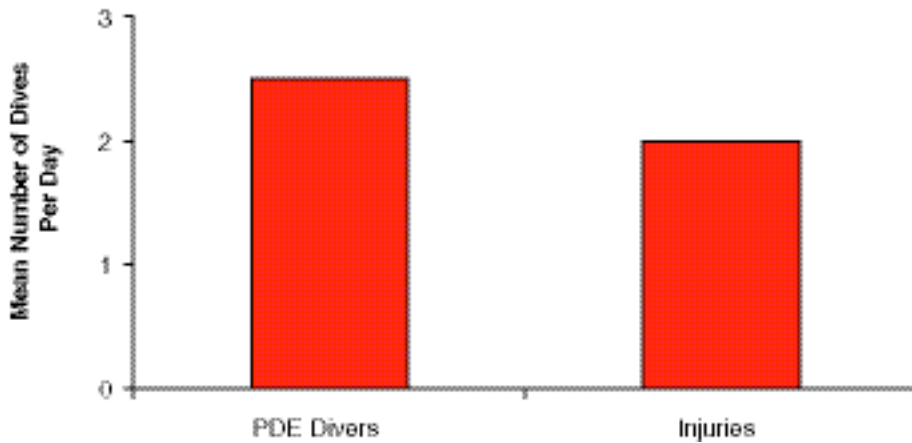


Figures 5.2-3 and 5.2-4 show how the PDE and injury populations differed in number of dives per series and average number of dives per day. Fewer dives per series and per day were reported by injured divers than by PDE participants. This information was not available for fatalities.



**Figure 5.2-3**  
Comparison  
of total number  
of dives in series  
by population  
for 2003.

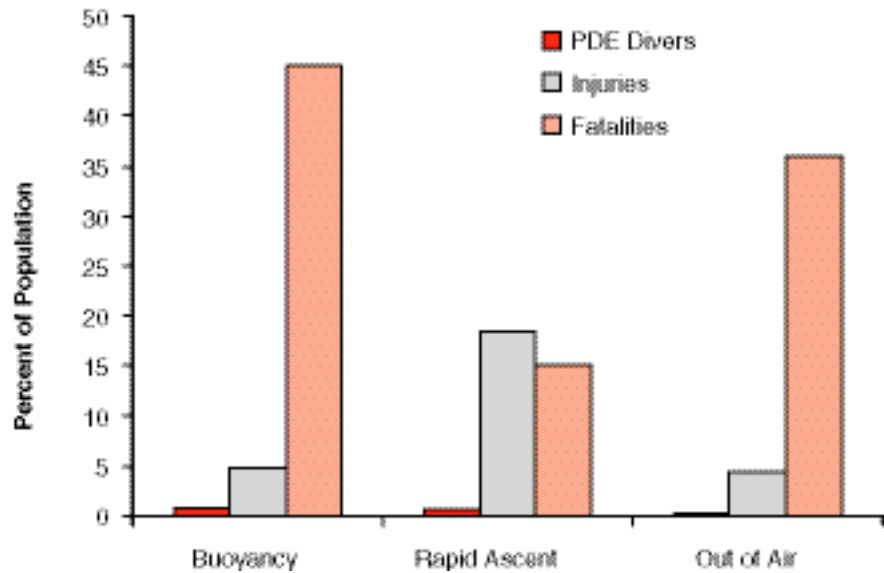
Figures 5.2-3 and 5.2-4 show how the PDE and injury populations differed in number of dives per series and average number of dives per day. Fewer dives per series and per day were reported by injured divers than by PDE participants. This information was not available for fatalities.



**Figure 5.2-4**  
Comparison  
of number  
of dives per day  
by population  
for 2003

Figure 5.2-5 shows that difficulty in maintaining buoyancy and running out of gas were rarely reported by PDE and injured divers but were frequent among divers who died. Fatality data were based on witness reports and investigations. Rapid ascents were more common in injuries and fatalities than in PDE participants.

**Figure 5.2-5  
Comparison  
of diving problems  
by population  
for 2003.**



The simple comparison of the three population samples must be interpreted with caution. While PDE may not be representative of the general population of recreational divers, there were many fundamental similarities between PDE divers and injured divers. Characteristics related to impaired fitness, such as increased age, heart disease and obesity, are consistently linked to compromised diving safety. Divers should be aware of their physical limitations and dive, or choose not to dive, accordingly. Some problems encountered in diving, such as running out of air, loss of buoyancy control, and rapid ascent, appear to represent a significant threat to diver safety. Good training, maintenance of fitness, and careful pre-dive planning may reduce the risk of unfortunate outcomes.

# 6. Breath-Holding Incidents

## 6.1 Introduction

Breath-hold diving as discussed in this section pertains to in-water activity involving some diving equipment but the absence of self-contained or surface-supplied breathing gas. Breath-hold divers may operate in a wide range of environments, pursue an assortment of goals, and wear various combinations and designs of suit, weight belt, mask, snorkel and/or fin(s).

Breath-hold diving is gaining popularity as an underwater sport. Potentially physically challenging, serious injury or death can result from hypoxic loss of consciousness or other complications. Development of a formal program to collect and disseminate information regarding breath-hold injuries and fatalities is desirable to improve both awareness, training and procedural development.

DAN has maintained a diving incident database since 1987. While breath-hold / freediving / snorkeling incidents fall outside the original purview, some cases have been reported to DAN. This is the first annual report to incorporate a review of breath-hold data. Our intention is to summarize all of the data now held. We will initiate a new dedicated surveillance program targeting injuries and incidents in breath-hold diving in the upcoming year and provide standard summaries of the incoming data in future reports.

The purpose of incident data collection and analysis is not to assign blame but to learn from past events. Some accidents are just that – unfortunate events that can occur even when sound experience, planning, equipment and support are in place. These cases serve as a reminder of the fundamental risks and remind us to take as much care as we can in all things. Other accidents arise from flaws – flaws in equipment maintenance, equipment use, training, or procedures. These cases may demonstrate the necessity to make changes that can reduce the risk for all participants in the future. One of the challenges of accident reviews is that all the facts are very rarely known. The effort can require a substantial amount of deductive reasoning and occasionally some guesswork to interpret events.



In this review, we will summarize the known data and describe the common hazard patterns that appear in the records. The case reports found in Appendix C will provide brief summaries of documented information. The reader will be left to interpret these cases – hopefully with critical consideration of his or her own practices.

## 6.2 Available Records

The available records for 1994-2004 incidents were augmented through internet searches and reviewed. A total of 172 separate incidents were referred to in the files. Cases were excluded from this review if some written record confirming the actual date of the event could not be found, or if the reported event occurred outside of North America and the available information was too limited to be evaluated (note: future data collection will likely focus on events occurring within North America and the Caribbean region).

One hundred forty-five cases were included in this summary. Comprehensive records were generally available for only rare high profile events. Virtually all of the reported cases (98 percent, n=142) involved fatalities. The three injury cases included two shark attacks and one near drowning.

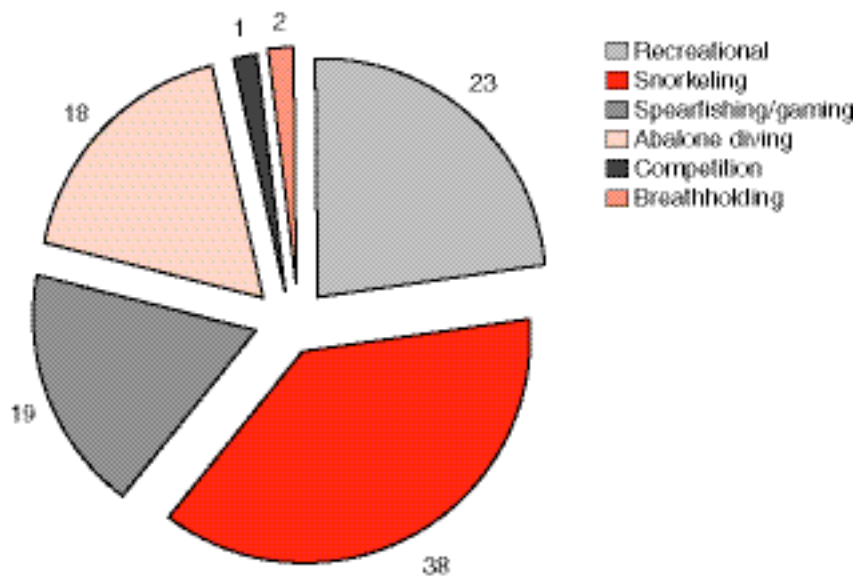
Incidents were reported in 19 different countries. Seventy-five percent (n=108) occurred in the United States. Ninety percent of the U.S. incidents occurred in three states: Hawaii (34 percent; n=37), Florida (31 percent; n=34) and California (24 percent; n=26). The concentration on U.S. incidents reflects the limited focus of the available reports rather than a true worldwide pattern. The distribution of U.S. incidents does reflect the popularity of breath-hold activities in certain states. It is also possible, however, that the popularity of diving in specific areas has produced a greater awareness of DAN's effort in incident data collection and a submission of more cases. This could contribute to an overrepresentation of these regions.

Categorical descriptions of the primary activity of the incident victim were available in 67 percent of the cases (n=97). The categories of the known cases can be seen in Figure 6.2-1. Snorkeling is the broadest category, including anyone wearing mask, snorkel and fins (but with no additional air supply) in the water. Snorkelers may remain completely on the surface or participate in some breath-hold diving from the surface. Freedivers typically wear a mask and some form of fin or fins only and direct their activity to breath-hold div-

ing from the surface. The nature of the dives will vary dramatically with the individual skill and training level of participants. Typical goals are training to improve vertical range or competition of the same nature.

Spearfishing / gaming incorporates the act of underwater hunting for food into the breath-hold exercise. Maximizing depth is generally not the motivator. Pool breath-hold is conducted as a training activity, with the primary focus on improving breath-hold time rather than increasing maximal depth. A variety of techniques, including relaxation and voluntary hyperventilation, may be practiced to increase performance in a relatively controlled setting.

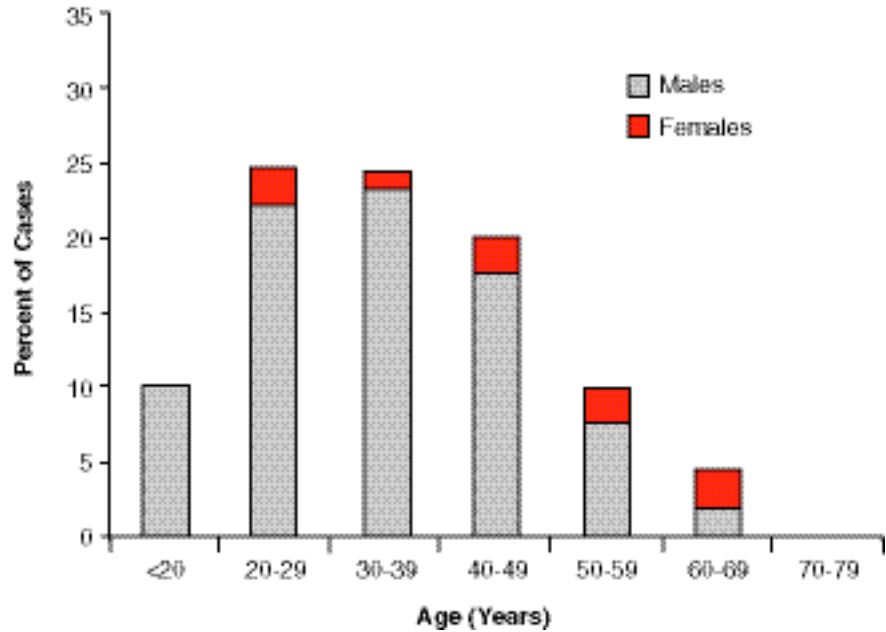
The relatively generic descriptors of "snorkeling" and "recreational freediving" were used in more than 60 percent of the cases with data. The rare appearance of the more specific descriptions of breath-hold competition and pool breath-hold activity reflect the relative rarity of those events.



**Figure 6.2-1:**  
Distribution  
(percentages)  
of described  
primary activity  
for breath-hold  
incident victims  
(n=97).

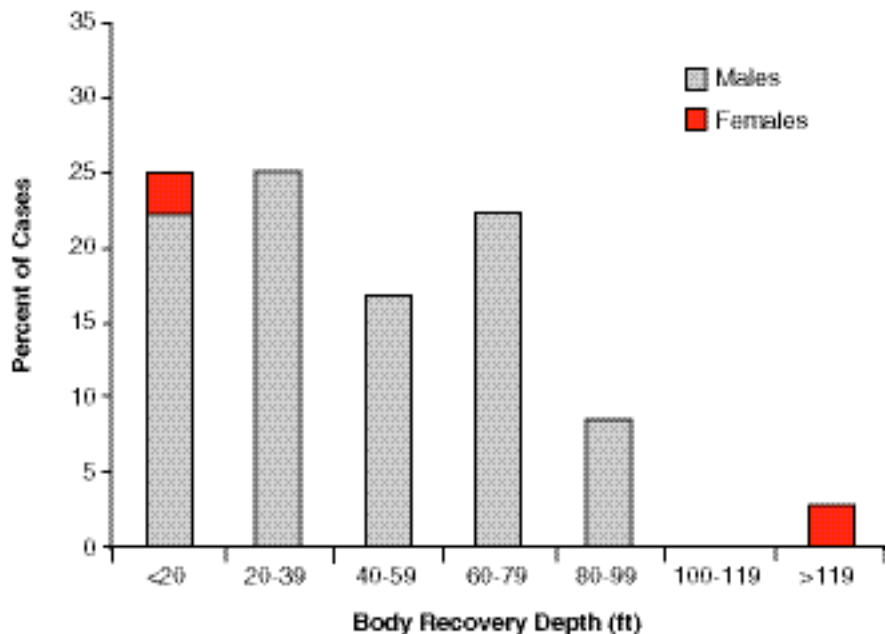
Figure 6.2-2 described the information known regarding gender and age. Gender was available in 96 percent of cases. Most of the known victims were male (88 percent). Age was available in 62 percent (n=90) of cases. The average age of victims ( $\pm$  standard deviation) was  $38.2 \pm 16.6$  years, ranging from 14 to 79 years. Sixty-nine percent of the victims were between 20 and 49 years of age.

**Figure 6.2-2**  
Age and gender distribution of breath-hold incident victims (n=90).



Bodies were recovered in 95 percent (n=135) of the fatal incidents. The recovery depth was available in only 25 percent (n=36) of the cases. Available recovery depths ranged from 0-406 feet / 0-125 meters (median = 38 feet / 12 meters), as shown in Figure 6.2-3.

**Figure 6.2-3**  
Recovery depth of body by depth and gender for fatal breath-hold incident victims (n=36).



## 6.3 Major Contributing Factors in Deaths

The cause of death reported for diving or breath-hold diving accidents is frequently drowning. Unfortunately, it is common for very little to be known about the contributing factors that lead to the more objective endpoint. The primary goal of accident reviews is to determine why they happen; to identify the problem or problems that set the stage for the ultimate outcome. If we had all the information, we might be able to ascertain several key elements: predisposing factors (e.g., failure to check an air supply), trigger events (e.g., losing a fin in heavy current), disabling conditions (e.g., heart attack), and the medical cause of death (e.g., drowning). When the available data are incomplete, only the major contributing factors may be obvious. It must be remembered that a host of more subtle factors may also have been involved. The key to benefiting from accident reviews is to fit the scenarios to your practices, and to try and identify (and correct) all of the elements that may increase your risk.

