

# Original articles

## Diving-related deaths in New Zealand 2000–2006

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### Key words

Diving deaths, deaths, drowning, scuba diving, breath-hold diving, diving accidents, case reports

### Abstract

(McClelland A. Diving-related deaths in New Zealand 2000–2006. *Diving and Hyperbaric Medicine*. 2007; 37: 174–88.) A review of the epidemiology of diving-related deaths over the seven years from 2000 to 2006 in New Zealand was undertaken. The circumstances of each case, the method of accident investigation and the coroner's reports were reviewed, assessing the detail, accuracy and appropriateness of each. Descriptive summaries are provided for the deaths related to scuba diving. In total, 56 diving-related fatalities, 40 scuba divers and 16 snorkellers, were identified and analysed. Of the 40 scuba diving deaths, 12 had clinically significant medical conditions. Research of diving practices and other factors that might contribute to these deaths allows trends to become apparent. It is accepted that diving fatalities are uncommon, but the fatality rate is unknown in New Zealand because the 'denominator', the number of dives undertaken each year, is unknown.

### Introduction

In New Zealand (NZ), drowning remains the third most common unintentional cause of death due to injury, and the rate is higher than in many comparable countries.<sup>1–3</sup> Of all drowning deaths, those related to diving are uncommon, contributing approximately 5% (5–10 deaths per year). The investigation of an accident or death during water activities, especially underwater diving, is greatly hampered by the fragmented and incomplete records. Greater understanding of the circumstances and causes of diving fatalities could result in a reduction of morbidity and mortality among those who dive for recreation or occupation.

Risk factors can be grouped into those that result from aspects of individual divers (level of experience, medical history, alcohol/drug use), equipment problems, environmental hazards, faulty technique, and rescue and resuscitation complications.<sup>4</sup> Fatalities often result when a 'chain' of errors occurs. Previous studies have relied on retrospective audit of case series, culminating in broad recommendations.<sup>5–11</sup> With a diving fatality being an uncommon though devastating event, retrospective qualitative studies can yield detail about causative factors which may be useful in formulating recommendations aimed at reducing the death toll. Prospective studies are difficult to implement and unlikely to yield more useful information that will impact upon the aim of improving the safety of all aspects of diving.<sup>12</sup>

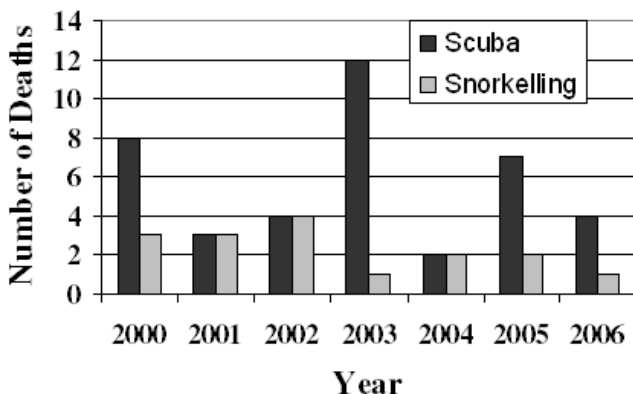
Diving fatalities in NZ waters for the period 1980 to 2000 have been reported.<sup>7</sup> The present retrospective review of diving-related fatalities covers the period January 2000 to December 2006. The year 2000 was included as review of cases in that year was incomplete in the previous report.

### Methods

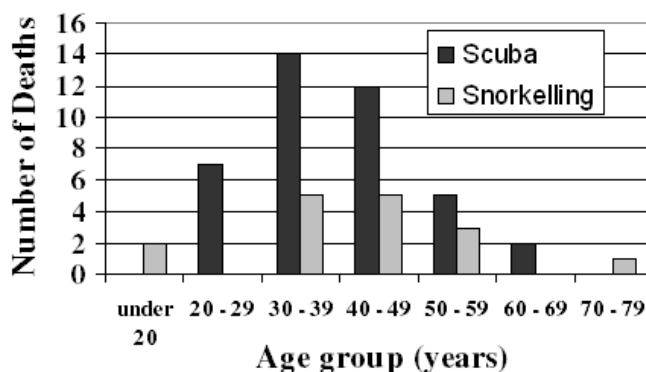
Application for ethics approval was initiated but the author was advised by the Chairman of the University of Auckland Ethics Committee that this was not required as all data used in this retrospective study were already in the public domain. Cases were identified from various sources. Water Safety New Zealand (WSNZ) maintains a database of drowning-related deaths (Drownbase™) and access was sought and approved. A spreadsheet of all known underwater-related drowning deaths from 2000 onwards was provided. The spreadsheet had 23 fields for each deceased person, the following headings being used: date of death, inquest number, family name, given name, date of birth, age, residence region, location region, site (km from shore), activity (scuba, snorkel, or free diving), purpose, ethnicity, gender, status (NZ resident or other), medical condition, fatalities (single or multiple), alcohol, rescue, resuscitation, buoyancy, and a brief synopsis of events. The individual files of the diving-related sub-group were fully examined.

Another source was coroners' reports; the Tribunals Division of the Department of Courts in Wellington was visited to examine the file information held for each identified case. The paper files of all finalised coroner's inquests are stored at that site. A search of the Coronial Index Registrations database allowed identification of diver fatalities. To ensure all police reports were examined, the National Police Dive Squad base was visited to examine the files held there. Further collateral information was sought and obtained from the accident investigator of the NZ Underwater Association (NZUA). Newspaper articles were also obtainable for a few of the cases. For diving-related deaths more data fields were necessary to capture specific factors: the methodology of Davis et al was followed, giving a total of 30 fields.<sup>7</sup>

**Figure 1**  
Annual diving fatalities in New Zealand



**Figure 2**  
Number of fatalities by age group and type of diving



**Results**

The majority of cases listed ‘drowning’ as the main cause of death. Drownbase™ provided 45 cases of diving-related fatalities from 2000 to 2006 inclusive. Individual deaths included in Drownbase™ must be due to drowning, as concluded by the Coroner, otherwise they are discarded. Of the 45, 28 were scuba divers, 14 snorkel divers, and 3 classified as free divers. For example, a cause of death of arterial gas embolism would not be included in Drownbase™. The case of one 59-year-old snorkel diver was discarded by the author because, although he intended to go snorkelling, he was found dead above the high-water mark (a coroner’s inquest was not held). Further information was obtained from the Accident Investigator for the NZUA (Taylor L, personal communication, 2006), who had identified eight scuba diver deaths that were not listed in Drownbase™. The National Police Dive Squad formally investigates deaths if the body is found. Their reports were reviewed for additional information on individual cases. A further four scuba divers were identified from police and media records. In total, 40 scuba diver and 16 breath-hold diver fatalities were identified for the period 1 January 2000 to 31 December 2006.

18 to 78 years). Only five (12.5%) of the scuba divers were female (case numbers SC 00-03, SC 00-04, SC 03-06, SC 03-12, SC 05-01), and all breath-hold divers were male.

Thirty (75%) of the scuba divers were of European ethnicity, and of the other 10, seven were Maori, one Polynesian islander, one Japanese, and one was not defined. However, amongst the breath-hold divers the majority (nine, 56%) were Maori. All diving fatalities occurred in the sea. The geographical regions in which deaths occurred are shown in Figure 3.

**DIVING EXPERIENCE**

Of the scuba divers, 20 (50%) were inexperienced, using the criteria of less than two years’ diving.<sup>1</sup> No internationally agreed definition of experience exists. Dive-training certification was confirmed or highly likely for 31 divers, and not available for six. The remaining three divers were untrained. Although some divers had been certified for many years, the infrequency of their diving put them at greater risk.

