Mortality trends and the impact of exposure on Australian coastal drowning deaths, 2004–2021

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Abstract

Objective: The aim of this study is to characterise Australian coastal drowning trends and evaluate impact of exposure on drowning risk.

Methods: Descriptive epidemiological analysis of unintentional fatal drowning occurring July 2004-June 2021 at Australian coastal sites (beaches, rock platforms, bays, harbours, offshore locations etc.). Total population, exposed-person and exposed-person-time rates per 100,000 population were calculated by age, sex, socio-economic status, remoteness category and pre-submersion activity. Annual trends were assessed using joinpoint regression. Exposure-based rates used estimates from Surf Life Saving Australia's National Coastal Safety Survey.

Results: The cumulative unintentional coastal fatal drowning rate was 0.43 per 100,000 Australian residents (95%CI: 0.41–0.45) and did not change throughout the study period (p=0.289). The exposed-person rate was 0.67 per 100,000 coastal visitors (95%CI: 0.62–0.72), and there were 0.55 coastal drowning deaths per 10 million coastal visitor hours (95%CI: 0.51–0.59). Men, older people and residents of lower socio-economic and remote areas had higher drowning rates; rock fishing and scuba diving had the highest activity exposure-based rates.

Conclusions: Education- and policy-based coastal safety interventions should focus on identified risk factors to reduce annual coastal drowning rates.

Implications for Public Health: Exposure-based risk measurements are important for developing and prioritising interventions; assessments based on counts or total population measures alone may misinform prevention efforts.

Keywords: Drowning, Injury prevention, Exposure, Beach safety

Introduction

The coast is a core component of Australian identity with significant economic, social and cultural importance. Coastal zones, including beaches, rock platforms, tidal bodies such as bays and harbours, and offshore locations, can also be dangerous: dynamic environmental hazards interact with human factors to create complex risk profiles that change with time, place and circumstance.[1,2] Many types of fatal and non-fatal coastal incidents occur, for example, medical episodes while involved in coastal activities, trauma from falls or surf zone impact events, or interactions with marine wildlife.[3] However, drowning is the chief safety concern at coastal sites, and its prevention has been a long-term priority in Australia.[4]

Drowning is a global health problem,[5] with coastal-related submersion events a primary concern for communities with ocean access.[6] In Australia, governmental and non-governmental organisations engage in prevention activities including education, lifeguard and other emergency response services, safety legislation enforcement, and modification of environmental hazards.[7] Australian water safety organisations have also invested in robust surveillance systems resulting in high-quality drowning data and research to inform, guide and prioritise prevention initiatives.[8] These efforts have led to low fatal unintentional drowning rates in Australia compared with the burden in other regions (0.9 per 100,000 in Australia versus 14.5 in Oceania and 6.0 in central sub-Saharan Africa),[9] which continue to decrease with national-level strategies and sector-wide collaboration.[7]

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Australia is a world leader in coastal drowning research.[6] However, coastal drowning studies to date have focused on specific topics,[10] activities,[11] person factors[12] and particular locations.[13] National coastal drowning and fatality information is presented annually in industry reports by Surf Life Saving Australia (SLSA),[3] but no long-term national-level epidemiological analysis of unintentional coastal drowning deaths exists.

Analyses of this nature are important as describing variation in frequency and understanding the patterns of occurrence in a population are foundational for lessening the drowning burden.[14] One major challenge in drowning epidemiology is estimating the population at risk because exposure to water varies. This makes identifying high-risk populations for focused prevention efforts difficult and population-based risk measurements limited and potentially misleading. Important advancements have been made in exposure-based drowning risk measurements in the Australian context; most notably by Mitchell et al. who used revised exposed population and exposed person-time estimates from a state-wide population health survey[15]; and by Morgan and Ozanne-Smith in research developing and testing methods of measuring water exposure on surf beaches.[16,17]

Our study advances understanding of Australia's unintentional fatal coastal drowning burden in two ways. First, we examine national-level coastal drowning burden and trends over a 17-year study period and assess for meaningful increases or decreases in fatal unintentional coastal drowning rates. Second, we approach the problem from multiple perspectives by using national coastal drowning risk measurements based on total population, exposed-person, and exposed-person-time estimates from combined mortality and SLSA's National Coastal Safety Survey (NCSS) data.[18] This study aims to provide a comprehensive perspective of Australia's burden of coastal fatal drowning for relevant coastal safety stakeholders, ensuring prevention and education efforts, and their funding, are focused on those populations and activities representing the highest risk.

Method

This retrospective descriptive epidemiological analysis of fatal unintentional coastal drowning occurring in Australia (i) describes person, environment, time and geographic based factors of coastal drowning deaths; (ii) assesses trends in coastal drowning rates; and (iii) evaluates the impact of exposure to the coast, and participation in coastal activity, on drowning risk.

Data Sources

Drowning data

SLSA maintains a total population, coronial-based mortality dataset of all fatalities, from drowning and other causes, occurring at Australian coastal sites, including beaches, coastal rocks and offshore, the latter of which describes the coastal and oceanic water area beyond the surf zone and inshore area from 500 meters up to 200 nautical miles.[3] For each fatality, information from the National Coronial Information System is supplemented with details from media reports and SLSA's Incident Report Database to populate over 100 data fields. We included fatal unintentional coastal drowning cases occurring between 1 July 2004 (when SLSA records began) and 30 June 2021. Fatal drowning is defined as *death following respiratory impairment from submersion or immersion in liquid*[19] and was determined using coronial findings. Coastal describes the *foreshore, seabed, large tidal bodies of water such harbours, bays, or inlets*.[3] We excluded drowning deaths occurring from external Australian territories and the Torres Strait because the NCSS, described in the following sections, did not gather responses from these areas.

Population data

Australian resident population data were sourced from the Australian Bureau of Statistics (ABS). We used ABS estimates for annual resident population as of June of the preceding financial year for 2004–2020 by age group and sex; and used the 2006, 2011 and 2016 ABS data releases for socio-economic and remoteness information. The Socio-Economic Indexes for Areas (SEIFA) Index of Relative Socio-Economic Advantage and Disadvantage deciles provide a measure of socio-economic conditions by geographic area, which we converted to quintiles for analysis.[20] Using the Australian Standard Geographical Classification (ASGC), remoteness areas in Australia are divided into five categories based on relative access to services: major cities, inner regional, outer regional, remote, and very remote.[21] We linked SEIFA and remoteness data to each case based on the postcode of the decedent's residence as per coronial data: deaths occurring in the years 2004–2008, 2009–2013 and 2014–2021 were linked to SEIFA and remoteness information for their residence postcode from the 2006, 2011 and 2016 data releases, respectively; the 2021 data release was not available at the time of analysis. Cases where resident postcode was unavailable (n = 260, 13.16%) were excluded from SEFIA and remoteness category analyses.