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**Entanglement:** Entanglement represented the most common major contributing factor of those reported for breath-hold divers. The five identified entanglement cases included two separate instances involving kelp, one with spearfishing line, one with an anchor line, and one with both spearfishing line and anchor line. Breath-hold divers have very little time to disengage themselves from entanglement or obstruction before the most modest dive can become fatal. Care must be taken in both equipment selection and procedures. Spearfishing would be safer using pole spears or other devices that did not employ long lines. Breath-hold diving is also best consid-

ered an optional activity than a required one. The use of freediving to clear a stuck anchor, for example, can be quite hazardous, particularly in rough seas or in depths that approach the limits of the diver.

Diver-Boat Interactions: Four cases involved boat strikes while breath-hold divers were on the surface. Dive flags and surface watchers were present in some cases. This is clearly a significant risk in relatively high traffic areas. Bright colored garments can improve the visibility of the divers, and the presence of dive flags in immediate proximity to the divers can increase the vigilance of passing boaters.

Diver-Animal Interactions: As stated previously, the non-fatal incidents included two shark attacks. There were another two cases involving fatal shark attacks and one case of a fatal encounter with a jellyfish. Sharks are likely attracted to spearfishing breath-hold divers. In some cases it may be speculated as to whether the diver was a primary target or was mistaken for more typical prey. Even if brightly colored suits do not create a "hands off" label for sharks, they should make the breath-hold diver more visible on the surface.

Solo / Inadequately Supported Activities: Fatal cases were reported for solo breath-hold divers in pool, freshwater spring and ocean environments. It is likely that the presence of another person would have changed the outcome in at least some of these cases. Unsupported, or inadequately supported, activity is more likely to occur as the exposures become more extreme.

Several cases were reported in which the individuals in immediate attendance were unable to rescue an unresponsive breath-hold diver because of the depth of the victim. The safe margin for error shrinks as exposure intensity increases. The one up, one down buddy system can provide adequate safety backup only if the dive depth is not beyond the limit of either partner under the stressful conditions that an incident would produce. Practically speaking, the buddy system is only appropriate for conservative exposures. The support of breath-hold divers with greater capabilities or by gas-breathing divers is important as the severity of exposures increases. The safety system necessary for protection during extreme exposures is extensive and requires an organized and dedicated group structure.

Behavioral Errors: The clearest example of behavioral errors during breath-hold diving is likely the presence of mind altering drugs. Alcohol ingestion preceded at least two of the fatal cases reported. The true impact of the alcohol cannot be determined, but it is possible that it contributed to decisions that ultimately contributed to the accidents.

A more elusive behavioral error involves the use of excessive hyperventilation prior to breath-hold. Hyperventilation can dramatically decrease the partial pressure of carbon dioxide in the blood. Since carbon dioxide is the primary trigger for inspiratory drive, the urge to breathe is delayed until normal blood levels are restored. This translates into longer breath-hold times. Hyperventilation, however, increases the body's oxygen stores only slightly. The longer breath-hold times will result in the oxygen partial pressure in the blood falling below normal (hypoxia). Problematically, hypoxia provides a surprisingly weak trigger for the inspiratory drive. A diver who hyperventilates too much may fall unconscious due to hypoxia without ever being aware of an urge to breathe. This is known as hypoxic loss of consciousness (HLOC).

A further complication of breath-hold diving to depth is that the increased pressure with depth compresses the gas in the lung and effectively increases the partial pressure of oxygen in the blood. The problem here is the reversal of the effect as the diver surfaces. The oxygen partial pressure is reduced much faster than by consumption alone as the ambient pressure is decreased. Unconsciousness can develop rapidly in the final part of the ascent, when the relative rate of pressure decrease is greatest. This phenomenon is referred to as shallow water blackout.

Breath-hold divers who choose to use hyperventilation normally experiment to try and predict their personal safe limits. However, if used too aggressively, even small increases in dive depth, exertion or breath-hold duration can produce a very hazardous situation. Excessive hyperventilation contributing to HLOC or shallow water blackout may represent the underlying cause of death in many of the breath-hold fatalities with no other apparent explanation. This is very difficult to document in most cases, but it is a risk that can clearly be reduced by conscious choice.

The final behavioral error to be mentioned is the failure to ditch a weight belt when appropriate. There are several cases of fatality victims being retrieved with weight belts still attached. It is difficult in most to know if hypoxia impaired the ability to respond. At least one case, though, highlights a lack of thought during a stressful event. One of the non-fatal cases involved an exhausted breath-hold

diver who still was still wearing his weight belt when help arrived at his surface position. The victim described his condition immediately prior to rescue as impending blackout. Ditching the belt at any point in the development of this incident would probably have been an effective self-rescue.

Equipment Problems: The records contain at least one case of a diver who became unconscious as he neared the surface during ascent from a breath-hold dive and quickly sank beyond the point at which those on the surface could reach him. Weighting during breath-hold diving may be considered to optimize performance, but the more important consideration of weighting is for safety. A breath-hold diver should be slightly positively buoyant close to the surface to minimize the risk of sinking should a problem develop in shallow water.

Impaired Health and Fitness: The available records contain at least three fatal cases involving heart trouble, three involving seizure and at least one involving inadequate fitness that resulted in a double fatality. The demands of breath-hold diving can be significant, particularly in open water where rough water or currents may have to be overcome. Inadequate fitness reserves may leave breath-hold divers unable to cope with normal challenges that can arise.

## 6.4 Summary

While a small number of high profile fatality cases may be widely reported, limited information is available for most breath-hold accidents. Non-fatal incidents are rarely reported. Data from both fatal and non-fatal cases would provide valuable information to improve awareness, facilitate training and promote procedural evaluations. This is the first annual report to incorporate a review of breath-hold incident data. Breath-hold incident data reviews will be a standard component of future annual reports.



# Appendix A: Dive Injury Case Reports

## Case 1 — Aggressive dives in teenage diver with pain only symptoms and full resolution

The diver was a 14-year-old male who had been certified for approximately two years, making 30 dives per year. He was in good health and had no history of illness.

He performed two dives on one day; both included safety stops. The first dive was to 90 fsw (27 msw), with a one-hour surface interval, and the second dive was to 80 fsw (24 msw). He used open circuit scuba, air and a dive computer to calculate his dive profiles. His dives were uncomplicated and within the limits of his dive computer.

After surfacing from his last dive, he experienced mild pain in his left knee. He also experienced dizziness, which he felt was quite severe. Within 10 minutes he began feeling moderate pain in his right elbow and a fairly severe headache. At that time, he was placed on surface oxygen.

After 20 minutes on oxygen, his symptoms had stabilized and had begun to subside. After one hour of oxygen, all symptoms were minimal. During transport to a local hospital, he was without oxygen, and he felt some recurrence of elbow pain. His symptoms were greatly reduced by the time he reached the hyperbaric facility and completely resolved during a standard U.S. Navy Treatment Table 6 (TT6).

The diver had no problems with joints and had never had these types of symptoms before. The immediate onset of pain and dizziness concerned other divers and frightened the injured diver. First aid oxygen at 15 liters per minute via a non-rebreather mask seemed to be effective in reducing and almost eliminating symptoms before treatment. To

prevent a worsening or a return of symptoms, oxygen should be maintained until divers are released to professional medical care. Symptoms occurring immediately after the dive indicate a potentially severe injury and should be addressed early as in this case. Neurological symptoms may have been present in this case, but a brief neuro exam was not done on-site.

## Case 2 — Teenage diver with pain-only symptoms in first two dives after certification

The diver was a 19-year-old male in good health and physically fit. He had no history of recent illness or injury. To complete his open-water certification, he first performed two dives to 30 feet (9 meters). On the following day — his first day of diving as a certified diver — he performed two dives, the first was to 80 feet (24 meters) for 20 minutes with a three-minute safety stop at 20 feet (6 meters). After a 60-minute surface interval, he made a dive to a maximum of 70 feet (21 meters) for 20 minutes, with a three-minute safety stop at 20 feet (6 meters). When he left the water, he had no symptoms and reported no problems during the dive. All ascents were normal and there were no equipment problems.

The diver continued on with his day after these dives, without symptoms until approximately 10 hours later when he had the gradual onset of left knee and ankle pain, then right elbow pain. In the next hour, his symptoms increased in severity, and he contacted his dive instructor. He was then referred to the local hospital for evaluation.

He was placed on high flow oxygen in an emergency department and transferred to the hyperbaric center. He experienced minimal

improvement on oxygen before being treated with a TT6. After this therapy, he experienced partial relief. During the next two days, he twice received treatment via TT6. Symptoms improved with each treatment, but he was left with mild residual pain in his left ankle. Symptoms completely resolved within 10 days, and the diver elected not to return to scuba diving.

### Case 3 — Symptoms of cerebral and spinal cord decompression illness after a relatively innocuous dive

This 32-year-old male diver was in good health; he had been certified for 11 years. He has performed more than 400 dives in the past five years and approximately 20 dives in the last 12 months.

An experienced deep and decompression diver, he decided to do a sight-seeing dive on a shipwreck to a depth of 89 feet (27 meters). The dive lasted about 20 minutes, with a three-minute safety stop at 15 feet. He experienced no problems during the descent or ascent phases of the dive. This windy day caused a two-foot or more surface chop. After he surfaced, he hung out on a line off the side of the boat while other divers entered the water.

Within seconds of boarding the dive boat and taking off his dive gear, he began to experience symptoms in the following order: left wrist pain, stomach soreness with nausea and vomiting, slurred speech and then numbness and weakness in both legs. He received emergency oxygen and was taken to shore; he experienced some improvement in all symptoms. An ambulance met him and took him to the regional hospital.

While at the hospital, he received oxygen, and, except for the numbness in the legs, all symptoms completely resolved. Due to his short profile, he did not think he had DCI. He was

diagnosed as having transient cerebral ischemia, and he was discharged with only numbness in the left leg.

He was taken off oxygen and discharged. About 30 minutes after discharge and during the drive home, all symptoms returned and his leg numbness had progressed to weakness, which made walking difficult. He was taken to a second hospital and again started on oxygen. To rule out neurological disease or injury, he received diagnostic procedures. These tests were negative.

A hyperbaric service provider was then contacted, and he was referred to a third hospital. He began his first hyperbaric treatment 14 hours after he had exited the water and first experienced symptoms. Although he felt significant relief during the first half of his hyperbaric therapy, most symptoms returned to near pre-treatment levels by the end of his first recompression treatment. In addition, weakness in his lower extremity increased and included urinary retention. He was treated with a TT6 the following day and a U.S. Navy Treatment Table 5 (TT5) for the next five days, with gradual improvement each day. The seventh treatment yielded no further change in the diver's symptoms.

One year after his DCI, he continues to have significant numbness in his left leg and less numbness in the right. He cannot run, and uneven ground presents problems with balance. He intends to stay out of diving for one more year, but he hopes to return to much shallower and shorter dives. Urinary incontinence has resolved but he still experiences intermittent loss of urgency when his bladder is full.

#### Case 4 — Pain-only DCI made worse during altitude exposure and developed mild neurological symptoms

This 28-year-old female diver had been certified for eight years, and she had performed fewer than 20 dives in that time period.

While on an island-hopping vacation in the Caribbean, she planned to do her first dives in more than one year. She has had no history of injury or illness and is in good health.

Her dives started with an 85-foot (26-meter) multilevel dive for 40 minutes, including a three-minute safety stop at 15 feet. After a 50-minute surface interval, she performed a 45-foot (14-meter) multilevel dive for no longer than 50 minutes, also with a safety stop. Her dives were uneventful; she went with her dive group, using open circuit scuba on air and determining her exposure limit by following the dive master.

Approximately 17 hours later, she awoke with mild to moderate right elbow pain, which she could not explain. She had not injured her elbow or been involved in any heavy lifting or exercise. The pain lessened a little as the morning progressed, but it continued throughout the day. Later, about 26 hours after her last dive she boarded an unpressurized aircraft and flew (approximately 3,000 feet above sea level) to a neighboring island. During her flight she experienced bilateral tingling in both hands; she described the sensation as mild. Both the pain and tingling persisted for the rest of the day.

She again took an unpressurized flight the following day and had increased numbness and tingling in both hands; she described those sensations as moderate. She also experienced additional pain in her shoulders, elbows and biceps. Symptoms continued throughout the day. Feeling she may have had DCI, she contacted the DAN emergency line for consultation.

The diver was referred to the local clinic where she could receive a physical evaluation and surface oxygen, if needed, for possible DCI symptoms. There is no local working chamber and evacuation is not possible at night because the surrounding airports have no landing lights. She decided to wait until the following morning when she took a low-flying unpressurized craft to an island where the recompression chamber staff had been alerted of her arrival.

A local physician evaluated her, and she received surface oxygen for the first time. After evaluation, the physician made a diagnosis of neurological DCI; she was given a TT6. She responded slowly to recompression and high-pressure oxygen. She received two additional oxygen-breathing periods at 60 fsw (18 msw). By the end of her treatment she only complained of mild tingling in both hands, primarily in the left hand. Twenty-four hours after recompression all symptoms had resolved. She did complain of momentary pain in her affected joints; that resolved over the next two or three days. Without complaint, she flew back to the United States more than three days after her last hyperbaric session.

Flying exerts additional decompression on divers, and there is a concern that it may worsen the symptoms and reduce chances of complete relief. It is always best to seek medical attention as soon as you develop suspicious symptoms or symptoms that are new to you and seem unrelated to any activity you may have performed.

Without any treatment for three days in this case, symptoms were evolving. That alone could have contributed to the progression of symptoms. As is often the case when treatment is delayed and when altitude is involved post dive, the resolution of symptoms under treatment was gradual.

### Case 5 — Neurological DCI after a deep, decompression technical dive

The diver, a 27-year-old female scuba instructor, who had been certified for four years, had made more than 250 dives since certification. She was also a technical dive instructor.

She had no history of injury and was in good physical health. She was taking an anti-anxiety medication. She planned to do her first 150-foot decompression dive on air, using open circuit scuba and a dry suit. She followed her dive computer to perform this dive and made her required stops. After the dive, she only commented about the extreme narcosis she had felt during the dive.

Approximately one hour after the dive she noticed a dull ache in her right hand; it was accompanied by mild numbness and tingling. Twenty minutes later, she noticed a throbbing, dull, cramp-like ache in her right wrist and elbow. She mentioned this to a fellow instructor and was placed on 100 percent oxygen via demand valve regulator. During the next 30 minutes, she experienced aching in her right shoulder and a generalized itching over her torso. This was followed by a red, marbled-patterned rash on the back of both shoulders, her abdomen, her right leg and arm. She also experienced nausea.

Placed on oxygen, she experienced slight improvement of her symptoms. Still on oxygen, she was then transported to the nearest hospital for evaluation. The initial assessment at the hospital also noted extreme fatigue and dizziness. She was transferred to a second hospital that had a chamber for treating divers.

