

DIVING ACCIDENTS - WHY?

A REVIEW OF NAUI DIVING INCIDENTS REPORTS

John Hardy

Over 100 people lose their lives each year in scuba diving accidents.

URI has done excellent work but has not been able to review causative factors. Over 700 accident reports on file at NAUI Headquarters were reviewed taking a close look at possible causes. Training accidents were reviewed separately with special tabulations done on particular problems. Eight significant areas of causative factors were identified. Commentary with recommendations are provided on each area with particular emphasis on training modifications.

Two divers are moving slowly and uneasily through the water. The water is cold, visibility is limited and the divers are now deeper than they expected to be. Each is getting tired and cold. The first dive of the new year finds them more than usually nervous.

A late party, little sleep, much alcohol, even a couple of joints and very little food all contribute to a sense of unease, nervousness, even apprehension. The heavy use of tobacco coupled with little consistent exercise and no recent medical exam finds the divers not very fit.

Diving equipment has always been such a nuisance to them that neither of their tanks or regulators have ever been serviced since purchased. They just do not dive enough to get into all that fancy buoyancy control equipment or all those gauges.

The first diver, Joe, begins to have difficulty breathing, but thinks it is just his lack of fitness. He should not be low on air yet. He is sure his air always lasted much longer than this - last year. Besides it would be embarrassing to run out of air before his buddy, Hal, did.

Joe sees something of interest and moves in for a closer look. Sure enough, it is a partly buried anchor with the line still tangled in the weeds. He pulls and tugs, breathing harder all the time. Suddenly, there is no more air. He looks around, but his buddy has gone. He tries to move higher to see better, but something is holding him down...weeds...line...something.

Meanwhile, Hal has missed Joe and is looking around in a rather random manner, swimming hard to and fro. He sees Joe and moves over to him. Now Hal realizes that Joe is not breathing - fear grips him.

He thinks, "What was it we learned in the diving course?" He has had no refresher. No reinforcement.

"Ah, get Joe to the surface, but he is tangled". "No knife".

His air is low, it has already become hard to breathe.

"Try to pull him clear. Can I do it? No air at all! Go for the surface, now alone. Got to get out of here. Just cannot seem to get up, too heavy, swim harder, no air left. Got to hold breath to make the surface!"

Joe's body lies alone entangled in deep water.

Hal's body settles to the bottom in even deeper water, also alone.

... No two divers would ever make this many mistakes? Not so. This double tragedy is from actual occurrences in the recent review of the causes of over 700 diving accidents. The chain of events is frightening: cold, poor visibility, deep water, fatigue, stress, poor fitness, poorly equipped divers, ego, not staying together, poor skill levels. The result - two divers lost.

Two more tragedies that might have been prevented, thus two more reasons why legal actions, insurance and legislation will continue to be major problems for the sport of scuba diving.

In an effort to identify the causes of diving, accidents and suggest reasonable solutions, the National Association of Underwater Instructors (NAUI) conducted a complete review of all accident reports on file at NAUI Headquarters. The purpose of this work was to deal with causes of accidents, and more particularly, the role of training as a causative factor. The University of Rhode Island (URI) Reports deal with the statistics of location, day month, sex, age, autopsies and so forth. Thus, the URI Reports provide vital background information which compliments this study for a more complete understanding of diving accidents.

Results

Table I was developed by reviewing all available diving accident reports and counting each causative factor apparently contributing to the accident. The eight major categories are listed with individual sub-categories listed by frequency. These results may be biased due to geographic distribution or incompleteness of some reports (see Appendix A). The importance is not the exact percentage of a particular cause, but that these are now identified as primary causes of diving accidents.

Table II provides the same information as Table I when looking only at accidents that occurred during training. Since this is a much smaller statistical sample, a change of just one to five possible causes could completely change the order of the eight causative areas. Again, of primary importance is the identification of these listed causes as the ones most often contributing to diver training accidents.

