A review of snorkelling and scuba diving fatalities in Queensland, Australia, 2000 to 2019

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Abstract
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Introduction: This study examined all known diving-related fatalities in Queensland, Australia, from 2000 to 2019 to determine likely causes and potential countermeasures.
Methods: Data were extracted from the Australasian Diving Safety Foundation fatality database, including previously published reports. The National Coronial Information System was searched to identify diving-related deaths in Queensland for 2014–2019 and data were extracted, analysed, and combined with previously published data covering the period 2000–2013. Descriptive statistics and parametric and non-parametric tests were used to analyse these data.
Results: There were 166 snorkelling and 41 scuba victims identified with median ages of 59 and 49 years respectively, and 83% of snorkel and 64% of scuba victims were males. One quarter of snorkel and 40% of scuba victims were obese. Two-thirds of the snorkellers and three quarters of scuba divers were overseas tourists. Contributory predisposing health conditions were identified in 61% of snorkel and 50% of scuba victims. Nine scuba victims died on their first dive.
Conclusions: The increase in snorkelling deaths likely reflects increased participation, higher age, and poorer health. The main disabling condition in both cohorts was cardiac-related. Pre-existing health conditions, poor skills, inexperience, poor planning, supervision shortcomings and lack of effective buddy systems featured in both cohorts, and apnoeic hypoxia in breath-hold divers. Suggested countermeasures include improved education on the importance of health and fitness for safe diving and snorkelling, increased emphasis on an honest and accurate pre-activity health declaration and subsequent implementation of appropriate risk mitigation strategies, improved supervision, better buddy pairing, and on-going education on the hazards of extended apnoea.

Introduction

Extending from just south of the Tropic of Capricorn towards the coastal waters of Papua New Guinea, the Great Barrier Reef (GBR) is approximately 2,300 km long and 72 km wide at its widest point, covering an area of almost 350,000 square kilometres off the Queensland coast. It is reportedly the largest system of coral reefs, mangroves and estuarine environments worldwide. The abundance and diversity of marine life is immense with some 400 species of coral and 1,500 species of fish.[1] As such, it has long been a mecca for scuba divers and snorkellers, both local, interstate, and international. Beyond the GBR is the Coral Sea with some spectacular dive sites, and, in addition to the tropical waters, southern Queensland hosts a variety of temperate water species and is popular with predominantly local divers.

Scuba diving and snorkelling are conducted in a hostile environment and some fatalities are inevitable, whether resulting from adverse conditions, inexperience, equipment issues, inadequate health and fitness, or attitudinal and oversight shortcomings. Diving-related tourism is an important income source for Queensland and, in 1992, a regulated Code of Practice (COP) for diving activities was introduced. This has been periodically updated, the latest version being released in 2018 with another version due for release in 2022.[2] The COP is regulated and overseen by a team of specialised diving inspectors from WorkSafe Queensland who investigate serious incidents occurring in a diving workplace, which includes commercial recreational snorkelling and scuba diving operations. Fatalities are also investigated by the police and subsequently the coroner.

Although fatalities occurring in Queensland are sometimes well-publicised and may appear to be common, given the amount of snorkelling and scuba diving that occurs there, especially on the GBR, the number of fatalities appears to be relatively low. In an earlier review, it was estimated that the fatality rate for international scuba divers in Queensland was considerably lower than estimates from a variety of

other locations and it was postulated that the existence of the COP may help to mitigate the risks.[3]

The aim of this research was to examine all known diving-related fatalities in Queensland waters from 2000 to 2019 to determine likely causes and potential countermeasures.

Methods

This represents a complete, or near-complete, case series of snorkelling and scuba diving fatalities that occurred in Queensland waters from 1 January 2000 to 31 December 2019. For inclusion, the scuba diver must have been reported to have been wearing a scuba set.

ETHICS APPROVAL

Ethics approvals for the collection and reporting of these data were received from the Victorian Department of Justice Human Research Ethics Committee to access the National Coronial Information System (NCIS; CF/21/18434)[4] as well as the Queensland State Coroner.

SEARCH

Historical data (1970–2000) were obtained from the Australasian Diving Safety Foundation (ADSF) diving fatality database and Project Stickybeak reports.[5–8] Information gathered during previous published investigations for 2000 to 2013[9,10] were reviewed and relevant further data extracted from these, and, where necessary the underpinning coronial documents.

A comprehensive keyword search was made of the NCIS for scuba diving-related deaths in Queensland for the period 1 January 2014 to 31 December 2019. Keywords included scuba, compressed air, compressed gas and div*, snorkel*, breath-hold and div*, and underwater fishing. Data obtained from the NCIS was matched with those held on the ADSF fatality database. Additional reports were obtained directly from the Queensland State Coroner.

REVIEW PROCEDURE AND OUTCOME MEASURES

The investigator reviewed all datasets. Data were extracted for each case and entered into a specially created, anonymised and protected Microsoft Excel® spreadsheet. Where available, these data included demographics, health factors, training and experience, origin of victims, dive location and conditions, buddy circumstances and oversight, dive purpose and depth, equipment used and resuscitation factors.

ANALYSIS

A chain of events analysis (CEA) was performed for each case using existing templates.[10,11] Descriptive analyses based on means and standard deviations (SD) or medians and interquartile ranges (IQR), and Mann-Whitney U tests for comparisons of age or body mass index (BMI), as appropriate, were conducted using SPSS® Version 25 (IBM Armonk, NY; 2017). The level of statistical significance assumed was $P = 0.05$. Annual fatality rates and 95% confidence intervals were calculated based on an exact binomial method as implemented in the binomial test in the R statistical package.[12]

TOURISM RESEARCH AUSTRALIA DATA

Since 2005, Tourism Research Australia has conducted annual surveys of international and national tourists who have visited various Australian states and territories. The International Visitor Survey samples 40,000 departing, short-term international visitors over 15 years of age annually. It is conducted in the departure lounges of major international airports and utilises computer-assisted personal interviewing. The survey results are weighted to data on international visitor numbers over the period.[13]

While these data can measure overseas visitors to Queensland who dived on their trip to Australia, they are not sufficiently detailed to determine if these activities were done in Queensland. However, it was evident from the data that (depending on the year) people who had visited Queensland accounted for 80–90% of snorkellers and scuba divers. Based on Tourism Research Australia advice the denominator used to calculate death rates was therefore reduced by a commensurate amount.