By the time she was first recompressed, her skin symptoms had greatly lessened. She received a TT6, with favorable results and a resolution of her aches, tingling and numbness and skin rash. The following day, she

again experienced mild pain in the same joints from the day before. She traveled home and presented herself to the local medical center and hyperbaric facility for a second evaluation. When she stood or walked, she was slightly unsteady due to her dizziness. She also experienced joint and muscle pain. She was given a second TT6, with minimal resolution of muscle and joints and dizziness. All her symptoms resolved over the next three weeks.

In this case symptoms occurred shortly after the dive with deterioration until recompression. The early onset and progressive evolution indicate serious decompression sickness (DCS). First aid surface oxygen administered early may have slowed down the progression of symptoms; however, it is not possible to judge about efficacy of surface oxygen based on one case. This diver returned to pool instruction in two months and to deep diving in four months. When she resumed diving, she had no return of symptoms.

### Case 6 — Cerebral and spinal cord DCI after repetitive deep diving

The diver, a 58-year-old male scuba instructor, who had been certified for 30 years, had completed many hundreds of dives and more than 100 in the past year. He had a history of lower back pain, he was overweight for his height, but he led an active lifestyle. He used no medication other than occasional ibuprofen for his back pain.

During a weekend dive vacation in islands offshore from the United States, he performed six dives over two days. On the first day, he did three dives with no required decompression. His deepest dive was to 110 feet (34 meters). The second day he performed three dives; all were multilevel, with no required decompression. The first dive was to 100 feet (30 meters), and the last two were to no greater depth than 81 feet (25 meters). He planned all dives using his dive computer; he



made safety stops on all dives, and he used compressed air. He had no problem during ascents or with his equipment.

About 20 minutes after he reached the surface and removed his gear, he noticed an ache, much like a stomach cramp in his abdomen. It gradually moved up his chest and encircled his lower trunk. He then noticed numbness and weakness in his left arm, followed by back pain.

The boat crew noticed that he could not communicate effectively. He was immediately started on high flow oxygen. Crew members contacted DAN for assistance in arranging an evacuation to the U.S. mainland. The dive vessel was seven hours from the nearest land. A rescue helicopter was arranged to pick the diver up at sea and carry him to the nearest hospital and hyperbaric facility.

The diver reached the hospital approximately six hours after he had surfaced from his dive. When he was admitted, he had weakness in his legs and was unable to walk. His abdominal pain and left arm numbness and weakness had almost cleared. His mental status was still altered. Shortly after admission, he received TT6. He received a second TT6 later the same day and a third the following day. Each time he received some resolution of his symptoms. All symptoms resolved except for his back pain.

On his third and final day of treatment he received two, two-hour treatments that did not resolve his back pain. He was discharged with continuing mild pain.

This is a case of serious paralytic form of DCS, which sometimes results in permanent disability. In this case, neurological symptoms resolved completely except mild back pain that may have been unrelated to diving. This may be due to beneficial effects of surface oxygen the diver received early. He was also fortunate that he received emergency assistance

soon enough from a helicopter during the daylight hours. Thus, the diver could be transported over a considerable distance. He was able to return to scuba instruction and recreational diving.

### Case 7 — Spinal Cord DCI after a missed decompression stop

The diver was a 46-year-old female, who had been certified for three and a half years, had made more than 100 dives, 30 of which occurred in the past 12 months. She was physically fit, had no health concerns and was very active. She lived in the Caribbean and dived weekly.

She performed a single dive to 130 feet (40 meters) using her dive table. It was a multi-level, open-circuit scuba dive on air with a safety stop. Unfortunately, a later calculation found that, given her total bottom time, she should have done a decompression stop.

Approximately 15 minutes after leaving the water, she began experiencing a sharp pain in her back, which shot around through her rib cage. This caused her to have difficulty breathing. She experienced altered vision like flashing lights, but she had no headache or sinus-related symptoms. She then developed numbness and tingling on the right side of her body, from her rib cage down her arm and leg.

Thinking she must be having a migraine eadache, she continued with her day. She put her dive gear in the car and prepared to drive home. During the drive home, she became dizzy and nauseated. Friends then drove her to the

hospital. While she was en route to the hospital, her dizziness and shortness of breath became more extreme; she eventually lost consciousness.

After a brief evaluation, she was placed in the hyperbaric chamber and a TT6 was adminis-

tered, during which all symptoms improved. After her treatment, her symptoms continued to improve during the evening. The following morning, they were mild to minimal. She was treated on a TT5, with resolution of all symptoms. She was diagnosed with spinal cord DCI and a possible inner ear DCI.

The diver was fortunate in that she lived very close to an island recompression chamber and that her friends recognized her symptoms as serious. After the diver recovered she felt that she had been too tired and dehydrated to dive that day. She had had quite a lot to drink the night before. She did not have any return of symptoms and returned to diving three months later.

### **Case 8 — Flying with pain-only symptoms that worsen after flying**

The diver, a 44-year-old female who has been certified for 12 years, was a regular diver, with 60 dives in the past 12 months. She was in good health, on no medication and her only health concern was occasional lower back pain.

During her annual dive vacation to the islands, she performs 16 dives over six days using air and open-circuit scuba. Midweek, her deepest dive was to 112 feet (34 meters). Her final day of diving she did three dives: the first dive was to 95 feet (29 meters); the second was to 90 feet (27 meters); and the last was to 79 feet (24 meters).

She used a dive computer to plan her multi-level profiles and her surface interval times. The last day of diving was complicated by the fact she was cold on all three dives and her buoyancy compensator device (BCD) periodically inflated. This took her up and down in the water column several times, but not all the way to the surface.

Shortly after exiting the water on her last dive, she began to experience sharp pain in her right hand, especially around the joint in her right thumb. In the next four hours, this grew from a mild achiness or soreness to pain and gradually involved her right forearm, elbow and shoulder. She attributed the discomfort to muscle strain and continued on with the rest of her day. Except for diving, she had not exerted herself. The following day when she awoke, the pain had resolved. This confirmed to her that this was simply pain due to muscle strain.

On the second day after diving, she awoke with a mild ache in the joints of her right arm. Again, she wasn't concerned. Almost 48 hours after diving and the onset of her original symptoms, or mild achiness in her joints, she flew out the afternoon of the second day.

Her first flight to the United States took two hours. On this flight, she developed pain symptoms similar to those after her dives. The second flight took a little more than four hours, and her right arm pain worsened and reached its highest level of severity. She experienced no change in her symptoms when she landed. After two days of continuous pain, which was unaffected by positioning or movement of the extremity, she called DAN for assistance.

A DAN medic referred her for evaluation to the local hospital with a recompression chamber. She saw the dive physician the following morning and received a TT6; her arm pain greatly improved. Over the course of the day, it again worsened, but the pain did not reach its pretreatment level. After her original treatment, she was given a TT5 each day for two days. Each time the symptoms lessened to some degree. She was left with some mild discomfort for several weeks after recompression

therapy before her discomfort finally resolved. She has not had the opportunity to return to scuba diving.

The pain of DCI can be very difficult to diagnose. Recognizing potential symptoms of DCI early can decrease the time between the onset of symptoms and the evaluation of those symptoms and recompression. Symptoms after a dive should always alert the diver that DCI may be a possibility.

### **Case 9 — Neurological DCI after diving and then flying**

The diver, a 45-year-old female in good health, had been certified for 15 years; she made approximately 10-15 dives each year. Twelve years ago, she experienced an episode of DCI, with complete resolution of her symptoms. Since that time, she has continued to dive without difficulty.

This dive trip involves a week's diving in a remote island group in the Indian Ocean. In four days, she performed six dives — all uneventful.

On the fourth day, she made one dive to a maximum depth of 72 feet (22 meters), but she was diving at a location she had been flown to. Her dive party flew to various sites to look for dive locations. During the flights, she noticed numbness developing in both her hands and feet. This was followed by generalized muscle and joint aches and some mental confusion.

For evaluation, she was taken to the local hyperbaric clinic. She was found to have numbness and tingling in her hands, legs and feet. These symptoms were accompanied by muscular weakness in both legs. She also complained of pain throughout her entire body. She was recompressed on a Comex 12 Table, with a reduction of all symptoms and

the elimination of the body pain and confusion. During the next two days, she received two more oxygen therapy treatments for two hours each. Her symptoms completely resolved.

She waited two days and flew home on a regularly scheduled flight; she experienced no difficulty; however, the following morning she awoke with generalized achiness in her joints and chest pain on her left side. On exertion, she experienced some shortness of breath and fatigue. A local physician evaluated her, recommending a standard two-hour oxygen therapy session to determine if her symptoms could be quickly resolved. She decided not to have a test treatment in the chamber and let the aches resolve on their own. She has not returned to diving.

Altitude exposures can provoke bubble formation in otherwise safe divers. This diver was fortunate that her symptoms resolved with treatment. Symptoms occurring after treatment during a flight home are not uncommon. In this case all symptoms resolved and the diver followed medical advice and waited six months before returning to scuba.

### **Case 10 — Inner Ear DCI, joint pain and probable pulmonary barotrauma with chest pain after repetitive deep dives**

This 49-year-old male diver was a certified dive master who had been diving for 14 years; he made approximately 75 dives per year. He had an active lifestyle, but he was slightly overweight and had a medical history of lower back surgery and occasional back pain. He had no other illnesses or health problems.

He was diving in cold water using a dry suit, open circuit scuba and two dive computers to plan his intended dives. In one day, he performs two dives to 116 feet (35 meters). Both



dives required some decompression. He performed his required decompression stops and spent a few extra minutes at his shallow stops.

Five minutes after exiting the water on his second dive he experienced the sudden onset of chest and shoulder pain. Although this began as moderate pain, it quickly escalated to severe pain. Twenty minutes after his dive, he began to get extremely dizzy; he noticed a decrease in hearing from his right ear. He became nauseated, and he experienced dizziness and an inability to stand or sit without supporting himself. He could not open his eyes without increasing both the dizziness and rapid eye movement (nystagmus) back and forth. He was placed on surface high flow oxygen and taken from the dive site into the local hospital, which operated a hyperbaric chamber.

His assessment in the hospital revealed pain in his left side, in the joints from his shoulder down to his knee. He experienced some shortness of breath from his chest pain. His hearing loss on the right side was determined to be significant. A chest X-ray revealed a small amount of air in the central portion of his chest. There was no indication of a partial or complete deflation of the lung. He is also found to have mild middle ear barotrauma.

With surface oxygen prior to his first recompression table, his shoulder and chest pain and his shortness of breath resolved. He received a TT6, with resolution of all body aches and pains. His decreased hearing, nystagmus and vertigo remained. On the following two days, he received two more TT6s. Both lessened his symptoms, but only to a very small degree. Due to his resistance to therapy and persistent vertigo, he received another week of daily TT5s to resolve his symptoms. He was advised to not return to diving for at least three months after all symptoms had cleared.

It is difficult to immediately determine whether cerebral symptoms such as vertigo and nystagmus are caused by DCI or severe barotrauma. Both diagnoses require a thorough and immediate evaluation for proper treatment. Knowledgeable dive leaders trained in field evaluation and oxygen use can shorten the time between symptoms and evaluation at a hospital. That happened in this case.

# Appendix B: Dive Fatality Case Reports

## Proximate Cause: Air Embolism

**03-25 Inexperienced diver with progressive symptoms and death long after exiting water**

### Cause of Death: Air embolism

This 42-year-old female had been diving for two years and had made fewer than 20 lifetime dives. She had taken an introductory cave diving course but had not received formal certification. She was taking pseudoephedrine for cold symptoms. On the second day of diving to explore a freshwater cave system, the decedent completed two dives. The dive profiles included obligated decompression stops and appeared to be uneventful, except for possibly a rapid ascent toward the end of the second dive. While carrying equipment up a hill after the completion of diving, the diver experienced chest and leg pain. As she lifted her equipment into a truck, she lost consciousness. An autopsy was performed and demonstrated a patent foramen ovale. While the dive profile and initial symptoms were more consistent with decompression sickness, the timing of symptoms and the terminal event most likely represented an air embolism, possibly as a result of arterializing venous bubbles.

**03-66 Solo night dive on rebreather in underwater mine system**

### Cause of Death: Air Embolism

This 48-year-old male was an experienced technical diver. Diving without a buddy, he made a night dive using a rebreather in an underwater mine system. After a dive to 115 feet (35 meters) for 15 minutes, the diver was found unconscious. The coroner determined the cause of death to be an air embolism. An autopsy was performed, but the report was not made available.

**03-86 Diver ran out of air, switched to snorkel, lost consciousness at surface**

### Cause of Death: Air Embolism

This 58-year-old male held open-water certification he had received two years earlier. He made a 30-minute dive to 30 fsw (feet of sea water; 9 msw, or meters of sea water) and signaled to his buddy that he was out of air. The decedent ascended, switched over to his snorkel and grabbed the ladder; he then lost consciousness. At autopsy, the medical examiner ruled the death had been due to a cardiac event based on negative findings (using appropriate special procedures) for air embolism. However, the history was just too compelling for an air embolism, and the autopsy findings may be minimal in such cases. The autopsy did disclose coronary artery disease, fatty change of the liver and patchy myocardial fibrosis, so a cardiac event was certainly possible.

**03-02 Inexperienced diver panicked, made rapid ascent to the surface without buddy and lost consciousness**

### Cause of Death: Air Embolism due to Rapid Ascent

This 41-year-old female had been a certified open-water diver for five months and had made 16 lifetime dives. She was making a dive from a boat with a buddy. The diver descended with her buddy, but panicked and went to the surface without her buddy. At the surface, the decedent called for help and then lost consciousness. An autopsy was performed and the medical examiner determined the death was due to atherosclerosis (where an artery narrowed by plaque buildup blocks or limits blood flow, also known as coronary artery disease) of the artery that supplies blood to a part of the heart that controls conduction of the heartbeat (the atrio-ventricular node). While

this is known to be potentially fatal, the history of a panicked ascent — calling for help on the surface prior to losing consciousness — and the dive profile (30 fsw for less than 4 minutes) were more consistent with an air embolism. From toxicology studies, the anti-seizure medication, phenytoin, was found. While it is a medication that is prescribed to prevent seizures, it is also used in resuscitation.

**03-12 Inexperienced diver lost consciousness at surface after solo quarry dive  
Cause of Death: Air Embolism due to Rapid Ascent**

This 38-year-old male possessed initial open-water certification and had made fewer than 20 lifetime dives. Diving without a dive buddy, he made a shore-entry dive into a quarry. The dive was to 30-40 feet (9-12 meters) for approximately 25 minutes. After ascending, the diver had some type of problem at the surface and lost consciousness. His wife pulled him to shore, but resuscitation efforts were unsuccessful. An autopsy was performed, but the report was not made available. According to the investigative report, the autopsy did not show evidence of coronary artery disease, but the pathologist thought a coronary artery spasm may have occurred. That opinion would have been made without an appreciation for diving physiology. In this case, the most likely cause of death was air embolism.