TABLE I
GENERAL ACCIDENTS CAUSATIVE FACTORS CONTRIBUTING TO ACCIDENTS

	Causes	Percent
MEDICAL AND PSYCHOLOGICAL FACTORS:		
Decompression sickness, fatigue, drugs, heart trouble, stress, medical problems, cold, cramps, poor fitness, bad air	159	20
DANGEROUS ENVIRONMENTAL CONDITIONS:		
Surf, caves, deep, currents, visibility, ice, obstacles	150	19
BUDDY SYSTEM FAILURE:		
Loss of contact, diving alone	113	14
EQUIPMENT DIFFICULTIES:		
Misuse, lack of knowledge, trouble with regulator, lack of needed equipment, unable to use	102	13
RUNNING "OUT-OF-AIR":		
"No-Air", reserve misuse, air not on	92	11
ASCENT DIFFICULTIES:		
Buoyant, emergency swimming, buddy breathing, normal	78	10
ENTANGLEMENT:		
Kelp, weeds, lines nets, equipment	52	7
BUOYANCY CONTROL PROBLEMS:		
Overweighting, not wearing or using BC, BC not functioning	51	6
TOTALS:	797	100

TABLE II
ACCIDENTS DURING TRAINING CAUSATIVE FACTORS
CONTRIBUTING TO ACCIDENTS

	Causes	Percent
MEDICAL AND PSYCHOLOGICAL FACTORS: Stress, heart trouble, fatigue, drugs, medical problems	40	34
ASCENT DIFFICULTIES: Buoyant, emergency swimming, buddy breathing, normal	24	20
DANGEROUS ENVIRONMENTAL CONDITIONS: Deep, surf, visibility, obstacles, ice	16	14
BUDDY SYSTEM FAILURE: Loss of contact, diving alone	12	10
RUNNING "OUT-OF-AIR": "No-air"	10	9
EQUIPMENT DIFFICULTIES: Lack of knowledge, unable to use, misuse	8	7
BUOYANCY CONTROL PROBLEMS: Not wearing or using BC, overweighting, BC not functioning	4	3
ENTANGLEMENT: Kelp	4	3
TOTALS:	118	100

ANALYSIS AND COMMENTARY

Here is the data gathered through the reading of the accident reports plus the collective insights gained by the reviewers. These insights were items that did not "fit" the compiling of causes, but did indicate certain problems. The report is not intended to report precise statistical data, but to report the possible causes of diving accidents. Opinions and recommendations by the author are labelled as such.

Medical and Psychological Factors

General Accidents - 20%

Training Accidents - 34%

Decompression sickness was the most common non-fatal accident reported, most likely due to the need for chamber treatment. It should not be assumed from this that decompression sickness is the most common non-fatal accident. Several important insights were gained by a careful repeated review of just the decompression sickness cases:

- * Most cases were not fatal.
- * Most victims were experienced divers.
- * In most cases, neither bottom nor surface time was recorded.
- * Most cases involved over-extension of the tables but some cases were well within no-decompression limits.
- * Age (over 35) and poor physical condition seemed to increase the likelihood.
- * There appeared to be a number of cases which may have been decompression sickness, but were not reported as such.

An effort was made to review possible problems with decompression meters in decompression sickness cases. But there was not enough useable information to make

any statements about the meter per se. It was indicated that if a meter was abused or not maintained, was used with no other instruments or was used without an understanding of the meter's limitations or of decompression in general, then there were difficulties.

Many problems were indicated by the reports but not actually recorded in the reports. These hard to find causes appeared to include heart attacks, air embolisms, fatigue, cold, stress or panic, poor fitness and the use of drugs, including alcohol.

A chain of events often appeared. The diver was cold and/or tired - stress level increased - the diver made a mistake - panicked, and death followed. The key link in this chain was the mistake which could have been anything from entering heavy surf to not maintaining the buoyancy control equipment properly and included all the other causes presented in this report.

Human error at three levels repeatedly appeared. In order of frequency they were:

1. The victim's error.
2. The buddy of the victim's error.
3. The instructor of the victim's error.

The use of drugs, including alcohol, increased significantly in the more recent reports. This may be a product of more complete reporting and/or a general increase in the use of drugs in the society at large. The use of drugs before diving appears to definitely predispose the diver to an accident.

