

SCUBA Associated Mortality in BC: 1996-2008

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Hyperbaric Medicine Terminology

- Hyperbaric chamber "The Chamber"
- HBO treatment "A Dive"
- Spinal DCS "A Spinal Hit"
- Musculoskeletal DCS "The Bends"
- Pulmonary DCS "The Chokes"
- Cerebellar DCS "The Staggers"
- Pulmonary Barotrauma "The POPS"

The
"Schits"



Purpose:

- To identify factors associated with SCUBA mortality in British Columbia
- To identify interventions that might be effective in reducing SCUBA associated mortality and morbidity

Methods:

- Review of documentation provided by BC Coroner
- All information reviewed personally by DH
- Data collected using standard research form, supplemented by dictated comments

Source Materials:

- Coroner's Inquest
- Witness accounts
- Police reports
- EHS reports
- Hospital records
- Forensic photos
- Post mortem results
- Toxicology Dive computer data
- Gas analysis
- Equipment inspection reports

Results:

- Number of deaths
- Certification
- Experience
- Health issues
- Drugs/Alcohol
- Platform
- Breathing apparatus

Results:

- Breathing gas
- Purpose of dive
- Buddy / solo
- Number of dives
- Depth
- Deco
- Mode of dive planning

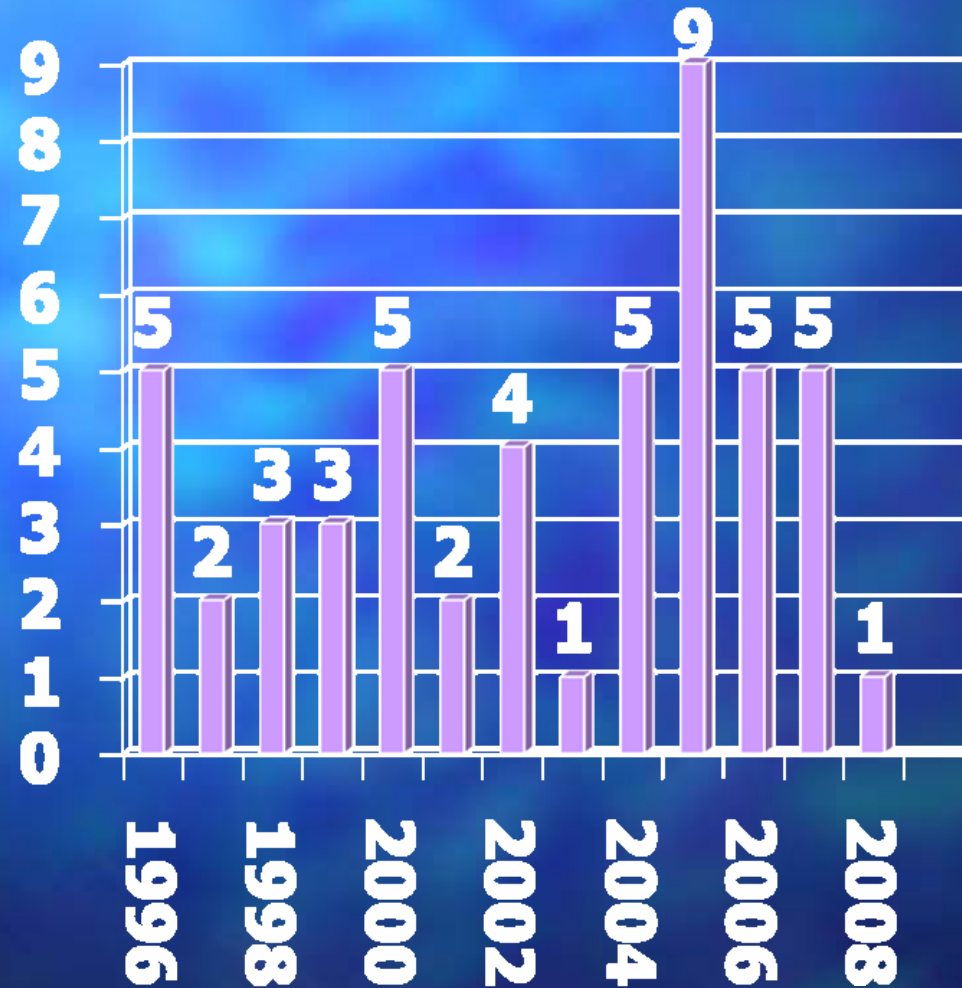
Results:

- Events leading to death
- Forensic evidence
 - Gas
 - Equipment
 - Autopsy
 - Cause of death
 - Alternate cause of death