**03-19 Experienced technical diver made rapid ascent, lost consciousness at surface  
Cause of Death: Air Embolism due to Rapid Ascent**

This 47-year-old female was an experienced diver with technical diving certification. She and a buddy made a dive from a boat to 55 fsw (17 msw). For an unknown reason, the decedent made an unplanned, rapid ascent to the surface after seven minutes of bottom time. At the surface, she was visibly distressed and

then quickly lost consciousness. The autopsy disclosed abundant intracardiac gas and gas in the coronary arteries. She also had pulmonary adhesions. The medical examiner determined the cause of death to be an air embolism.

**03-29 Inexperienced diver, separated from buddy, made rapid ascent, lost consciousness at surface  
Cause of Death: Air Embolism due to Cardiac Rapid Ascent**

This 51-year-old male had advanced open-water certification with 18 lifetime dives completed. He had a known cardiac problem for which he took medication, but the details of his medical history are incomplete. With a buddy, the diver made a dive to a wreck to a maximum depth of 95 fsw (29 msw). He separated from his buddy early in the dive and made a rapid ascent to the surface. At the surface, the diver was witnessed to lose consciousness after removing his mask. The coroner decided not to perform an autopsy and concluded the cause of death was drowning due to a cardiac event, even with the loss of consciousness witnessed at the surface. In all likelihood, this represented an air embolism with possibly some contributing natural disease factors. An autopsy in this case would have been useful.

**03-60 Resort course student, panicked after mask flooded, made rapid ascent and lost consciousness at surface  
Cause of Death: Air Embolism due to Rapid Ascent**

This 23-year-old female was taking an introduction to scuba "resort course." She had had no previous diving experience. The instructor for the course was newly certified as an instructor. The dive, which included a group of four divers, was to 30 fsw for 22 minutes. Her mask flooded and she panicked, resulting in a rapid ascent to the surface. Once there, she

indicated that she was fine, then rapidly lost consciousness and could not be resuscitated. This was a fairly classic story for an air embolism.

**03-72 Experienced diver died while spearfishing, separated from buddy, found later**

**Cause of Death: Air Embolism due to Rapid Ascent**

This 40-year-old male was an experienced diver with open-water certification. He made a shore-entry dive with a buddy but began the dive with a tank that was less than half full. Because he had less air than his buddy, they quickly separated; the decedent went to 58 fsw (18 msw) while his buddy descended past 100 fsw (30 msw). The two reunited briefly but again went off in different directions. The decedent's buddy surfaced and could not locate the other diver. The body was located an hour later by the Coast Guard. The cause of death was determined to be an air embolism. The autopsy also disclosed focally severe coronary artery disease and fatty change of the liver.

**03-71 Inexperienced diver ran out of air, did emergency ascent and lost consciousness at surface**

**Cause of Death: Air Embolism due to Insufficient Air**

This 59-year-old male, who was obese, had recently been certified and had completed 10 lifetime dives. He went to 68 fsw (21 msw) for 21 minutes. During the ascent, the decedent's buddy stopped at the safety stop, but the decedent continued to the surface. At the surface, he called for assistance and lost consciousness. The medical examiner ruled the cause of death to be an air embolism. The diver's tank was empty.

**Proximate Cause: Drowning / Air Embolism**

**03-10 Elderly diver with multiple health problems on advanced open-water training dive to wreck, developed problem on bottom**

**Cause of Death: Drowning due to Air Embolism**

This 67-year-old female had been diving for 11 years, but her certification status and level of experience are unknown. She had a history of early onset dementia, aphasia and osteoporosis. During what was apparently part of an advanced open-water certification course, the diver was making a "training dive" on a wreck. Possibly over-weighted, she developed an unknown problem on the bottom (30 feet), approximately 12 minutes into the dive. The medical examiner determined the cause of death was accidental drowning. The dive profile and evidence on the decedent's computer (an ascent rate violation) made an air embolism a likely contributing factor. She was also found to have fatty infiltration of the right ventricle of the heart, which has been associated with sudden cardiac death.

**03-33 Experienced diver did five successive spearfishing dives, sank after rapid ascent to surface, found on bottom.**

**Cause of Death: Drowning due to Air Embolism**

This 23-year-old male was an experienced, certified diver. He was using nitrox to make a series of deep (in excess of 110 fsw / 34 msw) dives to spearfish. After completing at least four dives, his final dive, without a buddy, was to 122 fsw (37 msw). The decedent speared a large grouper and made a rapid ascent. He descended again and, while the speared grouper came to the surface, the diver

did not. Another diver went down and pulled the decedent to the surface. The stricken diver never regained consciousness, and the diver who rendered assistance required treatment for decompression sickness. The decedent had a stringer full of grouper attached to his body; his tank was empty. The medical examiner determined the cause of death to be drowning secondary to an air embolism.

**03-47 Diver with advanced certification, questionable competency, made multiple dives into kelp bed, separated from buddies, lost consciousness on surface**

**Cause of Death: Drowning due to Air Embolism**

This 41-year-old male had advanced open-water certification and eight years of diving experience. He had been described as not a very competent diver. The diver made a series of dives with dive buddies into a kelp bed. The decedent had been having buoyancy trouble all day. During the fourth dive of the day, the decedent separated from his buddies and ascended. At the surface, he called for assistance before losing consciousness. The death was determined to be a drowning secondary to an air embolism. The autopsy also disclosed mild coronary artery disease.

**03-48 Experienced rescue diver made night dive on leftover nitrox and ran out of air**

**Cause of Death: Drowning due to Air Embolism**

This 18-year-old male possessed rescue diver certification and had received his initial open-water certification 18 months earlier. He had completed at least 130 dives. The diver made a shore-entry night dive using nitrox. This was the third dive of the day, and the diver and his buddy went to 93 fsw (28 msw) for 25 minutes. One report states that the decedent may have used the same tank of gas to complete

more than one dive. The decedent ran out of breathing gas and made a rapid ascent. At the surface, he lost consciousness. While his death was ruled to be a drowning, it was more likely that he drowned after suffering an air embolism.

**03-53 Solo diver made several ascents and descents for game collection, lost consciousness at surface**

**Cause of Death: Drowning due to Air Embolism**

This 52-year-old male had open-water certification but had an unknown amount of diving experience. He made a solo dive from a boat to gather lobster or other marine life. Another person, snorkeling in the same area, watched the diver make several descents and ascents. After one ascent, the diver lost consciousness after surfacing. Resuscitation efforts were unsuccessful. The autopsy findings were consistent with drowning, but postmortem imaging studies showed abundant air in the heart and great vessels. Other findings included left ventricular hypertrophy (overgrown or excessive development of an organ or body part) and moderate coronary artery disease. The medical examiner concluded that the diver drowned secondary to an air embolism.

**Proximate Cause: Cardiac**

**03-14 Diver with unknown certification and experience level, had cardiac event while diving**

**Cause of Death: Cardiac Dysrhythmia**

This 53-year-old male allegedly suffered a fatal cardiac event while diving. An autopsy report, if an autopsy was performed, was not made available. There was no information available on the diver's certification status, level of experience or the circumstances surrounding the fatal event.



**03-74 Poorly conditioned diver lost consciousness on swim back to shore after dive  
Cause of Death: Cardiac Dysrhythmia due to Hypertrophic Cardiomyopathy**

The information of the diving-related death of this 50-year-old obese male was incomplete. He held open-water certification, but the amount of diving experience was unknown. The diver completed a shore-entry dive to 20 fsw (6 msw) for 49 minutes. During the surface swim back to shore, he lost consciousness and could not be resuscitated. The autopsy disclosed mild atherosclerosis of the coronary arteries, a 600-gram heart with marked thickening of the wall of the left ventricle and changes characteristic of hypertrophic cardiomyopathy. This heart problem is known to cause sudden death and is the most common cause of sudden, non-traumatic death in athletes.

**03-76 Experienced diver with hypertension, had problem at depth, lost consciousness after surfacing  
Cause of Death: Cardiac Dysrhythmia due to Left Ventricular Hypertrophy**

An experienced diver with rescue diver certification, this 39-year-old male had a medical history that included both hypertension, for which he took medication, and obesity. The diver and his buddy planned a shore-entry dive to 129 fsw (39 msw), but the buddy could not equalize and aborted his dive. The decedent hooked up with other divers at depth, but after five minutes of bottom time, he signaled that he had a problem and needed to ascend. He surfaced and lost consciousness, requiring another diver to bring him to shore. The autopsy disclosed hypertensive heart disease with hypertrophy of the left ventricle of the heart. Unfortunately the autopsy was performed after the body was embalmed, adding

artifacts and eliminating some possible findings. While an air embolism cannot be excluded, the most likely source of this diver's problem at depth was cardiac in origin.

**Proximate Cause: Drowning / Cardiac**

**03-09, Experienced but extremely obese diver, in distress at depth, died before surfacing**

**Cause of Death: Drowning due to Cardiac Dysrhythmia**

This 53-year-old male, an experienced diver with open-water certification, was morbidly obese. In his diving history, he had nearly drowned. On the day before, the diver had completed one dive, but he declined to do a second dive. He said he did not feel well. The decedent apparently felt better the next day, and two dives were planned. For the first dive, he descended with a buddy to 60 fsw (18 msw). He seemed fatigued, coughing frequently while at the bottom. Late in the dive and in obvious distress, he was observed grabbing his chest. He was assisted to the surface where he was unconscious; CPR was performed. Resuscitation efforts were unsuccessful. After an autopsy, the medical examiner ruled the death as a drowning due to a cardiac event.

**03-26 Student diver in poor physical condition, multiple health problems, lost consciousness during ascent**

**Cause of Death: Drowning due to Cardiac Dysrhythmia**

This 57-year-old male was a student in an initial open-water certification class. His medical history included sleep apnea and a heart valve replacement. He was also significantly overweight. During the ascent on one of his check-

out dives, the diver lost consciousness. At that time, the instructor had gone back to depth to assist another student. The decedent was found unconscious at the surface. While an air embolism is certainly possibly with this dive profile, the autopsy revealed coronary artery disease and a heart that weighed more than three times what would be expected for this man. He also had valvular heart disease. The medical examiner determined the cause of death to be drowning secondary to a cardiac event.

**03-27 Experienced technical diver made wreck dive using a rebreather, separated from buddy team, found unconscious on bottom**

**Cause of Death: Drowning due to Cardiac Dysrhythmia**

This 58-year-old male, an experienced diver with technical diver certification, was making a dive on a wreck in a four-person buddy team. Before the dive, the diver had complained of fatigue; he did not dive the day before with the others in the group. During this dive, the decedent decided to go off on his own. Since he had a habit of doing this, the buddy separation did not alarm anyone. Since the dive was to 104 fsw (32 msw), the diver used a rebreather apparatus. The decedent was found on the bottom, unconscious. An autopsy was not performed. The rebreather was out of breathing gas, but an additional "bailout" pony bottle was full.

**03-42 Advanced certified diver with unknown experience, hypertension, heart problems and tobacco abuse, made wreck dive and lost consciousness on bottom**

**Cause of Death: Drowning due to Cardiac Dysrhythmia**

This 51-year-old male had a medical history that was significant for hypertension and dilated cardiomyopathy (a condition where the heart muscle becomes weakened and loses

strength to pump blood throughout the body), requiring multiple medications including an anticoagulant. He also continued to smoke. He had had advanced open-water certification and had been diving for four years, but his experience level was not documented. The decedent and a buddy made a dive to a wreck at 110 fsw (34 msw) for 10 minutes. He had difficulty ascending, and others witnessed that he lost consciousness at the bottom. He was brought to the surface, but resuscitation efforts were unsuccessful. The autopsy revealed dilated cardiomyopathy, focally severe coronary atherosclerosis and numerous cardiac medicines present on toxicology. The diver's equipment was also improperly configured, and he had tucked several of his hoses into his wetsuit.

**03-43 Student diver in poor health, panicked at depth, brought unconscious to surface**

**Cause of Death: Drowning due to Cardiac Dysrhythmia**

This 52-year-old male was a student in an initial open-water certification class. His medical problems included morbid obesity, diabetes, obstructive sleep apnea and hypertension. The decedent stopped taking his blood pressure medication two days before the open-water dives because he thought he should dive without any medications in his system. The diver made three check-out dives that were remarkable only for his having trouble equalizing his ears. After descending to 51 fsw (16 msw) with a buddy, the decedent appeared to be in distress and panicked on the bottom. He was assisted to the surface but was unconscious and could not be resuscitated. The medical examiner ruled the death as being due to drowning secondary to a cardiac event. An air embolism cannot be entirely excluded, but the diver appeared to have lost consciousness at depth, which makes a cardiac event more likely.



### **03-52 Diver certified within last year, lost consciousness on surface after uneventful dive**

#### **Cause of Death: Drowning due to Cardiac Dysrhythmia**

This 35-year-old male had been certified for nine months, but the extent of his diving experience was unknown. He made a shore-entry dive with a buddy to 40 fsw (12 msw) for 35 minutes. The dive was uneventful, but at the surface after the dive he lost consciousness. An autopsy showed focally severe atherosclerosis of the coronary arteries. An air embolism cannot be completely excluded, but there was no history of a rapid ascent or any evidence of barotrauma at autopsy.

### **03-61 Unknown experience and certification level, diver experienced problem on surface after dive**

#### **Cause of Death: Drowning due to Cardiac Dysrhythmia**

Little information was available on the death of this 54-year-old male who made a boat-entry dive into the ocean. After ascending, he had some unspecified problem at the surface. An autopsy was performed, but the report was not released. According to the information available, the death was cardiac related.

### **03-68 Experienced but poorly conditioned, previous smoker, on game collection dive, lost consciousness on surface post dive**

#### **Cause of Death: Drowning due to Cardiac Dysrhythmia**

This 51-year-old male was an experienced diver with multiple dive certifications. He was obese, had been a smoker in the past, and had sought medical care for chest pains within a week of this dive. At that time, his stress electrocardiogram was normal. The diver felt poor enough to skip the first dive of the day, but he participated in the second. He and a buddy went to 45 fsw (14 msw) for 30 minutes to

gather lobster. The two divers surfaced, and the buddy made it back to the boat first. The buddy saw the decedent hanging onto the dive buoy and signaling to the boat before letting go and sinking back below the surface. The stricken diver was brought to the boat and resuscitated, but he died in a hospital the next day. The autopsy did not show significant coronary artery disease, but he did have a markedly thickened left ventricle and a heart that weighed more than one and a half times the amount it should have weighed. The cause of death was most likely drowning secondary to a cardiac event.

### **03-77 Poorly conditioned, infrequent diver in refresher course aboard cruise ship, made emergency ascent to safety stop, lost consciousness at surface**

#### **Cause of Death: Drowning due to Cardiac Dysrhythmia**

This 53-year-old female was open-water certified but had not made a dive in four years. She was making a dive as part of a refresher course while traveling aboard a cruise ship. The diver was morbidly obese. After descending to 70 fsw (21 msw), the diver signaled that she needed to make an emergency ascent. She made a safety stop, then went to the surface where she vomited and lost consciousness. The autopsy disclosed a markedly enlarged heart with fat infiltrating the right ventricle. The death was ruled a drowning due to a cardiac event, with the possibility of an air embolism.

