Building the Evidence Base for River Drowning Prevention

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Bachelor of Arts (Government and International Relations & Social Policy) *USyd*

Master of Public Policy *USyd*

25 July 2019

A thesis by portfolio of publications submitted in partial fulfilment of the requirements of the degree of Doctor of Philosophy (Health) within the College of Public Health, Medical and Veterinary Sciences, Division of Tropical Health and Medicine, James Cook University, Townsville, Australia.

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Student Biography

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National Manager – Research and Policy, Royal Life Saving Society – Australia

Amy is a passionate drowning prevention researcher and practitioner and is the leading expert worldwide on river drowning prevention. She has been working in drowning prevention research, policy and practice for the last 12 years. In her current position as National Manager – Research and Policy with Royal Life Saving Society – Australia her duties include the production of the National Drowning Report, maintaining the National Fatal Drowning Database, conducting research, analysing policy and evaluating drowning prevention programs. Within her role she also establishes and maintains research partnerships with a range of institutions including James Cook University, Griffith University, Curtin University, University of Technology Sydney and the University of Queensland among others.

Amy has authored 39 peer-reviewed articles, as well as 60 professional reports, and has been a lead author and presenter on over 60 conference papers, both domestically and internationally. Amy has been awarded the Royal Life Saving Commonwealth Diploma, an International Life Saving Federation Citation of Merit, awarded the Achievement in Practice in Injury Prevention and Safety Promotion Award in 2017 and in 2018 won gold in the print category of the International Safety Media Awards.

She has been involved in the development of Australian Standards on Personal Flotation Devices and the review of Standards Associated with the Safety of Private Swimming Pools. Amy has been a key contributor to the Australian Water Safety Council and a lead/contributing author to the last three iterations of the Australian Water Safety Strategy (2008-2011, 2012-2015, 2016-2020).

Amy regularly appears on television and radio having been interviewed on BBC World News, the Today Show, Nine Afternoon News, the Project, ABC Midday Report, ABC News 24 and Sky News among others. She is often quoted in print media discussing drowning statistics and prevention strategies. Publications she has appeared in include: The Sydney Morning Herald, The Daily Telegraph, The Brisbane Times, The West Australian and The Age among others.

Amy worked as an Australian Youth Ambassador for Development (AYAD) in Da Nang, Vietnam where she worked on the inaugural year of the SwimSafe program, a survival swimming program, designed to reduce the unacceptably high rates of child drowning in Vietnam. Tasks include project management and monitoring in the field, establishment and maintenance of the SwimSafe website and facilitating bi-lingual training sessions for staff.

Amy has been a member of the conference organising committee for the Australian Water Safety Summit 2014, the World Conference on Drowning Prevention 2011 (Vietnam), the World Conference on Drowning Prevention 2015 (Malaysia), the Non-Fatal Drowning Symposium 2017 and the Australian Water Safety Council Boating Safety Forum at the Marine 17 Conference, 2017. She is a member of the national organising committee for the forthcoming World Safety 2020 conference, with a focus on fostering engagement opportunities for, and participation by, students and early career researchers. She is also a member of the national organising committee for the Australasian Injury Prevention and Safety Promotion Conference in Brisbane in November 2019.

She has been an abstract reviewer for the Australian Water Safety Summit 2014, the World Conference on Drowning Prevention 2015 (Malaysia) and 2017 (Canada), as well as the Australasian Injury Prevention and Safety Promotion Conference 2017 and 2019. Amy also coordinated the Scholarship program for the World Conference on Drowning Prevention 2011, securing funds and managing applications that saw 56 successful applicants from 23 countries attend the conference.

Amy holds honorary appointments with the Injury Division of The George Institute for Global Health and the Health and Psychology Innovations (HaPI) Research Laboratory at Griffith University. She is a member of the Australasian Injury Prevention Network (AIPN) Executive Committee and their Communications Coordinator. She is a member of the International Life Saving Federation's Drowning Prevention and Public Education Commission and the Australian and New Zealand Safe Boating Education Group (ANZSBEG).