**NUMBER OF FATALITIES**

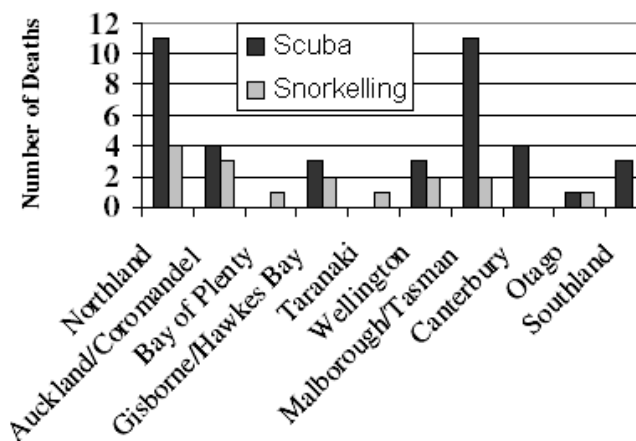
For scuba diving the number of fatalities each year ranged between 2 and 12 divers, with a mean of 5.7. Breath-hold diver deaths were steady between 1 and 4 per year (mean 2.3, Figure 1).

**DEMOGRAPHICS**

The snorkelling group combines snorkellers and free divers, as the use of these terms was poorly defined, the majority of snorkellers being seafood collectors with some incorporating free diving in the process. The age groupings of the fatalities are shown in Figure 2.

The mean age of the scuba divers was 39.6 years (range 21 to 69 years), and of the breath-hold divers 42.9 years (range

**Figure 3**  
Fatalities by geographic region of New Zealand



## SCUBA DIVING PRACTICES

All the cases involved open-circuit air breathing except for one technical diver (SC 05-05) using closed-circuit rebreather apparatus. There were no fatalities in divers using surface-supplied breathing apparatus (SSBA).

Of the 40 scuba divers, 11 were solo divers, and in 13 other cases buddy separation had occurred, that is, only 16 (40%) were following standard safe diving practice and diving with a buddy at the time of the accident. Seafood collection was the main reason for scuba diving, and would be a factor in buddy separation or the choice to dive solo. Four of the divers were wreck diving, including two female tourists on dive charters.

Three divers were documented to have run out of cylinder air. This may have been a factor in other cases as the assessment of cylinders is dependent on their early retrieval and inspection by experienced divers or the police. Only one diver had released their weight belt and four divers were overweighted.

Death was related to dangerous sea currents in the triple fatality in 2000 (SC 00-01, SC 00-02, SC 00-03), and in the death of SC 05-06. In another case (SC 00-07) the sea swell is likely to have caused one diver to sustain a head injury on rocks and drown; exhaustion due to the swell would be a contributing factor in several other deaths due to drowning, especially shore-based dives.

## BREATH-HOLD DIVING PRACTICES

Solo diving was a common factor in the 16 deaths in this group. Seafood collection was the reason for breath-hold diving in 14 of the cases, and drowning was the universal autopsy finding and coroner's verdict. In four cases it is likely that underlying cardiac disease contributed to the death. In one case (BH 04-02) an epileptic seizure is the

probable cause of drowning. One diver was struck by a boat, which resulted in loss of consciousness due to head injury and subsequent drowning; another appears to have sustained a head injury on rocks in rough seas and drowned. Two cases of hypoxic blackout, aggravated by previous hyperventilation or ascent, occurred with drowning.

## RESCUE AND RESUSCITATION

Rescue and resuscitative efforts are difficult to quantify and interpret. Vigorous and prolonged basic cardiopulmonary resuscitation (CPR) was performed on some cases; in one other case no resuscitation efforts were made despite timely retrieval onto the boat.

## AUTOPSY PROCEDURES

Five bodies of scuba divers were not found. In a further three cases there were delays of 12 hours or more in body recovery, thereby limiting autopsy findings due to decomposition and to tissue erosion by sea creatures, such as sea lice. Most of the autopsies appeared to follow the guidelines of the Royal College of Pathologists of Australia, although this was not specified. Those performed in the major cities were done by specialist forensic pathologists. The pre-autopsy use of CT imaging versus plain radiography versus no imaging probably reflects the ready availability of the service; it is site dependent.

## CAUSES OF DEATH

Of the 40 scuba diving deaths, 12 (30%) had significant medical conditions that may have disqualified them from diving (Table 1). Another experienced diver had evidence of myocarditis on autopsy implying sudden cardiac death as a cause (coroner's inquest yet to be held). Arterial gas embolism was recorded as the cause of death in nine cases, with a possible tenth case (SC 02-01 – delay in body recovery).

**Table 1**  
**Scuba divers with clinically significant pre-existing medical conditions**

CASE	Age	Medical condition
00-04	58	Neurologic – recent unexplained syncopal episode
00-06	29	Respiratory – old tuberculosis and dense pleural adhesions
01-03	47	Neurologic – massive cerebrovascular accident
02-02	68	Cardiac – coronary artery disease, type 2 diabetes mellitus
02-03	34	Cardiac – cardiomegaly, myocarditis, coronary artery disease
03-03	69	Cardiac – coronary artery disease
03-04	30	Gastro-intestinal – Crohns disease, on medication
03-07	34	Cardiac – severe coronary artery disease
03-09	41	Cardiac – coronary artery disease
05-01	53	Neurologic – migraine medication (sustained gastric rupture)
05-03	55	Cardiac – symptomatic coronary artery disease 6 years
06-03	53	Respiratory – pleural adhesions; also patent foramen ovale

Two divers died from severe head injury sustained when struck by boats – one was a scuba diver, the other a breath-hold diver, but neither had a visible ‘diver below’ flag or a buddy. One experienced diver was killed when struck by the tail of a whale. Another diver died from carbon-monoxide contamination of his air cylinder.

#### **Fatality case summaries: scuba diving**

##### **SC 00-01, SC 00-02, SC 00-03**

Triple scuba diving fatality, students on a Master Diver course attempting a 30 msw drift dive rapidly dragged in a strong ebb tide to 92 metres’ sea water (msw).

Cause of death: Massive arterial gas embolism and drowning in two cases; third deceased not recovered, presumed accidental drowning.

This tragedy, in which, as well as the three deaths, three of four survivors suffered decompression sickness, will be the subject of a separate detailed report as it was by far the worst diving accident in New Zealand diving history.

##### **SC 00-04**

Poorly conditioned diver with a medical history of chest pain and a unexplained syncopal episode, drowned after a sudden loss of consciousness at a depth of 18 msw.

Cause of death: Unexplained loss of consciousness resulting in salt-water aspiration and drowning, with arterial gas embolism secondary to pulmonary barotrauma sustained during a rescue ascent.

This 58-year-old female had a history of chest pains associated with breathlessness and a previous episode of syncope in a pool approximately one year earlier (possible transient ischaemic attack). She was an inexperienced diver, on her ninth dive since completing her open water diver certificate, although a competent swimmer. With an experienced dive buddy and in calm sea conditions, she initially was underweighted and they ascended from 6 msw to add more weight, then descended again. At 18 msw her buddy noted her regulator appeared partially dislodged and then twice fell out of her mouth. She stopped swimming, and appeared to cease breathing, with a small stream of bubbles exiting past the mouthpiece. Her buddy inflated her buoyancy compensator device (BCD) and brought her to the surface. Resuscitation was attempted. CT imaging prior to autopsy showed widespread cerebral and systemic vascular air embolism. Autopsy showed aspiration of sea water and widespread gas embolism from pulmonary barotrauma. Her equipment was in good condition.

##### **SC 00-05**

Experienced diver in good condition, apparent drowning soon after ascent.

Cause of death: Arterial gas embolism.