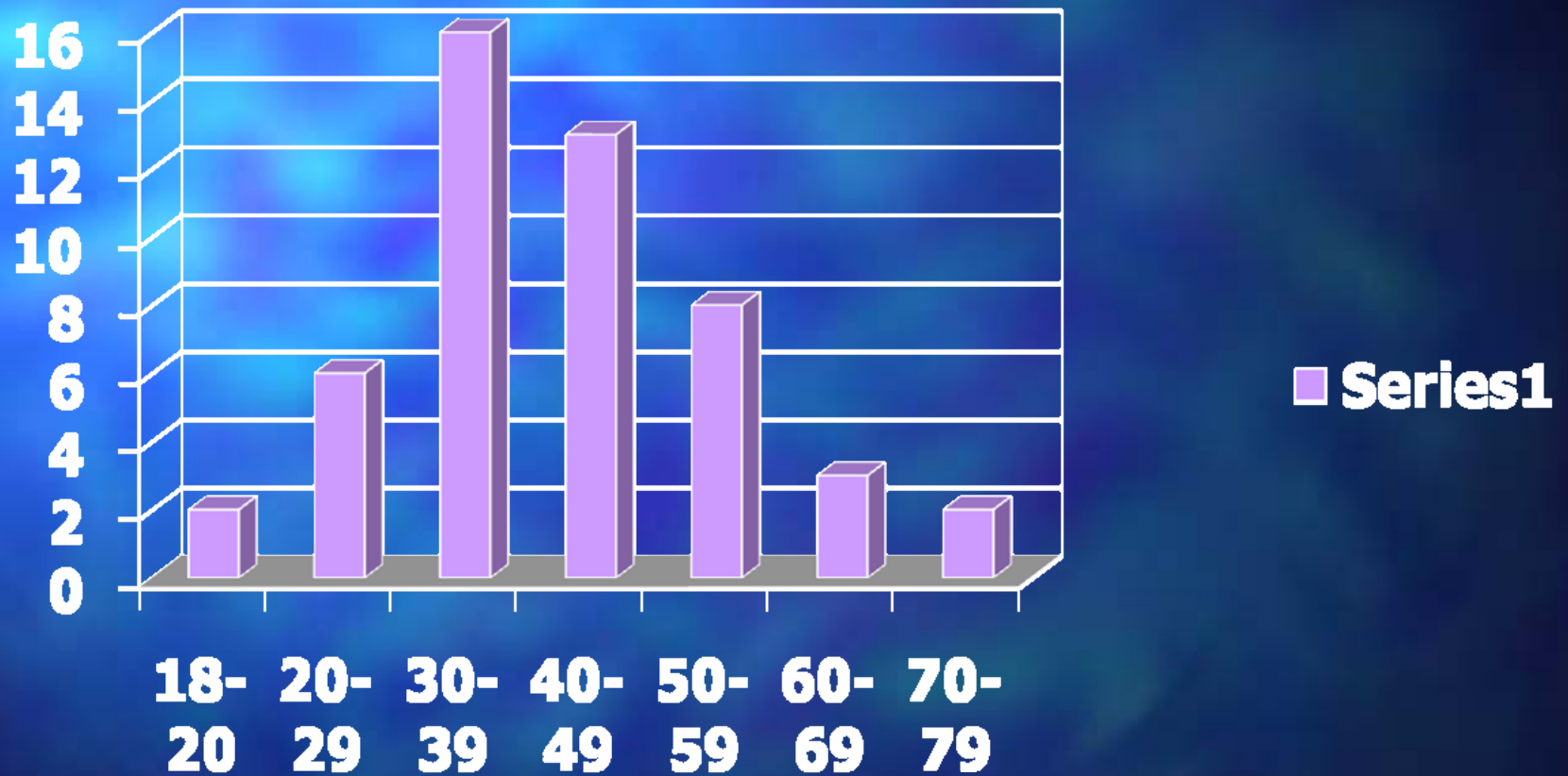
Number of Deaths 1996 - 2005

- 50
- Mean 5 per year
- Range 1 – 9 per year

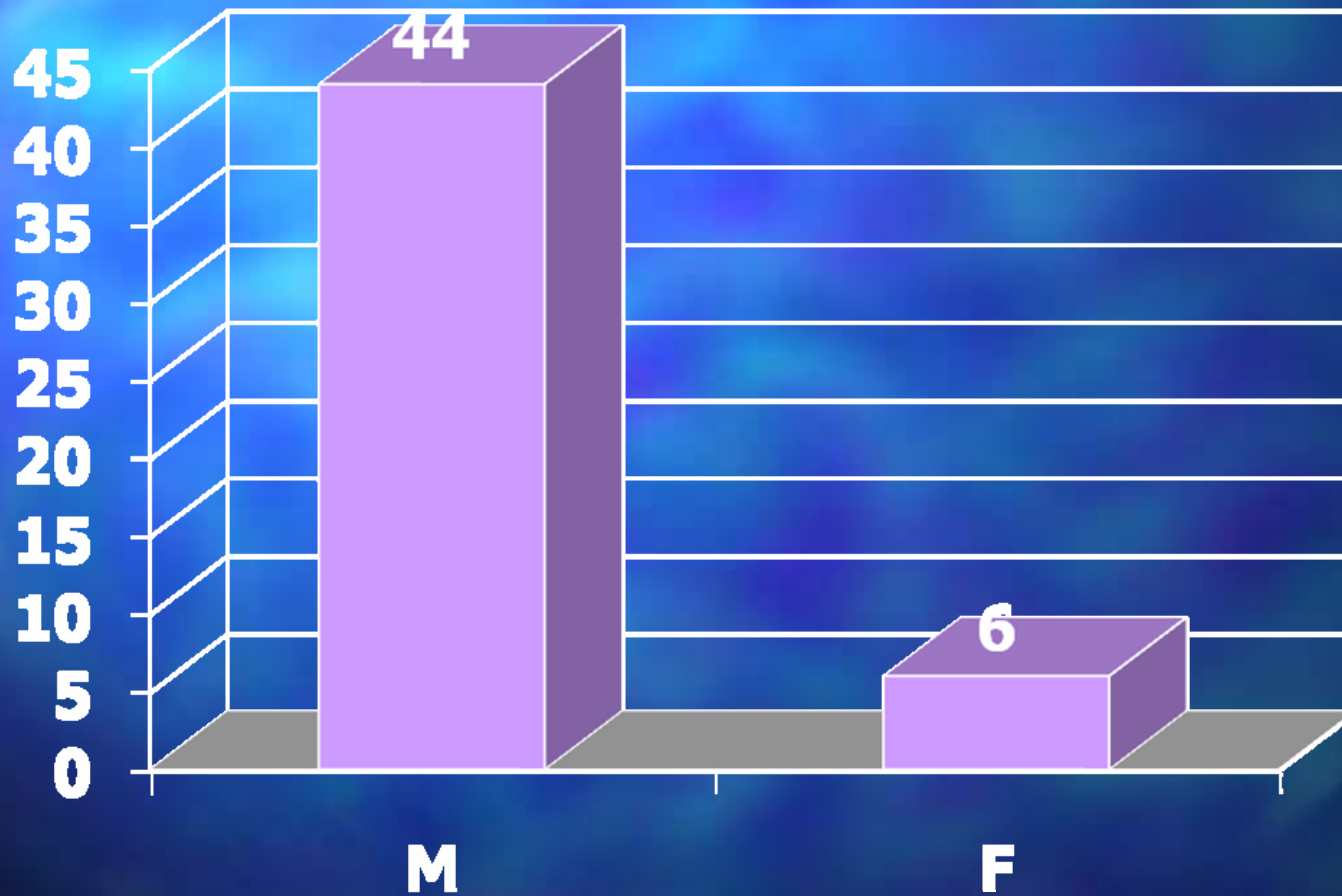