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Acknowledgements

Regardless of how passionate you are about the subject matter, completing a PhD is a challenge, especially when you are a part time, external student, with a full time job. There are many people, beyond those specifically mentioned below, who have encouraged and supported me throughout this journey, and I would sincerely like to thank them. Those who deserve a specific mention are as follows:

To my darling son Finn, you make every day a joy. Having you was the best mid-PhD distraction I could have hoped for! Thank you for your "typing" and "painting" and being resilient enough to cope when I was away. I love you very much. To my other darling, my (soon-to-be) husband Leigh. Thank you for picking up the slack and single-dadding it while I spent weeks away collecting data, Sundays in the office writing and making the bi-annual trips to Townsville. Thank you for helping me to follow this incredibly indulgent path, and keeping my spirits up while I did so. I love you. To my unborn son or daughter, thank you for the in-utero kicks, spurring me on while I finished this thesis.

To my parents, Stuart and Kerrie Peden. Thank you for always being interested in what I was up to, reading my papers and always tuning in to (and often recording) my interviews when I was on television. Thank you for instilling in me the confidence and resilience to complete this massive undertaking.

Thank you also to my brother Zander, my sister-in-law Lou and my gorgeous nieces (Queen) Matilda and (Princess) Ivy. Your interest in what I was up to and your willingness to step in and take care of Finn undoubtedly played a role in me being able to complete my thesis. Thank you.

To my parents in law, Sue and Buzz Holden. Thank you for your interest in my work, your support and your willingness to take care of and feed Finn (and sometimes Leigh and I) when I had to go away or recover. Your role in me completing the PhD cannot be underestimated. To my niece, Marcelle, and nephew, Charles, thank you for the at least 30 minutes you put in on the highlighters when I was doing my literature review!

To my primary supervisor Associate Professor Richard Franklin. I want to thank you for your patience in my slow start, housing me at your place, the guidance and support, the late night Skype calls and early morning (well really any time of the day) text messages. It's been fun and I predict big things for the post-doc! Also a big thank you to Emily, Ro-Ro, Spencer and Quinn for letting me stay when I came up to Townsville, feeding me and letting me take over the spare room and sometimes the kitchen table. I will miss those visits!

To Professor Peter Leggat my secondary supervisor. Thank you for the advice, support and good humour throughout. The champagne and chips were always very welcome. I look forward to celebrating with a bottle of the good stuff when I graduate! Thank you also to Stacey Pidgeon and Matthews Riggs for their assistance with data collection in the field.

Sincere thanks to my employer Royal Life Saving Society – Australia (RLSSA), for the support, not only financial, but also the study leave to go to Townsville, collect data and write up my results. Seeing the results of the research embedded in river drowning prevention initiatives such as 'Respect the River' and 'Don't Let Your Mates Drink and Drown' has been rewarding and being able to speak to the community about the findings as they come to light has been an added bonus. Together I am sure that lives will be (and already have been) saved as a result of the combined efforts of the PhD research and RLSSA's community awareness and advocacy initiatives around the country.

I would also like to acknowledge and thank James Cook University (JCU) and the Graduate Research School (GRS). I was incredibly fortunate to receive several grants from the College of Public Health, Medical and Veterinary Sciences Higher Degree by Research Enhancement Scheme (HDRES). These grants allowed me to present at international conferences and to publish several of my papers as open access publications, making my research more accessible to practitioners and those outside the academic sector.

I would like to acknowledge and thank the following participants of the Delphi process who kindly volunteered their time to be a part of the project: Dr. Shayne Baker, Dr. Steve Beerman, Dr. Elizabeth Bennett, Dr. Joost Bierens, Dr. Lyndal Bugeja, Dr. Tessa Clemens, John Connolly, Mike Dunn, Professor Gerry Fitzgerald, Dr. Julie Gilchrist, Andrew Gissing, Dan Graham, Jonathan Gueverra, Professor Sebastian Jonkman, Dr. Olive Kobusingye, Dr. Mike Linnan, Scott Liske, Michael Martino, Tom Mecrow, Dr. David Meddings, Jonathan Passmore, Dr. Linda Quan, Dr. Aminur Rahman, Dr. Colleen Saunders, Dr. Becky Sindall, Dr. David Szpilman, Evan Walter, and Aaron Wright.