Heart attacks were counted separately. Other medical problems were collectively reported as they did not occur nearly as often. Nearly all of these medical problems indicated the person should not have been diving, such as: respiratory impairment, regular medication, ear and sinus problems, epilepsy, recent serious operation, injury or illness.

Bad air was the least often found cause in this category. Again, the lack of complete reports, in this case, no analysis of the air after the accident, could cause this figure to be too low. Lacking further evidence it appears that the quality of air supplied to and used by sport divers is very high and bad air is an extremely minor problem.

Recommendations and Opinions

Divers need to stay fit. This includes regular medical exams, exercise, rest, good diet and avoiding harmful habits. In addition, divers should avoid getting tired, cold or excessively stressed during dives.

Student divers need to learn the medical and psychological reasons why to not dive. Instructors have an obligation to screen students as much as possible for the student's own health and safety. This screening should include: proper use of medical history forms, medical exams when needed, water skill and endurance evaluations, and a careful "tuning in" to student's physical and mental condition.

Conditions during diver training need to be controlled to avoid excessive stress, cold or fatigue. It is very likely that more students should be counselled during training, that diving is not in their best interest.

Dangerous Environmental Conditions

General Accidents - 19%

Training Accidents - 14%

Surf in California and caves in Florida are major problems. Ice and obstacles (trees, ledges, debris) are significant problems in fresh water, inland lakes. The deep diving problem was scattered in several areas with some dives being made to depths beyond any reasonable sport limit (200 feet or more). Most victims in cave diving

and ice diving accidents were not properly trained or equipped.

Dangerous environmental conditions were often just one of several problems the diver was having, each of which the diver may have been able to handle, if it had not happened in surf, in a cave, under ice, or in deep water.

Recommendations and Opinions

Sport divers should be discouraged from cave and ice diving until they are properly equipped and have had special training.

Instructors need to take great care in not exposing student divers to conditions beyond their ability.

Student divers need to develop, during training, a strong sense of the importance of the decision to not dive. Therefore, it is suggested that instructors should cancel more open water dives right on location, explaining why they are doing so, directly to the students.

If the normal local diving conditions include surf, current or low visibility, then instructors have an obligation to teach students how to handle these conditions during all diving courses. This instruction needs to be conducted under close supervision and controlled conditions.

Buddy System Failure

General Accidents - 14%

Training Accidents - 10%

Diving alone does not kill divers, but being alone when something goes wrong does make it more difficult to escape safely. If a buddy were near at hand when the following problems occurred, then many fatal accidents might have been near misses: entanglement, out-of-air, bad air, heart attack, equipment difficulty, cramps, ruptured eardrum, fatigue, nitrogen narcosis, decompression sickness, head injury, regurgitation and air embolism.

Because of the inability of divers to stay together or due to diving alone, no one is then available when significant problems occur. No matter how experienced or well trained the diver, if some of these problems occurred in the water when alone, the chances of the diver surviving are greatly reduced.

Recommendations and Opinions

Instructors need to teach not only the tremendous importance and value of buddy diving, but also how to find and select a buddy, how to stay together, plus how to make buddy diving easy and enjoyable.

Equipment Difficulties

General Accidents - 13%

Training Accidents - 7%

Equipment difficulties tended to be interrelated with each other and with other categories of causes. Usually an equipment difficulty did not appear as a sole or primary cause of trouble. The vast majority of the problems with equipment were human errors concerning the use, care and selection of the equipment.

Dives can be made without certain items of equipment, but when these pieces of equipment are needed and not in use, this lack of equipment may then contribute to an accident. Missing items of equipment included: submersible pressure gauges, buoyancy control equipment, protective suits, snorkels, depth gauges, compasses, and watches.

Misuse of equipment was the most frequent equipment difficulty.