Activity-based coastal participation data

Activity-based participation data were sourced from SLSA's NCSS. The NCSS has been described in detail elsewhere[18] but, briefly, is an annual coastal activity and knowledge survey of a representative sample of the Australian population; the specific activity-based data from the survey used in this study are described in the following section. The first NCSS was conducted in 2014 and has been repeated each year thereafter by a professional market research agency (OmniPoll: http://www.omnipoll.com.au) and SLSA. Participants are recruited by a third-party market research online panel company based on pre-determined demographic quotas and respond to questions related to coastal exposure including which coastal activities the respondent participates in and how often. Survey responses were post-weighted by OmniPoll to reflect a representative sample of the Australian population. This study uses NCSS responses from 2014 through 2021 (n=13,617).

Statistical analysis

We described the number and proportion of all unintentional coastal drowning deaths that occurred in Australia between 1 July 2004 and 31 June 2021 by age group and factors related to the person and incident. We then calculated cumulative and annual crude fatal drowning rates per 100,000 population by age, sex, SIEFA quintile, remoteness and pre-submersion activity for the 17-year study period. Population-based rates were calculated using cases residing in Australia at the time of death as the numerator: residents, students and those on working visas were included; short-term overseas visitors (tourists), asylum seekers and cases where residency could not be determined were excluded (n=301). Denominator data were sourced from ABS population estimates. Trends and changes in annual fatal drowning rates were described and assessed using

Table 1: Person and event characteristics by age group for all cases of fatal unintentional coastal drowning, Australia, 2004/2005–2020/2021 (N=1,976).

Variable	Age Unknown N (%)	Age 0–15 N (%)	Age 16–29 N (%)	Age 30–44 N (%)	Age 45–59 N (%)	Age 60+ N (%)	All Ages N (%)
Total	16 (0.8)	57 (2.9)	422 (21.4)	478 (24.2)	462 (23.4)	541 (27.4)	1976 (100)
Person Characteristics							
Sex							
Female		18 (7.1)	45 (17.7)	49 (19.4)	68 (27)	72 (28.6)	252 (100)
Male	NP	39 (2.3)	377 (22.)	429 (25.1)	394 (23)	469 (27.4)	1712 (100)
Unknown	12 (100)						12 (100)
Residence SEIFA Quintile							
1–2	NP	20 (6.4)	68 (21.8)	63 (20.2)	73 (23.4)	87 (27.9)	312 (100)
3–4		12 (3.6)	65 (19.5)	80 (24)	83 (24.9)	94 (28.1)	334 (100)
5–6		7 (2.4)	64 (22.2)	84 (29.2)	64 (22.2)	69 (24)	288 (100)
7–8		11 (3.3)	78 (23.6)	86 (26.1)	72 (21.8)	83 (25.2)	330 (100)
9–10		6 (1.3)	88 (19.5)	112 (24.8)	115 (25.4)	131 (29)	452 (100)
Unknown	15 (5.8)	NP	59 (22.7)	53 (20.4)	55 (21.2)	77 (29.6)	260 (100)
Residence Remoteness							
Major Cities of Australia		32 (3)	254 (23.6)	274 (25.4)	244 (22.6)	274 (25.4)	1078 (100)
Inner Regional Australia		16 (4.4)	57 (15.8)	76 (21)	93 (25.7)	120 (33.2)	362 (100)
Outer Regional Australia	NP	8 (3.8)	36 (17.2)	54 (25.8)	57 (27.3)	53 (25.4)	209 (100)
Remote Australia			15 (30.6)	13 (26.5)	10 (20.4)	11 (22.5)	49 (100)
Very Remote Australia			NP	8 (44.4)	NP	6 (33.3)	18 (100)
Unknown	15 (5.8)	NP	59 (22.7)	53 (20.4)	55 (21.6)	77 (29.6)	260 (100)
Residence Distance to Drowning Location							
< 10 km		22 (4.4)	81 (16.2)	97 (19.4)	123 (24.7)	176 (35.3)	499 (100)
10–50 km		14 (3.2)	105 (23.6)	110 (24.7)	109 (24.5)	107 (24.0)	445 (100)
> 50 km (Interstate)		NP	36 (27.7)	31 (23.9)	31 (23.9)	28 (21.5)	130 (100)
> 50 km (Intrastate)		12 (2.4)	114 (22.8)	148 (29.5)	116 (23.2)	111 (22.2)	501 (100)
International	13 (6.4)	NP	48 (23.5)	43 (21.1)	38 (18.6)	61 (30)	204 (100)
Unknown	NP	NP	38 (19.3)	49 (24.9)	45 (22.8)	58 (29.4)	197 (100)
Event Characteristics							
Drowning Location State							
NSW	NP	21 (3)	164 (23)	154 (21.6)	191 (26.8)	180 (25.3)	712 (100)
NT		NP	8 (18.7)	17 (39.5)	11 (25.6)	6 (14)	43 (100)
QLD		10 (2.5)	90 (22.4)	96 (23.9)	84 (21)	122 (30.4)	402 (100)
SA		8 (6.1)	26 (19.9)	22 (16.8)	34 (26)	41 (31.3)	131 (100)
TAS	NP	NP	15 (16.3)	26 (28.3)	25 (27.2)	22 (23.9)	92 (100)
VIC		11 (4)	52 (18.8)	81 (29.4)	50 (18.1)	82 (29.7)	276 (100)
WA	13 (4)	NP	67 (20.9)	82 (25.6)	67 (20.9)	88 (27.5)	320 (100)
Activity							
Swimming/Wading	NP	32 (5.7)	160 (28.4)	120 (21.3)	102 (18.1)	149 (26.4)	564 (100)
Boating	13 (2.9)	9 (2)	51 (11.5)	106 (24)	98 (22.2)	165 (37.3)	442 (100)
Rock Fishing	NP	NP	41 (19.3)	57 (26.9)	65 (30.7)	47 (22.2)	212 (100)
Snorkelling		NP	33 (22.3)	43 (29.1)	25 (16.9)	46 (31.1)	148 (100)
Watercraft		NP	31 (21.7)	37 (25.9)	38 (26.6)	34 (23.8)	143 (100)
Fall		NP	39 (37.1)	14 (13.3)	24 (22.9)	24 (22.9)	105 (100)
Scuba Diving			9 (11.3)	29 (36.3)	29 (36.3)	13 (16.3)	80 (100)
Attempting a Rescue		NP	18 (24.7)	25 (34.3)	19 (26)	8 (11)	73 (100)
Other	NP	NP	8 (32)	5 (20)	NP	5 (20)	25 (100)
Jump		NP	14 (63.6)	5 (22.7)	NP		22 (100)
Fishing			NP	5 (27.8)	NP	8 (44.4)	18 (100)
Non-Aquatic Transport			NP	5 (25)	6 (30)	6 (30)	20 (100)
PWC			NP	6 (35.3)	7 (41.9)	NP	17 (100)
Unknown			13 (12.2)	21 (19.6)	40 (37.4)	33 (30.8)	107 (100)
Between SLS Flags							
Yes		NP	5 (16.1)	5 (16.1)	11 (35.5)	8 (25.8)	31 (100)
No	NP	51 (3)	372 (21.6)	411 (23.9)	415 (24.1)	471 (27.4)	1721 (100)
Unknown	15 (6.7)	NP	45 (20.1)	62 (27.7)	36 (16.1)	62 (27.7)	224 (100)