Results

HISTORICAL

Thirty-nine percent of all snorkelling and scuba diving deaths in Australian waters from 1970 to 2019, inclusive, occurred in Queensland, comprising 55% of the total snorkelling and 24% of the scuba fatalities. The proportion of scuba deaths in Queensland remained relatively stable over the period. However, the proportion of snorkelling deaths occurring in Queensland waters was subject to a variety of peaks and troughs, likely related to rises and falls in tourist numbers and increased snorkelling activity elsewhere. Snorkel and scuba diving fatalities in Queensland and Australia as a whole from 1970–2019 are displayed in Figure 1.

During this extended period there were a total of 352 diving-related deaths in Queensland, including 102 in scuba divers, 235 in snorkellers/breath-hold divers, and 15 in divers using surface-supplied breathing apparatus (the latter are not addressed in this report). While the average annual deaths of scuba divers remained stable over time, there was a substantial increase in annual snorkelling deaths over the period. There was also an increase in the ages of both snorkel and scuba victims (Table 1).

Figure 1
Snorkel (SN) and scuba (SC) diving fatalities in Queensland and Australia as a whole from 1970–2019

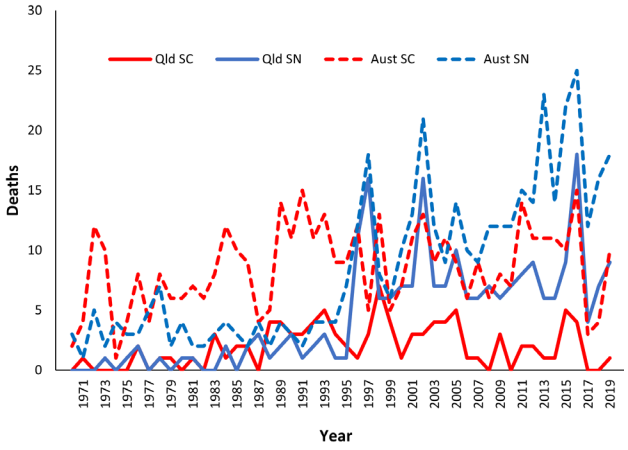


Figure 2
Body mass index categories of snorkel and scuba victims of diving fatalities in Queensland 2000–2019

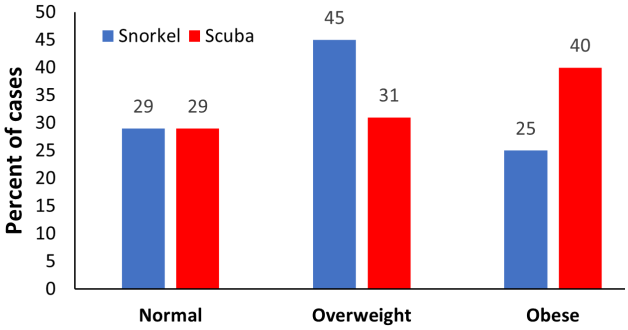


Table 1
Deaths and demographics of snorkel and scuba victims of diving fatalities in Queensland for 1970–1999 and 2000–2019

Parameter	1970–1999		2000–2019	
	Snorkel	Scuba	Snorkel	Scuba
Deaths / Deaths per year	69 / 2.3	61 / 2	166 / 8.3	41 / 2.1
Age, median (IQR)	42 (28, 66)	41 (33, 59)	59 (37, 69)	49 (33, 59)
Sex (% male)	70	75	83	63

STUDY PERIOD 2000 TO 2019

Data were available for 166 snorkelling/breath-hold and 41 identified scuba diving fatality victims in Queensland during this period. These represented 84% of the snorkelling and 23% of the scuba fatalities throughout Australia.

Demographics

The median (IQR) age of the deceased snorkellers in Queensland was 59 (37, 69) which was significantly higher than snorkel victims in other states and territories where the median age was 39 years ($P < 0.001$). The range was 16 to 83 years.

The median (IQR) age of the scuba divers was 48 (32, 57) with a range of 20 to 71 years. Although the median age of scuba victims elsewhere in Australia was lower, at 46 years, this difference was not significant ($P = 0.63$). The snorkel victims in Queensland were significantly older than the scuba victims ($P = 0.02$). Eighty-three percent of the snorkel victims and 64% of scuba victims were males.

The BMI was available for 138 snorkellers, including 117 males and 21 females, with a mean (SD) of 27.6 (5.3) $kg.m^{-2}$ and range of 17.4 to 50.0 $kg.m^{-2}$. Seventy percent of the combined snorkeller group were overweight (45%) or obese (25%) and there was no significant difference between the sexes ($P = 0.87$). Similarly, the BMI was available for 35 of the scuba victims, including 23 males and 12 females. The mean (SD) BMI being 28.0 (4.6) $kg.m^{-2}$ with a range of 20.0 to 37.6 $kg.m^{-2}$. Thirty-one percent were overweight and 40% obese (Figure 2). There was no significant difference between the sexes ($P = 0.92$).

Experience and certification

Thirteen of the snorkellers were documented to have had some formal diving certification. One was a free diving instructor, two were scuba instructors, another two were dive masters and at least eight others were scuba certified. Forty-two percent of the snorkellers had little or no prior experience, and 27% were reported to have been 'experienced'. No relevant information was available for the remaining cases. One half of the experienced snorkellers were diving solo, and most were spearfishing or practicing breath-holding.

Seven of the scuba victims were participating in a 'resort dive' (i.e., a non-certification scuba experience), 16 were certified as open water divers, four as advanced open water

divers, one was an instructor, and another commercially certified. Certification status was unreported in seven cases. Nine of the scuba victims died on their first dive, 12 were novices (0–30 dives post-certification), 14 were 'experienced' (31–200 dives) and at least five 'very experienced' (> 200 dives). No indication of experience was available for one victim. Four of the 'very experienced' victims were over 50 years of age and their deaths appeared to have been cardiac-related.

Location and setting

One hundred and fifty-nine (96%) of the snorkelling incidents occurred in the sea, five in a pool, and one each in a lake and mineshaft. Of those which occurred in the sea, 142 (89%) were on the GBR. Ninety (54%) of the snorkelling incidents occurred in a 'commercial' (mainly supervised recreational diving) setting and 75 (46%) in a private setting. All but three of those in a commercial setting occurred on the GBR. Fifty-nine incidents in a private setting occurred on the GBR and the remaining 16 occurred further south.