Number of Deaths 1996 - 2008



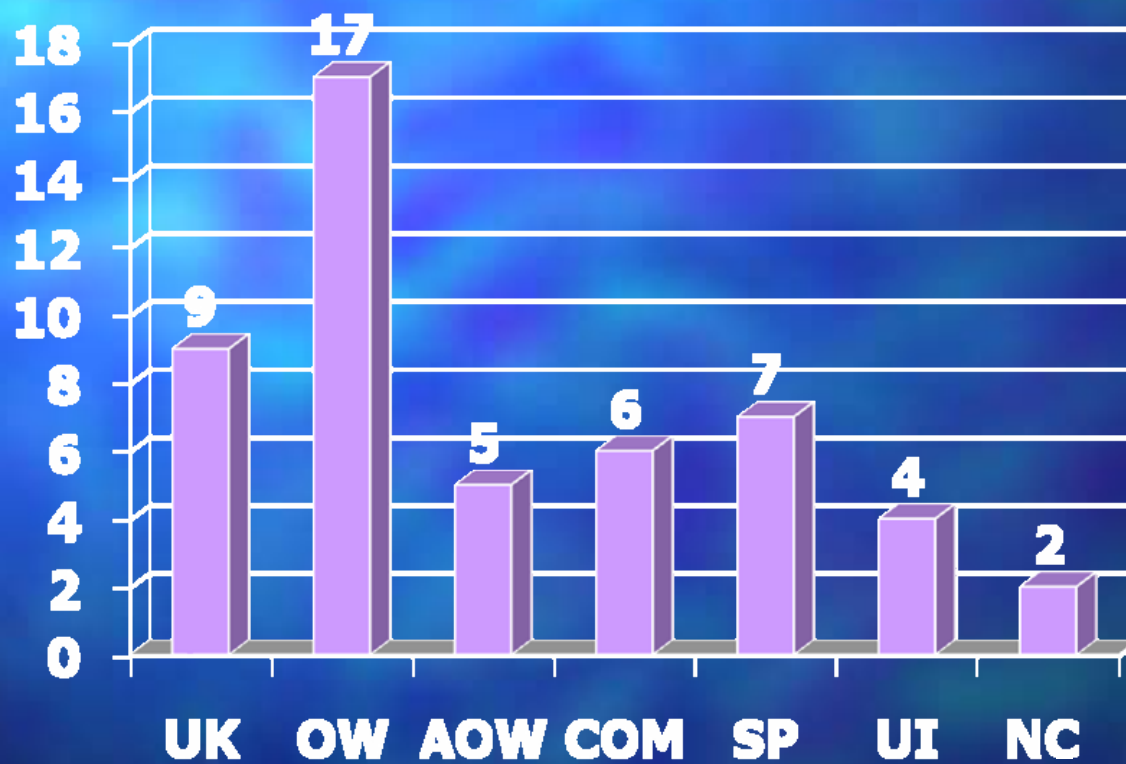
Age of Divers



Gender of Divers



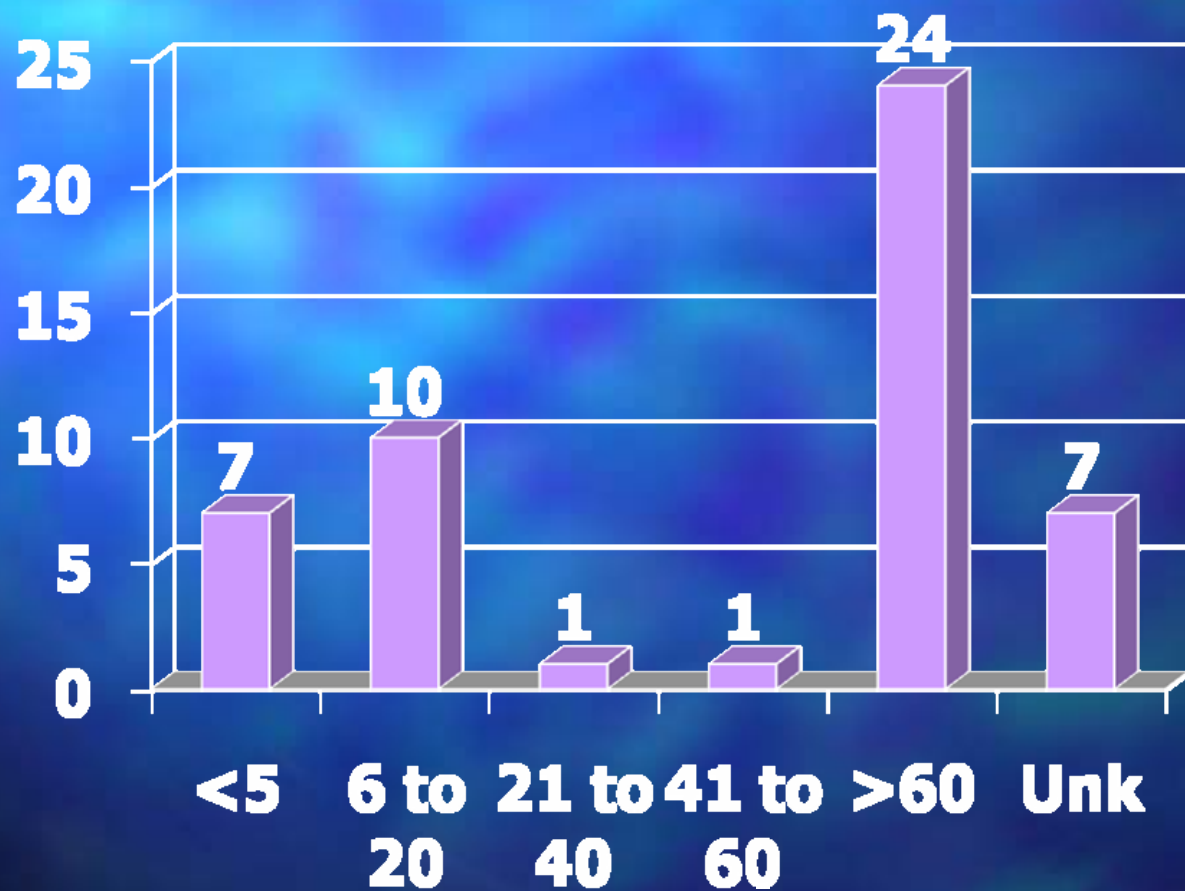