My final thanks go to those who participated in this research, in particular those that took the time out of their day at the river, usually wearing their swimmers, to complete a survey and be breathalysed. Thank you to those who informally shared with me their experiences of their local river, who confided in me about the drowning deaths they knew of and their own experiences with non-fatal drowning in the river. It is for these communities that I have undertaken this research, in the sincere hope that lives will be saved as a result of this work and we can all enjoy our beautiful rivers, creeks and streams safely.

Statement of Access

I, the undersigned, author of this work, understand that James Cook University will make this thesis available for use within the University Library and, via the Australian Digital Theses network, for use elsewhere.

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Statement of Sources

Declaration

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education.

Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

__30/05/2019_______________

Signature Date

Statement of the Contribution of Others

The following identifies the contribution of others on the thesis.

Assistance	Contributors
Tuition fee support	Australian Government Research Training Program Scholarship Royal Life Saving Society - Australia
Financial support	Royal Life Saving Society – Australia Higher Degree Research Enhancement Scheme, James Cook University
Supervision	A/Prof Richard Franklin, James Cook University Prof Peter Leggat, James Cook University
Data collection	A/Prof Richard Franklin, James Cook University Mrs Stacey Willcox-Pidgeon, Royal Life Saving Society – Australia Mr Matthew Riggs, James Cook University
Statistical support	A/Prof Richard Franklin, James Cook University Prof Peter Leggat, James Cook University Dr Daniel Lindsay, James Cook University
Editorial assistance (manuscripts)	A/Prof Richard Franklin, James Cook University Prof Peter Leggat, James Cook University A/Prof Peter Aitken, University of Queensland
Editorial assistance (thesis)	A/Prof Richard Franklin, James Cook University Prof Peter Leggat, James Cook University
Infrastructure	Royal Life Saving Society – Australia James Cook University

Statement of the Contribution of Others - Publications

This is to certify that this thesis embodies original work undertaken by the candidate, except where the contribution of others has been acknowledged in the publications. To my knowledge none of the papers has been submitted in support of any other award of this or any other University or Institution.

A copy of each of the published papers, as they appear in the journal, can be found in Appendix 1.

Thesis chapter	Publication No.	Publication on which based	Role of each author (**AEP is the HDR candidate**)	I confirm the candidate's contribution to this paper and consent to the inclusion of the paper in this thesis
2 (Literature Review)	1	**Peden AE**, Franklin RC, Leggat PA (2016) Fatal river drowning: the identification of research gaps through a systematic literature review. *Injury Prevention* 22: 202-209: doi:10.1136/injuryprev-2015-041750	AEP and RCF conceptualised and designed the study. AEP conducted the analysis, drafted the initial manuscript and approved the final manuscript as submitted. RCF carried out quality control of analysis, reviewed and revised the manuscript and approved the final manuscript submitted. PAL reviewed and revised the manuscript and approved the final manuscript as submitted.	Name: Amy Peden Signature and date: 28-04-2019 Name: Richard Franklin Signature and date: 5-05-2019 Name: Peter Leggat Signature and date: 7-05-2019
4 (Results – Part 1	2	**Peden AE**, Franklin RC, Leggat PA (2016) The Hidden Tragedy of	AEP and RCF conceived and designed the experiments. AEP collated and cleaned the	Name: Amy Peden

Epidemiology)		Rivers: A decade of unintentional fatal drowning in Australia, *PLoS ONE* 11(8): e0160709 doi: 10.1371/journal.pone.0160709	data. AEP and RCF analysed the data. AEP, RCF and PAL wrote the paper.	Signature and date: 28-04-2019 Name: Richard Franklin Signature and date: 5-05-2019 Name: Peter Leggat Signature and date: 7-05-2019
	3	**Peden AE**, Franklin RC, Leggat PA (2016) Alcohol and its contributory role in fatal drowning in Australian rivers, 2002-2012, *Accident Analysis and Prevention*, 2017, 98: 259-265. doi: 10.1016/j.aap.2016.10.009	AEP and RCF conceived the study design. AEP collated and cleaned the data. AEP conducted the analysis. RCF provided advice on analysis. AEP drafted the manuscript. RCF reviewed and revised the manuscript. PAL reviewed and revised the manuscript.	Name: Amy Peden Signature and date: 28-04-2019 Name: Richard Franklin Signature and date: 5-05-2019 Name: Peter Leggat Signature and date: 7-05-2019
	4	**Peden AE**, Franklin RC, Leggat PA, Aitken P. Causal Pathways of Flood Related River Drowning Deaths in Australia. *PLoS Currents Disasters*. 2017 May 18. Edition 1. doi:	AEP and RCF conceived the study design. AEP collated and cleaned the data. AEP conducted the initial analysis. AEP and RCF conducted the causal pathway analysis and conceptualised the flow charts. AEP drafted the manuscript. RCF reviewed and	Name: Amy Peden Signature and date: 28-04-2019 Name: Richard Franklin Signature and date: 5-05-2019 Name: Peter Leggat Signature and date: 7-05-2019