### **03-81 Heavy smoker with chest pains for one week prior to dive, made game collection dives, found unconscious on bottom**

#### **Cause of Death: Drowning due to Cardiac Dysrhythmia**

This 43-year-old male had open-water certification and moderate diving experience. He was a heavy smoker and had complained of

chest pains for a week prior to this dive. The diver had similar complaints two months previously, and some follow-up appointments were scheduled but he had not been evaluated yet. Without a buddy, the decedent made a short dive to 12 fsw (4 msw) to check out the area and then returned to the surface. He was collecting lobster and returned to depth but never surfaced. Another diver found him unconscious on the bottom. Resuscitation efforts were unsuccessful. The autopsy disclosed severe coronary artery disease, hypertrophy of the left ventricle of the heart and evidence of previous injury to his myocardium. Toxicology studies also revealed cocaine and ethanol in his blood. Cocaine alone can result in a fatal cardiac event, but combining cocaine with severe coronary artery disease practically assures it.

### **Proximate Cause: Drowning / Insufficient Air**

#### **03-15 Inexperienced diver made personal task dive without fins, panicked on surface and sank to bottom**

##### **Cause of Death: Drowning due to Insufficient Air**

This 56-year-old male had basic open-water certification with fewer than 20 lifetime dives. He entered the water alone to check an air conditioner unit; he tied a line to himself, but did not use fins. He made two excursions to a depth of 12 feet and appeared to panic while attempting to remove his buoyancy compensator on the surface. The decedent sank to the bottom where he was found still wearing a weight belt. The autopsy disclosed aortic stenosis (thickening and hardening of the leaflets of the aortic valve in the heart, preventing the valve from opening properly), atherosclerotic cardiovascular disease and hypertrophy of the left ventricle of the heart. The medical examiner determined the death to be due to aortic stenosis, but the history was

more consistent with an accidental drowning. An air embolism cannot be excluded and certainly the natural disease processes may have contributed to the fatality.

#### **03-17 Diver with heart problems, made spearfishing dive, separated from buddy, found dead on surface with empty tanks**

##### **Cause of Death: Drowning due to Insufficient Air**

This 52-year-old male received his initial open-water certification six years earlier. He had a medical history that was significant for heart disease and peptic ulcer disease. The diver also complained of chest tightness prior to the dive. He and a buddy were spearfishing, but they became separated after 15 minutes. The buddy eventually returned to the boat, but the decedent was missing. He was found floating unconscious and with an empty tank. The cause of death was determined to be drowning, but a cardiac event as a contributing factor cannot be excluded.

#### **03-21 Experienced diver, made three dives for game collection, died on his fourth solo dive to retrieve equipment**

##### **Cause of Death: Drowning due to Insufficient Air**

This 71-year-old male was a certified diver with four years of experience. He was overweight and took medication for high blood pressure. The diver and his buddy were using a surface supplied diving apparatus to collect lobster. They completed three uneventful dives. To retrieve a piece of equipment, the decedent put on scuba gear and went off on his own. He did not return to his buddy, and the decedent's body was recovered an hour later. The cause of death was determined to be drowning. The autopsy disclosed moderate hypertensive atherosclerotic cardiovascular disease and a benign kidney tumor. The occurrence of a cardiac event cannot be excluded.

**03-22 Inexperienced diver made his second dive made with half-empty tank, surfaced in distress, removed equipment and sank below the surface**

**Cause of Death: Drowning due to Insufficient Air**

Since he became certified, this 51-year-old male had open-water certification and had completed approximately 10 dives during the year. Without a buddy, he made a pair of shore-entry dives to approximately 70 feet (21 meters). According to investigative reports, the diver changed tanks between dives, but he did not use a full tank for the second dive. During the second dive, observers saw the diver at the surface calling for help. He struggled on the surface and removed some of his equipment before disappearing below the surface. The autopsy revealed changes consistent with drowning, along with focal, moderate coronary artery disease. The history was also indicative for an air embolism, which cannot be excluded in this case even with the autopsy findings.

**03-28 Inexperienced diver, made wreck dive in cold water, unfamiliar with drysuit and equipment, ran out of air and drowned**

**Cause of Death: Drowning due to Insufficient Air**

This 50-year-old male had advanced open-water certification, with fewer than 20 lifetime dives. He had been a diver for six months. The diver was making a wreck dive in cold water with a large group but no designated buddy. He wore a drysuit but had little experience with the equipment. Approximately 20 minutes into the 90 fsw (27 msw) dive, the decedent panicked. He had exhausted his air supply, and he possibly also had a regulator problem. Other divers on the trip reported that their first stages "froze up." The decedent grabbed first the octopus of a student diver on the trip, and then grabbed the student's primary. The student broke away from the dis-

tressed diver. The decedent was found on the bottom, unconscious, and with his regulator out of his mouth. Resuscitation efforts were unsuccessful.

**03-55 Infrequent diver made night dive for game collection, regulator free-flow, ran out of air, never surfaced**

**Cause of Death: Drowning due to Insufficient Air**

This 40-year-old male was a certified diver who had not made a dive in at least a year. In search of lobster, he made a night dive to 65 fsw (20 msw) for 45 minutes. The diver had a free-flow problem with his regulator and rapidly exhausted his air supply. When he was down to 300 psi, he signaled to his dive buddy that he wanted to ascend. During the ascent, the buddy last saw the diver at approximately 10 fsw (3 msw), but he could not locate him at the surface. The decedent's body was recovered the next day. In addition to changes consistent with drowning, the autopsy disclosed mild coronary atherosclerosis and hypertrophy of the left ventricle of the heart. When his body was recovered, a catch bag with 20 pounds (9 kilograms) of lobster remained attached to the diver. The additional drag from the catch bag and the free-flowing regulator would have contributed to the rapid use of the diver's air supply.

**03-67 Cave diver with little experience, in poor condition, ran out of gas in cave and separated from buddies**

**Cause of Death: Drowning due to Insufficient Air**

This 50-year-old male was an experienced diver with tech / cave diving certification but modest cave diving experience. He had no known medical problems except for obesity. To explore a cave system, the diver made a shore-entry, mixed gas dive with two dive buddies. The dive was to a maximum depth of 140 feet (43 meters), and the decedent was

using a scooter for the first time. The decedent may have experienced a drysuit problem, but in any event his gas supply (primary and reserves) became exhausted, and he needed to share breathing gas with one of his buddies. The diver and his buddies became separated during ascent, and his body was recovered approximately an hour later. In addition to changes consistent with drowning, the autopsy showed left ventricular hypertrophy.

**03-69 Advanced open water course diver, started dive low on air, ran out of air on ascent, lost consciousness before reaching surface**

**Cause of Death: Drowning due to Insufficient Air**

This 54-year-old male, a student in an advanced course, had received his initial open-water certification three years earlier. He was making a shore-entry training dive in a lake, and he descended to 82 feet (25 meters). He complained of being cold on the bottom and signaled that he desired to ascend. The decedent began the dive with less than 1,000 psi, and he quickly exhausted his air supply. The dive instructor released the decedent's weight belt during the ascent, and the diver lost consciousness before reaching the surface. Resuscitation efforts were unsuccessful. The autopsy demonstrated changes consistent with drowning as well as moderate coronary artery disease and evidence of previous ischemic injury to the heart. Toxicology studies also demonstrated cannabinoids (any of various chemical constituents of cannabis or marijuana) in the blood. The medical examiner ruled the death a drowning, but a cardiac event certainly may have been contributory.

**03-75 Diver with uncertain dive certification and experience, tobacco and alcohol abuse, made wreck dive on nitrox, ran out of gas, separated from buddy, found two days later**  
**Cause of Death: Drowning due to Insufficient Air**

This 28-year-old male was reported to have technical diving certification, but the same report indicated that he had completed fewer than 20 lifetime dives. He was a smoker and had consumed alcoholic beverages the night before making a dive to a wreck at 67 fsw (20 msw) using nitrox. The diver ran out of breathing gas and was making his way back to the boat using the surface line when he was handed his buddy's buoyancy compensator because his could not be inflated (no gas remained). His buddy had also been low on gas, and the decedent slipped below the surface. The body was recovered two days later. The autopsy revealed mild coronary artery disease and changes associated with drowning.

**03-82 Infrequent diver performed personal task dive, separated from buddy, body recovered two days later**

**Cause of Death: Drowning due to Insufficient Air**

This 45-year-old male had received his open-water certification five years previously but had not been diving in more than a year. He and a buddy were trying to recover a sunken outboard motor from the bottom of a lake. Visibility was poor, and the divers became separated. The buddy surfaced, but the decedent did not. His body was recovered two days later at a depth of 90 feet (27 meters). The diver's tank was empty.



**03-88 Solo diver with unknown certification and experience, entrapped on wreck dive  
Cause of Death: Drowning due to Insufficient Air**

There was little information available surrounding the death of this 47-year-old male. His certification status, amount of experience and frequency of diving were unknown. It was known that he habitually made solo dives from his boat without any topside support. Apparently he died after becoming entrapped and exhausting his breathing gas during a wreck penetration dive. An autopsy was performed after the body was recovered, but the report was not made available.

**03-24 Experienced technical diver made cave dive using scooter, separated from buddy and drowned  
Cause of Death: Drowning due to Insufficient Air due to Entrapment in Cave**

This 42-year-old male was an experienced technical diver with cave diving certification. He made a cave dive to 94 feet (29 meters) using a scooter for transit. A silt-out occurred during the dive, and the diver and his buddy became separated. The decedent's body was recovered one hour later. Toxicology studies revealed the presence of narcotic and antidepressant medications. The gas source had been exhausted.

**03-34 and 03-35 Double Fatality. Insufficient and possible faulty equipment, both divers trapped under ice and died  
Cause of Death: Drowning due to Insufficient Air due to Entrapment under Ice**

One of two divers involved in a double fatality that occurred during a dive under ice in a quarry, this 30-year-old male diver had rescue diver certification and was experienced.

The other of two divers involved in a double fatality that occurred during a dive under ice,

this 31-year-old male diver had no dive training or documented certification.

Neither diver had any formal training in ice diving, though it was reported that they had made dives under ice in the past. They rented equipment that was likely not sufficient for the water temperatures in which it was going to be used. There were signs posted that prohibited trespassing and locked gates surrounding the entry point. They had a rope that was tied to a tree on the surface and entered the water through a hole in the ice, but neither diver was attached to the other end of the rope.

When they did not return to the surface to meet their ride home at a prearranged time, a search was conducted. The extreme weather precluded recovery efforts until the next morning. Both bodies were recovered more than 300 feet (61 meters) from the entry point in the ice. Contributing factors to these diving deaths included a lack of topside support, inadequate and poorly maintained equipment, evidence of use of alcoholic beverages prior to the dive and worsening weather while the divers were under the ice. One diver's regulator and buoyancy compensator leaked when tested. The autopsy findings were consistent with drowning as a cause of death.

**03-36 and 03-37 Double Fatality. Uncertified and inexperienced divers made freshwater canal night dive with insufficient equipment, both ran out of air in tunnel and drowned  
Cause of Death: Drowning due to Insufficient Air due to Entrapment in a Tunnel**

Two others, one a 21-year-old and the other a 23-year-old, were involved in a double fatality diving incident. Neither diver had any formal dive training or certification.

The divers decided to enter a freshwater canal that contained a siphon or tunnel that assists the flow of water underground. By definition, the water flow consists of a strong current. For the night dive, neither diver had a depth gauge, octopus or alternate air source, and they used no line to guide them back to the entry point. The plan was apparently to follow the tunnel to depth (100 feet / 30 meters below the surface) until they could exit the tunnel to the surface farther down the siphon. The divers did not know that a grate covered the exit to the tunnel. Additionally, signs prohibiting trespassing and swimming were posted at the entry point.

When the divers could not be accounted for, a recovery mission was launched. The bodies were recovered 30 hours later. The pathologist performing the autopsies determined the cause of death to be drowning for both individuals. Interestingly enough, the pathologist was quoted as saying that the small amount of water in the lungs was proof of deep water drowning and that air escaping from the chest cavity upon opening it indicated cold water drowning. Neither of these statements had any scientific basis. Debris was also found in the airways of both divers. This is not uncommon in drowning deaths.

### **Proximate Cause: Drowning / Various Causes**

**03-07 Poorly conditioned, infrequent diver with multiple health problems, died unwittingly in game collection dive**  
**Cause of Death: Drowning**

This 51-year-old male was a certified diver who had been diving for 14 years, but he had made fewer than 100 lifetime dives. He was obese and had a history of esophageal reflux, depression and herpes. This diver and another diver entered the water to collect shellfish. Though they were diving as a buddy team, it

appeared that they entered the water separately. After the buddy returned to shore, the decedent could not be located. The body was recovered three hours later in 6 feet (2 meters) of water. The medical examiner performed an external inspection, not a complete autopsy. The cause of death was determined to be drowning. Toxicology revealed the presence of antidepressant medication as well as morphine and codeine. The medical examiner also detected a small amount of ethanol, which may or may not have been due to postmortem production. The medical examiner thought that maybe a shallow-water blackout contributed to the drowning, but this showed a lack of understanding of the physiology of shallow-water blackout. The contribution of natural disease processes in this case could not be determined with certainty and, without an autopsy, a cardiac event cannot be excluded.

**03-08 Inexperienced diver in advanced class in freshwater, overweighted, panicked, instructor surfaced for help, diver found unconscious on bottom**  
**Cause of Death: Drowning**

This 29-year-old male possessed initial open-water certification and had made six lifetime dives. A student in an advanced open-water certification course, the diver was making a set of dives in a river with three other students and the instructor. The diver was wearing excessive weight and appeared to panic on the bottom (75 feet / 23 meters) after silt was kicked up. When the instructor attempted to render assistance, the diver grabbed the instructor's regulator. After unsuccessful attempts to help the diver, the instructor went to the surface for additional personnel. The diver was found on the bottom, unconscious and with his regulator out of his mouth. Resuscitation efforts were unsuccessful. The autopsy findings were consistent with a drowning death.

**03-11 Inexperienced diver performing dry-suit demonstration with group, separated from group, descended too far with another group, lost consciousness on bottom  
Cause of Death: Drowning**

This 26-year-old male had been a certified diver for five years but had made fewer than 20 lifetime dives. The diver was obese and had a history of asthma for which he used an inhaler. He was involved in a drysuit demonstration in a quarry, but he obviously had little experience himself. The decedent and a group of divers were supposed to descend to 50 fsw (15 msw), but he became separated from his own group and descended with another group to 120 fsw (37 msw). The diver's buddy saw him descend too far and went down to retrieve him. The decedent was witnessed to lose consciousness on the bottom and was pulled to the surface. Resuscitation efforts were unsuccessful. The autopsy disclosed hypertrophy of the left ventricle of the heart, in addition to changes consistent with drowning. The contribution of natural disease processes to this death was uncertain.

**03-20 Experienced diver made cold water dive, new drysuit, regulator free-flowed, panicked, rapid ascent to surface  
Cause of Death: Drowning**

This 40-year-old female was a very experienced diver with open-water certification. She had a medical history that was significant for obesity, hypertension, elevated serum cholesterol and depression. At the time of this dive, her medications included an anti-depressant drug. She and a buddy made a shore-entry dive into a lake. The water was cold and visibility was poor. The diver was using a new drysuit, and at 40 feet (12 meters) and 10 minutes into the dive, she suddenly panicked and grabbed her buddy. Also, her regulator apparently was free-flowing. The divers rapidly went to the surface, but the buddy, unable to jettison the diver's weights, could not keep

her at the surface. The autopsy disclosed changes consistent with drowning as well as papillary carcinoma of the thyroid gland and a fatty liver. An examination of the equipment revealed that the weights could not be jettisoned in the configuration used, and the regulator was in poor repair and ill suited for diving in cold water. The history of a rapid ascent made an air embolism a possibility, though the buddy noted that the diver did not lose consciousness on the surface.