This healthy, 49-year-old male with 25 years of diving experience had not dived recently. He was on a dive charter boat in calm conditions. His buddy was his 14-year-old son,

inexperienced and on his first dive since gaining his open water certificate. Diving as part of a group of six divers, they decided to ascend after one diver ran low on air. The deceased still had 1,150 psi of air in his tank. Upon surfacing, they started to swim into the current towards the boat but soon were tired and initially had to rest on the rocks. The deceased was slower and buddy separation occurred. The deceased was found floating face down in the sea without his mask and snorkel. Weight belt was still worn. After a difficult retrieval, no pulse was palpable but no resuscitation attempt was made (doctor and nurse present). CT imaging prior to autopsy the next day showed probable gas embolism.

Autopsy showed arterial gas embolism of the right carotid artery and aorta. Lungs were congested. Police inspection of the diver’s equipment found no faults. The Coroner noted the lack of resuscitation efforts and proper seamanship (the skipper had also dived, leaving the boat in the control of an unqualified person).

##### **SC 00-06**

Inexperienced student, first dive since open water course, using hire dive gear, history of lung disease.

Cause of death: Drowning.

This 29-year-old male had limited English and had completed an open water course in New Zealand two months earlier. He had a history of pulmonary tuberculosis as an infant. However, his dive medical was not written in English and he had not documented his history of lung disease. With an experienced buddy, this was his first dive since his course. They planned to dive to 15 msw depth. Three to five minutes after descent the deceased inflated his BCD and rapidly ascended despite efforts by his buddy to slow his ascent. He complained that his mouthpiece was leaking water and he had difficulty clearing it. His buddy surfaced and checked the regulator but found it functioning normally. The deceased switched to using his spare regulator, but appeared uncomfortable with the placement and required his buddy to show him how to place the mouthpiece into his mouth. The deceased wanted to rest for five minutes before they descended again. As with the first descent, the deceased was too buoyant and required his buddy to assist him to descend through the first 2 msw. On the bottom, at a maximum depth of 15 msw, they signalled ‘OK’ to each other and started exploring for seafood. Regular buddy checks were done. About 15 minutes into the dive, the buddy, who was leading the dive, could not see the deceased. Within a maximum time of 15 seconds he then located him in an unconscious state, lying on his side on the bottom. His regulator mouthpiece was not in his mouth, and bubbles were being expelled. The buddy tried to insert his own mouthpiece and spare mouthpiece into the deceased’s mouth but trismus prevented this. He ascended rapidly dragging the victim with him. On surfacing, the victim was unresponsive and making gurgling noises. CPR was immediately attempted but not effective. On shore, with the aid of passing travellers, CPR was continued for 30 minutes until a local doctor confirmed his death.

Autopsy showed dense old adhesions obliterating the right pleural cavity, with right upper lobe volume reduced. Both lungs were consistent with drowning. Microscopy showed localised barotrauma with interstitial emphysema in the right upper lobe only.

Police inspection of his equipment found no faults. His weight belt (9.7 kg) was not dropped during the rescue. The computer showed a rapid ascent warning.

#### SC 00-07

Well-conditioned diver in rough sea conditions who sustained a closed head injury and probable loss of consciousness leading to drowning. Shore dive.

Cause of death: Drowning secondary to a closed head injury.

This 32-year-old male was undertaking a shore dive with a buddy. He possibly had a history of untreated high blood pressure. The sea conditions were poor. Shortly after entering the water the pair decided to abort the dive due to poor visibility and rough swell. During the swim to shore they became separated by a line of rocks. The deceased was seen about 60 m from shore, floating face down and unresponsive. A local resident retrieved the deceased who was found with his mask off and scuba equipment floating beside his left leg. Once on shore, CPR was unsuccessful.

Autopsy showed a left-sided head injury with an 8 cm deep scalp contusion and skull fractures of the parietal bone and base of skull. He had associated facial abrasions. The Coroner noted the lack of regulation regarding teaching of CPR during scuba diver training and the importance of the buddy system. No equipment faults were identified.

#### SC 00-08

Well-conditioned, experienced diver in a group searching for seafood.

Cause of death: Uncertain – body not recovered.

This 33-year-old male had obtained a PADI Advanced Diver Certificate three months earlier and dived regularly since. He was on a club boat trip with eight other divers. On the trip back from the main dive site, four of the divers dived for scallops at 22 msw. Three divers, including the deceased, dived together. During the 30-minute dive, the deceased appeared "OK". He had passed his catch bag to a buddy for tying to a float line, and signalled he was ascending. The remaining air in their tanks was sufficient for a controlled ascent. The deceased did not surface. A surface search was undertaken and a call for assistance was made after 55 minutes. The body was never recovered. The police report noted poor logging of the details of previous dives by the club members, the failure to mark the place of the dive (the float had been retrieved), and the delay in alerting search and rescue services. From the information available the dives undertaken that day would have necessitated decompression stops, raising the possible scenario that decompression

illness could have occurred. He was using equipment only seven months old.

#### SC 01-01

Well-conditioned diver, ascent from scallop dive, swimming back to boat, then loss of consciousness, dive cylinder empty.

Cause of death: Arterial gas embolism.

This healthy, 40-year-old male was an experienced diver. He was diving with a buddy for scallops. His ascent to the surface appeared trouble free, but he then lost consciousness within a few minutes. On inspection his tank was empty.

No autopsy report was available, however the Coronial Index registration states the cause and circumstances of death as '*cerebral arterial gas embolism which happened either whilst diving or immediately after surfacing from diving*'.

#### SC 01-02

Experience diver with cerebrovascular disease on medication.

Cause of death: Massive brain infarction secondary to severe atherosclerosis.

This 47-year-old experienced diver had a past medical history from his general practitioner indicated that he likely suffered transient ischaemic attacks for over two years prior to his death. He was treated for hypertension, but medication (felodipine, inhibace, aspirin) compliance was variable. He was an ex-smoker. He had a family history (father) of cerebrovascular disease. Four months earlier he had been seen by a neurologist and an MRI was requested, but he missed the appointment. On this dive he was accompanied by three other people, but diving solo. He was diving to a depth of 25 msw for about 15 to 20 minutes and apparently ran out of air. He surfaced, swam back to the boat and initially appeared well but then deteriorated on board. He was transported to hospital and underwent recompression treatment, but died three days later. A CT scan of his brain showed new infarctions and an old cerebrovascular accident. Autopsy showed severe brain infarction secondary to pre-existing severe atherosclerosis. Death was most likely due to stroke secondary to atherosclerosis rather than cerebral arterial gas embolism. His equipment was poorly maintained. His BCD was old (pre-1985) without an automatic over-pressure valve. His dive cylinder was out of date, with a worn O-ring. He was not overweighted (8.7 kg).

#### SC 02-01

Experienced diver, no buddy, descended to 30 msw to free an anchor, but did not surface, body found four days later.

Cause of death: Drowning, possible barotrauma.

This healthy, 35-year-old male was experienced (PADI Advanced Open Water, 1993). His near-new equipment was purchased in November 2001, but on the fatal dive he had a borrowed weight belt and was overweighted

(12 kg). His computer was not turned on for these dives but when analysed the log showed he had violated ascent rates on all previous dives. He was diving alone. This day he wanted to retrieve his boat anchor lost the day before. He undertook several descents, surfacing after 10 minutes to get a speargun, then returning it to the boat and diving for another 10 minutes to 22–24 msw to successfully find his lost anchor rope. Then he descended again to free the snagged anchor of a neighbouring boat at 31 msw depth. He did not surface. The body was found at depth four days later by a search-and-rescue team. He was still wearing all of his equipment. His autopsy showed drowning but decomposition prevented definitive diagnosis of barotrauma and gas embolism. The police report confirmed he was overweighted, had probably run out of air, had a history of rapid ascents and unsafe diving practices (including previously running out of air), and was at increased risk of decompression illness. He did not release his weight belt. The Coroner emphasised the complacency and human error in this case.