		10.1371/currents.dis.001072490b 201118f0f689c0fbe7d437	revised the manuscript. PAL reviewed and revised the manuscript.	Name: Peter Aitken Signature and date: 13-05-2019
5 (Results Part 2 – Exposure)	5	**Peden AE**, Franklin RC, Leggat PA (2018) Exploring visitation at rivers to understand drowning risk, *Injury Prevention*, Published Online First: 06 June 2018. doi: 10.1136/injuryprev-2018-042819	AEP and RCF conceptualised the study, designed the survey questionnaire, conducted the analysis, drafted and revised the manuscript. AEP collated and analysed the fatal drowning data. PAL provided oversight and advice on study design, analysis and revised the manuscript.	Name: Amy Peden Signature and date: 28-04-2019 Name: Richard Franklin Signature and date: 5-05-2019 Name: Peter Leggat Signature and date: 7-05-2019
	6	**Peden AE**, Franklin RC, Leggat PA (2018) Breathalysing and surveying river users in Australia to understand alcohol consumption and attitudes towards drowning risk, *BMC Public Health*, 18(1): 1393.	AEP and RCF were responsible for study design, questionnaire development and piloting, and data collection. AEP cleaned and coded the data, performed the statistical analyses and drafted the manuscript. RCF and PAL made critical revisions to the manuscript.	Name: Amy Peden Signature and date: 28-04-2019 Name: Richard Franklin Signature and date: 5-05-2019 Name: Peter Leggat Signature and date: 7-05-2019
	7	**Peden AE**, Franklin RC, Leggat PA, Lindsay, D (Under Review) Observing patterns of river usage	AEP, RCF and DL conceptualised the study. AEP and RCF developed the data collection tools and collected the data (alongside	

			Matthew Riggs and Stacey Pidgeon). AEP cleaned and coded the data. AEP analysed the data with assistance from RCF and DL. AEP drafted the manuscript. RCF, PAL and DL made critical revisions to the draft manuscript.	Name: Amy Peden Signature and date: 28-04-2019 Name: Richard Franklin Signature and date: 5-05-2019 Name: Peter Leggat Signature and date: 7-05-2019 Name: Daniel Lindsay Signature and date: 07-05-2019
	Short Report 1 (SR1)	**Peden AE**, Franklin RC, Leggat PA. The Flood-Related Behaviour of River Users in Australia. *PLOS Currents Disasters.* 2018 Jun 14 . Edition 1. doi: 10.1371/currents.dis.89e243413a0625941387c8b9637e291b.	AEP and RCF were responsible for study design, questionnaire development and piloting, and data collection. AEP cleaned and coded the data, performed the statistical analyses and drafted the manuscript. RCF and PAL made critical revisions to the manuscript.	Name: Amy Peden Signature and date: 28-04-2019 Name: Richard Franklin Signature and date: 5-05-2019 Name: Peter Leggat Signature and date: 7-05-2019
6 (Results Part 3 – Prevention)	8	**Peden AE**, Franklin RC, Leggat PA. Preventing river drowning deaths: Lessons from coronial recommendations. *Health*	AEP and RCF conceptualised the study. AEP collated, cleaned and coded the data and conducted the analysis. RCF assisted with the analysis using a (modified) SMART	Name: Amy Peden Signature and date: 28-04-2019