All the scuba incidents occurred in the sea with 33 (83%) on the GBR and the remainder further south. Thirty-four (83%) of the scuba incidents occurred in a commercial setting and the balance occurred during private diving activities.

Origin of victims

Thirty-three (20%) snorkelling victims were Queenslanders, 19 (11%) were interstate visitors, and 111 (67%) were overseas tourists. The final three were from overseas, two of whom were working in Australia and the other studying.

Eight of the scuba victims were from Queensland, two from interstate and 31 were overseas tourists. The origins of all overseas victims are shown in Table 2.

Supervision and buddy / group situation

At least 58% of the snorkellers were under supervision and at least one third had set off unsupervised. However, the level of supervision varied greatly, from a one-to-one in-water guide to a single lookout for 100 guests in commercial settings, to one lifeguard for more than 200 swimmers in a public setting. Serious issues in supervision were evident in some incidents as discussed later.

Eight of the snorkellers collapsed on returning to the boat or pontoon so their buddy situation is excluded. Forty-six (28%) set out solo and without any supervision. Of the remaining 112 snorkellers who set out with a buddy or amongst a group, 45 were still together when the incident occurred, while seven separated during the incident. Twenty-one victims were amongst (sometimes loosely) supervised groups in a commercial setting but were essentially snorkelling solo as they were not allocated to buddy pairs.

Table 2
Origin of overseas tourists involved in snorkel and scuba diving fatalities in Queensland 2000–2019

Region	Snorkel *n* (%)	Scuba *n* (%)
Asia	37 (32)	6 (19)
North America	32 (28)	16 (52)
Europe	22 (19)	3 (10)
United Kingdom	17 (15)	5 (16)
New Zealand	4 (4)	0 (0)
Africa	1 (1)	0 (0)
Unknown	1 (1)	1 (3)

Five of the scuba divers set out solo, 18 became separated before the incident and another seven during their incident. Only 14 divers were still with a buddy or buddies.

Dive purpose

The vast majority (137, 83%) of snorkellers were sightseeing, 21 (13%) were spearfishing, four (2%) were practicing breath-holding, and the remainder were work-related. Similarly, the vast majority (29, 71%) of the scuba divers were sightseeing, seven were participating in resort dives, one was under training, two were working, and the activity of one was unknown.

Depth of incident

At least two-thirds of the snorkellers were likely surface snorkellers and at least one quarter were breath-hold diving to some extent. One hundred and twenty-one (73%) of snorkelling incidents occurred on the water surface, 13 underwater, and eight after exiting the water. The remainder were unknown. Twelve of the scuba incidents occurred at the surface and 13 at depths up to 10 metres of seawater (msw). Another 10 incidents occurred between 10 and 30 msw. Two divers collapsed on the boat post dive and, in four cases the incident depth was unknown.

Swimming skills (snorkellers), buoyancy aids and weights

There was no information about the swimming ability of 60 snorkelling victims. Of the remainder, 80 (48%) were reported to have been competent swimmers and 25 (15%) weak or non-swimmers. Only 14 of the weak/non-swimmers were wearing a floatation aid. Most of the snorkellers (122, 75%) were wearing fins. However, at least 21 (13%) were not and, of these, at least five were reported to have been weak swimmers. Seventeen of the snorkellers were reported to have been wearing weights, all but one of whom were breath-hold diving. Only three of these had ditched their weights before being found. There were several reports where a single person on a tender was unable to

lift a (generally overweight or obese) snorkeller aboard, so delaying the rescue and reducing the likelihood of successful resuscitation.

In two scuba cases no body was recovered, four victims collapsed after boarding the boat or platform, 22 were 'rescued' (16 on the surface and six underwater), and 12 divers were 'recovered' from underwater after a search and associated delay. Thirty-five of the scuba divers were still wearing their weights when found, 20 had uninflated buoyancy control devices (BCDs) and half were found both wearing weights and with uninflated BCDs.

Resuscitation

In water rescue breathing was performed to some extent on at least 16 of the snorkellers (in one case using a scuba demand valve to provide ventilations) and on five of the scuba divers. Airway management complications from regurgitation, water, froth, pulmonary oedema fluids, clenched teeth and poor positioning were reported in at least 70 (42%) of the snorkel and 22 (54%) of the scuba incidents but likely occurred in more as relevant details are usually not sought or included in the reports.

Basic life support (BLS) was performed in at least 138 (83%) of the snorkelling and 37 (90%) of the scuba incidents. In most of the others it was inappropriate due to the long delay in body recovery or absence of a body. In most of the commercial scenarios, resuscitation was commenced by trained staff, sometimes assisted by bystander medical professionals. Supplemental oxygen was reported to have been provided during initial resuscitation in 75 (46%) of the snorkelling and at least 26 (62%) of scuba incidents. However, it was not available when required in 22 snorkelling and seven scuba incidents (five of the latter being in a private setting). Supplemental oxygen was not applicable in 24 snorkel and three scuba incidents, and there was no information about oxygen administration in 46 snorkelling and six scuba cases.

An automated external defibrillator (AED) was available at or near the site and used onsite in at least 66 (40%) of the snorkelling and 10 of the scuba incidents. In two-thirds of the snorkelling incidents (and in all the scuba cases) the victim was under the direct supervision of a commercial operator. Most of the others were at sites such as island resorts or public beaches where the individuals were snorkelling independently. Shocks (from one to seven) were given in 19 of the snorkelling cases, no shock in 43, and it was unclear in the remaining four cases. No shock was given in six scuba cases, with one to four shocks delivered in the remainder. In most cases, there was no clear indication of the time from likely cardiac arrest to AED attachment. However, in only 18 cases it appears that attachment could have occurred within 10 minutes or less. Pre-shock delays of 10 to 20 minutes and sometimes far longer were the norm.