Certification



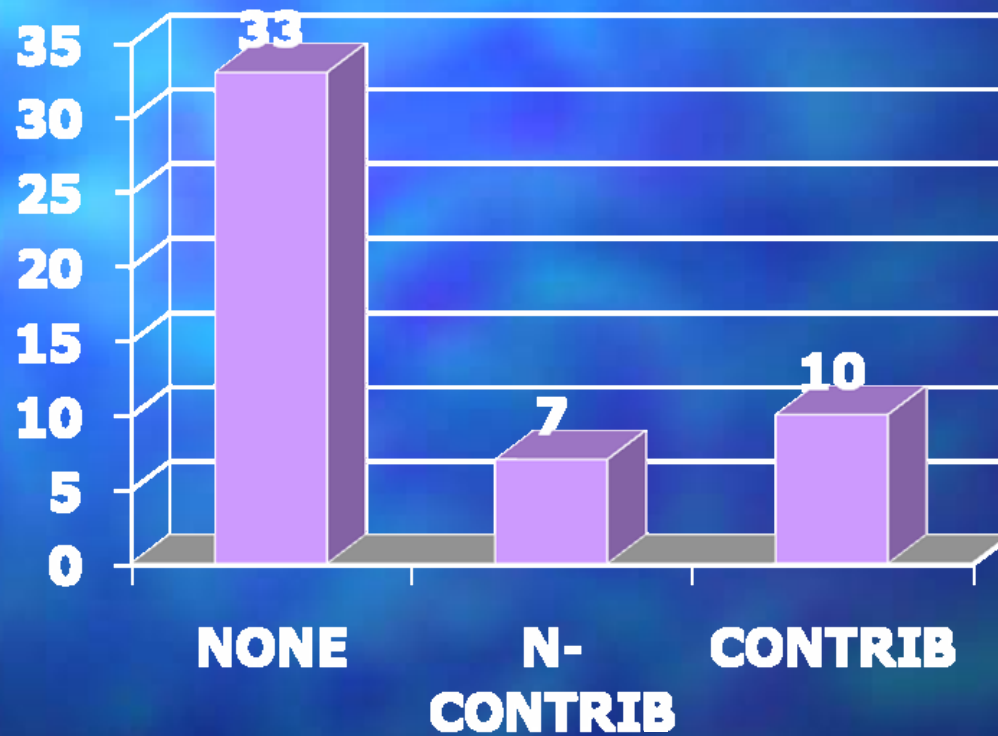
Experience

- Novice <5
- Inexperienced 6-20
- Intermediate 21-40
- Advanced 41-60
- Experienced >61