		Promotion Journal of Australia. 2017;00:1–9. doi: 10.1002/hpja.24	principle. RCF reviewed and revised the manuscript. PAL reviewed and revised the manuscript.	Name: Richard Franklin Signature and date: 5-05-2019 Name: Peter Leggat Signature and date: 7-05-2019
	9	**Peden AE**, Franklin RC, Leggat PA Developing drowning prevention strategies for rivers through the use of a modified Delphi process, *Injury Prevention*; Published Online First: 30 March 2019. doi: 10.1136/injuryprev-2019-043156	AEP and RCF conceptualised the study. AEP and RCF identified experts and AEP invited them to participate. AEP and RCF designed the surveys. AEP collated the data and conducted the analysis. RCF provided assistance and advice on data analysis. AEP drafted the manuscript. RCF reviewed and revised the manuscript. PAL reviewed and revised the manuscript.	Name: Amy Peden Signature and date: 28-04-2019 Name: Richard Franklin Signature and date: 5-05-2019 Name: Peter Leggat Signature and date: 7-05-2019
	Short Report 2 (SR2)	**Peden AE**, Franklin RC, Leggat PA. Cardiopulmonary resuscitation and first-aid training of river users in Australia: A strategy for reducing drowning. *Health Promotion Journal of Australia*. 2018;00:1–5. https://doi.org/10.1002/hpja.195	AEP and RCF were responsible for study design, questionnaire development and piloting, and data collection. AEP cleaned and coded the data, performed the statistical analyses and drafted the manuscript. RCF and PAL made critical revisions to the manuscript.	Name: Amy Peden Signature and date: 28-04-2019 Name: Richard Franklin Signature and date: 5-05-2019 Name: Peter Leggat Signature and date: 7-05-2019

Declaration on Ethics

The research presented and reported in this thesis was conducted within the guidelines for research ethics outlined in the National Statement on Ethics Conduct in Research Involving Human (1999), the Joint NHMRC/AVCC Statement and Guidelines on Research Practice (1997), the James Cook University Policy on Experimentation Ethics. Standard Practices and Guidelines (2001), and the James Cook University Statement and Guidelines on Research Practice (2001).

The research methodology received clearance from the:

- James Cook University Human Research Ethics Committee
    - Approval number: H6282
        - Papers 2,3,4,5 and 8
    - Approval number: H7166
        - Paper 9
    - Approval number: H7249
        - Papers 6, 7 and short reports 1 and 2
- Victorian Department of Justice Human Research Ethics Committee
    - Approval number: CF/15/13552
        - Papers 2,3,4,5 and 8
- Western Australia Coronial Ethics Committee
    - Approval number: EC20/2015
        - Papers 2,3,4,5 and 8

Copies of the ethics approvals can be found in Appendix 2.

Paper 1 being a systematic literature review, did not require ethics approval. Paper 5 features the findings of a computer assisted telephone survey (CATI) which was administered by the Central Queensland University. Prior to being administered, the survey received ethics approval from the Central Queensland University Human Research Ethics Committee (H14/09-203).

__30/05/2019__________________

Signature Date

Acknowledgement of Funding

I have been fortunate to receive several sources of funding while completing the thesis. RLSSA (my employer) provided $28,000 in direct funding to assist with data collection in the field, as well as in-kind support including study leave.

I was also fortunate to have been successful in receiving funding from JCU through the College of Public Health, Medical and Veterinary Sciences Higher Degree by Research Enhancement Scheme. I was awarded the following grants throughout my studies:

2015 – James Cook University Graduate Research Scheme Grants - $4,987.71
Successful in securing funds through the James Cook University Graduate Research Scheme Grants program to publish as Open Access a systematic literature review accepted into the A level Journal Injury Prevention (Impact Factor – 1.891).

2016 – James Cook University Higher Degree by Research Enhancement Scheme - $1,253.00
Successful in securing funds through the James Cook University Higher Degree by Research Enhancement Scheme for Open Access publishing fees to publish a 10 year review of drowning fatalities in rivers in PLoSONE (Impact Factor – 3.23).

2016 – James Cook University Higher Degree by Research Enhancement Scheme - $2,230.00
Successful in securing funds through the James Cook University Higher Degree by Research Enhancement Scheme for flights and registration fees to attend and present at the World Conference on Drowning Prevention (WCDP) 2017 in Vancouver, Canada.

2017 - James Cook University Higher Degree by Research Enhancement Scheme Round 2 - $1,000.00
Successful in securing funds through the James Cook University Higher Degree by Research Enhancement Scheme for conference registration fees for World Safety 2018 conference in Bangkok Thailand.