#### SC 02-02

Experienced diver, not dived for five years, poorly maintained equipment, solo dive, recent treatment for cardiac disease. Cause of death: Arterial gas embolism.

This 64-year-old male reportedly had 15 to 20 years of diving experience, but had not dived in the past five years. He was on medication, including metformin for type 2 diabetes mellitus, and simvastatin for dyslipidaemia. On this dive, he was with two other divers, but was solo diving to 13 msw for 23 minutes. His equipment was poor, with the BCD missing a toggle from the rear dump valve, putting him at risk of rapid ascent. He was seen by the boatman to surface, dive again, and resurface three minutes later in an unresponsive state. He had not jettisoned his weight belt. Resuscitation was attempted with the deceased still in the water. He was retrieved into the boat with difficulty once the other divers returned after 5–10 minutes. Unsuccessful CPR continued until after they reached the shore. He had not run out of air (tank pressure 1,400 psi).

Cause of death at autopsy was arterial gas embolism; the lungs were heavy and drowning was likely to be a factor. The coroner's report emphasised the need for regular servicing of equipment, maintaining skills and diving with a buddy.

#### SC 02-03

Solo diving for seafood, shallow water.

Cause of death: Drowning, patchy myocarditis at autopsy, coronary artery disease and cardiomegaly.

This 34-year-old male was solo diving for seafood in shallow water. He was of large build. His equipment was poorly serviced ("second-hand"), and in cold water he wore a short 3 mm wetsuit and no hood. He was diving for 40 minutes to a maximum depth of 4 msw; he then returned to shore with his catch. On returning to the water he soon got into difficulties. He disappeared below the surface,

and was rescued by a snorkel diver who had witnessed his distress. He was unconscious on retrieval from a depth of 1 msw. Resuscitation was attempted. Autopsy showed drowning, coronary artery disease (50% narrowing of the proximal left anterior descending coronary artery), patchy myocarditis, and cardiomegaly (540 g). Police inspection of his BCD showed it to be old and malfunctioning. He had been overweighted (14.5 kg).

The Coroner emphasised the need for regular medical assessments and servicing of equipment.

#### SC 02-04

Inexperienced diver, at depth of 32 msw, panic, rapid ascent.

Cause of death: Arterial gas embolism.

This healthy, 40-year-old, inexperienced male was diving in calm conditions with eight other divers, two being instructors. He was dive certified in 2000 but had completed only 11 scuba dives in total. He had dived twice the previous day, within decompression limits. After approximately 15 minutes at 27 msw he indicated he had a problem and showed the others his gauges. He had 900 psi of air pressure. He appeared agitated and spat out his regulator mouthpiece. He would not accept a spare regulator from a buddy or an instructor. His mask was full of water and he pulled it away from his face, consistent with panic. Other divers attempted to inflate his BCD but it seemed to be full already. A dive instructor attempted to ascend with the deceased, during which she tried to place her spare regulator in his mouth and operate it. Part way to the surface the deceased and the instructor parted, with the deceased sinking towards the bottom again. At 16 to 20 msw he was caught by two other divers. He had no regulator in his mouth. His weight belt was released and he was brought to the surface. Once on the boat, CPR was started. Some response occurred with a few spontaneous breaths, vomiting and possibly a palpable pulse, but ultimately resuscitation was unsuccessful.

CT imaging prior to autopsy showed cerebral and systemic gas embolism. Autopsy showed pulmonary and systemic gas embolism. Police inspection of his equipment showed that his regulator free flowed easily, and his BCD had a faulty dump valve with two other valves functioning normally. His tank contained 750 psi pressure. He was overweighted with 17 to 20 kg on previous dives.

#### SC 03-01

Poorly conditioned, uncertified diver, shore dive, no BCD, out of air, exhaustion and panic on swim back to shore.

Cause of death: Asphyxia secondary to drowning.

This healthy, 35-year-old male had stated to his buddy that he had over 20 years of diving experience. His buddy was experienced. They intended to dive for crayfish. He borrowed regulators, two full dive tanks, back pack and weight belt. Importantly he did not have a BCD. The borrowed

regulators had been 'recently serviced' according to the lender. Pre-dive, the deceased and his buddy checked their equipment. Despite the disapproval of the buddy diver, the deceased threaded his weight belt through his back pack. Sea conditions were a half-incoming tide, no big swell, little wind and overcast sky. Water visibility was 5 to 8 m. The first dive to a maximum depth of 9 msw was uneventful. They rested for half an hour, then re-entered the water with full tanks at 2030 hr. They descended and swam out to a wreck at 6 msw depth, 80 m from shore. After 20 minutes underwater the buddy had 1,800 psi remaining, and the deceased 1,200 psi. They commenced swimming back to shore. The deceased gave a 'low on air' signal, so his buddy gave him his second regulator. They surfaced from 6 msw depth as the buddy's air supply finished. The buddy had his BCD to give positive buoyancy, whereas the deceased had no BCD. With the shore about 100 m away, the deceased rapidly found it hard to swim. Despite being aided by his buddy, who released his own weight belt and helped to support him with his BCD, both were exhausted within 8–10 minutes and were still 50–70 m from shore. The deceased panicked and had his knife in his hand on a lanyard, putting the buddy at risk of injury. The buddy tried to calm him and jettison his tank, but the deceased was lunging with the knife. They separated, and the buddy made it to shore exhausted. The alarm was raised with the police and Coastguard at 2130 hr, now dusk. Two boats were sent to the scene, and conditions by that time were quite rough with a heavy swell, and an ebb tide. The body was retrieved 100 m from shore by boat at 2152 hr. Resuscitation attempts were unsuccessful.

Autopsy gave a cause of death of asphyxia from drowning. His BMI was 36.5 kg.m<sup>-2</sup>. No alcohol was present but he had a blood tetrahydrocannabinol level of 1.5 mcg.L<sup>-1</sup> (significance not determinable) consistent with smoking a cannabis cigarette 1 to 12 hours earlier. Police inspection of his equipment confirmed that it was very substandard. His tank was empty. The back pack still had weights attached but his weight belt had been released. He was probably overweighted (13 kg). His regulator was old, modified and in need of servicing as it free flowed. His fins were old and not designed for scuba diving. His wetsuit was also old and unsuitable for the cold-water conditions. The Coroner noted the many errors of planning and judgement.

#### SC 03-02

Solo diving for seafood, shore dive, heavy weight belt, cylinder detached from BCD, possible asthma, called for help but not found.

Cause of death: Drowning.

This 28-year-old male was inexperienced; he had been certified in 2000 but had not dived for 18 months. He had a medical history of productive cough and use of an anti-asthma inhaler. He was a non-smoker. He had near-new equipment. He was diving with others for seafood but solo at the time of the incident. On his computer a maximum depth

of 7.3 msw was logged. The sea conditions were rough. He was seen approximately 30 m from shore. Two calls for help were heard by family members on shore but he could not be located. Police and search-and-rescue personnel were mobilised, and five hours later his body was found amongst kelp but not entangled. The tank had come loose from his BCD and harness.

Autopsy showed asphyxia from drowning in association with mild chronic bronchitis. His BMI was 31 kg.m<sup>-2</sup>. Police inspection of his equipment confirmed its good condition, including that of his drysuit. His tank still contained 600 psi of air pressure. His computer showed he had not violated dive limits. However, he was overweighted.

#### SC 03-03

Solo diver in shallow water, found deceased, weight belt discarded.

Cause of death: Ischaemic heart disease associated with atherosclerotic coronary vascular disease.