CHAIN OF EVENTS ANALYSIS

Predisposing factors

Two hundred and thirty-four likely or possible predisposing factors were identified in 160 of the 166 snorkelling incidents, and 59 were identified in 38 of the 42 scuba cases. The most frequent of these were health-related, which likely influenced the outcome in 102 (61%) of the snorkel and one half of the scuba victims. The most common were ischaemic heart disease (IHD), obesity and hypertension, in both groups. In snorkellers, a variety of other health factors such as a history of cardiac arrhythmias, diabetes, epilepsy, and the presence of alcohol were implicated. Autopsies often revealed undiagnosed IHD, cardiomegaly and left ventricular hypertrophy, all of which predispose to cardiac arrhythmias.

Lack of skills and experience were identified as contributing factors in at least 50 of the snorkelling and 12 scuba incidents although they may well have been a factor in others. In snorkellers, they were most often associated with a primary drowning. Nine of the scuba victims were uncertified – seven participating in organised resort dives and two on their first dive supervised by a friend. Three were certified with very few or no subsequent dives for at least one year, and another two had done few dives since training. One diver who had trained in a dam was doing their first ocean dive which was in a strong current. The final victim was very experienced but had not dived for more than two years. At least nine of these scuba deaths were associated with primary drowning or cerebral arterial gas embolism (CAGE).

Poor planning decisions were implicated as contributing to 55 of the snorkelling and seven of the scuba fatalities. Most of the snorkelling cases involved the decision to snorkel or breath-hold solo and usually unsupervised. Other factors included setting off in conditions that were obviously beyond the victims' skill levels. Five of the scuba deaths resulted from decisions to dive in adverse conditions; two of these involved resort dive participants who became separated from their instructors in poor visibility. Another two involved non-instructor-certified divers teaching friends at unsuitable sites. The other involved an instructor taking a certified, albeit inexperienced diver into a strong current without having a pre-agreed separation plan.

Activity-related predisposing factors were evident in 27 snorkelling/breath-hold incidents. Twenty-two involved extended breath-hold diving, five in a pool. Pre-dive hyperventilation was either witnessed or probable in at least seven cases. Seventeen of the victims had set out solo, four had separated before or during the incident, and only one was still with a buddy. Four of the other five deaths with activity-related predisposing factors involved spearfishing in areas with large sharks or crocodiles. The final incident involved a large stingray.

Unsafe supervision was identified as a factor in 18 snorkelling and seven scuba incidents, of which 12 snorkel and all the scuba occurred in a commercial setting. Seven of the snorkel cases involved a failure of the lookout(s) to notice that the victim was missing until a post-dive head count or notification by others. Others involved poor selection of suitable conditions for inexperienced and/or elderly snorkellers due to current or chop, and/or the area to be supervised being too large to be effectively monitored. Two involved poor supervision of an inexperienced snorkeller/weak swimmer by more experienced buddies. Others involved inexperience and distraction of lookouts. Four of the scuba cases involved poor in-water supervision of uncertified or very inexperienced divers. Another involved a dive operator's failure to provide a guide to oversee a novice on their first open water dive and in difficult conditions. One case was associated with poor surface supervision of a solo diver.

Organisational shortcomings were identified in at least 15 snorkel and five scuba incidents, a likely underestimate. Inadequate training of snorkeller lookouts, too few lookouts for the number of snorkellers or the size of the snorkel area, poor selection of snorkelling area due to prevailing or likely evolving conditions, and briefing inadequacies were identified. In one case, a staff member gave poor advice about the relevance of a medical condition apparently with adverse consequences. Three scuba incidents involved resort dives which were conducted in poor visibility, and which resulted in the victims separating from the instructors. In at least two of these, the instructors were swimming in front of the group and facing ahead. In one, it was noted that the divers had not been briefed on weight belt ditching or separation procedure. One incident resulted from a poorly organised commercial dive where there was inadequate functional equipment from the outset. The other involved poor maintenance of, and procedures for, the use of a dive club's compressor which led to serious air contamination. Other problems included faulty, or lack of readily available oxygen equipment or AEDs.

Equipment inadequacies were identified as contributing factors in 17 snorkelling and four scuba incidents, at least 13 of which resulted in primary drowning. With snorkellers, these mainly involved the lack of fins and/or personal floatation devices in weak or non-swimmers, an overly tight floatation device, an overly tight wetsuit, and obvious overweighting in at least one breath-hold diver. The scuba incidents included the occupational dive mentioned above, a faulty pressure gauge, and contaminated cylinder air in two cases.

Triggers

In all, 201 likely or possible triggers were identified from 148 of the snorkelling incidents and 56 triggers were identified from 37 of the scuba incidents. Various environmental factors triggered 93 snorkelling and 25 scuba fatalities. Sixty-eight of these environmental triggers in snorkellers and 14 of those in scuba divers appear to have arisen from the direct effects of immersion which redistributes circulation and can impact cardiac function and lead to cardiac arrhythmias in susceptible persons. Adverse surface conditions, current and poor visibility were implicated in at least 24 snorkel and 11 scuba incidents, in some cases compounding the cardiac effects of immersion by increasing exertion and anxiety. Seven other environmental triggers involved snorkellers' encounters with dangerous marine creatures (two sharks, two crocodiles, two Irukandji, one stingray). Anxiety (reported by witnesses) was identified as a probable trigger in at least six snorkel and 10 scuba cases but very likely contributed to others. Water aspiration through the snorkels of novices was identified as the probable trigger in 45 snorkelling incidents but was likely to have occurred in more. Extended apnoea, with or without hyperventilation, was the trigger in 21 fatal breath-hold incidents.

There were four gas supply-related triggers in scuba divers which involved two divers who ran out of air, one who became nauseated from oil contamination and one diver whose air was severely contaminated with both carbon monoxide and carbon dioxide. Other scuba incident triggers included trauma and inadequate decompression.