2018 – James Cook University Higher Degree by Research Enhancement Scheme – Round 1 - $1,500
Successful in securing funds through the James Cook University Higher Degree by Research Enhancement Scheme for part funding of open access publication fees to publish the breathalysing river users study in BMC Public Health (Impact Factor – 2.420).

2019 – James Cook University Open Access Publication Support - $2,000

Awarded $2,000 to support open access publication of an article from this thesis due to meeting candidature requirements on time. These funds were used to publish the Delphi study of river drowning prevention strategies as an open access publication in Injury Prevention (Impact Factor – 1.891)

Abstract

Introduction: Rivers account for a significant proportion of the global burden of drowning. Rivers are the leading location for unintentional fatal drowning in Australia. Through a public health approach, this research provides a framework to develop a detailed understanding (epidemiology, risk factors and strategies for the prevention) of unintentional fatal river drowning in Australia.

Methods: A mixed methods approach was used including: a systematic literature review; epidemiological analysis of a 10-year total population case-series and review of coronial recommendations; a CATI survey, community surveys, breathalysing and direct observation; and a modified Delphi process to develop prevention strategies.

Results: Males (80%), adults (85%), alcohol (41%) and increasing geographical remoteness (very remote 29 times [RR= 28.8] the risk of drowning compared to major city residents) are key risk factors for river drowning. Similar numbers of males and females visit rivers, often for different activities with river visitations more likely in the afternoon, on hot days, weekends and public holidays. Adjusting for exposure, older males (75+ years) had the greatest relative risk (RR= 1.12). Blood alcohol concentrations ≥0.05% were seen among both males and females with alcohol consumption at rivers more prevalent in the afternoon and early evening. Eight percent of river drowning cases generated coronial recommendations. Prevention strategies considered more likely to be effective included: avoiding alcohol; flood-related early warning systems; child supervision; learning to swim; lifejackets; and community-wide rescue and resuscitation skills.

Discussion: Preventing river drowning presents is a wicked problem, where usage of such locations is encouraged, often accompanied with alcohol consumption and a lack of on-site rescue services. Enacting legislation and subsequent enforcement are challenging due to mixed use, geographical dispersal and isolation. River drowning attracts an estimated economic burden of $318.70 million dollars per annum. Further investment in the development, implementation and evaluation of evidence-based drowning prevention interventions is warranted. Strategies such as community wide rescue and resuscitation skills, especially in remote locations, must be considered.

Conclusion: This research, the first to specifically explore river drowning in the world, highlights the value of taking a public health approach. By building a broad evidence base of the causal factors increasing river drowning risk, the likelihood of prevention strategies being effective is enhanced. Research findings were used in the development of the 'Respect the River' and 'Don't Let Your Mates Drink and Drown' drowning prevention programs, in partnership with Royal Life Saving Society – Australia, which have contributed to an 18% reduction in river drowning to date.

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Executive Summary

Rivers account for a significant proportion of the global burden of unintentional fatal drowning, estimated by the World Health Organization (WHO) to be 360,000 deaths annually. In Australia, rivers are the leading location for unintentional drowning, with the Australian Water Safety Strategy highlighting rivers as a key location where drowning reductions are needed to achieve an overall 50% reduction in unintentional fatal drowning in Australia by the year 2020. Despite this, there has been little focused research on river drowning and its prevention. Using a public health approach, this research provides a framework to develop a detailed understanding of the epidemiology, risk factors and strategies for the prevention of unintentional fatal drowning in rivers in Australia.

This thesis includes 11 publications in total; nine original articles and two short reports. A mixed methods approach was used, commencing with a systematic literature review framed around the identification of research gaps which included: a lack of an agreed definition for rivers; a lack of consensus among identified risk factors; few prevention strategies recommended (34.5% of published papers) and even fewer implemented and evaluated (3.4%). Further population-level research is recommended, particularly in low- and middle-income countries (LMIC) around prevention strategies.

A 10 year (2002/03 to 2011/12) national, total population epidemiological study was undertaken. Data collection was undertaken using a data triangulation method, with cases primarily drawn from the [Australian] National Coronial Information System (NCIS), as well as reports from media, police and lifesaving organisations. Overall burden and risk factors were explored, with a focus on alcohol (where a BAC ≥0.05% was deemed contributory to drowning), flooding (both slow onset and flash flooding) and coronial recommendations (assessed against a modified SMART principle and the Hierarchy of Control).