This 69-year-old male had 20 years of diving experience "off and on"; no record of certification could be found. He had a past medical history of hypertension and type 2 diabetes mellitus, and was on oral medication (metformin, diamicon, felodipine). He was separated from his buddy, diving for shellfish in shallow water (3 msw). After 15 minutes his buddy found the deceased's weight belt (5.4 kg) and mask on the seafloor and on surfacing found him floating unconscious. CPR was unsuccessful.

Autopsy confirmed coronary artery disease as the cause of death. Police inspection of his dive equipment showed it was old but had no faults.

#### SC 03-04

Experienced, diving for seafood with buddies, buddy separation.

Cause of death: Not confirmed – body recovered after nine months.

This 30-year-old male was experienced, diving in the same area over the previous five years. At the time he was well conditioned, although he had a past history of Crohn's disease with an exacerbation 11 months earlier requiring long-term immunosuppressive treatment. With four other divers, he was searching in calm water for crayfish. They dived to 27 msw then ascended to 15–18 msw. His buddy ran low on air and surfaced, leading to buddy separation. The deceased's bubbles were tracked for about 15 minutes, and then those on the boat concentrated on picking up the other divers who had surfaced. The deceased did not surface and no trace was apparent. Search and rescue was initiated but not successful. Nine months later his body was found at 28 msw depth. Autopsy could not confirm the cause of death. From the position of his body under a rock it is possible he was attempting to catch a crayfish and ran into difficulty.

**SC 03-05**

Diving for seafood, out of air.

Cause of death: Hypoxic brain injury.

This healthy, 32-year-old male was inexperienced, having completed his PADI open water dive training the previous day. He was on a dive charter with ten other divers to collect oysters. The sea conditions were good. He dived with his buddy to a maximum of 22 msw, but mostly at 16 msw, with good visibility. The duration of the dive was 20 minutes. They ascended as they were low on air, during which time the deceased dropped his catch bag. On surfacing the buddy found that the deceased had not surfaced. He was retrieved from the seabed at 15 msw, and CPR commenced. He was transported to the regional hyperbaric unit but died the next day.

Autopsy showed hypoxic brain injury. Police inspection confirmed the equipment was new and that the cylinder was empty.

**SC 03-06**

Inexperienced, obese, certified diver, wreck diving, loss of consciousness at 22 msw, overweighted.

Cause of death: Pulmonary barotrauma, unexplained episodes of brain ischaemia.

This healthy, 23-year-old female had obtained her open water certificate two years earlier but apparently had not dived since. She was with 10 other divers and two instructors. Prior to the dive, she successfully completed a diving knowledge review test and a PADI document on safe diving practices. During the trip to the dive site, she had mentioned to a fellow diver that she felt slightly seasick, but she did not vomit. In good sea conditions, about 20 minutes into the dive, she was seen to be slowly sinking at 22 msw depth and when attended by an instructor she appeared unresponsive and not breathing. Her regulator had to be held in her mouth and was purged. She was brought to the surface (9–11 metres per minute as logged on her computer, although its alarm indicated this rate was exceeded for a short time) with manual breaths being initiated by the rescuer. She was lifted into the boat and had a palpable pulse. Her airway was cleared and she appeared to respond by squeezing the hand of an attendant. Oxygen was supplied. During transport back to land she deteriorated, appearing to 'swell up', and spontaneous breathing ceased. CPR was initiated, to which she responded with spontaneous respiration after about five minutes. However, after approximately 10 minutes she ceased breathing again. On shore, she was attended by paramedics, and transferred to the base hospital by helicopter. Advanced resuscitation was undertaken, including intubation, left intercostal catheter insertion, and inotropic support. She died en route to tertiary hospital care.

Chest X-ray prior to autopsy showed massive surgical emphysema; skull X-ray did not demonstrate intravascular gas. Autopsy showed changes due to shock, resuscitation

and pulmonary barotrauma. The histology of her brain showed signs of global hypoxia/ischaemia, probably 5–10 days previously, suggesting recurrent events leading to the final episode of syncope. The possibility of a dysrhythmia such as long QT syndrome was raised. Her BMI was 38.2 kg.m<sup>-2</sup> (weight 86 kg, height 1.50 m). No hire equipment faults were identified. She had been overweighted (14 kg). Air pressure remaining was approximately 1,000 psi.

**SC 03-07**

Poorly experienced, significant cardiac disease, mask leak and rapid ascent.

Cause of death: Left ventricular failure caused by severe coronary artery disease; arterial gas embolism.

This 34-year-old male was dive certified one year earlier. For his dive medical examination he was referred to a cardiologist because of dyslipidaemia, mild hypertension, and a strong family history of ischaemic heart disease (a brother had a myocardial infarct at age 35 years). He was treated for his risk factors, but did not have further investigations such as an exercise ECG test. He had logged 91 dives. He was on a dive charter and dived with a buddy to 16.7 msw for a duration of 8 minutes. The water visibility was 3 m. At the seafloor, his mask leaked and, despite help from his buddy, he elected to surface. He surfaced rapidly and boarded the boat. His condition deteriorated and he had a cardiorespiratory arrest. Despite CPR, he died before the boat reached shore. Autopsy showed pulmonary oedema and severe multivessel coronary artery disease, with his left anterior descending coronary artery greater than 90% occluded and the right coronary artery totally occluded. He had scarring from an old posterior myocardial infarct. He also had systemic arterial gas embolism. His weight was 79.5 kg, height 1.72 m (BMI 27 kg.m<sup>-2</sup>). No faults were identified on police inspection of his equipment; his computer logged an ascent violation.

**SC 03-08**

Experienced diver, struck by the tail of a whale.

Cause of death: Presumed injuries or drowning.

This healthy, 38-year-old, experienced, certified diver died while attempting to free a humpback whale entangled in the rope of a craypot. The sudden forceful slapping of the tail fluke impacted on the area of water in which the diver was last seen and he did not resurface. His body was not recovered.

**SC 03-09**

Inexperienced, uncertified, solo diver, undiagnosed coronary artery disease.

Cause of death: Coronary artery disease.

This 41-year-old male was inexperienced and not certified, although he had his own equipment. He had a history of dyslipidaemia, but had had no dive medical examination performed. The previous night he had consumed alcohol and



cannabis. In calm conditions, he dived solo to a depth of about 5 msw, and after 20 minutes surfaced. He appeared exhausted to his shore companion as he hauled himself onto a rock 10 metres away. During his swim back to shore, he called for help and became unconscious; his companion pulled him from waist-deep water. Resuscitation by emergency services was not successful. Autopsy showed he had likely died from coronary artery disease. Inspection of his equipment showed it was old but functioned adequately.

#### SC 03-10

Inexperienced, certified diver on a group trip, buddy separation, overweighted, found two hours later.

Cause of death: Drowning.

This healthy, 27-year-old male was one of 14 divers on a boat trip; five of the divers were completing a rescue diver course. He had completed a PADI open water course 14–18 months earlier in 2002, but had dived only about four times since then. His buddy was also inexperienced. In calm conditions, they dived to 11 msw where the buddy had a fin problem and ascended, resulting in separation. It was another 70 minutes before the alarm was raised that the deceased was missing and a search was initiated. Two divers from another boat found his body in 19 msw. The weight belt (13 kg) was still worn, but his mask was missing and his regulator out of his mouth. His tank had slipped down the back pack. Autopsy showed drowning had occurred. Police inspection of his hire equipment showed no faults; there was approximately 2,500 psi remaining tank pressure (giving an approximate dive time of five minutes). He was overweighted with a 13 kg weight belt.

#### SC 03-11

Experienced but infrequent diver, buddy separation.

Cause of death: Uncertain – body not recovered.

This 35-year-old male was an experienced diver but had not dived in the past year. In good conditions, he was on a dive for crayfish with buddies and was last seen at 5 msw clinging to the boat anchor chain. He signalled he was ascending because of a “gear problem”. His buddies continued with the dive to 22 msw, and after surfacing 20 minutes later they found that the diver was not in the boat. An extensive search by boats and helicopter for five hours failed to find him. His equipment was near new.