Disabling agents (DA)

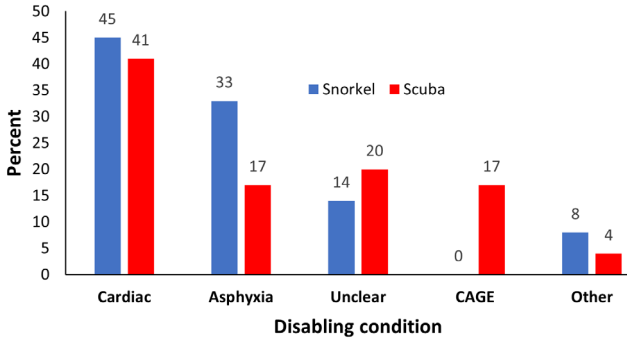
Disabling agents (i.e., actions or circumstances associated with the triggers that caused injury or illness) were identified in 148 of the snorkelling fatalities, the majority (95, 64%) being medical-related, predominantly IHD. Pre-existing cardiac arrhythmias were implicated in five deaths, epilepsy in two. Immersion pulmonary oedema was identified as the likely disabling agent in two snorkelling incidents but may well have been present in more. Apnoeic hypoxia was the likely disabling agent in 21 of the 22 deaths involving extended hypoxia (the other possibly associated with IHD). Other likely disabling agents in the snorkel incidents were laryngospasm from water aspiration through snorkels (17), environmental (10), and buoyancy-related (3).

Thirty-six disabling agents were identified in the scuba incidents with insufficient information to determine likely agents in six cases. Half of the disabling agents were medical-related, all but one with cardiac disease or abnormality. The other likely disabling agents identified were ascent-related (7), buoyancy-related (5) and gas supply-related (3).

Disabling conditions (Figure 3)

The disabling condition directly responsible for death or incapacitation followed by death from drowning, was identified in 142 of the snorkelling fatalities but was unclear in the remaining 24, including seven where no body was found. The disabling condition in the other 'unclear' cases

Figure 3
Disabling conditions for snorkel and scuba victims of diving fatalities in Queensland 2000–2019



was either asphyxia or cardiac as there were indications of both. The most prevalent disabling conditions were cardiac-related (74), asphyxia (primary drowning) (55) and trauma (five). Immersion pulmonary oedema was the likely disabling condition in two cases but was identified as a possibility in five. Of the 65 snorkellers with a cardiac disabling condition for which the BMI was known, 26 (40%) were obese. By comparison, only 2 (4%) of the 46 asphyxia victims with known BMIs were obese.

The likely disabling condition was identified in 33 of the scuba divers but was unclear in the remaining eight. In three, it was difficult to determine whether the disabling condition was cardiac or CAGE as there were indications of both. In one of these, immersion pulmonary oedema was another possible differential diagnosis. There were 17 cases where the disabling condition appeared to have been cardiac-related. Of these, eight of the divers were known to have been under medical care for some related condition, although the extent of the predominantly heart disease was likely unknown. Five of these had declared their condition to the dive operator, two having produced medical clearances, albeit from doctors without dive medical training. None were under special observation during the dive. Twelve scuba divers had not declared any medical conditions, and in another two cases, it was unclear. Five victims were not under any medical care and there was no indicative information in four cases. One scuba death resulted from carbon monoxide poisoning and one diver died from fulminant decompression sickness.

ACTIVITY AND FATALITY RATES

Based on its annual visitor surveys, Tourism Research Australia data estimated that the average annual number of international visitors who snorkelled in Queensland between 2005–2019 inclusive was 429,849 (95% CI: 410,076–449,622). (Smith D, personal communication, 2022) Over that period, there were 81 deaths in snorkellers from overseas so the average annual fatality rate for overseas visitors in Queensland was 1.25 deaths per 100,000 snorkellers (95%CI: 1.00–1.56).

Similarly, the estimated average annual number of international visitors who went scuba diving in Queensland during that period was 192,403 (95% CI: 178,742–206,064) and there were 19 deaths among this group. This yields an annual fatality rate of 0.66 deaths per 100,000 international scuba divers (95% CI: 0.39–1.02). Note: This rate is higher than estimated in an earlier report[3] as the denominator provided by Tourism Research Australia had been subsequently reduced to provide a more accurate estimate.

Discussion

The ages of both the snorkel and scuba victims during the study period were substantially higher than over the previous three decades, likely reflecting the increasing age of diving participants generally.[14,15] The more than threefold increase in annual snorkel deaths between the periods seems largely reflective of the increased number of participants and their health status and probable lesser aquatic experience and skills. Many of the victims, especially the snorkellers, were older overseas tourists with pre-existing medical conditions which contributed to their demise. More than 80% of the incidents occurred on the GBR, with one half of the snorkelling and the vast majority of the scuba deaths occurring in a commercial setting. One third of the snorkellers had set off solo and many others were snorkelling without a designated buddy in a large group. In addition, many snorkellers and scuba divers who set off with a buddy became separated before their incident. Although the majority of snorkel victims were under supervision, the efficacy of this varied greatly as a result of pre-activity screening, sea conditions, and supervisors' ratios and experience. Many victims were inexperienced, and some died on their first snorkel or scuba experience. Fatalities in experienced breath-hold divers were mainly attributable to apnoeic hypoxia.

Resuscitation was attempted in most cases but was often belated due to delays in the recognition of the incident and subsequent rescue or recovery of the victim.

DEMOGRAPHICS

The substantially higher age of the snorkellers in Queensland is likely a reflection of older tourists particularly from overseas visiting the GBR and snorkelling. Worldwide there has been an increasing incidence of scuba fatalities in older divers.[9,16–18] The high prevalence of health-related conditions identified in both cohorts of victims is consistent with the increased likelihood of adverse health conditions in an older demographic.[19] Some conditions increase the risk of an incident in the water, whether snorkelling or scuba diving.

The high proportion of obesity in victims, especially the scuba divers, is cause for concern given its association with significant health conditions including sudden cardiac death.[20,21] Obesity has been implicated as a potential risk factor for a scuba diving fatality.[9,22]

PRE-EXISTING HEALTH CONDITIONS

The finding that pre-existing health conditions likely contributed to such a high proportion of both scuba and snorkelling fatalities is sobering, highlighting the need for participants to be sufficiently fit and healthy to participate in relative safety. Existing or potential divers and snorkellers with chronic medical conditions may require assessment at regular intervals. With the mix of circulatory changes associated with immersion, exertion, anxiety, exhilaration, saltwater aspiration and breathing resistance, snorkelling and scuba diving involve an array of potential triggers to a cardiac event in a susceptible person.[23] Some of the victims were under treatment for relevant medical conditions although relatively few had declared a pre-existing condition. Some individuals may have intentionally withheld information for fear of not being allowed to participate, while others might not have realised the reality of the potential risks and the importance of notifying the operators to enable risk mitigation strategies to be implemented. Many victims had undiagnosed heart disease and appeared to be reasonably healthy. Obesity could be used as a precautionary signal to trigger closer observation, especially in scuba divers.