Specific problems included:

- * Regulators attached incorrectly
- * Back packs mounted improperly
- * Quick releases not used on weight belts or scuba straps
- * Weight belts not clear to be ditched
- * Snorkels not worn on masks (in conditions of strong current, this may be an acceptable procedure but not under most conditions)
- * Spearguns loaded out of the water
- * Divers using BC's as lift bags
- * BC or vest not maintained or checked
- * BC not inflated for surface resting
- * Air not turned on or not turned on all the way
- * Cylinders not internally inspected
- * Valves not serviced
- * Using torn or ill-fitting wet suits
- * Fin straps not properly buckled or secured
- * Overweighting and/or over inflation of BC
- * Improper positioning of the reserve valve
- * No maintenance or home maintenance of the regulator (these two were the reasons behind most of the items listed as "trouble with regulator")

Recommendations and Opinions

Other equipment difficulties appeared to concern not knowing how to use the equipment, possible because of not being provided training during the original scuba course, forgetting previous training, using unfamiliar rented or borrowed equipment, or using equipment which was not available during training.

There are definitely some changes needed in diver training to provide more equipment skills, i.e. the selection, use and care of equipment. These equipment skills need emphasis without compromising other vital diving skills. Emphasis should be placed on the following:

- * Selection of proper and complete quality equipment for the particular diving activity and environment.
- * Proper preventative maintenance by the individual diver and regular professional service.
- * Using new or unfamiliar equipment only under controlled conditions.
- * More equipment handling during diving courses.
- * More training on buoyancy control systems, both weights and inflatable devices.
- * Limitations and need for training on new and advanced equipment.
- * Not loaning equipment to untrained divers.

Running "Out-Of-Air"

General Accidents - 11%

Training Accidents - 9%

The quotation marks around "out-of-air" are important because most of these situations were actually low-on-air problems (100-500 psi).

Many divers had no submersible pressure gauge or reserve. Of those divers who did have them, many did not use them. Although the air not being turned on was an uncommon accident, it did lead to several unfortunate fatal accidents.

Reserve misuse or trouble with the reserve was one of the more surprising findings of the report. All of the experienced divers and instructors doing the review at first had assumed that this problem would be due to the reserve being in the wrong

position (due to not being checked or accidentally bumped or pulled down). But, in 9 out of 11 fatal cases, the victim did not use the reserve when the air ran low, but panicked and went for the surface.

Table III presents the action taken by divers involved in "out-of-air" situations. The near equal distribution (one-third/one-third/one-third) is interesting, but the question remains, "What action was taken by divers who were completely successful?" The cases reported here reflect accidents or unsuccessful actions.

TABLE III
ACTION TAKEN WHEN "OUT OF AIR"

	Causes	Percent
Independent ascent to the surface	34	37
Buddy breathing ascent to surface	31	33
Unable to surface (panic, overweighted, entangled, cave, ice)	<u>28</u>	<u>30</u>
TOTALS:	93	100

Recommendations and Opinions

When divers are low on air, tired and cold, near the end of the dive, in deep water, they may increase their respiration rate. This is exactly the wrong behaviour under such conditions.

Training definitely needs to emphasise slow, deep, relaxed breathing; no "panting into the regulator"; avoiding deep diving; taking it easy; keeping 300-600 psi for the surface; use of both submersible pressure gauges and reserve warning mechanisms (audio or J-valve); turning air valves all the way on; double checking reserve, gauge and regulator function before entering the water; better buoyancy control; and ascent procedures.

Ascent Difficulties

General Accidents - 10%

Training Accidents - 20%

This was an extremely difficult category to list in order of frequency, due to the confusion of terms used for ascents. It was obvious that normal ascents caused the fewest problems and are the most often used ascents, but a number of accidents did occur. Normal ascents and other ascents where everything was done "right" still led to air embolisms. Clear and direct evidence is not generally available in these reports, but medical problems, such as: respiratory impairment from heavy smoking, recent cold or infection, or previous lung diseases were indicated in these "correctly" done ascents, or it may be that ascent was not actually done correctly.

When making reference to air embolism, in this report, all related injuries: pneumothorax, emphysema, etc. are included. No attempt was made to sort the injuries or to make medical value judgements. It appears there may be more air embolism related injuries than reported, but these could not be counted.