#### SC 03-12

Well-conditioned, certified but inexperienced and infrequent diver, buddy separation, rapid descent as negatively buoyant, ill-fitting fins which came off.

Cause of death: Drowning.

This healthy, 40-year-old female was an infrequent diver since obtaining her PADI open water certification in 1989, having scuba dived only 30 times and not in the preceding six years. Diving with an experienced buddy in good conditions, she used borrowed equipment. No buoyancy check was

done. She was seen to descend rapidly from the boat, but her buddy decided to return to the surface from 1.5 msw to get his gloves. He had not communicated with the deceased and buddy separation occurred. No air bubbles indicative of her position were seen by the boatman. A few minutes thereafter her fins floated to the surface. She was found unresponsive on the seabed at 7 msw by a pair of divers who had come to assist in her search. She was still wearing her mask and weight belt, her BCD was not inflated and her regulator was out of her mouth. She was not entangled. Attempt at resuscitation is not known. Autopsy showed drowning. Police inspection of her equipment showed 3,000 psi of cylinder pressure. Her fins were too large for her. There were no equipment faults, but she was overweighted. She probably panicked and did not release her weight belt.

#### SC 04-01

Experienced solo diver, collecting seafood, hit by a boat when surfacing.

Cause of death: Severe head injury (from a boat propeller).

This healthy, 46-year-old male was experienced and diving in calm sea conditions. He had been diving with two other divers, but was diving solo for scallops at 20 msw. A boat motored over the area in which he was diving and he sustained a severe open head injury causing death. The ‘diver below’ flag was not visible to the skipper of the launch. Autopsy confirmed unsurvivable open head injuries.

#### SC 04-02

Experienced solo diver, failed to surface.

Cause of death: Asphyxia due to carbon-monoxide poisoning.

This healthy, 35-year-old male was an experienced diver. He was diving alone, telling his boatman he would be diving for only 15 minutes, but he failed to surface. He was found at 9 msw the following day. Autopsy was limited by decomposition and damage from sea lice. Police inspection of his equipment showed a cylinder air pressure of 2,850 psi. The carbon-monoxide analysis was 13,600 +/- 300 parts per million (NZ and British Standards require less than 10 parts per million). Also there were increased levels of carbon dioxide and methane. A second cylinder owned by the deceased and filled at the same dive shop returned a similar analysis. He was overweighted (17.5 kg) and had not released his weight belt. His other equipment had no faults. The Coroner stated that death was due to asphyxia due to his cylinder gas being contaminated with carbon monoxide, “*brought about by an idiosyncratic malfunction of the air-compressing equipment*”.

#### SC 05-01

Tourist, inexperienced diver with medical problems.

Cause of death: Gastric rupture and arterial gas embolism.

This 53-year-old female passed a PADI advanced open

water course in 2004 and had logged 18 scuba dives while in Australia. She had a medical history of previously treated hypertension, dyslipidaemia, and migraine headache (medicated with sumatriptan and prochlorperazine). She took diclofenac for osteoarthritis of an ankle. She was on a guided wreck dive by boat in calm sea conditions. She was with a buddy, another pair of divers and their instructor. She dived to a maximum of 26.5 msw for 24 minutes. During ascent up the shot line to the 5 msw decompression stop, the deceased continued to ascend and was grabbed by her buddy. While decompressing at 5 msw she became unresponsive. She was retrieved onto the boat and CPR was commenced. Resuscitation was unsuccessful and ceased once a paramedic had arrived by helicopter. Prior to autopsy, CT imaging showed significant cerebral and systemic intravascular gas. She had a severe pneumoperitoneum caused by rupture of the stomach, causing upward displacement of the diaphragm. Autopsy showed a 55 mm laceration of the lesser curvature of the stomach. Multiple rib fractures and sternal fracture secondary to CPR were present. Moderate coronary artery atherosclerosis was present. Police inspection of her equipment showed 1,000 psi in her cylinder and no faults.

#### SC 05-02

Inexperienced, uncertified, solo diver, rapid ascent.  
Cause of death: Cerebral arterial gas embolism.

This healthy, 27-year-old man was inexperienced, and not certified (he had failed to complete a PADI open water dive course three months earlier). With borrowed diving equipment he dived alone on a wreck in calm sea conditions. His companion, a female, non-diving partner, remained on their boat. He consumed one beer, a pie and a cigarette half to one hour before the dive. At the dive site he was seen to descend but then surfaced after 10–20 minutes and called for assistance in a distressed state. He lost consciousness, and it took 10 minutes to retrieve him onto the boat with the aid of other boaties. Resuscitation was commenced and he survived to hospital but died four days later. Autopsy findings were cerebral arterial gas embolism secondary to pulmonary barotrauma. A small flap-competent atrial septal defect was found. Police inspection of his borrowed equipment showed a regulator defect with the second stage needing servicing as it was hard to breathe through. The maximum depth on his gauge was 12 msw, although the police inspection report suggested it was probable that he had descended to 25 msw and consumed all his air without locating the wreck he was searching for and then panicked. His cylinder was empty. He had not released his weight belt.

#### SC 05-03

Experienced, solo diver with a history of heart disease.  
Cause of death: Drowning secondary to probable cardiac dysrhythmia. Coronary artery disease.

This 57-year-old male was an experienced diver, first certified in 1984. He had a medical history of angina going back to 1997, for which he regularly visited a cardiologist

and had been assessed as having mild coronary artery disease and dyslipidaemia. He was on a six-day boat trip with other divers. The sea conditions were flat calm with good visibility and water temperature of 9°C. The deceased was last to enter the water, his buddy had already descended. He was first to surface 14 minutes later and was seen kicking towards the shore. The other divers surfaced and were picked up by the boat. The deceased was then seen floating motionless on his back; his BCD was inflated, mask on, and weight belt still worn. His catch bag floated nearby. He was blue with froth at his mouth. He was retrieved onto the boat using a cage due to his size. CPR was commenced and emergency services attended by helicopter, but he had died. Autopsy showed a moderately enlarged heart (460 g) with 75% stenosis of the right coronary artery and 70% stenosis of the left anterior descending coronary artery. His lungs were heavy due to drowning, with evidence of gastric aspiration. His weight was 109 kg, height 1.85 m (BMI 32 kg.m<sup>-2</sup>).

#### SC 05-04

Experienced diver with buddy, dragged deep in current.  
Cause of death: Uncertain – body not recovered.

This 43-year-old male was PADI Advanced Open Water certified three years earlier, and passed specialty dive courses on his way to completing over 100 dives. He was on medication for dyslipidaemia but otherwise well. He was a member of a dive boat charter group and the previous day had completed two dives. He was diving for crayfish in an area known for its treacherous waters; two years earlier two scuba divers went missing but were found alive many hours later. The site was said to be safe for diving at low tide, for 15 to 20 minutes only. The weather was good with a slight breeze of 10–15 knots and good water visibility. In the morning the divers completed one dive on a shipwreck. They then travelled to another site. The deceased and his buddy dived to 33 msw, then ascended to 24–26 msw because of the current. After 12 minutes they were ascending to the surface when they were suddenly dragged deep in a turbulent current to between 50 and 64 msw. The buddy released his weight belt and inflated his BCD in order to ascend to the surface but the deceased did not surface. An extensive search for his body was unsuccessful. His buddy required retrieval for treatment of decompression sickness.

#### SC 05-05

Experienced, solo diver using rebreather apparatus.  
Cause of death: Hypoxia, hyperoxia or hypercapnia, possibly followed by drowning.