EXPERIENCE

Many of the snorkel victims were inexperienced and some had very poor aquatic skills. A leaking mask or water aspiration through the snorkel can readily trigger panic and, in some cases, laryngospasm and subsequent unconsciousness and drowning. It is important that snorkel operators carefully screen prospective snorkellers and provide training, buoyancy support and close supervision where indicated. The use of well-fitting fins should be actively encouraged. The COP requires that "*all at risk snorkellers should be directed to wear and/or use a flotation or other device which is able to support the wearer in a relaxed state*." However, despite these measures being implemented by compliant operators, some deaths remained difficult to prevent due to pre-existing health issues and logistical challenges.

Whereas experience improves diving-related skills and environmental understanding, it can also breed complacency. Many of the more experienced snorkel victims were diving solo or with an intentionally loose 'buddy system'. A large proportion of these succumbed to apnoeic hypoxia after extended breath-holding with, or without, hyperventilation. The likelihood of blackout varies between dives and pushing one's breath-hold limits without a capable and ready rescuer is precarious. Despite this information being available for a long time, many breath-hold divers remain falsely confident that it won't happen to them.

The deaths of seven scuba divers during resort dives is concerning. However, three of these were associated with undeclared and possibly undiagnosed cardiac disease so might not have been easily avoidable. Four of the incidents (including one of the cardiac deaths) involved poor planning and/or supervision which led to separation of the victim and the instructor, likely resulting in panic and subsequent drowning in three divers. It is essential that, in such activities, the instructor very carefully assesses the existing and potential conditions and adjusts ratios or abandons the activity accordingly, as well as positioning themselves to maximise oversight of all participants.[2,24] The victim of the final resort dive incident panicked when their mask flooded, and, despite the efforts of the instructor, made a rapid breath-hold ascent which resulted in pulmonary barotrauma.

Many highly experienced scuba divers have been diving for long periods and often belong to the older cohort of divers who are more likely to have pre-existing disease, often cardiac-related.[14] It is recommended that all divers aged 45 years or over undergo a medical assessment with a focus on cardiovascular evaluation, preferably by a doctor trained in diving medicine to monitor their on-going fitness to dive.[25]

BUDDY SITUATION AND SUPERVISION

As in other reports, many of the deceased snorkellers and some of the scuba divers had set out solo or separated prior to their incident.[9,10,22,26,27] Others snorkelled alone within a large group. In such scenarios, if serious problems arise, they often go unnoticed for an extended period making survival unlikely. Even if unable to perform a rescue, a vigilant buddy can often alert others and set a rescue in motion.

Operators should ensure that pre-snorkel briefings include strong advice to set out and remain with a buddy and the benefits of doing so. Participants should be assisted with buddy selection, if required. Despite this, it is inevitable that some individuals will choose to set off alone or separate, intentionally, or otherwise.

Problems with supervision included inadequate identification or monitoring of weak swimmers or inexperienced snorkellers, poor site selection due to conditions and/or size and ineffective lookouts. In any setting, particularly commercial, it is important to assess a person's skills and experience and to have a system to readily identify at risk participants so that they can be more closely monitored. Many operators in Queensland have introduced risk mitigation strategies including encouraging the use of personal floatation devices or other floatation aids and colour coding on snorkels to indicate an increased risk and in-water supervision. This is to be applauded and should be encouraged elsewhere.

The COP requires that in commercial settings, dive site risk assessments are conducted considering the conditions as well as all aspects of the conduct of the dive operation, including entries and exits, risk of separation, searches for divers, rescues, and evacuations.

With large groups of snorkellers to observe, it can be difficult for a lookout to recognise a problem, especially if they are relatively inexperienced, tired, or distracted. There is a need to ensure that there are sufficient lookouts to effectively supervise an area, considering the size, shape and geographical features of the site, the prevailing conditions, the number of snorkellers and the effectiveness of the vantage point. These lookouts should be adequately trained in observation and monitoring techniques, always remain vigilant and be relieved at regular intervals to avoid fatigue or complacency.

Prompt identification of a distressed or unconscious snorkeller or diver, together with rapid rescue, will maximise the chances of survival. However, substantial delays in recognition do occur as it can sometimes be difficult to determine whether a motionless snorkeller is unconscious or just quietly observing the scenery below. Many of these deaths are silent and signs of distress absent or overlooked. It is better to have a high index of suspicion and run the risk of over-reacting. In addition, suitable rescue techniques need to be identified and practiced ensuring that they can be done swiftly and effectively when needed.

BRIEFING

In some cases in commercial settings it was reported that the victims did not attend or did not pay attention to the briefing and so might have missed important information that could have prevented their incident. A thorough pre-snorkel or dive briefing is an important safety and risk mitigation tool which is especially necessary for the inexperienced, but also may provide valuable insights and local knowledge for experienced divers and snorkellers. Such a brief should be located and timed to minimise distractions. It should inform participants of the potential risks associated with certain health conditions and highlight the importance of honestly declaring these to the operator to enable them to implement safety processes. Similarly, participants should be encouraged to declare their swimming ability and snorkelling experience. The brief should also highlight the importance of the buddy system, of staying in the designated area, the likely site conditions (e.g., currents) and marine life, what to do if they need assistance and the timing and recall procedure, among other things.

Confusion arising from language issues can create a problem with briefings. Some operators have staff who provide briefs or translation in key languages. To assist with this, WorkSafe Queensland has published an informative dive and snorkelling guide, currently available in 14 languages, which should be made readily available to non-English speaking participants.[28]

RESCUE AND FIRST AID

It is very important for a diver who is likely to become unconscious underwater to initiate self-rescue and try to attain positive buoyancy to reach the surface where they will generally be more easily located. As in other series, many of the scuba victims were still wearing their weights and had uninflated BCDs.[9,22,27] The COP now requires that resort dive participants are taught how to inflate and deflate their buoyancy devices on the surface.

It is also important for breath-hold divers to adjust their buoyancy to be positively buoyant in the last few metres to the surface. In that way they will be more likely to rise to the surface if unconscious.