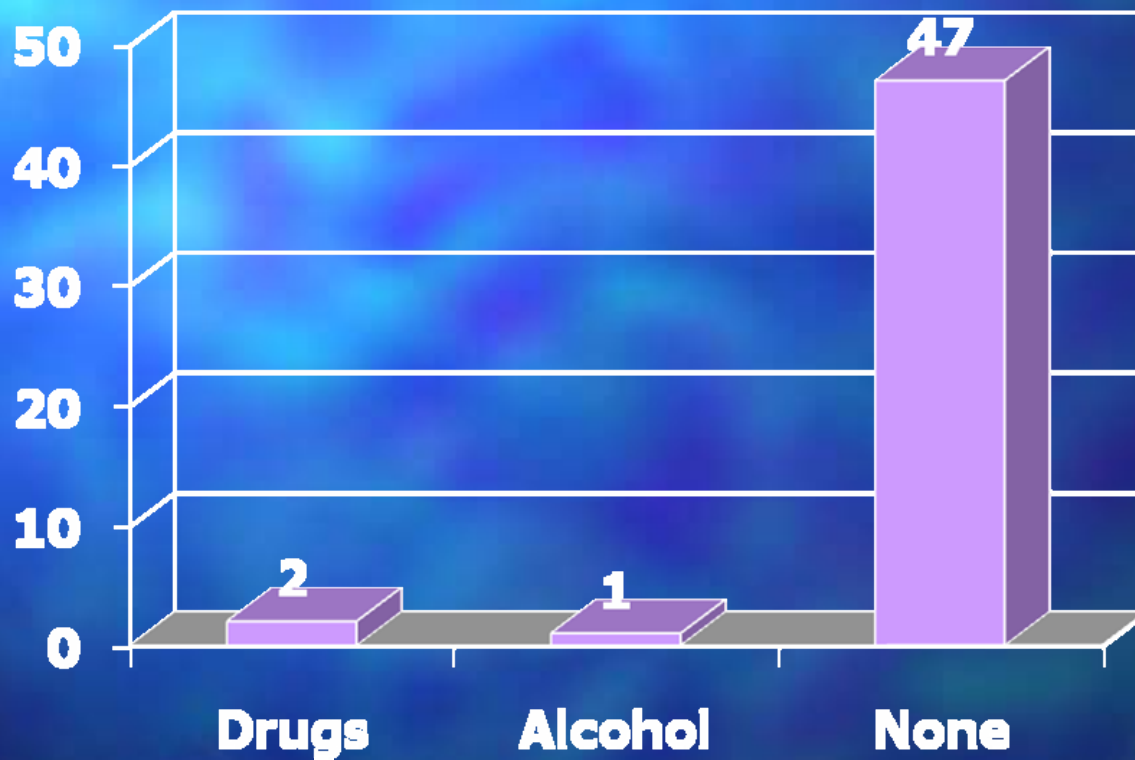
Experience



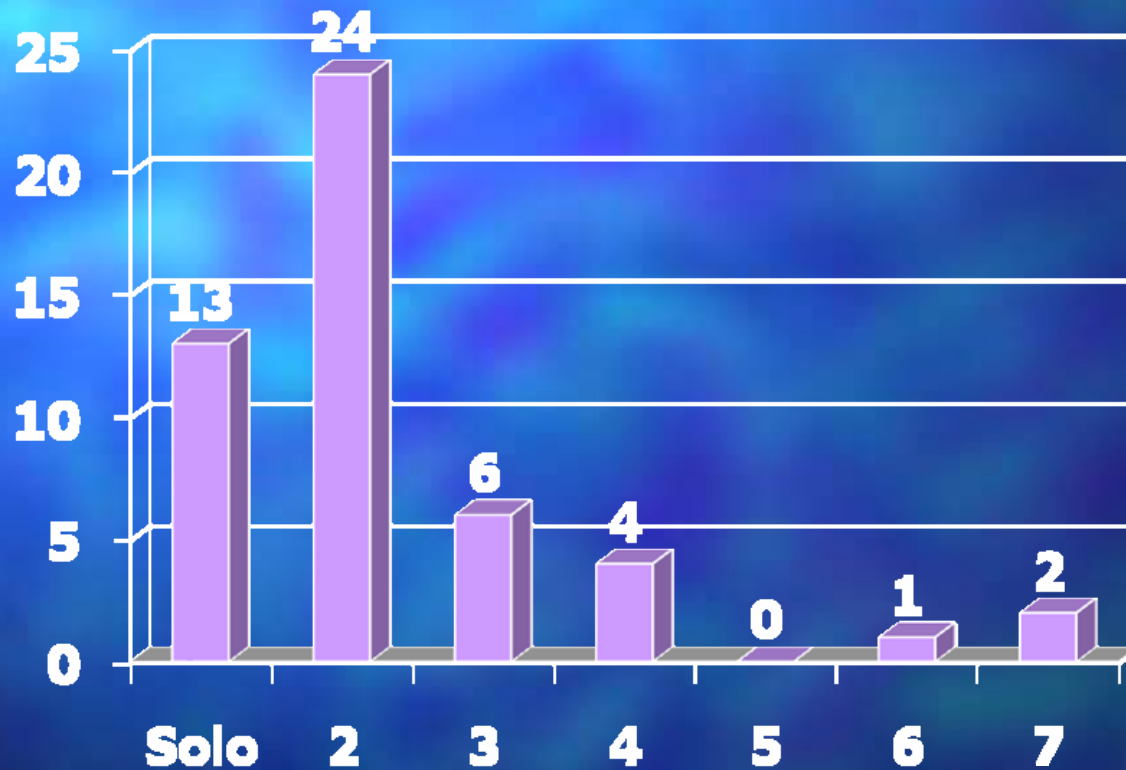
Health Issues



Drugs / Alcohol

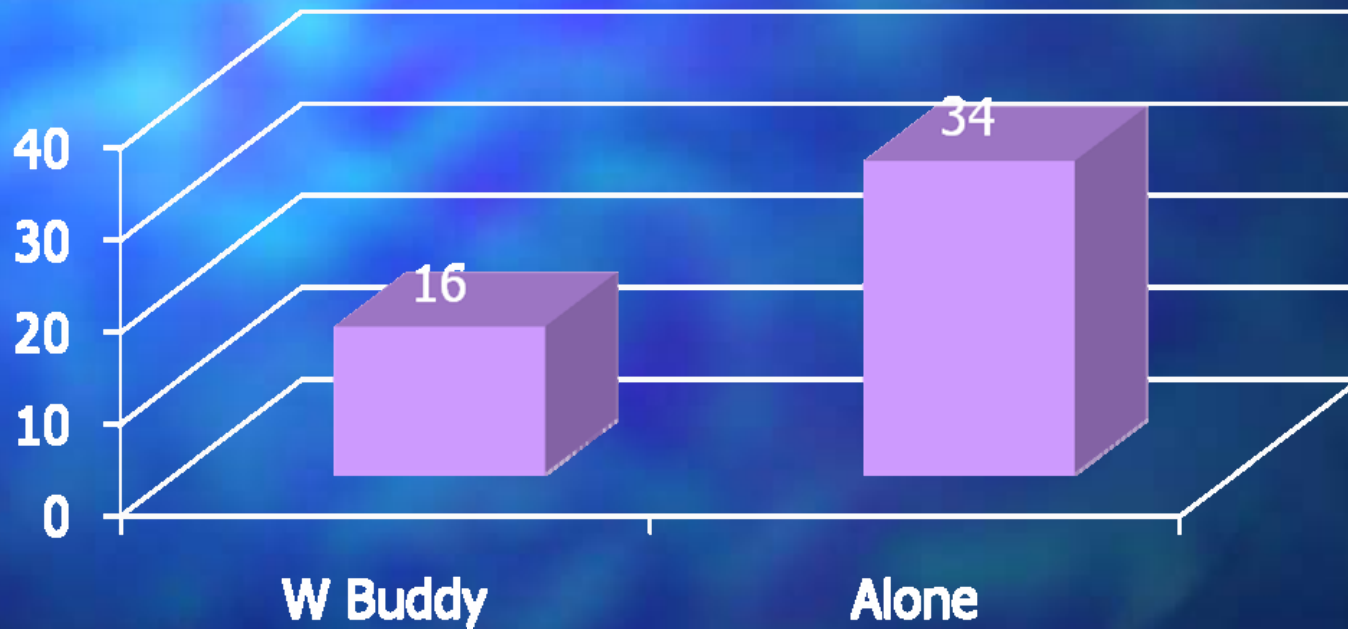


Number in Diving Party

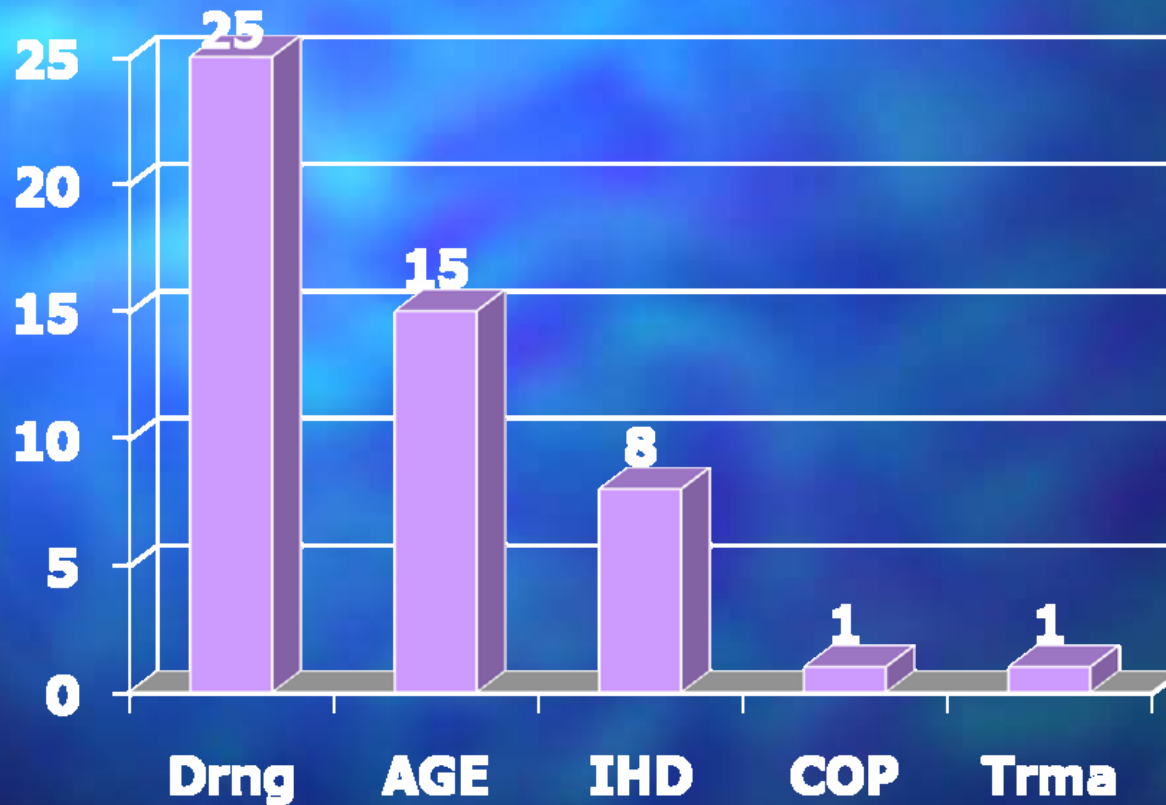


Died alone

W Buddy / Alone



Cause of Death (Coroner)



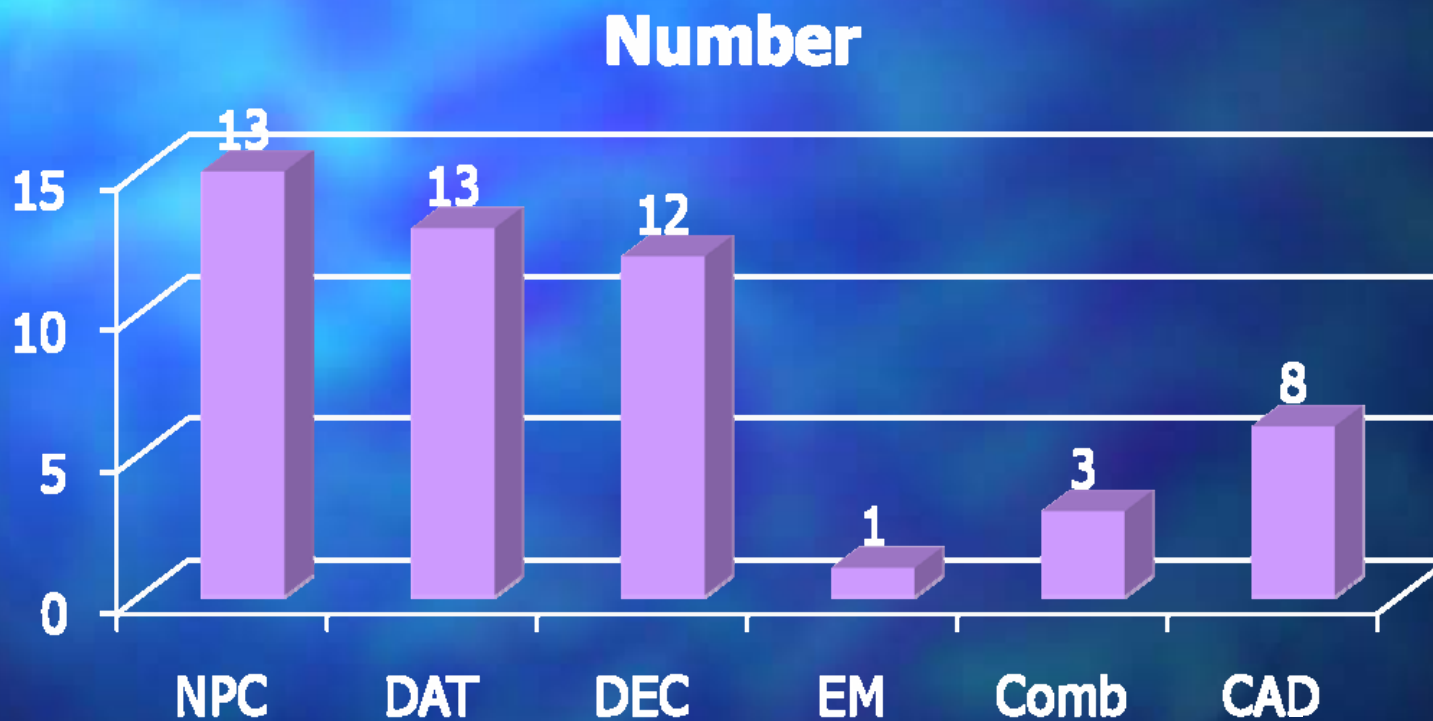
Comments

- Interesting Cases
- Death Under Instruction
- Preventable Deaths
- Cardiac Deaths
- Conflicting COD Conclusions

Cause of events leading to death

- No preventable cause identified
- CAD
- Potential preventable cause identified
 - Equipment related
 - Diver action major triggering event (DAT)
 - Diver error in response to unanticipated events (DEC)
 - Combined factors

Cause of events leading to death



Equipment- CASE # 9: COP

- Urchin harvester on SCUBA
- 40 ft depth on third cylinder
- Dive #1 felt dizzy, nausea, tachycardia, surfaced
- Diver #2 found upright on bottom, regulator in mouth, 2,000 psi in tank, weights on, mask on.