While the octopus appears to have definite possibilities for improving diver safety, its use is also causing some problems. These problems appear to centre around: 1) where and how it is attached; 2) the procedures to be used when it is needed; 3) the actual first and second stage combination used.

Table IV provides additional detail on the apparent problems which caused buddy breathing to fail. There appears to be a problem when buddy breathing is aborted. This aspect needs more study.

TABLE IV
PROBLEMS DURING BUDDY BREATHING ASCENTS

	Causes	Percent
1. Aborted and changed to swimming ascent	20	43
2. Disorientation or panic	15	33
3. Struggle over regulator	4	9
4. Unable to clear regulator	4	9
5. Donor runs out of air	<u>3</u>	<u>6</u>
TOTALS:	46	100

Recommendations and Opinions

Buddy breathing has become an area of increasing concern. It is a difficult skill, to learn and maintain, and often appears to be unsuccessful. Since the frequency of successful buddy breathing ascents versus other forms of ascent is not known recommendations in this area are limited. But in order to give some indication of which ascents are being used, an informal survey of ascents made under emergency conditions by experienced divers was conducted. All possible types of ascents were mentioned as having been used successfully, but independent emergency swimming ascents were by far the most often given as the successful method used. Buoyant and octopus ascents were the next two most commonly mentioned successful ascents.

Using the insights gained from repeated detailed readings of these ascent accidents, the best available recommendations for diver ascent procedures are (in order of preference):

1. Make a normal ascent after stopping activity, breathing easily and getting control of the situation.
2. Make a shared air ascent, using the buddy diver's extra regulator, if the buddy is so equipped and is closer than the surface, or if there is an obstruction to the surface (ice, cave, wreck, heavy kelp, etc.)
3. Make an emergency swimming ascent in a manner as near to a normal ascent as is possible: looking up, regulator in mouth, swimming a bit faster, exhaling more and inhaling less (lungs at near normal volume).
4. Make a buoyant ascent by ditching weights and/or inflating the buoyancy system; with regulator in mouth, looking up, and exhaling more rapidly.
5. Make a buddy breathing ascent only when the other options are not available.

In a comparison of ascent difficulties with general accidents and training accidents, ascents moved from sixth place to second place; from 10 percent of the causes. But also note that general diving accidents were involved 78 times while training accidents only 24 times. Ascents are definitely of serious concern during diver training, but the simplistic answer of not providing ascent training would simply move some accidents from training situations to general diving situations and most likely cost even more lives. The changing pressure during scuba diving is a unique and possibly risky aspect that does need more careful attention.

In order to more effectively and safely teach ascents, during diver training some recommendations are possible from reviewing these accident reports. Instructors should:

1. Provide lecture coverage on all forms of ascents used by sport divers.
2. Provide pool or shallow confined water training in normal, octopus, emergency swimming, buoyant, and buddy breathing ascents. Several of these procedures can be practiced horizontally.

3. Provide open water training in normal, octopus, emergency swimming ascents and buddy breathing in a stationary position.
4. Provide complete training in lecture, pool and open water on buoyancy control during ascents, ascents, at the surface, at the bottom and in midwater.
5. Make all open water emergency swimming ascents as similar to a normal ascent as possible, ie. regulator in the mouth, looking up, going slowly, but exhaling more and inhaling less, ie. keeping lung volume as near normal as possible.
6. Have divers look up as much as possible while making all ascents.
7. Make careful use of medical history forms with medical exams and chest x-rays when needed, plus take special care with any student who has recently had a cold, or is a heavy smoker.
8. Provide close supervision during _{all} ^{as}cent training.

Instructors during open water ascent training should:

1. Not have students make any ascent that cannot be stopped or that is done at a high rate of speed, such as a buoyant ascent.
2. Not have students make "free ascents" or do a "blow and go".
3. Not have students' air turned off.
4. Not have students breathe off BC's.
5. Not have students buddy breathe vertically.
6. Not have students take the regulator out of their mouth during ascents.
7. Not have students make anything but normal ascents from depths greater than 40 feet.
8. Not put students under undue pass/fail stress during ascents.