This experienced, 48-year-old male was on a boat trip with other divers. He was first certified in 1997 and had passed advanced diving courses, including being trained in the use of his 'Buddy Inspiration' rebreather equipment. He had no past medical history. He dived solo to 'test dive' his new drysuit and collect mussels for fishing. Fifty minutes later he had not resurfaced and a search by his companions found his body at 15 msw. He had not released his weight belt (5.3

kg). An unsubstantiated report suggests he may not have turned on the oxygen supply to his rebreather.

#### SC 05-06

Buddy separation.

Cause of death: Uncertain – body not recovered.

This 44-year-old male was an experienced diver. He had no past medical history. He was diving with four others. Buddy separation occurred and he did not resurface. His body was never recovered despite an extensive search.

#### SC 05-07

Inexperienced diver, cylinder valve not fully opened, compounded by buddy separation.

Cause of death: Hypoxia as a consequence of maladjustment of diving equipment.

This 29-year-old male was inexperienced having logged only 14 scuba dives in the seven years since open water certification in 1998. He had undertaken a refresher course in 2005. He had no past medical history. Weather and water conditions were excellent. He was diving for scallops with five companions, two of whom also dived. Buddy separation occurred. He did not surface. Search and rescue was initiated. His body was found the next day at 18.2 msw, attached to a full catch bag and weight belt (13.2 kg) still in place.

Autopsy was limited by damage due to sea lice and decomposition. Police inspection of his equipment showed the tank valve was opened only a quarter turn and the regulator's performance was reduced. The tank contained 1,470 psi air pressure.

#### SC 06-01

Diving from shore for crayfish.

Cause of death: Drowning.

This 37-year-old male was diving from shore for crayfish and seafood. His certification and experience are not available. He had no past medical history. The conditions were good with calm seas. He failed to surface and his body was found by a search team two hours later.

#### SC 06-02

Experienced, solo crayfish diver who ran out of air.

Cause of death: Hypoxia.

This healthy, 41-year-old, experienced diver was certified in 1982, and had done at least 30 dives in the preceding two years. In good conditions, he went by boat for a crayfish dive with one companion. He did not surface after 25 minutes and his boatman raised the alarm. His body was found by the Police Dive Squad the next day at 25 msw. He had 25 crayfish in his catch bag, which was secured to him without entanglement. Police inspection showed his equipment to be relatively new. The weight belt (10 kg) was not released. His cylinder was empty.

#### SC 06-03

Poorly conditioned diver, rapid ascent and cardiac arrest when swimming to shore.

Cause of death: Arterial gas embolism, patent foramen ovale, old pleural adhesions.

This 53-year-old male's diving experience is unknown. He was said to have had two 'heart attacks' eight years previously, but was not on any regular medication. There was no documented recent dive medical examination. He was diving with three others approximately 40 m from shore. He surfaced after 30 minutes due to a 'BCD problem' and while swimming to shore lost consciousness. Resuscitation was commenced by his companions and continued by ambulance staff, but he died. Prior to autopsy, CT imaging at 18 hours showed extensive intra-arterial gas in the cardiac chambers and aorta. No cerebral intravascular gas was seen.

Autopsy showed arterial gas embolism. There were old pleural adhesions and mild emphysema, a patent foramen ovale (6 mm probe patency) and no evidence of myocardial infarction.

#### SC 06-04

Experienced diver with buddy, uneventful dive, sudden loss of consciousness and submersion when on surface.

Cause of death: Drowning, myocarditis (inquest yet to be held).

This 55-year-old male diver was an experienced diving instructor. He had no past medical history. On a dive charter with other experienced divers, he surfaced from 32 msw with his buddy, and was preparing to exit the water (he had removed his mask) when he sank. Attended by his buddy he was poorly responsive and she could not manage to bring him to the surface. He sank to the sea floor at 32 msw, and was rapidly retrieved (weight belt released) to the surface by another diver. Resuscitation was attempted. Autopsy showed drowning and myocarditis. The equipment inspection report is awaited, but initial assessment is that there were no faults.

#### Fatality case summaries: breath-hold diving

Information on the breath-hold diver deaths was generally very limited and, therefore, this is summarised in Table 2.

#### Discussion

Since the publication of the work of Davis et al the average number of diving fatalities in NZ waters each year does not appear to have altered. For the period 1980–2000, the estimated minimum scuba drowning rate was 5.8 deaths per 100,000 divers per year.<sup>7</sup> For the present series, if we make the same assumptions for the number of active scuba divers in New Zealand, the mean rate of scuba diving fatalities was 5.7 per year. The number of dives performed each year in New Zealand waters is unknown, and there is no system for

collecting information on the number of cylinder fills.

Because these were both retrospective, documentation-based surveys, and follow-up investigations from family, diving associates and general medical practitioners were not undertaken, all figures are likely to be underestimates. Another criticism leveled at this type of study is that there is often inadequate information, and over-interpretation of the data is the rule with repetition of dubious statistics (Edmonds C, personal communication, 2007). The case analyses should be undertaken by at least two independent assessors (which was not the case here), who then reach a consensus diagnosis. Otherwise, individual prejudices are inevitable, as seen with the invaluable but flawed analyses in Project Stickybeak, for example.

It has long been claimed by the diving industry that the fatality rate is very low for recreational divers, estimates being 2.0–2.9 per 100,000 divers per year. These figures for ‘active divers’ often assume that divers have only one basic qualification for ocean diving, and do not account for the extremely high incidence of ‘drop-out’ following certification. This factor magnifies the denominator appreciably and reduces the apparent incidence. Monaghan’s analysis in 1989 of PADI data gave a higher rate of 20–30 fatalities per 100,000 ‘active divers’ per year.<sup>13</sup> Unreliability of the denominator data is mostly overcome by the British Sub-Aqua Club, which recorded 39 diving deaths amongst members (average membership 38,712) during the 2000–2006 period, giving a death rate of 14.4 per 100,000 divers per year.<sup>14</sup> This involved one of the best trained and disciplined recreational diving organisations. In those countries that collect more specific diving data, recreational scuba death incidences per 100,000 diving days or 100,000 dives were reported as 2.9 and 2.05 respectively.<sup>5,12</sup> Based on an assumption of 10–15 dives or diving days per year for active divers, this is consistent with a death rate of 20–30 deaths per 100,000 divers per year.

It is apparent from this type of case series that the aim of many divers is the collection of seafood. Many divers (how many is unknown) do not obtain formal certification to dive, learning from family or friends. Cylinder fills can be purchased for the non-certified by the certified friend or family member. Familiarity with the fill station staff can allow a scuba diver to obtain fills for many years after they have passed their dive course, ignoring the ravages of time on their dive competence, and medical and physical fitness.

Lack of medical conditioning or fitness for diving has been highlighted previously by Acott.<sup>15</sup> In the present case series, 12 divers had conditions that would have disqualified them from scuba diving, either forever or until further investigations had been performed. For want of attending a competent diving medicine physician some of them might be alive today, pursuing less risky recreational pastimes. As Acott and others have pointed out, the exertional demands of scuba diving can be great, exceeding 12 times the normal

metabolic rate. Water conditions can change rapidly, calling on all the physical attributes of a diver to survive whilst trying to avoid the added burden of panic.

Two tourists, both female (SC 03-06 and 05-01), died while on supervised scuba diving charter trips. Both were diving on the same attractive, but not necessarily easy, open water wreck. Interestingly one had an uncommon problem of gastric rupture. This complication has been described previously.<sup>15–17</sup> The cause of death of SC 03-06 was drowning but the possibility of an underlying cardiac cause of syncope could not be established. Her BMI of 38 kg.m<sup>-2</sup> may have been an important factor.