**03-31 Older diver lost consciousness during long surface swim after night dive  
Cause of Death: Drowning**

This 63-year-old male, obese and with a history of hypertension, held advanced open-water certification and had made 70 to 80 lifetime dives. The diver made a night dive with a buddy to 50 fsw (15 msw). At 10 minutes into the dive, the decedent signaled to his buddy that he wanted to ascend. On the surface, the decedent could not inflate his buoyancy compensator. He had experienced fatigue during the long surface swim. The diver lost consciousness and could not be resuscitated. An autopsy was not performed and the death was certified as a drowning, with natural disease processes as contributing factors.

**03-32 Older diver separated from buddy, died on surface in rough seas  
Cause of Death: Drowning**

This 77-year-old female was an experienced open-water diver. She and her buddy made a dive in a strong current with rough seas. The decedent became separated from her buddy and another diver pair, an instructor and student, also became separated. The decedent and the dive instructor were together on the surface in a rough sea. When the decedent lost consciousness, the instructor attempted resuscitation, but his efforts were unsuccessful. The instructor was rescued 24 hours later. The autopsy report was not made available, but



the cause of death was determined to be drowning with evidence of blunt force injuries also present.

**03-40 Diver with history of stroke and marijuana abuse, removed floatation equipment at surface and drowned with weight belt on**  
**Cause of Death: Drowning**

This 41-year-old male had a history of a stroke at age 38. He was a certified diver with a moderate amount of open-water experience. The decedent and his dive buddy completed two dives from a boat to 30 fsw (9 msw) for approximately 30 minutes. At the end of the second dive, he had already removed his regulator and buoyancy compensator when he unexpectedly let go of the ladder and drifted off. The body was recovered with the weight belt still in place. The autopsy disclosed mild coronary artery disease, hypertrophy of the left ventricle of the heart and myocardial scarring. Urine toxicology was positive for cannabinoids. The case was ruled as a drowning by the medical examiner, with the possibility of some natural disease processes contributing to the death. This case makes a great argument for a diver keeping the regulator and buoyancy compensator on until back in the boat, or, at least, removing the weight belt prior to giving up the means of floatation and life support in the water.

**03-45 Student diver in poor condition, separated from instructor in rough seas and drowned**  
**Cause of Death: Drowning**

This 61-year-old female was a student in an initial open-water certification class. She received her pool training six months earlier and was completing the open-water dives. The diver was obese and had significant medical problems, though it seems they were diagnosed at autopsy. The diver and her instructor made a beach entry, and she struggled to adjust her fins while breathing through a

snorkel in a rough sea. The diver and the instructor became separated before they descended, and the instructor called for help after he could not locate his student. The student was found at the surface, floating unconscious. The autopsy demonstrated changes consistent with drowning. Additionally, the decedent had evidence of pulmonary emphysema and ischemic heart disease (obstruction of blood flow to the heart).

**03-46 Elderly diver separated from buddy, body recovered on bottom**  
**Cause of Death: Drowning**

This 79-year-old male made a boat dive to 50 fsw (15 msw). His certification status and amount of diving experience are unknown. The diver and his buddy became separated, and the decedent did not surface from the dive. His body was recovered from a ledge near the bottom. If an autopsy was performed, no report was made available. No conclusions can be drawn about the contribution of natural disease processes to this diver's death.

**03-49 Poorly conditioned diver, tobacco abuse, died in solo game collection dive**  
**Cause of Death: Drowning**

This 44-year-old male diver entered the water alone to gather scallops. It was unknown if he was a certified diver. He was obese and a smoker. There was little information on the circumstances surrounding his death, which was ruled to be due to drowning with the possible contribution of cardiovascular disease. An air embolism cannot be entirely excluded.

**03-51 Experienced diver struggled, disconnected hose prior to descent and sank**  
**Cause of Death: Drowning**

This 55-year-old male, certified as a rescue diver, had made approximately 100 lifetime dives. He was making a shore-entry dive with a buddy, but stopped approximately 15 yards (13.7 meters) from the beach prior to descent.

The diver attempted to repair his gear and disconnected the hoses as he struggled on the surface. The diver's buddy attempted to assist him, but the diver grabbed at the buddy and the buddy had to move away. Unfortunately, the diver did not remove his weight belt, and he sank below the surface. After the body was recovered, an autopsy was performed. It showed changes consistent with drowning as well as moderate atherosclerosis of the aorta.

**03-54 Advanced certified diver with multiple health problems, history of erratic diving behavior, made deep dive, rapid descent and panicked, separated from buddy, found on bottom unconscious**

**Cause of Death: Drowning**

This 25-year-old female, certified in advanced open-water, was a frequent diver]. Her medical history included hypertension controlled with medication, depression controlled with antidepressant medications, and Turner's Syndrome (a rare chromosomal disorder of females characterized by short stature and the lack of sexual development at puberty). The diver had a history of erratic behavior in the water, frequently running low on air and needing to buddy breathe on more than one occasion. She made a planned deep dive from a boat, rapidly descending to 80 fsw (24 msw). She panicked at that point and wanted to abort the dive. She soon became separated from her buddy. The divemaster retrieved her from the bottom at 143 fsw (44 msw). She was unconscious. The autopsy demonstrated changes consistent with drowning as well as moderate coronary artery disease and the incidental finding of a horseshoe kidney.

**03-56 Entanglement in safety line**

**Cause of Death: Drowning**

A certified diver, this 51-year-old male had not made a dive in the previous four years and may have made as few as three dives in the previous 15 years. He was morbidly obese. With a buddy, the diver was making a boat-entry dive in rough seas. He entered the water, became entangled in the mooring / safety lines and panicked. The diver spit out his regulator, which then became entangled. When others tried to assist him, he became combative. The autopsy disclosed findings consistent with drowning, as well as a fatty liver, hypertrophy of the left ventricle of the heart and peritoneal adhesions (scar tissue from inflammation, surgery or trauma in the lining of the abdominal cavity). The medical examiner called the manner of death "reflex cardiac arrest," but most likely it was a simple drowning due to panic in an inexperienced diver.

**03-62 Inexperienced diver died on surface before dive in rough seas**

**Cause of Death: Drowning**

This 27-year-old female was certified seven years before, but she had completed fewer than 20 lifetime dives. In poor weather, she was attempting a freshwater dive to view a wreck at a depth of 30 feet (9 meters). The diver was with a buddy, but they never descended. The decedent panicked on the surface and spit her regulator out. She did not comply when told to replace it. She also would not release her weight belt, so her buddy did that for her. A large wave caused her to aspirate water. She lost consciousness while being towed back to the boat. Resuscitation was

unsuccessful. It is unclear if an autopsy was performed, but the death was ruled to be a "dry drowning due to laryngospasm." The existence of so-called dry drownings had been disputed in the medical literature of the past few years. In all likelihood, this diver aspirated enough fluid to result in a fairly typical drowning.

**03-63 Inexperienced diver with heart problems, entered with buddy in rough seas, panicked at surface before dive and sank below**

**Cause of Death: Drowning**

This 26-year-old female had basic open-water certification with 11 lifetime dives. She had a medical history that included the repair of a "heart defect" two years earlier; she was also a smoker. The diver and a buddy were making a dive down to a wreck in rough seas and a strong current. At first, the diver aborted a dive after entering the water, but she decided to try again. After entering the water a second time, she again did not want to descend. She panicked and grabbed her buddy's mask as he attempted to render aid. While the dive buddy put his mask back in place, the decedent sank below the surface. A dive instructor pulled her to the surface where resuscitation efforts were unsuccessful. The autopsy findings were consistent with a drowning death.

**03-70 Infrequent diver with divemaster certification, medical conditions, lost consciousness on descent, possibly entangled in kelp**

**Cause of Death: Drowning**

This 51-year-old female was a divemaster who had not made a dive in the previous year and a half. Her medical problems included hypertension and depression. She and her buddy were swimming to the anchor line prior to descending. The buddy submerged before the decedent did; she seemed to descend slowly after her buddy. She was noted to have actual-

ly lost consciousness, however. Resuscitation efforts were unsuccessful. One unsubstantiated report stated that the diver had become entangled in kelp. The medical examiner ruled the cause of death was drowning. The autopsy also disclosed infiltration of the right ventricle of the heart by fat, which has been correlated to an increased risk of sudden death. Toxicology showed the presence of several anti-depressant medications along with pseudoephedrine and diphenhydramine.

**03-79 Experienced technical diver died during night dive using rebreather that was later found dysfunctional**

**Cause of Death: Drowning**

This 40-year-old male, a very experienced technical diver, made a quarry dive at night using a rebreather (nitrox as breathing gas). A group of 12 divers participated, and visibility was poor. After completing the dive, all of the divers ascended to the safety stop. When the rest of the divers then ascended to the surface, the decedent did not follow them. Found at a depth of 15 feet (5 meters), he was unresponsive. The medical examiner determined the cause of death to be drowning. A detailed examination of the rebreather revealed that there was carbon dioxide absorbent throughout the rig, an oxygen sensor had been inserted incorrectly and was not functioning, and the oxygen addition valve was partially blocked, resulting in a 75 percent decrease in flow. Several loose connections were also present. Rebreather rigs require meticulous maintenance, and errors in assembly may have tragic consequences, as in this case.

**03-83 Diver made solo shore entry dive to test equipment, surfaced in distress, pulled to shore by surface observer**

**Cause of Death: Drowning**

This 36-year-old male had an unknown certification status and level of experience. His medical history included a recent episode of

depression. The diver made a shore-entry solo dive to test out some equipment because he had planned to resume diving regularly. The diver used a line attached to his body; someone who stayed back on shore held it. He surfaced, called for help, and disappeared back below the surface. The person on shore pulled the diver in, but resuscitation efforts were unsuccessful. The cause of death was determined to be drowning, but the occurrence of an air embolism cannot be excluded.

**03-73 Experienced diver with history of panic attacks, panicked during dive, made rapid ascent, lost consciousness on surface  
Cause of Death: Drowning due to Rapid Ascent**

This 57-year-old male was an experienced diver with advanced open-water certification. His medical problems included hypertension, diabetes mellitus, obesity and a history of claustrophobia and panic attacks. He had experienced panic attacks on previous dive trips. When he was reluctant to let go of the ladder and enter the water on this dive, he stated, "This happens all of the time." The decedent finally went below the surface to a depth of 27 feet (8 meters), but he ascended after seven minutes. His ascent was rapid and, upon reaching the surface, he called for assistance. He was in a panic and would not take a regulator when offered to him. The diver then lost consciousness and could not be resuscitated. The autopsy disclosed changes associated with drowning in addition to hypertensive heart disease. Toxicology was positive for multiple antihistamines and benzodiazepines (tranquilizers that prevent or reduce anxiety, sleeplessness, muscle spasms, seizures, and other problems by slowing down the central nervous system). The history was consistent with an air embolism contributing to the drowning.

**03-01 Certified cave diver with history of narcolepsy, made solo dive in freshwater cave on nitrox and did not return  
Cause of Death: Drowning due to Entrapment in Cave**

This 35-year-old male was a certified cave diver with one year of cave diving experience. He was morbidly obese and had a history of narcolepsy. Diving without a buddy, the diver made a shore-entry dive into a cave system in a freshwater spring. He used a 34 percent nitrox mixture as a breathing gas, and the dive profile was planned to 108 feet (33 meters) for 20 minutes. The diver's body was recovered in a restrictive area within the cave where the current was brisk. From the position of the body, it appeared that he had been attempting to exit the cave system. The autopsy was consistent with drowning, though there was still breathing gas available in the tank.

**03-13 Experienced public safety diver, made personal task dive in freshwater, trapped on bottom, body recovered later  
Cause of Death: Drowning due to Entrapment**

This 30-year-old male was an experienced diver on the police dive team and had dive-master certification. The details of the event are incomplete, but apparently the decedent and his dive buddy entered a freshwater body of water for the purpose of raising a vehicle from the silt-covered bottom. They had no surface support for the task. According to the investigative report, the lift bags slipped, and the decedent became trapped on the bottom. His body was recovered later. An autopsy was performed, but the report was not made available.



**03-65 Inexperienced diver made night dive in freshwater, entangled in pipes on bottom, panicked and lost consciousness**

**Cause of Death: Drowning due to Entanglement**

This 21-year-old female, certified in open-water four months previously, was making her first set of dives after certification. She was morbidly obese. The planned night dive included a group of about 10 divers, with a mixture of open-water certified divers, students in an advanced open-water class and instructors. According to witness reports, the diver became entangled in some pipes on the bottom of the quarry and panicked. There are some discrepancies between the accounts of different witnesses, but it appears there is agreement that the decedent was brought to the surface unconscious after her gear was removed at depth. This would corroborate the history of entanglement on the bottom. The medical examiner ruled the death a drowning, possibly due to an air embolism. Since the decedent lost consciousness before ascending, she likely drowned because she was entangled on the bottom, and an air embolism would be unlikely.

**03-78 Poorly conditioned diver made shore entry dive with buddy, possibly overweighted, entangled in kelp**

**Cause of Death: Drowning due to Entangled in Kelp**

This 51-year-old female had been a certified diver for 20 years. She was obese and had a history of breast cancer. She and her buddy made a shore-entry dive and became entangled in kelp. The diver's buddy was able to break free from the kelp, but the decedent was not so fortunate. In addition to wearing the typical weight belt for a dive, she was also wearing ankle weights. The autopsy disclosed the incidental diagnoses of a nodular thyroid gland, uterine fibroids and ovarian cysts in addition to the changes associated with drowning.

**Proximate Cause: Unspecified or Body Not Recovered**

**03-03 Experienced diver made dive on rebreather, did not return**

**Cause of Death: Unknown Cause of Death, Body Not Recovered**

This 41-year-old male was an experienced diver with advanced certification, including formal cave diving certification. He was on a liveaboard, diving with a group. He did not appear to have a designated diving buddy. The decedent was using a rebreather apparatus and had a habit of diving long after the other divers had exited the water. He had performed previous dives during the trip that lasted up to two hours. The decedent did not return from this dive, and his body was never recovered.

**03-04 Experienced, poorly conditioned diver, separated from buddy at surface pre-dive in strong current and disappeared**

**Cause of Death: Unknown Cause of Death, Body Not Recovered**

This 56-year-old male was an experienced diver with nitrox certification. He was overweight and had undergone a knee replacement in the past. He was part of a group of four divers (two buddy sets) on a liveaboard. The divers were performing drift dives in a strong current. During the second dive of the day, each buddy team became separated. The decedent and his buddy became separated prior to descent. They were the last divers off the boat, and the decedent's buddy went below the surface without him. The diver did not return to the boat, and his body was never recovered. His tank and safety sausage were recovered miles from the decedent's last known location.