(continued)

TABLE 1. Continued

Variable	Age Unknown N (%)	Age 0–15 N (%)	Age 16–29 N (%)	Age 30–44 N (%)	Age 45–59 N (%)	Age 60+ N (%)	All Ages N (%)
Victim Alone							
Yes		NP	61 (13.)	105 (22.4)	142 (30.3)	157 (33.5)	469 (100)
No, w friends/family		45 (4.6)	262 (26.8)	251 (25.7)	200 (20.5)	219 (22.4)	977 (100)
No, w organised activity		NP	26 (17.3)	40 (26.7)	37 (24.7)	44 (29.3)	150 (100)
No, with strangers	14 (9.6)		21 (14.4)	26 (17.8)	34 (23.3)	51 (34.9)	146 (100)
Unknown	NP	5 (2.1)	52 (22.2)	56 (23.9)	49 (20.9)	70 (29.9)	234 (100)
Resuscitation Attempt		25 (3.8)	123 (18.8)	152 (23.2)	163 (24.9)	193 (29.4)	656 (100)
Confirmed Alcohol		NP	46 (21.9)	52 (24.8)	68 (32.4)	43 (20.5)	210 (100)
Confirmed Illicit Drugs			42 (33.3)	47 (37.3)	29 (23)	8 (6.4)	126 (100)
Confirmed Rip Current Present		22 (7.)	110 (35.5)	85 (27.4)	55 (17.7)	38 (12.3)	310 (100)
Weekday							
Sunday	NP	11 (2.8)	91 (23.4)	94 (24.1)	110 (28.3)	82 (21.1)	389 (100)
Monday		6 (2.7)	55 (25.1)	53 (24.2)	44 (20.1)	61 (27.9)	219 (100)
Tuesday	NP	8 (3.9)	39 (19.2)	43 (21.2)	43 (21.2)	69 (34)	203 (100)
Wednesday	NP	NP	38 (17.1)	54 (24.3)	48 (21.6)	77 (34.7)	222 (100)
Thursday		6 (2.8)	41 (19.4)	51 (24.2)	46 (21.8)	67 (31.8)	211 (100)
Friday		NP	42 (20.2)	39 (18.8)	51 (24.5)	72 (34.6)	208 (100)
Saturday		17 (4.8)	86 (24.4)	96 (27.8)	75 (21.3)	78 (22.2)	352 (100)
Unknown	13 (7.6)	1 (0.6)	30 (17.4)	48 (27.9)	45 (26.7)	35 (20.4)	172 (100)
Season							
Winter	NP	11 (2.8)	91 (23.4)	94 (24.2)	110 (28.3)	82 (21.1)	389 (100)
Spring		6 (2.7)	55 (25.1)	53 (24.2)	44 (20.1)	61 (27.9)	219 (100)
Summer	NP	8 (3.9)	39 (19.2)	43 (21.2)	43 (21.2)	69 (34)	203 (100)
Autumn	NP	NP	38 (17.1)	54 (24.3)	48 (21.6)	77 (34.7)	222 (100)
Unknown							
Incident Time							
Morning (6 am–12 pm)	NP	5 (1)	72 (15)	103 (21.5)	121 (25.7)	177 (37)	479 (100)
Afternoon (12 pm–6 pm)		35 (4.3)	197 (24.2)	195 (24)	182 (22.4)	204 (25.1)	813 (100)
Evening (6 pm–12 am)	NP	13 (6.3)	48 (23.4)	57 (28)	40 (19.5)	46 (22.4)	205 (100)
Night (12 am–6 am)		NP	34 (23.3)	34 (23.3)	43 (29.5)	34 (23.3)	146 (100)
Unknown	14 (4.2)	NP	71 (21.3)	89 (26.7)	76 (22.8)	80 (24)	333 (100)

joinpoint regression.[22] We assessed for changes in total annual drowning rates and for changes in rates by age, sex, SEIFA score, remoteness and activity.

Finally, for cases among those aged 16 or older occurring between 1 April 2013 and 31 March 2021, we assessed the impact of exposure on coastal fatal drowning risk by calculating cumulative population-based rates per 100,000 residents, exposure-based rates per 100,000 coastal visitors and activity participants, and person-time based rates per 10 million coastal/activity hours. Numerator data were sourced from the SLSA coastal fatality database; denominators were derived from ABS and NCSS data. The restricted age group and time-period for this analysis were selected because calculating rates requires the numerator and denominator to have the same population at risk and calendar period time: the NCSS includes only those aged 16 or older and began in April 2014 covering participation in coastal activities from "the last 12 months." Person-time-based rates are expressed per 10 million hours for presentation purposes, as several rates would have had to show the fourth or fifth decimal place if a smaller number of hours was selected.

The process of estimating exposure time was based on NCSS questions related to how often a person visited the coast or participated in specific coastal activities, and how long they typically spend at the coast or participating in the activity (Supplementary File 1). For total rates and rates by age, sex, SEIFA quintile and remoteness category, exposure estimates were based on the NCSS questions *How often do you visit the coast*?, which provides a monthly estimate of coastal visits; and *On a typical day, when you visit the coast, how many hours do you spend there*? For activity-specific exposure rates, calculated for boating, rock fishing, scuba diving, snorkelling, swimming/wading and watercraft (which includes surfing and bodyboarding), we used responses from the questions: *Now thinking about coastal activities, which of the following coastal activities have you participated in during the past 12 months*?; and, for each activity, *How often do you participate in these coastal activities*? and *On a typical day, when you participate in these activities, how many hours do you spend*?

For exposure-based rates per 100,000 coastal visitors and per 100,000 activity participants, we estimated the proportion of the population that visits the coast or participates in a specific coastal activity at least once per year, which we applied to ABS population estimates from the 2016 census to estimate an annual number of exposed persons. For person-time rates per 10 million coastal or activity hours, we estimated the number of annual hours exposed. For each NCSS respondent, we calculated the number of annual coastal visits and, for activity rates, specific activity sessions, by multiplying monthly visits/sessions by 12. Annual coastal/activity hours were calculated by multiplying the number of annual visits/sessions by the reported number of hours spent during a typical visit/session. Weighted averages of annual exposed coastal hours were calculated by group for age, sex, SEIFA score, and remoteness, then by age and sex for each category. Weighted averages of annual activity hours were calculated by group, then by age and sex. Exposed hours were multiplied by ABS population data from the 2016 census to develop annual person-time exposure estimates.

Annual estimates of exposed persons and exposed person-time were multiplied by eight for each year of the April 2013–March 2021 study period and served as the denominator for cumulative rates per 100,000 visitors/participants and per 10 million coastal/activity hours, respectively. For total population, exposed person and exposed person-time rates, we calculated within group rate ratios for age, sex and activity to evaluate relative differences in rates between the three measures.