CASE # 9: COP

- Compressor had shifted and engine exhaust melted through plastic pipe
- Compressor entrained engine exhaust
- Autopsy show CarboxyHB 51%
- Bubbles in epicardial vessels, cerebral arteries, right atrium, other tissues
- No barotrauma

CASE # 9: COP

- Pathologist postulated possible AGE as he tried to ascend
- Possible post mortem AGE when body recovered

Combined - CASE # 15

- Commercial diver on surface supply
- Diving in pulp mill effluent pond to clean intake screens
- Drawn into 30 inch pipe due to missing screen
- Decapitation, severe, massive crush when pipe constricted to 24 inches at turbine

DUI: 4 CASES

DEC - Deaths UI: Case # 17

- Shore dive for AOW
- 7 in group (3 plus 4)
- Surface current
- 15 – 20 feet visibility
- Silt reduced visibility to 1 –2 feet
- Students separated from instructor
- Instructors surfaced

Deaths UI: Case #17

- Diver 1 remembers trying to ascend from 100 ft with 500 psi
- Arrived at surface unconscious and foaming, mask off, reg out, BCD inflated
- Diver 2 found at 118 ft
- Mask on, reg out, weights on, no air

Deaths UI: Case #17

- Autopsy showed extensive intravascular air
- Likely ante-mortem
- COD drowning

Why did he not release weights?

DEC - Deaths UI: Case #20

- Dry suit cert (37 dives)
- Rented poorly fitting suit
- Soft built in booties
- No ankle weights or straps
- Buoyancy problems returning to shore
- Foot first ascent, trying to curl and vent
- Buddies lost sight

Deaths UI: Case #20

- Not found on surface
- Found in 10.5 FSW
- Mask partially off
- Regulator out

Deaths UI: Case #20

- Fins off
- Feet out of dry suit boots
- Autopsy – widespread systemic AGE

What if she had used a properly fitted dry suit, gators, or ankle weight?

DEC - Deaths UI: Case #34

- Nitrox certification (14 dives)
- Shore dive
- Second dive of day – 55 ft for 30 m
- Surfaced after safety stop while buddies remained at 10 fsw
- Called for help
- Sank past buddies to about 15 ft

Deaths UI: Case #34

- Arms flailing behind him, reg out
- Assisted to surface unconscious, frothing
- Full arrest at shore
- Autopsy – COD drowning, microscopic bubbles in some pulmonary vessels

What if he had used a regulator necklace?

NPC - Deaths UI: Case #16

- During 3rd OWC dive from boat
- 1st dive of day
- Descended to 60 ft with instructor and one other diver
- Visibility 20 feet
- Buddies lost track of her and surfaced to search

Deaths UI: Case #16

- Found on surface semiconscious
- CPR on boat
- Bilateral pneumos at shore
- Died in ICU with anoxic brain injury, AGE, pulmonary barotrauma
- Organ donor

Schit happens

DAT - Case # 2

- 2 divers on 3rd dive to salvage snowmobile
- Reg free flowed, ran out of air
- Used buddie's octopus
- Continued to fill lift bag until out of air

DAT - Case # 5

- Solo dive while intoxicated
- 6 beers and wine
- AGE

DAT - Case # 18

- Wreck penetration
- No formal wreck training, No line
- Silted out
- Observed to panic
- Buddy escaped and survived
- Found in wreck at 120 fsw , 0 psi
- Bubbles in circulation

DAT - Case # 22

- Solo working salvage dive below barge
- No backup
- Entangled and pulled under water without regulator in mouth

DAT - Case # 26

- Dive to 90' to video
- Removed fins
- Towed from above by buddy
- Allowed air to run out
- Buddy tried to bring up sharing air
- Lost grip, forced to leave him
- Drowned

DAT - Case #27

- Solo dive
- Dragged under water without regulator by improvised shoulder harness snagged on right wrist
- Unable to recover regulator
- Drowned

DAT- -Case # 28

- Started shallow dive with 900 psi
- Overweighted
- Surfaced with short swim to boat through kelp bed - submerged
- Separated from buddy on way to boat
- Found in 15 fsw holding on to piece of kelp, 0 psi

DAT - Case # 29

- Harvester, not surface supply qualified
- Elapsed medical certificate
- Found floating on surface
- AGE, CAD

DAT - Case # 30

- Dive on 25% nitrox to 140 fsw x 10 min
- Dive to 140 fsw for 10 min
- 25 min SI
- Dive to 190 for 24 minutes
- Unable to find 40% deco bottles
- "I am in trouble"

DAT - Case # 31

- Intentional dive to 230' fsw on air twins
- Severe narcosis at 170 fsw
- Buddy watched sink
- Found on surface 5 days later
- Reg in mouth
- #1 empty, #2 full
- Max depth 312 fsw

DAT - Case # 40

- Diving with no formal training
- No depth gauge, no timer
- No secondary air source
- Poorly fitting gear
- Separated from buddy
- Found at 40 feet, mask 20 feet away
- 0 psi

DAT - Case # 45

- Wreck penetration at @120 fsw
- Had spool of line – not used
- Silted up
- Buddy found exit
- Drowned after 20 minutes of entrapment
- Debris partially blocked door

DAT - Case # 41

- Diving post SDH
- Neuro impairment
- Overweighted
- Unfamiliar with gear
- Did not wait for buddies
- Deflated BCD by accident

DEC - CASE # 1, 2, 4

- Unable to maintain buoyancy at 90', body found at 340'
- Unable to maintain buoyancy at 90', body found in 300'
- Unable to maintain buoyancy at 90', sank to 200', uncontrolled ascent, died on surface with AGE

DEC - Case # 8

- Diving 30 minutes after meal
- Vomited under water at 60 fsw
- Panicked
- Refused regulator
- Drowned

DEC - Case #14

- Low on air at 50 fsw
- Lost fins
- Struggled to surface with help of buddy
- Out of air on surface
- Choking on snorkel
- Refused regulator
- Sank and drowned

DEC - Case #25

- Two divers salvaging motor from 90 fsw
- Filled lift bag, Checked air 750 psi
- Signalled to ascend
- Buddy did not arrive at surface
- Found on bottom, reg in hand, 0 psi
- Drowning, Air on CT

DEC - Case #39

- Entangled while freeing anchor line of commercial fishing boat
- Unable to recover regulator
- 1220 psi in cylinder

Regulator necklace?