There were 770 rivers drowning deaths across the study period, a quarter (27%) of all drowning deaths in Australia. Being male (80%), an adult (85.3%), a local (i.e. residing within 100 km of the drowning location; 74%), geographical remoteness (remote areas 10 times and very remote areas 29 times the risk or drowning in a river compared to those in major cities) were identified as risk factors.

Alcohol was known to be involved in 41% of cases (n=312), with 196 (70.3%) recording a BAC ≥0.05%. Two fifths (40.3%) of adult river drowning victims had a BAC ≥0.20%. Alcohol involvement was more likely for those who drowned as a result of jumping into the river (X^2=7.8; p<0.01), Aboriginal and Torres Strait Islander people (X^2=7.8; p<0.01) and those who drowned in the evening

(X^2=7.8; p<0.01) and early morning hours (X^2=16.1; p<0.01). Seventeen percent of river drowning deaths were known to involve flooding. When examining river drowning rates per 100,000 population (i.e. without considering exposure), people aged 75+ years drown at a rate that is twice (RR=2.24; CI: 0.13-38.24) as high as children 0-4 years. River flood-related drowning risk was 80 times higher for those residing in remote areas, and 230 times higher for those residing in very remote areas, when compared to major cities. Non-aquatic transport incidents (i.e. vehicles driving or being swept into floodwaters) was the leading cause of death during times of flood (55%; n=71).

Of the 730 (94.8%) closed cases of river drowning within the NCIS, 58 cases (8% of total; 16% Multiple Fatality Events [MFEs]) had recommendations, resulting in 71 unique recommendations. Recommendations were often low on the Hierarchy of Control, namely administrative recommendations (68%) and behaviour-related (19%), meaning they are less likely to be effective in preventing similar future deaths.

An exploration of exposure to rivers, including the role of alcohol consumption, was also undertaken as part of the thesis. A range of methods were utilised which included: a nationally representative computer assisted telephone interviewing (CATI) survey, as well as a community survey, breathalysing and direct observation were also undertaken at four river locations across two states (New South Wales [NSW] and Queensland [QLD]).

Males represented 80% of river drowning deaths, although in the CATI survey similar numbers of males and females were identified as visiting rivers, albeit for different activities (females for activities that did not involve entering the water [e.g. walking beside the river] and males for fishing and watercraft activities). After adjusting for exposure, males were 7.6 times more likely to drown at rivers; female drowning rate increased by 50% (0.06 to 0.09 / 100,000); older males (75+ years) had the greatest relative risk of river drowning compared to 18-24 year olds males (RR=1.12; CI: 0.59-2.14); males were more likely to drown with alcohol present (RR=8.5; CI: 2.6-27.4) and in a watercraft-related incident (RR=25.5; CI: 3.5-186.9) than females.

The community survey breathalysed of 684 river users, of which 16% had a positive BAC (Mean positive BAC = 0.068%; SD± 0.08; Range=0.001-0.334%), with 7.2% recording a BAC ≥0.050% (Mean BAC ≥0.050% =0.132%; SD ± 0.06). Those significantly more likely to record a BAC ≥0.050% at the river were: aged 18–34 years; resided in inner regional and low socio-economic areas; visited the river in the afternoon, with friends, on days with higher maximum air temperatures; were frequent river users (11+ times in the last 30 days); and those who spend longer in the water (301+ minutes). River users who recorded a BAC ≥0.050% were more likely to self-report engaging in risky activities (i.e. diving into water of unknown depth and jumping into the river from height). River users on

Australia day (a national public holiday) were significantly more likely to drink heavily (Mean BAC ≥0.05% = 0.175%; SD ± 0.09).

Seventy five percent (74.9%) of river users surveyed had undertaken cardiopulmonary resuscitation (CPR) training previously. Social determinants of health did not impact CPR training participation and currency of qualification with major city residents reporting a longer mean time (5.4 years) since last trained than remote and very remote locations (2.0 years) and people residing in low socio–economic areas had a shorter time since qualification last current (5.8 years) than those residing in areas deemed high (7.2 years).