Data cleaning and analysis was conducted using R (Version 4.2.0) and Tableau Desktop (Version 2021.3), and joinpoint regression was conducted using the Joinpoint Regression Program (Version 4.9.0.1). We used the pollster package in R (Version 0.1.3) to analyse NCSS survey data; confidence intervals for rates assumed a Poisson distribution were calculated using Ulm's method in the epiR package (Version 2.0.19).[23] We calculated crude rates only based on guidance for data categories with small numbers[24]; we did not calculate rates for categories with fewer than 16 cases because rates computed from a small number of cases have poor reliability.[25]

This study was conducted with ethics approval from the Victorian Department of Justice and Community Safety Human Research Ethics Committee (CF/21/15898) and the UNSW Sydney Human Research Ethics Committee (HC200950).

Results

From the 3,277 coastal fatalities that occurred between 1 July 2004 and 30 June 2021, 1,976 fatal unintentional coastal drowning cases were included (Supplementary File 2). Table 1 shows person and event characteristics by age group. The cumulative unintentional fatal coastal drowning rate was 0.43 per 100,000 Australian residents (95% CI: 0.41–0.45); and men, older people, and those living in lower SEIFA quintiles and more remote post codes had higher drowning rates (Figure 1).

Annual percent change (APC) from joinpoint regression results from each category is available in Supplementary File 3. There was little evidence for increasing or decreasing trends in any of the categories over the 17-year study period. Total coastal fatal drowning rates showed an APC of -0.6% (95%CI: -1.8–0.6), but the trend was not statistically significant (p=0.289). Significant trends identified in coastal drowning rates were among residents in remote Australia, which decreased 5.6% annually from 2004–2005 to 2020–2021 (APC 95%CI:-10.5–0.5; p=0.035); fall-related drowning rates, which decreased annually by 15.2% between 2007–2008 and 2015–2016 (APC 95%CI: -26.7–2.0, p=0.03) and then increased by 29.4% from 2015–2016 to 2020–2021 (APC 95%CI: 3.9–61.2, p=0.026); and recreational jumping drowning rates, which increased 15% annually from 2005–2006 to 2015–2016 (APC 95%CI: 5.3%–25.7%, p=0.007). In a note on improving data quality, the annual rate of coastal drowning where the preceding activity was unknown significantly decreased by 8.4% over the study period, 2004–2005 to 2020–2021 (APC 95%CI: -13.2–3.4; p=0.003).

Based on 13,617 NCSS respondents, an estimated 79.89% of the Australian population visits the coast at least once per year (95%CI: 79.08%–80.7%), and on average, each visit lasts 2.65 hours (95%CI: 2.62–2.67). Coastal fatal drowning rates per 100,000 population, per 100,000 coastal visitors and per 10 million coastal hours for the NCSS study period, April 2013–March 2021, are shown by demographic variables in Table 2 and by activity, age and sex in Table 3.

Coastal drowning rates per 100,000 coastal visitors were higher than per 100,000 population as the former relies on a smaller denominator—only those who visit the coast one or more times per year. Population-based and coastal visitor-based rates differed for the

Figure 1: Unintentional fatal coastal drowning rates per 100,00 Australian residents, July 2004 – June 2021.

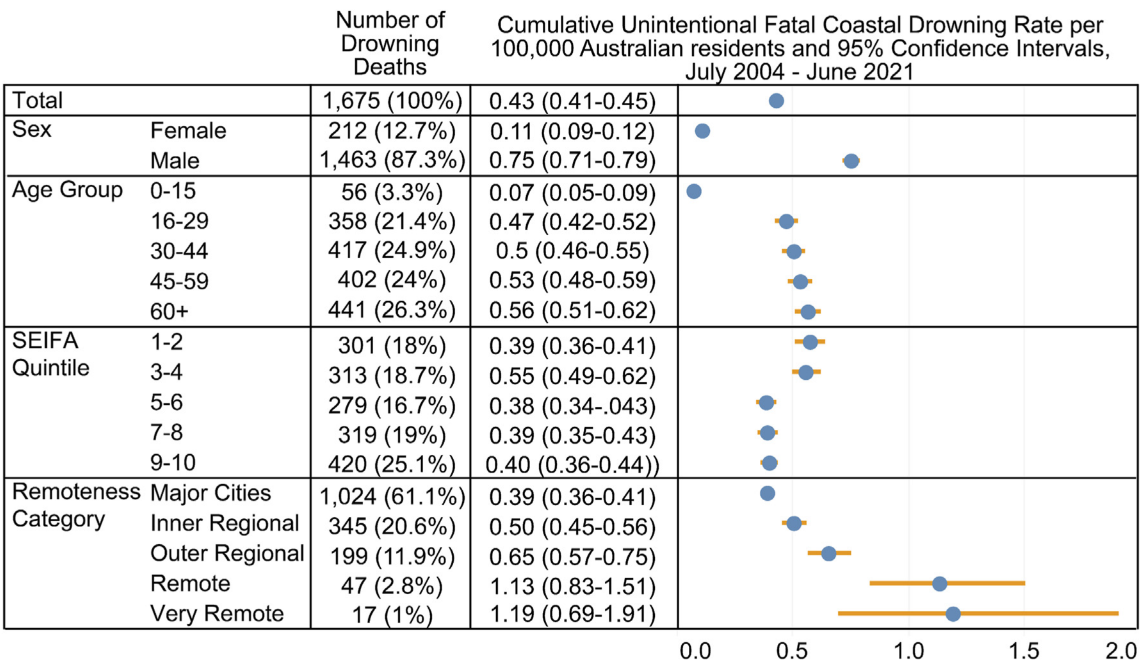

Table 2: Rates and 95% confidence intervals of unintentional coastal fatal drowning in Australia by demographic factors and activity using total population, exposed population (coastal visitor/activity participant), and person-time estimates (coastal/activity hours), April 2013 – March 2021.