These are the best recommendations available after retreated review of the available accident reports. Far more research needs to be done on ascents. The problems and the solutions are not simple or obvious. All of these recommendations came from specific fatal cases where the lack or use of a particular procedure definitely appeared to contribute to the accident.

Entanglement

General Accidents - 7% Training Accidents - 11%,

Entanglement has been viewed by some serious divers as a Hollywood movie or TV contrived situation that rarely occurs to divers. This is definitely not so! Entanglement contributes to at least seven percent of diving accidents, making it a problem needing serious attention. Kelp (mainly in California); weeds in lakes; lines (fishing, anchor, safety, etc.) in all waters; nets and equipment are all involved.

Recommendations and opinions

Buddy diving, use of a good knife, and underwater equipment handling during diver training are important in order to deal with entanglement. More controlled open water diving under the supervision of an instructor would increase diver skill and confidence, particularly the ability to think underwater and avoid entanglement or deal with it calmly.

Buoyancy Control Problems

General Accidents - 6% Training Accidents - 3%

Often, buoyancy control was indicated as a contributing cause, but the reports were not clear enough for it to be identified as being significant. Only the clear cases

were counted. Had accident reports been better, the buoyancy control problem might likely have been much higher in the list.

Overweighting, in particular, appeared to be a problem often not reported. Overweighting is also an increasing problem with newer systems, where the diver wears too much weight and then compensates with the buoyancy system.

Some divers did not use any inflatable devices to control buoyancy, others did not use adequate devices and still other divers did not maintain or check the devices so they would function when needed.

Fewer victims in these accidents had inflated their own flotation devices. No victim in any of the fatal reports successfully dropped their own weights, but most rescuers did ditch the victim's weights. Some weight belts or weight systems did not release when the victim or the rescuer attempted to ditch them.

Recommendations and Opinions

Much more training is needed during all diving courses on buoyancy control. Repeated use of conventional BC's and weight belts, along with at least an introduction to the newer or more advanced systems is needed.

Proper buoyancy control will make a distinct contribution to reducing accidents from other causative areas, particularly during ascents. Instructors should provide complete training in lecture, pool, and open water on buoyancy control during ascents, descents, at the surface, at the bottom and in mid-water.

Divers should weight themselves for neutral buoyancy, at the most common or shallowest depth. There is evidence that if a diver inflates the buoyancy control device or gets rid of the weights so surface floating is possible, this will often change a possible fatal accident into a near miss.

Location or Depth Accident Started

Table V provides information on the depth of the diver when the accident started. Some instructors have been saying, "most accidents start at the surface". In addition, URI has provided information on the depth of the body when recovered in fatal accidents, but no careful tabulation had yet been done on where the accidents started.

In the depth range underwater down to 60 feet, 43 percent of the accidents began. This range can be assumed to be the most common depth range for sport scuba diving. To be sure, most victims with or without rescuers went for the surface in an attempt to solve the problem and may have died on the surface and/or later been recovered from depth.

TABLE V
LOCATION OR DEPTH ACCIDENT STARTED

	Causes	Percent
Surface	115	26
0 - 60'	187	43
60 - 130'	96	22
Over 130'	38	9
TOTALS:	436	100

Experience of the Victim

Table VI deals with the experience of the victim. The URI reports for 1970 through 1974 indicate 8 to 9 percent of the fatal scuba accidents occurred during formal training compared to 15 percent in Table VI. This supports the view that the records available to NAUI are biased in the area of training.

Many of the victims who were untrained were recorded in the older case reports, particularly those prior to 1972. This number appears to be decreasing. The number of accidents occurring when non-divers were being "trained" by friends who were divers was still sadly larger than expected.

Judging by this table, the first 12 dives or first year of diving are the most hazardous. It has been pointed out by many authorities in sport diving, that the majority of divers probably drop out during the first year. Thus, far fewer divers are left, who may also be better divers.