The problem of a single person trying to drag an unconscious or semi-conscious person onto a small vessel is not uncommon in both commercial and private settings. Particularly where assistants are not readily available, a carefully prepared plan, appropriate equipment and practice may reduce the difficulty and associated delay.

In the commercial setting, once resuscitation was commenced it generally appeared to have been done with reasonable efficiency by appropriately trained staff. Supplemental oxygen was reported to have been provided in almost half of the cases, substantially higher that the 16% documented nationwide (under-reporting may well have occurred).[29] This is very likely a result of the requirements under the COP, coupled with better reporting, although under-reporting is still likely.

The increasing availably of AEDs, as required under the COP, is a positive development to be encouraged in other jurisdictions, especially considering an ageing diver population and the increasing prevalence of cardiac-related incidents. Unfortunately, their success to date in the diving setting has been rather limited, partly because of the significant delays from cardiac arrest to AED attachment in these environments. Improved supervision and efficient rescue can reduce this interval, increase the likelihood of the victim having a shockable rhythm and enhance the chances of survival. Appropriate supervision and rescue training and practice are essential to reduce delays.

FATALITY RATE

There appears to be a dearth of reasonably reliable and accessible information on international snorkelling fatality rates, so it is difficult to compare the snorkelling annual fatality rate from this study. However, the estimated rate for overseas scuba divers in Queensland is considerably lower than other published rates[3,30] suggesting that scuba diving in Queensland may be comparatively safe. This could be due in part to often more favourable conditions and easier diving when compared to more temperate environments. However, it is interesting to note that there was no significant increase in the average annual number of scuba deaths in Queensland between the periods 1970–1999 and 2000–2019 despite what was likely an increase in diving activity and an increase in the average age of divers with its associated risks. The more

stringent oversight and better management of diving because of the COP may have contributed to this.

CODE OF PRACTICE

The latest COP has incorporated possible mitigation strategies to most of the issues identified in this investigation, and, if conscientiously implemented together with the additional recommendations herein, are likely to prevent some future incidents. However, as mentioned earlier, some diving-related morbidity and mortality is inevitable despite all efforts.

DATA COLLECTION

Data collection and reporting for diving-related fatalities varies between various places, often depending on the familiarity and interest of the initial (usually local police) investigators with scuba diving or snorkelling and any follow-up systems in place. However, unless key questions are included in the incident proforma used, valuable information which could be used to improve safety can easily be missed. An example of a template for data collection for a scuba fatality can be found at: https://adsf.cdn.prismic.io/adsf/b198f7ef-9afa-4f0b-91b9-f70ef481595f_Data-Collection-1+%281%29.pdf.

LIMITATIONS

As with any uncontrolled case series, the collection and analysis of fatality data are subject to inevitable limitations associated with the incident investigations. Given that many incidents were unwitnessed, assertions in the reports are sometimes speculative. Important information may not be available, which rendered chain of events data incomplete and limiting conclusions that can be drawn.

The results of the international visitor survey are based on samples, rather than a census and therefore subject to sampling error. However, with relative standard errors for the number of participants at around 1.5% (snorkellers) and 3.3% (scuba) sampling error was not a major barrier to their use.

Comparisons between annual fatality rate estimates from different data sources can be unreliable due to a variety of factors including accuracy of denominator (and sometimes numerator) data.

Conclusions

While scuba diving deaths remained stable, there was a substantial increase in the number of snorkelling deaths in Queensland over the past two decades. This is likely a reflection of the increased number of participants, their higher ages and poorer health. However, considering the number of overseas participants the estimated fatality rates appear to be relatively low, which may in part be due to the existence and enforcement of a COP and better oversight and management.

Issues identified included pre-existing medical conditions, poor skills, inexperience, poor planning, supervision shortcomings and lack of effective buddy systems in both cohorts, and apnoeic hypoxia in breath-hold divers. The main disabling condition in both snorkellers and scuba divers was cardiac-related, and a high proportion of victims, especially scuba divers, were obese.

Potential countermeasures include increased education of the importance of health and fitness for safe diving and snorkelling, fitness-to-dive assessments for older divers and those with chronic health conditions, improved pre-travel health screening for tourists planning to snorkel, increased emphasis on the importance of an accurate pre-activity health declaration and subsequent implementation of appropriate risk mitigation strategies, improved supervision with higher supervision-to-participant ratios when appropriate, better buddy pairing, and continued and strengthened education on the hazards of extended apnoea for breath-hold divers.

References

1 Australian Museum. The Great Barrier Reef. [cited 2022 Feb 17]. Available from: https://australian.museum/get-involved/amri/lirs/great-barrier-reef/?gclid=EAIaIQobChMIneO067iF9gIVxX4rCh1fbwEbEAAYASAAEgLpw_D_BwE.

2 Queensland Government. Recreational diving, recreational technical diving and snorkelling Code of Practice 2018. Office of Industrial Relations - Workplace Health & Safety Queensland; 2018. [cited 2018 Feb 15]. Available from: https://www.worksafe.qld.gov.au/__data/assets/pdf_file/0025/23596/rec-diving-rec-tech-diving-snorkelling-cop-2018.pdf.

3 Lippmann J, Stevenson C, Taylor D McD, Williams J. Estimating the risk of a diving fatality in Australia. Diving Hyperb Med. 2016;46:241–6. PMID: 27966203. [cited 2022 Feb 17]. Available from: https://www.dhmjournal.com/images/IndividArticles/48March/Lippmann_dhm48123-30.pdf.

4 National Coronial Information System (NCIS) [Internet]. Administered by the Victorian Department of Justice and Regulation. [cited 2020 May 15]. Available from: http://www.ncis.org.

5 Australasian Diving Safety Foundation. Diving-related fatality database and cumulative register. Data available to authorised internal researchers from: http://www.adsf.org.au.

6 Walker D. Report on Australian diving deaths 1999–2002. Melbourne: JL Publications; 2009.

7 Walker D. Report on Australian diving deaths 1994–1998. Melbourne: Divers Alert Network Asia-Pacific; 2002.

8 Walker D. Report on Australian diving deaths 1972–1993. Melbourne: JL Publications; 1998.

9 Lippmann J, Taylor D McD, Stevenson C. Scuba diving fatalities in Australia, 2001–2013. Diver demographics and characteristics. Diving Hyperb Med. 2020;50:105–14. doi: 10.28920/dhm50.2.105-114. PMID: 32557411. PMCID: PMC7481108.