		Drowning Deaths N (%)	Rate per 100,00 population (95% CI)	Rate per 100,000 exposed (95% CI)	Rate per 10 Million person-hours (95% CI)
Total		803 (100)	0.54 (0.50–0.57)	0.67 (0.62–0.72)	0.55 (0.51–0.59)
Sex					
Female	Age 16+	101 (12.6)	0.13 (0.11–0.16)	0.17 (0.14–0.2)	0.15 (0.12–0.19)
Male	Age 16+	702 (87.4)	0.96 (0.89–1.03)	1.18 (1.1–1.27)	0.88 (0.81–0.94)
Age					
16–29	Both sexes	174 (21.7)	0.5 (0.43–0.58)	0.6 (0.51–0.69)	0.43 (0.37–0.49)
	Female	19 (2.4)	0.11 (0.07–0.17)	0.13 (0.08–0.21)	0.11 (0.07–0.17)
	Male	155 (19.3)	0.88 (0.75–1.03)	1.04 (0.88–1.22)	0.66 (0.56–0.78)
30–44	Both sexes	205 (25.5)	0.53 (0.46–0.61)	0.63 (0.55–0.72)	0.52 (0.45–0.59)
	Female	23 (2.9)	0.12 (0.07–0.18)	0.14 (0.09–0.21)	0.12 (0.08–0.19)
	Male	182 (22.7)	0.95 (0.82–1.1)	1.13 (0.97–1.3)	0.86 (0.74–1)
45–59	Both sexes	194 (24.2)	0.53 (0.46–0.61)	0.71 (0.61–0.82)	0.59 (0.51–0.68)
	Female	33 (4.1)	0.18 (0.12–0.25)	0.24 (0.16–0.33)	0.22 (0.15–0.3)
	Male	161 (20.1)	0.9 (0.77–1.05)	1.2 (1.02–1.4)	0.91 (0.77–1.06)
60+	Both sexes	230 (28.6)	0.58 (0.51–0.66)	0.76 (0.66–0.86)	0.74 (0.64–0.84)
	Female	26 (3.2)	0.12 (0.08–0.18)	0.17 (0.11–0.25)	0.19 (0.13–0.28)
	Male	204 (25.4)	1.09 (0.95–1.25)	1.38 (1.19–1.58)	1.17 (1.01–1.34)
Residence SEIFA Quintile					
1–2	Age 16+, both sexes	143 (17.8)	0.61 (0.51–0.72)	0.83 (0.7–0.98)	0.62 (0.52–0.72)
	16–29	31 (3.9)	0.59 (0.4–0.84)	0.77 (0.52–1.09)	0.47 (0.32–0.66)
	30–44	29 (3.6)	0.54 (0.36–0.78)	0.72 (0.48–1.03)	0.69 (0.46–0.99)
	45–59	35 (4.4)	0.61 (0.43–0.85)	0.87 (0.61–1.21)	0.66 (0.46–0.92)
	60+	48 (6)	0.67 (0.49–0.89)	0.94 (0.69–1.24)	0.67 (0.49–0.89)
	Female	12 (1.5)	a	a	a
	Male	131 (16.3)	1.14 (0.95–1.35)	1.5 (1.25–1.78)	0.95 (0.8–1.13)
3–4	Age 16+, both sexes	159 (19.8)	0.67 (0.57–0.78)	0.86 (0.73–1)	0.61 (0.52–0.72)
	16–29	32 (4)	0.63 (0.43–0.88)	0.76 (0.52–1.07)	0.45 (0.31–0.64)
	30–44	38 (4.7)	0.68 (0.48–0.94)	0.85 (0.6–1.17)	0.61 (0.43–0.84)
	45–59	46 (5.7)	0.78 (0.57–1.04)	1.06 (0.78–1.42)	0.75 (0.55–1)
	60+	43 (5.4)	0.6 (0.43–0.8)	0.78 (0.56–1.05)	0.68 (0.49–0.92)
	Female	24 (3)	0.2 (0.13–0.29)	0.25 (0.16–0.38)	0.18 (0.12–0.27)
	Male	135 (16.8)	1.16 (0.97–1.38)	1.49 (1.25–1.76)	1.05 (0.88–1.24)
5–6	Age 16+, both sexes	130 (16.2)	0.46 (0.38–0.54)	0.58 (0.48–0.69)	0.51 (0.42–0.6)
	16–29	27 (3.4)	0.42 (0.28–0.61)	0.51 (0.33–0.74)	0.39 (0.26–0.57)
	30–44	39 (4.9)	0.52 (0.37–0.72)	0.62 (0.44–0.84)	0.49 (0.35–0.68)
	45–59	26 (3.2)	0.37 (0.24–0.54)	0.51 (0.33–0.75)	0.43 (0.28–0.62)
	60+	38 (4.7)	0.5 (0.36–0.69)	0.66 (0.47–0.9)	0.74 (0.52–1.01)
	Female	14 (1.7)	a	a	a
	Male	116 (14.5)	0.83 (0.69–1)	1.04 (0.86–1.25)	0.82 (0.68–0.99)
7–8	Age 16+, both sexes	141 (17.6)	0.45 (0.38–0.54)	0.55 (0.46–0.65)	0.45 (0.38–0.53)
	16-–29	34 (4.2)	0.45 (0.31–0.62)	0.53 (0.36–0.74)	0.36 (0.25–0.5)
	30–44	36 (4.5)	0.42 (0.3–0.59)	0.48 (0.34–0.67)	0.38 (0.26–0.52)
	45–59	31 (3.9)	0.42 (0.28–0.59)	0.54 (0.37–0.76)	0.48 (0.33–0.68)
	60+	40 (5)	0.53 (0.38–0.72)	0.68 (0.48–0.92)	0.79 (0.56–1.07)
	Female	21 (2.6)	0.13 (0.08–0.2)	0.16 (0.1–0.25)	0.14 (0.09–0.21)
	Male	120 (14.9)	0.79 (0.66–0.95)	0.95 (0.79–1.14)	0.75 (0.63–0.9)
9–10	Age 16+, both sexes	203 (25.3)	0.47 (0.41–0.54)	0.57 (0.49–0.65)	0.51 (0.44–0.59)
	16–29	41 (5.1)	0.4 (0.28–0.54)	0.45 (0.32–0.61)	0.37 (0.26–0.5)
	30–44	57 (7.1)	0.48 (0.36–0.62)	0.56 (0.42–0.72)	0.5 (0.38–0.65)
	45–59	52 (6.5)	0.5 (0.38–0.66)	0.64 (0.48–0.83)	0.6 (0.44–0.78)
	60+	53 (6.6)	0.52 (0.39–0.68)	0.67 (0.5–0.87)	0.69 (0.52–0.91)
	Female	30 (3.7)	0.14 (0.09–0.19)	0.17 (0.11–0.24)	0.18 (0.12–0.26)
	Male	173 (21.5)	0.84 (0.72–0.97)	0.98 (0.84–1.14)	0.76 (0.65–0.88)

(continued)