Solo diving and buddy separation remain the standout features of this case series, as with other published series. Coupled with inexperience, the likely outcome for the diver is drowning precipitated by panic and exhaustion, and sometimes pulmonary barotrauma and arterial gas embolism. Poorly managed underlying medical conditions also feature. There is little safety margin in diving, that comes only with following the well-established guidelines that are regularly in the media courtesy of the NZ Underwater Association and the National Police Diving Squad. The buddy system is one of the foundations of scuba diver training; the awareness of improved safety is exemplified by the ‘buddy rope’ mentioned in dive internet chat rooms, and mandatory for Royal Navy divers if scuba diving (but not on SSBA).

Buoyancy control, or as PADI teaches ‘peak performance buoyancy’, is another foundation of training in scuba diving. The data are lacking on whether the divers in this case series performed buoyancy checks, but it could be assumed that this was not part of their routine pre-dive check. Four scuba divers were thought by the police inspection team to be overweighted. There was no definite history of weight-belt release by any of the divers, although one scuba diver had possibly dropped his weight belt. Also there was the tragic drowning of a breath-hold diver who had the weight belt catch around his legs while entrapped in kelp in the wash from a large passing boat.

One of the scuba divers had a missing toggle on their BCD – probably not a factor in his death but still reflective of poor equipment maintenance. Regular dive equipment maintenance follows from dive experience, so it is little wonder that some of the divers had equipment faults or buoyancy issues. The scuba diver (SC 03-01) who did not have a BCD and strapped some weights to his cylinder back pack was diving with an ‘experienced’, multiply ‘certified’ diver who should not have risked either of their lives by going near the sea that day.

Maori, who account for approximately 10% of the census population of NZ, remain overrepresented at 50% of the snorkellers due to their proclivity for the sea and seafood. Snorkelling without fins is not uncommon in this group of swimmers, but carries the risks of exhaustion and drowning

**Table 2. Summary of data recorded in 16 snorkelling**

Case	Age	Fins	Weight belt	Wetsuit	Risk factors
BH 00-01	43	Y	Y	?	Solo, no dive flag
BH 00-02	44	Y	Y	Y	Buddy separation
BH 00-03	37	?	Y	?	Solo, overweighted
BH 01-01	39	N	Y	Y	Solo, rough sea
BH 01-02	34	Y	Y	Y	Solo, rough sea
BH 01-03	40	N	Y	Y	Rough sea
BH 02-01	18	Y	Y	Y	Buddy separation
BH 02-02	31	Y	Y	Y	Solo, overweighted, current
BH 02-03	51	Y	Y	Y	Wash from passing ferry
BH 02-04	48	Y	Y	Y	Buddy separation
BH 03-01	54	N	Y	Y	Solo, medical
BH 04-01	47	Y	Y	Y	Buddy separation
BH 04-02	18	?	?	?	Buddy separation
BH 05-01	55	?	Y	Y	Solo
BH 05-02	78	?	?	?	Solo
BH 06-01	78	?	?	?	Rough sea, buddy separation

if sea conditions deteriorate. Comparison with snorkeller deaths in Australia shows similar factors are involved, but the reasons for undertaking breath-hold diving, the sea conditions and the population involved are dissimilar.

Regarding autopsy procedures, it is likely that the RCPA guidelines are followed by pathologists (Koelmeyer T, personal communication 2006).<sup>19</sup> However, it is apparent that the post-mortem reports, which are an integral part, had no standard format. Those written by forensic pathologists stated the need to interpret the examination findings in concert with facts produced by the police investigation, equipment inspection and analysis of the cylinder gas. There is a variation in what imaging is done; the guideline recommends that plain chest X-ray is an erect film and erect

abdominal X-ray is also indicated. In many instances supine X-ray is performed, which is less sensitive.<sup>19-22</sup>

As expected, drowning is the terminal cause of death in the majority of inquest reports. As in the DAN data, gas embolism is not uncommonly diagnosed as the primary cause of death, and we know that the inexperienced diver who panics may then suffer gas embolism due to a rapid, uncontrolled ascent. The teasing out of the sequence of events in each fatality can be difficult and in some cases it remains unknown due to lack of collateral history.

Delayed body recovery from the sea rapidly decreases the utility of an autopsy, as destruction by sea lice and other creatures is compounded by decomposition exacerbated by

**deaths in New Zealand, 2000–2006 (? – no data recorded)**

<b>Comment</b>	<b>CPR</b>	<b>Significant medical history</b>	<b>Cause of death</b>
Hit by boat	N	–	Drowning, head injury
Shallow (7 msw)	Y	?	Drowning
Shallow (5 msw)	Y	–	Drowning
Caught in current	Y	–	Drowning
–	N	–	Drowning
Panicked	Y	–	Drowning, head injury
Likely hypoxic blackout	Y (delay)	–	Drowning
Likely hypoxic blackout	N (delay)	–	Drowning
Caught in kelp, weight belt caught around legs	Y	–	Drowning
Shallow	Y	–	Drowning
Shallow (4 msw)	Y	Severe coronary artery disease, obesity	Drowning, likely primary cardiac arrest
Shallow, 'safe beach'	Y	–	Drowning
Shallow (2 msw), outdoor education course	Y	Epilepsy	Drowning
Shallow (2 msw)	Y	?	Drowning
Shallow (1–2 msw)	N	Coronary artery disease	Drowning, likely primary cardiac arrest
–	Y	Unspecified medical problems	Drowning

warm environments and wetsuits. Centralisation of autopsy services would improve the accuracy of reports but needs to be balanced against increased delays.

National Police Diving Squad investigations start on the water at the accident site and progress through to full testing of all the available dive equipment, in order to provide a full report to the Coroner. Documentation of diver certification and experience is sought, as well as expertise from manufacturers overseas to retrieve accurate dive profiles from computers, etc. The reports finish with recommendations about diving practices, which the Coroner always includes in the verdict.

This case series, like all others, demonstrates that many

diving fatalities are avoidable. Despite continued education on safe dive habits by NZUA, Water Safety NZ, dive training agencies, and the National Police Diving Squad,<sup>23</sup> and the reporting of coroner's verdicts, there has been no reduction in the number of deaths in NZ waters. The analysis by DAN of diver injuries (Project Dive Exploration) and fatalities is being extended to other areas of the world including the Asia-Pacific region, which will improve the ability to compare data from different regions as the methodology will be the same. However, local knowledge is a must and accurate information gathering during the period immediately after the accident is crucial to drawing conclusions about causation at a later date. With more knowledge, improvements in the education of divers about basic resuscitation can be implemented, especially for commercial dive trip operators.

In reality, the only good fatality rate is zero, six deaths per year are six too many. It is obvious from many studies that those with medical conditions would not be diving if they had received a full medical assessment and been advised of the risks. That they wish to dive reflects a positive life attitude, making it even more tragic when their death by drowning or gas embolism has been precipitated by a potentially treatable condition such as coronary artery disease.

More emphasis is being placed on fitness for diving and its evaluation. The diver with, for example, asthma, diabetes, or obesity should preferably have their dive medical examination performed by a qualified medical practitioner. These examinations should not be a 'one off' prior to the first open water course, but a regular ongoing feature of participation in recreational diving. Then the diver can be made aware of the risks of underwater diving and make their own sensible, informed decision.<sup>24</sup>

### Acknowledgements

Thanks to Mike Davis; Matt Claridge, Operations Manager, and Sarah Tomlinson, Executive Assistant, Water Safety New Zealand; Clifford Slade, Tribunals Division, The Department of Courts; Senior Sergeant Bruce Adams, Officer in Charge, National Police Dive Squad; and Lynn Taylor, Accident Investigator, New Zealand Underwater Association.

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**This paper is based on a dissertation submitted towards the degree of Master of Medical Science in the University of Auckland. Dr McClelland also presented at the SPUMS ASM, New Zealand, 2007.**