### **03-06 Diver attempted dive in strong current, disappeared below surface, body never found**

#### **Cause of Death: Unknown Cause of Death, Body Not Recovered**

This 49-year-old female received her initial open-water certification one and a half years earlier. She was in a group of three divers who were dropped off by a boat. Simultaneously, the dive boat was tending to several groups of divers in different areas. The current was very strong, and the divers felt conditions were not safe for making the dive. The dive boat picked up the other two divers in the group, but the decedent had disappeared below the surface, and her body was never recovered.

### **03-16 Experienced divemaster with chronic cardiac problems, signaled problems on the bottom and disappeared**

#### **Cause of Death: Unknown Cause of Death, Body Not Recovered**

This 58-year-old male was a very experienced divemaster and a dive shop owner. He had a medical history significant for severe coronary atherosclerosis, including a previous stent placement. The decedent had been taking several cardiac medications, including nitroglycerin. After diving the previous day, he had complained of shortness of breath. The diver and his buddy descended to 70 fsw (21 msw); after approximately 10 minutes he signaled to his buddy that he did not feel well, and they became separated. The diver's buddy ascended alone, but he did not see the missing diver at the surface. A body was never recovered.

### **03-23 Inexperienced diver, surfaced far from boat, separated from buddy on their underwater swim back and lost**

#### **Cause of Death: Unknown Cause of Death, Body Not Recovered**

While this 29-year-old female had advanced open-water certification, she had made fewer

than 20 dives since initial certification three years before. The dive profile was not available, but she and her buddy surfaced far from the boat and descended again to swim back. The buddy became low on air, and both divers were fatigued. They became separated, and the buddy was rescued on the surface a few hours later. The decedent's body was never recovered, though some of her equipment was found 13 days later.

### **03-30 Experienced diver lost in open-water dive**

#### **Cause of Death: Unknown Cause of Death, Body Not Recovered**

There are few details available regarding the death of this 75-year-old male who was an experienced, certified diver. He never surfaced from an open-water dive. His body was never recovered.

### **03-41 Experienced technical diver, problem with buoy during ascent, separated from buddy, body never recovered**

#### **Cause of Death: Unknown Cause of Death, Body Not Recovered**

This 60-year-old male, who was a very experienced technical diver, had made a wreck penetration dive using nitrox and a drysuit. During the ascent phase of the dive, there was some problem putting up a dive buoy. The diver's buddy motioned for the decedent to join him at the 40 fsw (12 msw) decompression stop, but then they became separated. The dive buddy returned to the boat, and the body of the missing diver was never recovered.

### **03-57 Divemaster and buddy lost in underwater cave system**

#### **Cause of Death: Unknown Cause of Death, Body Not Recovered**

This 22-year-old female was involved in a double diving fatality (there were an unusually large number of double fatality cases in 2003). She and her dive buddy planned a dive

into an underwater cave. This diver had dive-master certification, but barely 100 lifetime dives and no formal documentation of cave diving training. She was also on antidepressant medications. Her body was never recovered.

**03-58 Experienced dive instructor with unknown cave diving certification, planned dive to underwater cave system with buddy, both bodies were lost, never recovered  
Cause of Death: Unknown Cause of Death, Body Not Recovered**

This 24-year-old male was involved in a double diving fatality. He and his dive buddy planned a dive into an underwater cave system. This diver was an experienced dive instructor. It is not clear if he had formal documentation of cave diving training. His body was never recovered.

**03-85 Experienced diver attempted reach 400' on air, body never found  
Cause of Death: Unknown Cause of Death, Body Not Recovered**

This 21-year-old male was a very experienced diver with instructor and technical diving certifications. The night before this dive, the decedent was bragging that he would attempt a record dive to in excess of 400 fsw (123 msw) on air. These statements were made in association with the consumption of alcoholic beverages. The next morning, the diver and two dive buddies made a deep dive on a wall. The buddies turned back at the 300 fsw (92 msw) mark, but the decedent continued to descend. His body was never recovered.

**03-05 Open-water dive, limited information  
Cause of Death: Unspecified Cause of Death**

There is virtually no information available on this diving death that involved a 65-year-old female. She was apparently making an open-water dive in the ocean. Her certification sta-

tus, level of experience and the circumstances surrounding the event are unknown.

**03-80 Diver with history of breast cancer, made ocean dive, limited information  
Cause of Death: Unspecified Cause of Death**

Virtually nothing is known about the circumstances surrounding the death of this 44-year-old female. She had a history of treated breast cancer. Her certification status and diving experience are unknown. The investigative report states that the death involved an ocean dive, but over a year later, that the death was still under investigation. No additional information is available at this time.

**03-84 Inexperienced diver, low on air, lost consciousness at surface  
Cause of Death: Unspecified Cause of Death**

Information about the death of this 44-year-old male is incomplete. He possessed advanced open-water certification but had only made 20 lifetime dives over nine years. The diver had a history of back pain for which he took a muscle relaxant, and he may have been drinking alcoholic beverages the night before this dive trip. During the second dive of the day, the decedent ran low on air and surfaced with his buddy. He then lost consciousness. A cardiac event was suspected, but an air embolism is every bit as likely. If an autopsy was performed, the report was not made available for review.

**03-89 Diver collapses after shore dive, limited information  
Cause of Death: Unspecified Cause of Death**

There was virtually no information available on circumstances surrounding the death of this male whose age is unknown. It cannot even be said with certainty that the death was dive-related. The investigative report states



that the man collapsed upon returning to shore after an ocean dive. No other details are known.

## Proximate Cause: Other

### 03-18 Experienced diver developed respiratory distress during decompression stop, lost consciousness at surface

#### Cause of Death: Decompression sickness

This 47-year-old female was an experienced diver with nitrox certification. On her ninth consecutive day of diving, she entered the water for her third dive of the day. Previous dives that day were to a maximum depth of 105 and 112 fsw (32 and 34 msw). After diving to 139 fsw (42 msw), the decedent developed respiratory distress during a decompression stop. She lost consciousness on the surface and could not be resuscitated.

### 03-39 Experienced diver, electrocuted in freshwater lake

#### Cause of Death: Electrocution

This 52-year-old male had open water certification and documented diving experience. He entered the water alone off his boat dock to run electrical wiring for the dock. The decedent's body was not recovered until three days later. After the recovery, another diver suffered an electrical shock after diving to recover some of the decedent's gear. An autopsy report was not made available for review, but the coroner determined that the cause of death was drowning due to an electrocution. This probably represents simply an accidental electrocution due to faulty wiring.

### 02-64 Experienced instructor and technical diver, made dives in river, struck by boat

#### Cause of Death: Open Head Injury, Struck by Boat

This 40-year-old male was an experienced technical diver and dive instructor. He was making a series of dives in a river with a

buddy. Toward the end of a dive, the decedent's buddy ascended because he was low on air. The decedent did not surface in a reasonable amount of time, and a search was initiated. The body was recovered the next day, with evidence on the head and back of a propeller strike.

### 03-50 Infrequent diver, entangled in kelp

#### Cause of Death: Near drowning with complications due to entangled in kelp

This 42-year-old female received her open water certification five years previously, but she had not made a dive in at least two years. Shortly after descent, she apparently became entangled in kelp, panicked, and then grabbed at the regulators and masks of other divers who attempted to render aid. The diver was brought to the surface and transported to a local medical treatment facility, where she died of complications of near-drowning.

### 03-44 Infrequent diver lost consciousness at safety stop

#### Cause of Death: Asphyxia due to pneumothorax, spontaneous

This 32-year-old female had open-water certification, but she had not made a dive in the previous five years. A little anxious before the dive, she was paired with the divemaster. She made a seemingly uneventful dive from a boat to 76 fsw (23 msw) for 25 minutes. While at the safety stop, the diver lost consciousness and could not be resuscitated. The autopsy disclosed a pneumothorax and multiple blebs on both lungs. These blebs can rupture spontaneously and require treatment if the person is on the surface. When they rupture at depth, the results can be catastrophic, as it was in this case.

**03-59 Struggle at surface before dive, breathing difficulty at bottom, panicked and brought to surface**

**Cause of Death: Pulmonary edema**

This 57-year-old male received his open-water certification two years earlier and had made fewer than 30 lifetime dives. He made a dive from a boat to 110 fsw (34 msw) in a strong current to explore a wreck. It was his first dive of the year, and he struggled during the surface swim before descent. While at the bottom, the decedent experienced difficulty breathing; he would not accept alternate air sources from dive buddies. He panicked and was brought to the surface where resuscitation efforts were unsuccessful. The autopsy disclosed changes consistent with drowning as well as pulmonary barotrauma, hypertrophy of the left ventricle of the heart and moderate coronary artery disease. The medical examiner and coroner felt that this death was due to immersion pulmonary edema and that the pulmonary barotrauma was caused during the rescue efforts when the diver was rapidly brought to the surface. The diver's history of having breathing difficulties at the bottom supports that theory.

**03-87 Undiagnosed internal bleeding, difficulty breathing, lost consciousness during ascent**

**Cause of Death: Intraperitoneal hemorrhage due to ruptured spleen**

This 51-year-old male had advanced open-water certification and had been a diver for four years. He was taking several medications and had a history of high serum cholesterol levels. The decedent also reportedly complained of back pain for the week before this

dive. The diver made a freshwater dive with a buddy to a depth of 68 feet (21 meters). During descent, the diver seemed uncomfortable with his primary regulator and switched to his octopus. He signaled that he was having trouble with his air source and wanted to abort the dive. He lost consciousness during the ascent, and he was found face down on the surface. The autopsy disclosed a ruptured spleen, which must have been a result of previous trauma and was likely the source of his back pain. There was a large amount of blood in the peritoneal cavity, which would have resulted in both the difficult breathing and the loss of consciousness. The pathologist postulated that the increased ambient pressure and compression experienced during the dive contributed to the ruptured spleen, but that is not how increased pressure affects solid organs like the spleen.

**03-38 Reef-hook dive in strong current, entanglement and panic**

**Cause of Death: Anoxic brain injury due to near drowning incident**

This 45-year-old female was an experienced, certified diver performing a "reef hook" dive in rough seas and a strong current. She was part of a large group of divers off a liveaboard. The diver hooked onto the reef but could not unhook. She panicked and lost a fin and her mask as she struggled in the strong current. The diver was brought to the surface and received medical attention, with a subsequent transfer to a medical treatment facility. She died three days later.

# Appendix C: Breath-Hold Incident Case Reports

## Case Study #1

A 28-year-old female experienced competitive freediver was attempting a world record dive in the Caribbean in the No-Limits discipline. Weather had been poor and delayed the attempt until the afternoon, where conditions were still not optimal. She rode the sled down to the record depth of 561 feet (169 meters), and filled the lift bag that she would ride back to the surface. She had problems completely filling the bag, and on her ascent, at around 394 feet (118 meters), she became unconscious and began to float away from the ascent line. A series of safety divers carried her to the surface. She remained underwater for eight minutes and 40 seconds, exceeding the anticipated three minutes and 30 seconds.

Cardiopulmonary resuscitation (CPR) was unsuccessfully performed on the surface. The cause of death was determined to be drowning, and several factors were noted as contributing to the accident: the rough sea that adversely affected the lines traveled by the sled and inadequate lift provided by the lift bag.

## Case Study #2

A 22-year-old male decided to go freediving late one evening with two friends in a freshwater spring. His remained in the water after his friends tired of swimming and returned to shore. Some time later, his friends noticed that his light was no longer visible on the surface. They called for help, and a diver donned scuba gear to search the area. The victim was found at approximately 35 ffw (feet of fresh water; 11 mfw, or meters of fresh water). CPR was performed on the surface, but he never

regained consciousness. Cause of death was determined to be drowning. Before the incident, the decedent had been seen drinking.

## Case Study #3

Spearfishing with two friends off a boat anchored at 65 fsw / 20 msw, this 14-year-old male was observed to develop difficulties while nearing the surface on his ascent. He began to sink back down in the water. He did not release his weight belt. His companions dived into the water but were unable to reach him. The others flagged down a boat with a diver on board. The diver recovered the victim's body at approximately 65 fsw.

## Case Study #4

An 18-year-old male was recreationally freediving with a friend off a boat on a shallow ocean reef approximately 100 yards / 92 meters from shore. The experienced freedivers used the one up and one down system to monitor each other. After approximately one hour of alternating dives, the victim made a dive to 60 fsw / 18 msw. His partner noticed little movement during the first 30 seconds of the dive and became concerned at about 45 seconds. The anxiety of the event compromised the partner's freediving ability; he could not reach the victim. He then called for help, and county fire rescue divers recovered the victim. He had been submerged for more than 20 minutes. He did not regain consciousness.

## Case Study #5

Two men, one 74 years old and the other 79 years old, were diving for lobster approximately 100 yards offshore one afternoon. Both

were struck by a boat passing at high speed. The 74-year-old, struck by the hull, was mildly injured. The 79-year-old, struck by the propeller, was killed. A passenger on the boat indicated that she did not see the snorkelers until the last moment when they surfaced directly in front of the boat. The snorkelers were not using a divers down flag.

### Case Study #6

Two experienced male divers, one 33 years old and the other 77 years old, went abalone diving in rough conditions. The 77-year-old had been working all day and was tired from the outset. The men began in a partially protected cove, but bystanders observed a current carrying the older diver offshore. The younger diver swam out to assist him but was only able to bring him part of the way to shore before letting go. The younger diver then swam toward a rock and disappeared from view behind it. He was later seen floating. Divers later retrieved both bodies.

### Case Study #7

A 44-year-old male, on vacation in the South Pacific, was snorkeling when stung by a member of the rare species of Irukandji jellyfish. The venom causes a rapid rise in blood pressure and a cerebral hemorrhage. There is currently no anti-venom available for the sting. The victim died after more than two weeks in the hospital.

### Case Study #8

This 48-year-old male, snorkeling late one evening from the beach, separated from those who traveled with him to the beach. About an hour later, friends on shore saw the diver's light underwater. Rescue services recovered his body. An autopsy determined the death to be the result of a blocked coronary artery. Marked enlargement of the heart and narrowing of multiple coronary vessels was observed.

### Case Study #9

Two males entered the water at approximately 4:45 p.m. from an anchored boat to freedive for abalone off the coast. Shortly after entering, one of the men felt a pressure wave beneath him and, looking down, saw a large dorsal fin. After dropping his weight belt and swimming rapidly back to the boat, he turned to see only a large pool of blood in the water. His partner's body was recovered shortly thereafter at 15 fsw / 3 msw. An autopsy confirmed that a great white shark had caused the injuries.

### Case Study #10

A 16-year-old male, spearfishing from an anchored boat at approximately 90 fsw / 27 msw with a friend, became entangled in both the spearfishing line and the anchor line. Because of the depth, his partner could not assist him. After about 45 minutes underwater, he was brought to the surface by a diver from a passing boat. Resuscitation attempts were unsuccessful.

### Case Study #11

A 21-year-old male spent the day with friends offshore on a boat, enjoying in a variety of water sports. To do some late afternoon spearfishing, he tied a speargun to a float and entered the water. He surfaced with a fish and said he was going down for another he had just seen. His friends became concerned when they noticed that his float was no longer moving. When they pulled the float up, they found the still-loaded speargun. The victim's body was recovered two days later at 80 fsw / 24 msw close to the dive site.