TABLE 2. Continued

		Drowning Deaths N (%)	Rate per 100,00 population (95% CI)	Rate per 100,000 exposed (95% CI)	Rate per 10 Million person-hours (95% CI)
Residence Remoteness Category[c]					
Inner Regional Australia	Age 16+, both sexes	167 (20.8)	0.62 (0.53–0.72)	0.81 (0.69–0.94)	0.6 (0.51–0.69)
	16–29	23 (2.7)	0.44 (0.28–0.66)	0.53 (0.33–0.79)	0.34 (0.21–0.51)
	30–44	38 (4.7)	0.66 (0.47–0.9)	0.84 (0.59–1.15)	0.71 (0.5–0.98)
	45–59	44 (5.5)	0.63 (0.46–0.85)	0.87 (0.63–1.16)	0.64 (0.47–0.86)
	60+	62 (7.7)	0.68 (0.52–0.88)	0.92 (0.71–1.19)	0.68 (0.52–0.88)
	Female	16 (2)	0.12 (0.07–0.19)	0.15 (0.09–0.25)	0.13 (0.08–0.22)
	Male	151 (18.9)	1.15 (0.97–1.35)	1.48 (1.25–1.73)	0.94 (0.8–1.1)
Major Cities of Australia	Age 16+, both sexes	489 (61)	0.45 (0.41–0.49)	0.56 (0.51–0.61)	0.49 (0.45–0.53)
	16–29	121 (15.1)	0.45 (0.38–0.54)	0.54 (0.45–0.64)	0.4 (0.33–0.47)
	30–44	125 (15.6)	0.42 (0.35–0.5)	0.5 (0.41–0.59)	0.42 (0.35–0.51)
	45–59	116 (14.5)	0.45 (0.37–0.54)	0.6 (0.49–0.72)	0.53 (0.44–0.64)
	60+	127 (15.8)	0.48 (0.4–0.57)	0.62 (0.52–0.74)	0.76 (0.63–0.9)
	Female	67 (8.3)	0.12 (0.09–0.15)	0.15 (0.12–0.19)	0.15 (0.11–0.19)
	Male	422 (52.6)	0.8 (0.73–0.88)	0.98 (0.89–1.08)	0.78 (0.71–0.86)
Outer Regional Australia	Age 16+, both sexes	89 (11.1)	0.77 (0.62–0.94)	0.95 (0.77–1.17)	0.54 (0.43–0.66)
	16–29	15 (1.9)	a	a	a
	30–44	25 (3.1)	0.94 (0.61–1.39)	1.11 (0.72–1.64)	0.66 (0.43–0.98)
	45–59	24 (3)	0.79 (0.5–1.17)	1 (0.64–1.49)	0.59 (0.38–0.88)
	60+	25 (3.1)	0.7 (0.46–1.04)	0.93 (0.6–1.37)	0.47 (0.31–0.7)
	Female	14 (1.7)	a	a	a
	Male	75 (9.3)	1.29 (1.02–1.62)	1.51 (1.18–1.89)	0.85 (0.67–1.07)
Remote Australia	Age 16+, both sexes	18 (2.2)	1.15 (0.68–1.82)	1.6 (0.95–2.53)	2.03 (1.21–3.21)
Very Remote Australia	Age 16+, both sexes	13 (1.6)	a	a	a
Activity					
Boating	Age 16+, both sexes	179 (22.3)	0.12 (0.1–0.14)	0.71 (0.61–0.82)	1.26 (1.08–1.46)
	16–29	17 (2.1)	0.05 (0.03–0.08)	0.22 (0.13–0.35)	0.31 (0.18–0.5)
	30–44	48 (6)	0.12 (0.09–0.16)	0.68 (0.5–0.9)	1.06 (0.78–1.41)
	45–59	37 (4.6)	0.1 (0.07–0.14)	0.7 (0.49–0.97)	1.71 (1.2–2.36)
	60+	77 (9.6)	0.19 (0.15–0.24)	1.71 (1.35–2.13)	4.53 (3.57–5.66)
	Female	9 (1.1)	a	a	a
	Male	170 (21.2)	0.23 (0.2–0.27)	1.19 (1.02–1.38)	1.83 (1.56–2.13)
Rock Fishing	Age 16+, both sexes	93 (11.6)	0.06 (0.05–0.08)	1.04 (0.84–1.27)	1.14 (0.92–1.4)
	16–29	20 (2.5)	0.06 (0.03–0.09)	0.57 (0.35–0.87)	0.44 (0.27–0.67)
	30–44	24 (3)	0.06 (0.04–0.09)	0.87 (0.56–1.29)	1.11 (0.71–1.66)
	45–59	27 (3.4)	0.07 (0.05–0.11)	1.68 (1.11–2.45)	2.89 (1.91–4.21)
	60+	22 (2.7)	0.06 (0.03–0.08)	2.39 (1.5–3.62)	6.24 (3.91–9.45)
	Female	9 (1.1)	a	a	a
	Male	84 (10.5)	0.11 (0.09–0.14)	1.36 (1.09–1.68)	1.37 (1.09–1.69)
Scuba Diving	Age 16+, both sexes	32 (4)	0.02 (0.01–0.03)	0.89 (0.61–1.25)	2.42 (1.65–3.41)
	16–29	0 (0)	b	b	b
	30–44	9 (1.1)	a	a	a
	45–59	17 (2.1)	0.05 (0.03–0.07)	3.59 (2.09–5.75)	30.65 (17.85–49.07)
	60+	6 (0.8)	a	a	a
	Female	5 (0.6)	a	a	a
	Male	27 (3.4)	0.04 (0.02–0.05)	1.16 (0.77–1.69)	3.48 (2.29–5.06)
Snorkelling	Age 16+, both sexes	53 (6.6)	0.04 (0.03–0.05)	0.31 (0.23–0.41)	0.97 (0.73–1.27)
	16–29	13 (1.6)	a	a	a
	30–44	20 (2.5)	0.05 (0.03–0.08)	0.36 (0.22–0.56)	0.97 (0.59–1.5)
	45–59	13 (1.6)	a	a	a
	60+	7 (0.9)	a	a	a
	Female	6 (0.8)	a	a	a
	Male	47 (5.9)	0.06 (0.05–0.09)	0.53 (0.39–0.7)	1.21 (0.89–1.6)

(continued)

TABLE 2. Continued

		Drowning Deaths N (%)	Rate per 100,00 population (95% CI)	Rate per 100,000 exposed (95% CI)	Rate per 10 Million person-hours (95% CI)
Swimming/Wading	Age 16+, both sexes	218 (27.2)	0.15 (0.13–0.17)	0.27 (0.24–0.31)	0.55 (0.48–0.63)
	16–29	66 (8.2)	0.19 (0.15–0.24)	0.29 (0.22–0.37)	0.43 (0.33–0.54)
	30–44	49 (6.1)	0.13 (0.09–0.17)	0.21 (0.16–0.28)	0.34 (0.25–0.45)
	45–59	41 (5.1)	0.11 (0.08–0.15)	0.24 (0.17–0.32)	0.89 (0.64–1.21)
	60+	62 (7.7)	0.16 (0.12–0.2)	0.4 (0.31–0.51)	1.82 (1.4–2.34)
	Female	40 (5)	0.05 (0.04–0.07)	0.1 (0.07–0.13)	0.25 (0.18–0.34)
	Male	178 (22.2)	0.24 (0.21–0.28)	0.46 (0.4–0.54)	0.76 (0.65–0.88)
Watercraft	Age 16+, both sexes	63 (7.9)	0.04 (0.03–0.05)	0.28 (0.21–0.35)	0.13 (0.1–0.16)
	16–29	10 (1.3)	a	a	a
	30–44	17 (2.1)	0.04 (0.03–0.07)	0.25 (0.15–0.4)	0.08 (0.05–0.13)
	45–59	16 (2)	0.04 (0.03–0.07)	0.42 (0.24–0.68)	0.61 (0.35–0.98)
	60+	20 (2.5)	0.05 (0.03–0.08)	0.93 (0.57–1.44)	1.32 (0.81–2.04)
	Female	0 (0)	b	b	b
	Male	63 (7.9)	0.09 (0.07–0.11)	0.46 (0.35–0.58)	0.18 (0.14–0.23)