TABLE VI
EXPERIENCE OF THE DIVER/VICTIM

	Causes	Percent
Untrained	57	14
In training	60	15
Less than 1 year or 12 dives (certified)	145	36
One to three years or 12 to 48 dives (experienced)	79	20
More than 3 years or 48 dives (very experienced)	<u>60</u>	<u>15</u>
TOTALS	401	100

Training accidents tended to occur on the first open water scuba dive. Additionally, training accidents tended to be near misses when the instructor was immediately available.

CONCLUSIONS

Based on the wealth of information provided by these reports, several recommendations can be made for the modification of diver training courses. These recommendations are:

1. More controlled open water training under a variety of conditions, supervised by an instructor.
2. More careful medical and physical screening of student divers.
3. More emphasis on practical open water skills, particularly equipment handling, buddy diving, buoyancy control, dive planning and ascent procedures.
4. More emphasis on the prevention of fatigue, stress, getting cold, running out-of-air, emergency ascents, entanglement and decompression sickness.
5. More definite training in the environmental, medical, physical and psychological reasons why not to dive, when to abort dives or why to limit diving under certain conditions.
6. More emphasis on diving with complete, well maintained equipment of good quality.

Recommendations to already trained and certified divers include:

1. Know when not to dive; know when to abort the dive - never be embarrassed to do either.
2. Take an open water or advanced course.
3. Stay out of dangerous water conditions.
4. Get a regular medical exam and maintain physical fitness.
5. Buddy dive conscientiously with agreed upon procedures and a dive plan; know hand signals and each other's equipment; stay together.
6. Get complete quality equipment and maintain it well.
7. Know and use the equipment and procedures to avoid or handle running out-of-air, making emergency ascents, getting entangled and decompression.

8. Control buoyancy to make diving easier.
9. Get out of the water if cold, tired, hurt, out of air or not feeling well.

Additional research is definitely needed. A great deal more information could be gathered from an extensive study of near misses; taking a close look at what emergency procedures were used successfully. More accident reports are needed. All available information and reports should be sent to NAUI and URI. Also, far more and more complete autopsies are needed.

Specific aspects that need more study are:

- * Decompression meter use.
- * Non-treated decompression sickness.
- * Medical problems related to air embolism.
- * Problems due to drug use.
- * Ascent procedures.
- * Buoyancy control procedures.
- * Emergency and rescue procedures.
- * prevention of fatigue, cold and stress.

Information in the form of reproduceable safety handouts is provided with this report (see Appendix B). Much of this material was developed in conjunction with a review of this study.

Within the limitations stated in the basis and bias section (see Appendix A) of this report, this is the most extensive information available on the causes of diving accidents and the implications for both the practice and instruction of sport diving. The intention has been not to provide absolute statistical data, but rather to advance the current understanding of how sport divers get into trouble and by so doing, suggest how they can better enjoy a safe, comfortable open water scuba diving experience.

APPENDIX A

1. ACCIDENT REPORTS AND FORMS

- a) Accident Report forms - no charge
- b) US Underwater Fatality Statistics (URI) - \$2.00 each
- c) Diving Accidents - Why? (NAUI) - 52.00 each.

Write:	(For, a b or c)	(For a or b)
	NAUI Headquarters	URI Scuba Safety
	PO Box 630	PO Box 68
	COLTON CA 92324	KINGSTON RI 02881

2. ACKNOWLEDGEMENTS AND BACKGROUND

Over 500 volunteer hours, in addition to NAUI Headquarters Staff time have gone into carefully reviewing and compiling this information.

Reviewers included:

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Jon Hardy, Ken Kivett and Laurel Touchette, NAUI Instructors.

Mike and Rod Nachman, NAUI Divers.

3. BASIS AND BIAS

There was no attempt to find and review every case that occurred year by year in this report. URI reports provide that information. Table VII lists all available reports reviewed, by year.