### Case Study #12 – Non-fatal

A 33-year-old male and a partner were abalone diving when the condition of the wind and seas unexpectedly intensified. The pair decided to swim to shore. Once on the

shore, the victim decided to swim back out for a flotation tube he had left behind. Exhausted by the time he returned to shore the second time, he was swept off the rock by a large wave after removing his mask and one fin. He was pounded by the surf and rocks for some time before he managed to cling to a rock. A bystander who had climbed down a cliff assisted him when he was about to black out and slip off the rock. He was still wearing his weight belt at the time. He was treated in hospital for bruises and internal injuries.



# Glossary

## Acetaminophen

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

## Antihistamine

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

## Ambiguous DCS

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

## Arterial Gas Embolism (AGE)

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

## Barotrauma

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

## Body Mass Index (BMI)

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

## Bounce Dive

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

## Boyle's Law

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

## Cerebrovascular

Pertaining to the blood vessels of the brain.

## Chokes

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

## Coronary Artery Disease

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

## DARF (Diving Accident Report Form)

A form used by DAN from 1987 through 1997 to collect information about injured divers treated in recompression chambers.

## Decompression Dive

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

## Decompression Illness (DCI)

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

## Decompression Sickness (DCS)

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

## Depth-Time Profile — See Dive Profile

## DIRF (Diving Injury Report Form)

A form used by DAN from 1998 through 2004 to collect information about injured divers treated in recompression chambers.

## Dive Computer

Personal electronic devices that continually measure time and pressure during the dive, calculate remaining dive time, monitor ascent rate and provide instructions for decompression. Dive computers may employ any one of a number of mathe-

mathematical models to compute decompression status. Some dive computers are integrated with breathing gear and may measure the pressure in gas dive cylinders.

### Dive Log

The dive log is a document maintained by divers in which relevant information about dives is recorded. The amount of information depends on personal interest of divers. See Dive Log-7 for the computerized dive log information of interest for PDE.

### Dive Log-7 (DL-7)

A standard computer format for recording information about divers, their dive profiles and medical outcomes.

### Dive Profile

A set of depth-time-gas points describing the dive. The number of points depends on the minimal recording interval of dive recorder and can vary from one second to one minute. For use in PDE, the recording interval should be five seconds or less.

### Dive Recorder

An electronic device that records depth and time during the dive. The recorder does not calculate saturation of the body with inert gas and does not provide any instruction for decompression. Some recorders are designed as "black boxes," with no visible display, while others have a display to indicate current depth and time of dive.

### Dive Safety Lab (DSL)

A project similar to Project Dive Exploration developed and conducted by DAN Europe, with shared goals and methodology.

### Dive Series

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

### Diving Accident Report Form – See DARF

### Diving Injury Report Form – See DIRF

### EAN (Enriched-Air Nitrox)

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

### FAD (Flying After Diving)

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

**First Aid Oxygen** – See Surface Oxygen Treatment

### FRC (Field Research Coordinator)

A trained volunteer who helps DAN collect data for PDE.

### Feet of Sea Water (FSW)

A unit of pressure synonymous with depth in salt water. Thirty-three (33) fsw is equal to approximately one atmosphere, 1 bar, 14.685 pounds per square inch, or 0.01 kilopascals of pressure. The differences in density of sea water and fresh water result in small pressure differences at the same depth. Therefore, fsw must be distinguished from the ffw (34 feet of fresh water = 1 atmosphere). The fsw term is traditionally used by Navy and was adopted by the dive industry, while the ffw is rarely used. For metric conversions, the term is msw (meters of sea water).

### Freediving

Breath-hold diving conducted while wearing a mask and some form of fin or fins. Freedivers generally dive to depth and train to increase their range. Freediving is typically conducted in open-water settings. See also Breath-Hold Diving and Snorkeling.

**Heliox** – See Mixed Gas

### Health Insurance Portability and Accountability Act (HIPAA)

U.S. Federal legislation designed to protect the privacy and interests of individuals and their families. DAN collects dive injury and fatality information in compliance with HIPAA.

### Hypertension

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

### Hyperventilation

Voluntary ventilation of the lungs in excess of metabolic requirements (by increasing depth of breaths and / or rate of breathing). Often used to lower carbon dioxide content of the bloodstream and increase breath-hold time. Excessive hyperventilation will increase the risk of loss of consciousness due to hypoxia since hyperventilation does little to increase the body's oxygen stores.

### Hypoxia

Condition of lower-than-normal oxygen partial pressure in the blood. Also see Shallow Water Blackout.

### Hypoxic Loss of Consciousness (HLOC)

Loss of consciousness resulting from an acute state of hypoxia.

**Lung Barotrauma** – See Pulmonary Barotrauma

### Mean

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

### Median

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



## Glossary

### Mediastinal Emphysema (Pneumomediastinum)

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

### Mixed Gas

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

### Meters of Sea Water (MSW)

1.0 msw = 3.28084 fsw. See Feet of Sea Water (fsw).

### Multiday Diving

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

### Multilevel Dive

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

### Myocardial Infarction

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

### Nitrogen Narcosis

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

**Nitrox** – See EAN and Mixed Gas

### No-Decompression Dive or No-Stop Dive

A dive where direct ascent to the surface at 30-60 fsw (9-18 meters of sea water) per minute is allowed at any time during the dive without a decompression stop.

**Obesity** – See BMI (Body Mass Index)

**Oxygen-Enriched Air** – See EAN

### Oxygen Toxicity

The syndrome caused by breathing of oxygen at greater than sea level pressure. Oxygen toxicity primarily affects the central nervous system (CNS) and the lungs. CNS oxygen toxicity may come on immediately and be manifested by seizures, twitching, nausea and visual or auditory disturbances. It may occur in a highly unpredictable manner at partial pressures greater than 1.4 to 1.6 atm in an exercising diver. The manifestations of pulmonary oxygen toxicity take much longer to

develop (hours) but can occur at a lower partial pressure of oxygen (>0.50 atm). Pulmonary oxygen toxicity is caused by inflammation of the lung tissue itself, resulting in shortness of breath, cough and a reduced ability to perform exercise.

### Protected Health Information (PHI)

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

### Perceived Severity Index (PSI)

A measure of the severity of decompression injury (see page 48).

### Paresthesia

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

**Pneumomediastinum** – See Mediastinal Emphysema

### Pneumothorax

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

### Pulmonary Barotrauma

Damage to lungs from expanding gas. See Barotrauma

### Pulmonary Emphysema

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

### Pulmonary Overexpansion

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

### Rapid Ascent

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

### Recompression Treatment

Treatment involving a return to pressure. Typically completed in a recompression chamber but, in some cases, may involve an in-water return to pressure. Well-established, standard treatment tables exist for recompression chamber therapy. These include United States Navy Treatment Tables 6 and 6a (USN TT6 and TT6a).

### Repetitive Dive

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

**Representative Sample**

A group selected from a population for testing that reasonably represents the characteristics of the population.

**Residual Symptoms**

Symptoms remaining at the conclusion of treatment. May respond to additional treatments, be refractory to further treatment but eventually resolve spontaneously, or permanent.

**Resolution of Symptoms**

Symptoms resolving (disappearing) after appearance. Resolution may be spontaneous or in response to treatment.

**Safety Stop**

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

**SERF (Scuba Epidemiological Reporting Form)**

A new injury recording system for DAN that replaces the DIRF. It emphasizes collection of recorded dive profiles. (See page 64.)

**Shallow-Water Blackout**

Unconsciousness resulting from hypoxia and compounded by surfacing at the end of a breath-hold dive. The reduction in pressure associated with returning to the surface causes the oxygen partial pressure to fall faster than through metabolism of the gas alone. See also Hyperventilation, Hypoxia, and Hypoxic Loss of Consciousness.

**Snorkeling**

Swimming with mask, snorkel and fins. Snorkelers may remain at the surface or conduct breath-hold dives. See also Breath-Hold Diving and Freediving.

**Square Dive**

A dive in which the descent is made to a given depth and where the diver remains for the entire dive before ascending to the surface.

**Subcutaneous Air (Subcutaneous Emphysema)**

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

**Surface Oxygen Treatment (SOT)**

Oxygen delivered at the surface with a therapeutic intent. Gas may flow from the supply system in a continuous mode or through a demand valve upon inspiration of the conscious, spontaneously breathing injured person. The breathing circuit may be open (dumping exhaled gas) or closed (reusing exhaled gas after it is scrubbed of carbon dioxide). The delivery interface may be some form of simple non-breathing face-mask, a partial rebreathing facemask or a nasal cannula. The fraction of oxygen delivered to the injured person and the oxygen flow rate required will vary dramatically depending on system configuration and use.

**Trimix** – See Mixed Gas

**Type I DCS (DCS I, Musculoskeletal DCS)**

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

**Type II DCS (DCS II, Neurological or Cardiopulmonary DCS)**

Decompression sickness where there is any symptom referable to the nervous or cardiovascular system.

**Type III DCS (DCS III)**

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

**Underlying Cause of Death**

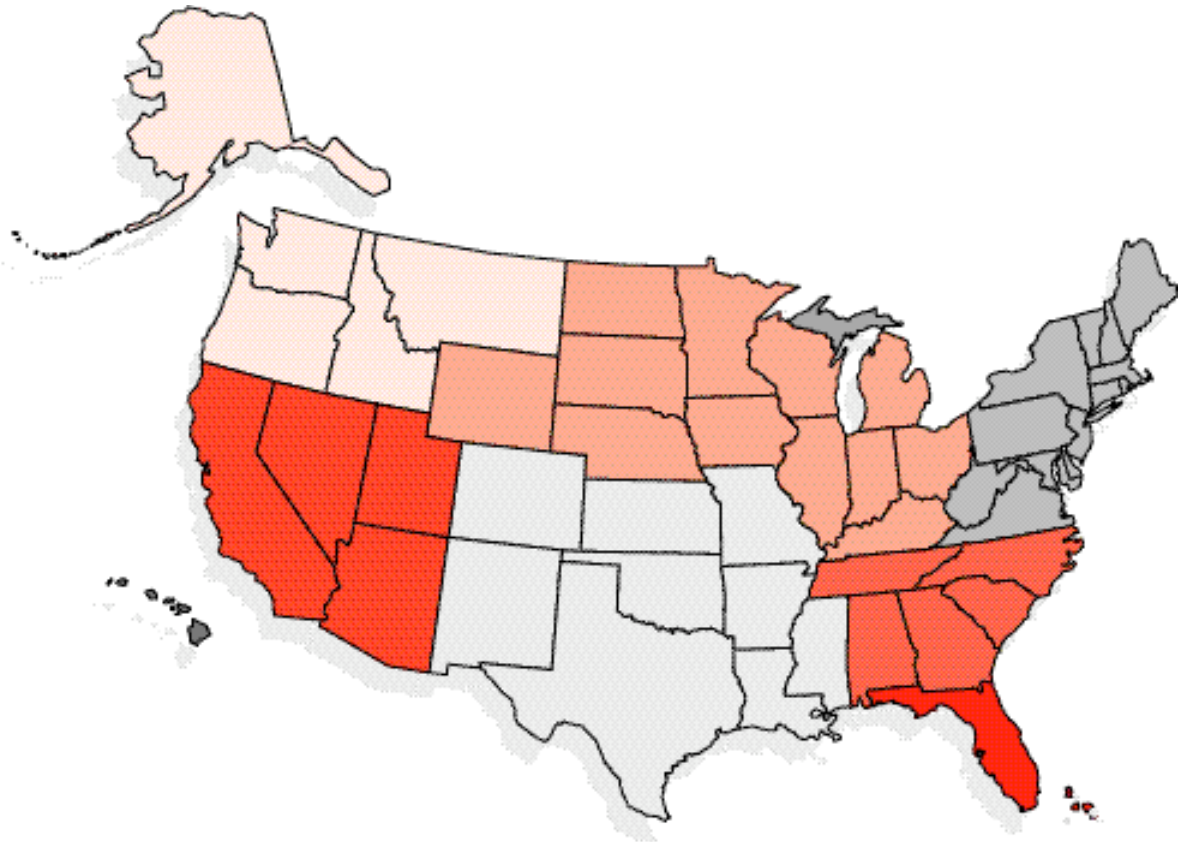
The problem(s) creating a situation resulting in death by an obvious means, for instance, drowning.

**URI (Upper Respiratory Infection)**

The most frequently reported acute health problem from the DAN sample of injured divers.

# INJURIES & FATALITIES BY REGION & STATE 2003

(Total number used in report analysis)



	Fatality	Injury
<b>Southeast Region</b>	<b>3</b>	<b>15</b>
Alabama	0	2
Georgia	0	1
North Carolina	1	10
South Carolina	2	2
Tennessee	0	0
<b>Southwest Region</b>	<b>12</b>	<b>24</b>
Arizona	0	0
California	10	21
Nevada	0	2
Utah	2	1
<b>Northeast Region</b>	<b>9</b>	<b>7</b>
Connecticut	0	0
Delaware	0	0
Maine	0	0
Maryland	1	0
Massachusetts	2	2
New Hampshire	0	0
New Jersey	0	0
New York	1	1
Pennsylvania	2	2
Rhode Island	3	0
Vermont	0	0
Virginia	0	2
West Virginia	0	0

	Fatality	Injury
<b>Gulf Region</b>	<b>5</b>	<b>3</b>
Arkansas	1	0
Colorado	0	0
Kansas	0	0
Louisiana	0	1
Mississippi	0	0
Missouri	3	0
New Mexico	0	1
Oklahoma	0	0
Texas	1	1
<b>Midwest Region</b>	<b>6</b>	<b>6</b>
Illinois	1	1
Indiana	0	1
Iowa	2	0
Kentucky	0	0
Michigan	2	0
Minnesota	0	1
Nebraska	0	0
North Dakota	0	0
Ohio	1	0
South Dakota	0	0
Wisconsin	0	3
Wyoming	0	0

	Fatality	Injury
<b>Northwest Region</b>	<b>1</b>	<b>14</b>
Alaska	0	1
Idaho	0	0
Montana	0	0
Oregon	0	2
Washington	1	11
<b>Pacific Region</b>	<b>2</b>	<b>4</b>
Hawaii	2	4
U.S. Territories	0	0
<b>Caribbean Region</b>	<b>28</b>	<b>162</b>
Florida	19	75
Caribbean	9	87
<b>Mexico/Central America Region</b>	<b>6</b>	<b>85</b>
Mexico	3	61
Central America	3	24
<b>Other</b>	<b>17</b>	<b>25</b>
Canada	9	11
Western Pacific	5	9
Middle East	1	1
Europe	1	1
South America	1	2
South Africa	0	1

# 2004 Publications

## Refereed Articles (primary literature)

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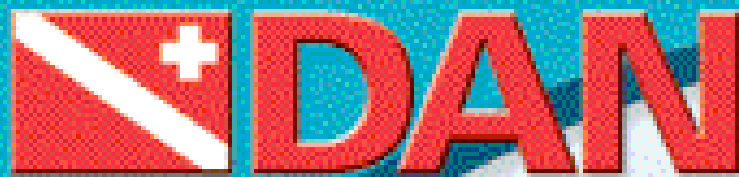
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# Notes



# Notes



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