[a]Rates not calculated due to fewer than 16 deaths.[25]
[b]Rates not calculated due to zero deaths.
[c]Rates for personal water craft (PWC), land-based fishing, Remote Australia, and Very Remote Australia categories not calculated due to small numbers.

total rate (0.56/100,000 population [95%CI: 0.53–0.6] *vs.* 0.71/100,000 coastal visitors [95%CI: 0.66–0.76]), the rate for those aged 60 years and older (0.58 [95%CI: 0.51–0.66] *vs.* 0.76 [95%CI: 0.66–0.86]) and the rate for males aged 16 and over (1.0 [95%CI: 0.93–1.08] *vs.* 1.23 [95% CI: 1.14–1.33]; Table 2). Confidence intervals for other demographic variables overlapped (Table 2). Rates and 95% confidence intervals based on coastal activity participation were higher than population-based counterparts, except for swimming/wading rates for females and those aged 16–29 and 35–44 (Table 3).

Within-group differences in coastal drowning rates varied when comparing the three different rate measurements (Table 3). Population, exposed person and exposed person-time rate ratios were similar for age; rate ratios for population and exposed person were similar when comparing males and females but attenuated in the rate per 10M hours (Table 3). Within-group differences for activity rates were magnified in the exposed-person rates and exposed-person-time rates, best highlighted in rates for those aged 60+ years involved in boating, rock fishing and swimming/wading (Table 3).

Discussion

Coastal drowning rates in Australia did not change over the 17-year study period. The lack of a statistically significant increase is encouraging and noteworthy as multiple conditions have made managing coastal safety more complex including a growing and diversifying population,[7] increasing disposable incomes allowing more time for recreation and leisure activities,[26] and infrastructure development increasing population density in urban coastal locations and expansion to suburban and inner regional coastal areas.[26] Conversely, the lack of any meaningful decrease in coastal drowning rates should be concerning given the significant financial investment in coastal safety by federal,[27] state[28] and local government,[29] as well as the substantial monetary and volunteer contribution from civil society organisations.[3]

Plateaued annual coastal drowning rates prompt important questions. Is the status quo, with current levels of funding, community engagement and education, and organisational infrastructure, the threshold of acceptable coastal drowning risk reduction in Australia? Some drowning prevention organisations have adopted "vision zero” statements and while the ethics, cost and rationale of similar approaches have been debated in other sectors such as road safety,[30] elimination of fatal drowning as a strategy has not been the subject of rigorous examination. Australia's comparatively low drowning rates[9] are a remarkable success and speak to the efforts of multi-sectoral action, particularly in a nation with strong beach and swimming cultures. Undoubtedly, coastal drowning rates have not increased due to existing efforts; however, coastal safety funding bodies and practitioners must consider if further reductions are possible, and if so, how this can be achieved.

Results from this study suggest that under current safety efforts, the coastal drowning rate is unlikely to change. Reduction of these already low rates, if possible, will require strategic intervention focused on modifiable risk factors, namely targeting the coastal activities people engage in and where they choose to do it. Which intervention strategies and risk factors, however, remain a major question. This study, by evaluating risk factors with exposure-based measurements, provides new information that can aid in this prioritisation process.

While age, gender, remoteness, and socio-economic status are not necessarily modifiable, analysing these factors serves a role in identifying populations at higher risk, allowing for prioritised intervention efforts. Males drowned at much higher rates than females across both population- and exposure-based measurements; but female drowning rates were incalculable for many activity variables due to so few deaths. Future work further defining the differences between age groups and genders would add value to the literature as coastal safety interventions may be more effective if designed specifically for men or women of particular ages: this study showed women aged 45–59 years and men in 60+ age group drowned at the highest rates. Interestingly, young adults in the 16- to 29-year age group had the lowest drowning rates in both population- and exposure-based risk measurements, and this group’s population rates did not change over the course of the study period (Supplementary File 3), which has implications for existing strategies.

Table 3: Rate ratios of unintentional coastal fatal drowning in Australia by selected activity and demographic variables using total population, visitor, and person-time estimates, April 2013–March 2021.

			Rate ratio per 100,000 population	Rate ratio per 100,000 exposed[a]	Rate ratio per 10 million person-hours[a]
Age	16–29	Both sexes	Ref	Ref	Ref
	30–44		1.06	1.06	1.22
	45–59		1.07	1.19	1.38
	60+		1.16	1.28	1.73
	16–29	Female	Ref	Ref	Ref
	16–29	Male	8.00	8.00	6.00
	30–44	Female	Ref	Ref	Ref
	30–44	Male	7.92	8.07	7.17
	45–59	Female	Ref	Ref	Ref
	45–59	Male	5.00	5.00	4.14
	60+	Female	Ref	Ref	Ref
	60+	Male	9.08	8.12	6.16
Sex	Female	Age 16+	Ref	Ref	Ref
	Male		7.27	7.08	5.73
	Female	16–29	Ref	Ref	Ref
		30–44	1.09	1.08	1.09
		45–59	1.64	1.85	2.00
		60+	1.09	1.31	1.73
	Male	16–29	Ref	Ref	Ref
		30–44	1.08	1.09	1.30
		45–59	1.02	1.15	1.38
		60+	1.24	1.33	1.77
Boating	Both sexes	16–29	Ref	Ref	Ref
		30–44	2.40	3.09	3.42
		45–59	2.00	3.18	5.52
		60+	3.80	7.77	14.61
Rock Fishing	Both sexes	16–29	Ref	Ref	Ref
		30–44	1.00	1.53	2.52
		45–59	1.17	2.95	6.57
		60+	1.00	4.19	14.18
Swimming/Wading	Both sexes	16–29	Ref	Ref	Ref
		30–44	0.68	0.72	0.79
		45–59	0.58	0.83	2.07
		60+	0.84	1.38	4.23
	Age 16+	Female	Ref	Ref	Ref
		Male	4.80	4.60	3.04

Footnote: SEFIA and Remoteness Categories not shown, activity categories without enough deaths not shown.
[a]Age and sex rates calculated per 100,000 coastal visitors and per 10M coastal hours; Boating, Rock Fishing and Swimming/Wading rates calculated per 100,000 activity participants and per 10M activity hours.