10 Lippmann J. Snorkelling and breath-hold diving fatalities in

Australia, 2001–2013. Demographics, characteristics and chain of events. Diving Hyperb Med. 2019;49:192–203. doi: 10.28920/dhm49.3.192-203. PMID: 31523794. PMCID: PMC6884103.
11 Lippmann J, Stevenson C, Taylor D McD, Williams J, Mohebbi M. Chain of events analysis for a scuba diving fatality. Diving Hyperb Med. 2017; 47:144–54. doi: 10.28920/dhm47.3.144-154. PMID: 28868594. PMCID: PMC6159623.
12 Ihaka R, Gentleman R. R: A language for data analysis and graphics. J Comp Stat. 1996;5:229–314. doi: 10.1080/10618600.1996.10474713.
13 Tourism Research Australia. International visitor survey methodology. [cited 2022 Feb 12]. Available from: https://www.tra.gov.au/international/ivs-methodology.
14 Lippmann J, Taylor D McD, Stevenson C, Williams JW. Challenges in profiling Australian scuba divers through surveys. Diving Hyperb Med. 2018;48:23–30. doi: 10.28920/dhm48.1.23-30. PMID: 29557098. PMCID: PMC6467821.
15 Cumming B, Peddie C. National Diving Committee (NDC) diving incidents report 2015. Elmsmere Port, Cheshire: British Sub Aqua Club; 2015 [cited 2022 Feb 10]. Available from https://www.bsac.com/safety/diving-incidents/annual-diving-incident-report.
16 Buzzacott P, editor. DAN annual diving report: 2017 edition (A report on 2015 diving fatalities, injuries and incidents). Durham (NC): Divers Alert Network; 2016. PMID: 29553634. [cited 2019 Sep 21]. Available from: https://www.diversalertnetwork.org/medical/report/AnnualDivingReport-2017Edition.pdf.
17 St Leger Dowse M, Waterman MK, Penny CE, Smerdon GR. Does self-certification reflect the cardiac health of UK sport divers? Diving Hyperb Med. 2015;45:184–9. PMID: 26415070. [cited 2022 Feb 17]. Available from: https://www.dhmjournal.com/images/IndividArticles/45Sept/StLegerDowse_45.3.184-189.pdf.
18 Denoble PJ, Pollock NW, Vaithiyanathan P, Caruso JL, Dovenbarger JA, Vann RD. Scuba injury death rate among insured DAN members. Diving Hyperb Med. 2008; 38:182–8. PMID: 22692749. [cited 2022 Feb 17]. Available from: https://www.dhmjournal.com/images/IndividArticles/38Dec/Denoble_dhm.38.4.182–188.pdf.
19 Australian Institute of Health & Welfare (AIHW). Heart, stroke and vascular disease – Australian facts. Last updated 12/01/2022 v19.0. [cited 2022 Feb 15]. Available from: https://www.aihw.gov.au/reports/heart-stroke-vascular-diseases/hsvd-facts/data.
20 Cohen A, Baker J, Ardern CI. Association between body mass index, physical activity, and health-related quality of life in Canadian adults. J Aging Phys Act. 2016; 24:32–8. doi: 10.1123/japa.2014-0169. PMID: 25700371.
21 Adabag S, Huxley RR, Lopez FL, Chen LY, Sotoodehnia N, Siscovick D, et al. Obesity related risk of sudden cardiac death in the atherosclerosis risk in communities study. Heart 2015;101:215–21. doi: 10.1136/heartjnl-2015-307485. PMID: 25410499. PMCID: PMC4791977.
22 Lippmann J, Lawrence C, Davis M. Scuba diving-related fatalities in New Zealand, 2007 to 2016. Diving Hyperb Med. 2021;51:345–354. doi: 10.28920/dhm51.4.345-354. PMID: 34897599. PMCID: PMC8920894.
23 Bennett M. Cardiac problems and sudden death. In: Edmonds C, Bennett M, Lippmann J, Mitchell SJ, editors. Diving and subaquatic medicine. 5th ed. Boca Raton (FL): Taylor & Francis; 2016. p. 449–57.
24 Lippmann J, Lawrence C, Wodak T, Fock A, Jamieson S. Provisional report on diving-related fatalities in Australian waters 2009. Diving Hyperb Med. 2013;43:194–217. PMID: 24510326. [cited 2022 Feb 17]. Available from: https://www.dhmjournal.com/images/IndividArticles/43Dec/Lippmann_dhm.43.4.194-217.pdf.
25 Jepson N, Rienks R, Smart D, Bennett MH, Mitchell SJ, Turner M. South Pacific Underwater Medicine Society guidelines for cardiovascular risk assessment of divers. Diving Hyperb Med. 2020;50:273–7. doi: 10.28920/dhm50.3.273-277. PMID: 32957130. PMCID: PMC7819720.
26 Lippmann J, Lawrence C, Davis M. Snorkelling and breath-hold diving fatalities in New Zealand, 2007 to 2016. Diving Hyperb Med. 2021;51:25–33. doi: 10.28920/dhm51.1.25-33. PMID: 33761538. PMCID: PMC8313781.
27 Lippmann J. Diving deaths downunder. In: Vann RD, Lang MA, editors. Recreational diving fatalities. Proceedings of the Divers Alert Network 2010 April 8–10 workshop. Durham (NC): Divers Alert Network; 2011. p. 86–97.
28 Queensland Government. Worksafe Queensland. Diving and snorkelling: Non-English-speaking participants. [cited 2022 Feb 10]. Available from: https://www.worksafe.qld.gov.au/safety-and-prevention/hazards/workplace-hazards/diving-and-snorkelling/non-english-speaking-participants.
29 Lippmann J. Rescue and resuscitation factors in scuba diving and snorkelling fatalities in Australia, 2001 to 2013. Undersea Hyperb Med. 2020;47:107–15. doi: 10.22462/01.03.2020.11. PMID: 32176951.
30 Denoble PJ, Marroni A, Vann RD. Annual fatality rates and associated risk factors for recreational scuba diving. In: Vann RD, Lang MA, editors. Recreational diving fatalities. Proceedings of the Divers Alert Network 2010 April 8–10 workshop. Durham (NC): Divers Alert Network; 2011. p. 73–83.

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