TABLE VII
ACCIDENT CASE REPORTS REVIEWED

Year	Fatal	Near Miss
1965	12	—
1966	17	—
1967	19	—
1968	18	—
1969	20	—
1970	36	—
1971	45	—
1972	51	2
1973	82	6
1974	51	26
1975	56	51
1976	75	84
1977	12	18
Unknown	<u>4</u>	<u>29</u>
	498	216
TOTAL ALL ACCIDENTS:	714	

As this study was limited to cases on file with NAUI, there are several biases which should be explained. These biases should not significantly affect the usefulness of the report.

- * As NAUI is an instructor association, with certain accident reporting requirements for insurance purposes, there is a greater proportion of training accidents than in the URI reports.
- * Much better records are available from Hawaii due to the efforts of Roy Damron, NAUI Instructor and from California due to Dr Takashi Hattori of Monterey, the Los Angeles County Department of Parks and Recreation, and San Diego Lifeguards.
- * Due to the number of NAUI instructors and their teaching activities in certain states, more and better reports are in NAUI's files from California, Hawaii, Washington, Texas, Florida and Massachusetts, and therefore, any environmental conditions or diving activities peculiar to these areas may be somewhat exaggerated in this report.
- * Some of the reports were obviously incomplete and inaccurate.
- * The near-miss reports tended to be more complete and filled out by instructors, particularly on accidents involving chamber treatment.
- * The accident report reviewers did not make value judgements, but recorded apparently known facts or causes.
- * In many case reports, certain facts were indicated, but due to lack of information, obvious inaccuracies or no autopsy being performed, these apparent facts could not be counted in this report. For example, decompression sickness, air embolism, heart attack, use of drugs, poor fitness, fatigue, cold or stress

may have been indicated but not explicitly reported. Information on the amount of weight used, use of reserve or pressure gauge, inflation of the flotation device and the type of ascent used were often omitted.

The total number of causes exceeds the total number of accidents as many accidents had multiple causative factors contributing to the accident. Also, due to incomplete reports, no cause could be determined in some of the accidents.

- * When the review of these cases began, 16 categories were developed for possible contributing causes. After the review of several hundred cases, it became obvious that only eight useable categories existed.
- * The reviewed reports included both general and training accidents of divers certified or in training by the several different diver certifying agencies.

PROBLEMS WITH THE MOSES SOLE

People who have read about the Moses sole (*Pardachirus marmoratus*) and the shark-repelling fluid it secretes wonder why, if this fluid is so effective it is not being used to protect divers and swimmers.

It has been found that though this toxin will repel sharks the effective use of the secretion will require the solution of several problems. The toxin itself is very unstable and some method of preserving it must be found. Then, because chemicals scattered around a diver disperse too fast to provide effective protection, the toxin would have to be incorporated into an ointment that a diver might apply to himself. It so, danger exists that the toxin may get into the bloodstream through the diver sustaining a cut. The toxin is both a neurotoxin and a homotoxin and will attack and destroy red blood cells. The ultimate solution to this problem may lie in the way the sole itself escapes such ill effects. This is still being investigated.

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ICEBERG TOWING IS A SOUTH SEA BUBBLE

The idea that Saudi Arabia and Adelaide could be supplied with fresh, though possibly centuries old, water seems to have been put back (as one might say) on ice. At a conference in Iowa in September, devoted to the theme of Iceberg Utilisation, Prince Mohammed el Faisat of Saudi Arabia supplied ice flown by helicopter from an Alaskan glacier to cheer the delegates. Apricot nectar was added to shavings from the two-tonne \$7500 ice cube. And now Cicero, the company set up in France to tow a berg to Saudi Arabia, has gone bankrupt and a number of people are left out in the cold, cold wind of adversity. Apparently it was found that the ice might melt when removed from its natural environment. This financial misadventure is unlikely to cool the ardour of future Merchant Venturers, as such persons would have been called in days of yore. In fact the Oceanic Research Foundation has plans to take a berglet the short tow from the coast of Antarctica to Macquarie Island.

It is likely they intend something a little stronger than apricot nectar with their ice cube when they reach their destination. But this is hardly a new initiative, for last century a sailing ship towed an iceberg to Valpariso in Chile. Men were MEN in those days!