Young men have been the subject of considerable coastal safety focus in recent years[12]; however, these results indicate attention is warranted for those in older age groups, a demographic already identified as a priority population for drowning prevention.[31] Co-design methods centring the focus population in the intervention design process have been used to develop beach safety education programs for adolescents and may serve as a useful model applicable for safety efforts that focus on older adults as well.[32]

In general, those living in more remote locations and in areas of lower socio-economic status have higher coastal drowning rates. These results are consistent with previous literature related to remoteness and socio-economic status,[33,34] but there is potential variation in this trend by age group. Overlapping confidence intervals denote alternative possibilities, but point estimates for person-time risk measures indicate those in the 60+ age group residing in major cities and, separately, areas with SEIFA decile scores of 5 or higher drown at higher rates than their peers residing in more remote and lower SEIFA quintile areas. Importantly, this pattern was not observed in risk measurements based on population or exposed-person estimates, underscoring how the population-at-risk selected as the denominator in risk measurement rates changes the perceived importance of a particular group or variable when considering factors for intervention.[15]

The evaluation of activities preceding the coastal drowning event highlighted the benefit of examining the burden of coastal drowning from exposure-based measurements of risk. Considering exposure offers a new perspective regarding which activities should be considered high risk and targets for intervention: swimming/wading had the highest population-based rates; but rock fishing had the highest exposed-person rates and scuba diving had the highest exposed-person-time rates. This study shows how prioritising activities for increased safety focus or funding based on population measures alone could be misleading[35]; risk involved with a particular activity is only relevant to the participants of that activity, and further, depends on the amount of the time spent participating. For example, an analysis of population-based rates would prioritise safety interventions related to coastal watercraft activities such as surfing or bodyboarding over scuba diving as the watercraft rates were twice as high. However, considering exposure, scuba divers drown at rates 3.2 times higher than watercraft users (exposed-person rates) and 18.6 times that of watercraft users considering the amount of time spent in the activity (exposed-person-time rates). Even exposed-person estimates may not accurately reflect risk of an activity: exposed-person swimming and watercraft rates were similar (0.27 to 0.28, respectively), but the person-time rate for swimming/wading was 4.2 times higher than watercraft.

While different regions and communities in Australia may have different risk profiles, this country-level analysis shows that males, older populations, those living in remote and lower socio-economic areas, and participants of high-risk activities with increased exposure-based mortality rates such rock fishing, scuba diving and boating should be prioritised by the Australian coastal safety sector. However, the nature of interventions that will improve safety and reduce drowning rates among these groups remains to be established. Evidence on the effectiveness of coastal safety programs and initiatives is sparse[6] although recent publications have contributed new knowledge.[36–38] In Australia, significant reductions in drowning mortality and morbidity have come from pool fencing laws,[39] which combine the three Es of injury prevention: an *engineering* solution to isolate people from the hazard which is then *enforced* by legislation and complimented by *education* efforts.[40] The coastal environment, compared with pools, presents a complex landscape for this traditional injury intervention approach.

Modifying beaches, rock platforms or any other type of coastal environment with engineering solutions is expensive and requires careful ecosystem and economic considerations. However, while actually isolating and eliminating hazards such as waves or rip currents is difficult, protective environmental modifications may indeed save lives. First, the provision of professional lifeguarding or volunteer lifesaving services to areas where there are none, and extension of existing services to cover more days and/or hours would serve an important protective role.[41,42] Second, coastal infrastructure such as car parks, access pathways, fencing and other facilities dictate in large part where people visit and spend time on the coast.[43] Construction of new, and modifications/improvement to existing infrastructure must occur with a safety lens, ideally leading people to recreate in safer areas away from hazards. Finally, while safety signage serves a legal purpose for land managers, its role as a protective environmental modification presents as ineffective at best,[44] and confusing and problematic at worst.[45] New "smart" signs have debuted on several Australian beaches, but effectiveness has yet to be established.[46]

Opportunities for broad safety legislation in the coastal space are limited; however, enforceable laws related to specific aspects of some high-risk activities, such as boating or rock fishing, may save lives. Boating regulations such as mandatory lifejacket laws and substance use laws are effective in Australia[47] although it is important to couple education efforts with legislation: Wilcox-Pidgeon et al. identified unsuitable and inappropriate lifejacket wear (improper size, fit, type) as an important factor in Australian boating-related drowning deaths.[48] Lifejacket use is also an important safety recommendation for rock fishers[11]; several local governments in Australia mandate lifejacket use while rock fishing, but evidence for this regulation's effectiveness is still emerging and, at present, inconclusive.[49]

Education has been the primary focus of coastal safety practitioners[50] and is the most frequently recommended prevention strategy in the literature,[6] yet, it is the least effective injury prevention strategy[51] as increased knowledge or awareness does not guarantee safer behaviour or decisions.[52] Recent studies have demonstrated that school- and community-based education programs can successfully improve coastal safety knowledge,[36,37] but translation to behaviour remains elusive even when following best practice. A recent study from Victoria highlighted the limitations of education efforts alone, finding that a 3-year education campaign directed at rock fishers with a primary safety message related to lifejacket use was largely ineffective.[38] This is an important issue that warrants further study: research must establish if awareness of coastal hazards and knowledge of coastal safety practices translates to safer behaviours, and if so, what mediating conditions exist as facilitators or barriers.

While this study offers several new perspectives on coastal drowning in Australia, limitations remain. Resident-based rates are likely underestimated as cases where Australian residency was unknown were removed. Additionally, some cases could not be linked to postcodes that affected estimates for SEIFA and remoteness although there is no reason to believe these unknown postal codes induced selection bias. Data from the NCSS, which informed exposed-person and exposed-person-time estimates, are subject to temporal bias as the survey was completed in April of each year after the Australian summer and does not account for variation in seasonal coastal visits or activity participation. This potentially leads to an overestimate of coastal exposure and therefore conservative exposure-based rates calculated on an annual basis. Coastal visitation in Australia is seasonal[13] and difficult to capture.[17] Further, there are limitations in applying exposure measures to a broad population when regional and local variations are likely; capturing more specific and precise elements of coastal exposure, for example in a focused region or among a specific community, represents an important opportunity for future research. Additionally, it was not possible from NCSS data to determine coastal visitation stratified by patrolled (lifeguarded) versus unpatrolled status. Future NCSS surveys could include questions about visitation to patrolled sites, which would further serve to estimate drowning risk based on the type (patrolled *vs.* unpatrolled) location. Although these estimates likely lack precision, they represent a major advancement in our understanding of the problem.

Conclusions

This study has shown that Australian coastal drowning rates have remained consistent over the past 17 years. While encouraging that rates have not increased, the failure to improve despite significant and ongoing investment and effort suggests new, specific approaches are required. To reduce coastal drowning rates, the Australian coastal safety sector must strategically focus efforts and resources, partnering with high-risk populations to co-design collaborative, effective interventions.

Conflict of interest

WK and RB have both received financial compensation from various local government and not for profit organizations for consulting projects related to beach safety. JL is employed by, and receives a salary from Surf Life Saving Australia, who owns the data used in this study.

Ethical information

This study was conducted with ethics approval from the Victorian Department of Justice and Community Safety Human Research Ethics Committee (CF/21/15898).

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Appendix A Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.anzjph.2023.100034.