DEC - Case # 44

- Became tangled in kelp in rough water
- Lost regulator and panicked
- Repeatedly refused buddy's regulator
- Drowned on surface

DEC - Case #47

- Surfaced after 30 min at 12 m, irritable
- Released boat and drifted off - flailing trying to recover regulator
- Did not inflate BCD
- Sank without regulator in mouth
- 0 psi
- AGE, PFO

Combined - Case # 32

- Buddy started with 2000 psi
- 600 psi starting ascent
- Buddy out of air at 80'
- Octopus damaged - choking
- Shared air
- AGE at surface

Combined - Case # 15

- Commercial diver on SS sucked into 30 inch pipe
- Absent grate
- Pumps on

Cardiac Deaths

- 8 deaths determined by Coroner related to CAD
- All male
- Age 50 to 70

CAD - Case #12

- 50 Y.O. M
- Multiple cardiac risks
- Become distressed during surface swim
- Sank and drowned
- No indication as to why he did not inflate BCD

CAD - Case #50

- 70 Y.O. M
- Known IHD
- Surfaced at end of second dive of day, confused, in distress
- Arrested in water

CAD - Case # 33

- 56 Y.O. M
- No known IHD
- Surfaced from 25 feet, gasping
- LOC within 2 minutes
- Tight LAD stenosis
- COD Coronary Insufficiency

CAD - Case # 37

- 53 Y.O. M
- No known IHD
- Feeling unwell after first dive
- Surfaced with buddy who was having buoyancy problems
- In distressed, called for help
- Sank and drowned
- Severe ASHD

CAD – Case # 21

- 57 Y.O. M
- No known IHD
- Felt tired after first dive
- Surfaced after second dive
- Climbed onto rock
- Cardiac arrest within 2 minutes
- Early AMI on autopsy

CAD - Case # 23

- 51 Y.O M
- No known IHD, obese
- Seemed nervous prior to ascent
- Arrived at surface in distress
- Spat out regulator
- Pink frothy sputum
- Arrested when pulled aboard boat
- Severe CAD

CAD - Case #46

- 65 Y.O. M
- Known IHD
- Untangling line from propellor
- Surfaced in obvious distress
- Arrested in the water

Implications

- What is happening?
- What implications does this have for cardiac screening?

What is happening?

- Mild to moderate exercise at increased partial pressure Oxygen at depth
- Sustained or increased exercise at surface on air

What implications does this have for cardiac screening?

- Should there be a protocol of mild to moderate exercise on supplemental oxygen followed by sustained exercise on air?

Lost Regulators

- 6 divers drowned on the bottom with air in cylinder and regulator out of mouth, no explanation
- Circumstances suggest unable to recover regulator
- Other cases observed to lose regulator
- Would a regulator necklace have made a difference?

NPC - Case # 36

- Solo working dive to gather golf balls
- Removed fins
- Overweighted
- Drowned near surface with full face mask dislodged
- 50 pounds of balls in bag

NPC - Case # 13

- Separated from buddies during ascent at 75 fsw
- Found on bottom at 107 next day
- 1500 psi
- Drowning ?AGE

NPC - Case #7

- Shore dive
- Separated from buddy
- Found next day, drowned on bottom
- 1500 PSI

NPC - Case #10

- Separated from buddies in low poor visibility
- No light
- No search for 25 minutes
- Found in 92 fsw
- AGE?

NPC - Case #11

- Separated at 25' during ascent
- Found on bottom at 45 fsw
- Drowning and bubbles
- AGE?

NPC - Case # 19

- Failed to surface with buddy after safety stop
- Found 100 yards away tangled in kelp
- Reg out mouth
- 750 psi
- Looking for lost camera?

NPC - Case # 38

- AGE without clear cause
- CAD, stent patent

NPC - Case # 35

- Novice diver surfaced from 80 feet
- Separated from buddy at 40 feet
- OK when surfaced, then disoriented, unconscious
- AGE

NPC - Case #43

- Over-weighted
- Separated from buddies at 42 min
- Found floating on surface
- Hood, mask, snorkel missing
- Computer showed rapid ascent at 45 minutes
- Drowned

NPC - Case # 49

- 19 y.o. fish farm diver
- Tethered on SCUBA in pen
- Tether went slack, then tight
- Found unconscious at 30 fsw
- DOA nursing station
- AGE

NPC - Case # 24

- Solo dive to spear fish
- Uncontrolled ascent previous day due to BCD valve
- Found dead on surface
- AGE

NPC - Case # 42

- Diving in 15 fsw to recover ramp
- Surfaced after 3 minutes without mask or regulator
- Swam, pulled himself short distance toward shore
- Extensive intravascular air, ASHD
- Coroner – lethal arrhythmia

NPC - Case # 6

- Diver with Hypertrophic CM, asthma, URI
- Difficulty with ears
- Separated while surfacing
- Found dead on rocks
- AGE

NPC - Case # 48

- 67 YO recovering motor in 70 fsw
- Tethered to surface
- Pulled to surface when bubbles changed
- Unconscious, reg in mouth
- Hydrocarbons in air – importance?
- ASHD, possible cardiac death

Cause of death and autopsy

- 11 cases of diver found on bottom with intravascular air at autopsy
- 6/11 cases clearly not associated with circumstances leading to AGE
- 5/11 AGE possible, but unlikely from circumstances
- 1/11 AGE primary cause of death
- 2/11 AGE secondary factor in death

Conclusions

- Possible to drown on bottom and have significant intravascular bubbles at autopsy
- IVA not reliable indicator of AGE
- Comments by Radiologists, Pathologists, Coroner suggest incomplete understanding of AGE

Conclusions

- 42% of deaths had no clearly identifiable preventable cause
 - 8 of these had IHD that might have been identified by screening
- 26% of deaths triggered directly by diver actions
- 30% of deaths associated with diver error

Conclusions

- 12% (6/50) drowned with air in cylinder and regulator out of mouth
- No apparent cause other than inability to recover regulator
- Regulator necklace?



Conclusions

- 56% of all deaths might have been prevented by better diver education or judgement
- 12% might have been prevented by effective cardiac screening
- 12% might have been prevented if they had been able to recover regulator

Conclusions

- Need for education of pathologists and Coroners regarding pathophysiology of SCUBA related injuries

Common factors in deaths

- Divers making unsafe decisions
- Divers making errors in response to problems arising during a dive
- Divers diving beyond their level of training or experience
- Divers who are unfit to dive

Solutions

- Improved diver training emphasizing safety, buddy system
- Education around safe diving practices
- Periodic reporting of events
- Improved diver medical screening
- Equipment to improve regulator recovery