When surveyed about their flood-related behaviour, 36% of river users stated they had driven into floodwaters and 19% had swum in a flooded river. Males were more likely to report having undertaken both activities (drive into floodwaters X^2=19.0; p<0.001; swum in a flooded river X^2=26.5; p<0.001). Those aged 18-24 years (X^2 =17.9; p<0.001) and those residing in outer regional areas (X^2=21.1; p<0.001) were more likely to have swum in a flooded river, those born in Australia (X^2=7.6; p=0.006) and residing in major cities (X^2=4.9; p=0.027) were more likely to self-report having driven into floodwaters. Those who reported doing both activities were significantly more likely to record contributory levels of alcohol (i.e. a BAC ≥0.05%) when breathalysed at the river.

Direct observations of river interactions saw higher average numbers on weekends (44.2 (SD± 32.7)) and the Australia Day public holiday (96.8 (SD± 58.1)) than an average day (39.4 (SD± 29.4)). More females (M=20.6; SD±16.0) than males (M=18.3; SD±14.5) and more adults (M=26.0; SD±20.9) than children (M=13.3; SD±11.2) were observed. More people were observed in water (M=20.6; SD±20.4) than beside or on water. River visitations varied by location observed.

For the modified Delphi process study within this thesis, potential river drowning prevention strategies were explored using a global panel of researchers and practitioners, representing both high-income countries (HICs) and LMICs. Prevention strategies assessed as being more likely to be effective include: avoiding alcohol, engineering and early warning systems to reduce the risks of flooding, child supervision, learning to swim, lifejackets, and community-wide resuscitation skills.

Rivers are constantly changing and dynamic environments, used by a diverse range of people for a wide variety of activities. The prevention of drowning in rivers presents a challenge, where usage of such locations is encouraged, often accompanied with alcohol consumption, a lack of on-site drowning prevention and rescue services (i.e. lifeguards, public rescue equipment) and difficulties around enforcement due to geographical dispersal and isolation.

Exposure studies identified males as being more likely to consume alcohol and participate in activities putting them in direct contact with water, when compared to females. Further research is still required to understand why males account for 80% of river drowning statistics, despite similar visitation figures among males and females. Further research on river visitation, usage, alcohol consumption and behaviours and attitudes at a population level, in real time are required. Alternative methods for collecting river usage data, including the use of technology should be explored. A challenge remains in the collection of these data in the late evening and early morning hours when alcohol-related river drowning deaths are more likely to occur. Further research on this aspect of river drowning risk is required, to build on the increased knowledge this study has generated regarding where river drownings occur and who is most at risk. The factors impacting decisions to consume alcohol at rivers also requires further elucidation.

Although signage was not identified in the Delphi process as being an effective strategy for preventing river drowning, signage continues to be used at rivers, often as a form of remote supervision. There is limited evidence supporting its effectiveness, with previous studies of signage at beaches finding negligible benefit. Further research is required, in particular identifying the impact, or not, of signage on behaviour at rivers.

There is no silver bullet for river drowning prevention, with a range of evidence-based strategies required, that try and address the challenges identified in this study. Rivers are the leading location for unintentional fatal drowning in Australia, accounting for the highest economic burden, an estimated cost to the economy of $318.70 million dollars per annum in lost productivity. Therefore, further investment in the development, implementation and evaluation of evidence-based drowning prevention interventions is warranted. With a study of non-fatal drowning requiring hospitalisation identifying rivers as a location where drowning is more likely to be fatal (with a fatal to non-fatal drowning ratio of 1:0.48), tertiary strategies such as community-wide rescue and resuscitation skills must also be included. This research, has provided evidence for the development of river drowning prevention programs including 'Respect the River' and 'Don't Let Your Mates Drink and Drown' in partnership with Royal Life Saving Society – Australia.

This study, the first to specifically explore river drowning in the world, highlights the value of taking a public health approach to river drowning prevention, and makes a number of recommendations around future research and practice to further reduce river drowning deaths. By building a broad evidence base of the causal factors which increase river drowning risk and enhance the likelihood of prevention strategies being effective in saving lives.

List of Papers Completed for Thesis

There were 9 original articles and 2 short research articles completed for the thesis. Following is each paper's title, full reference and abstract.

Paper 1 – Fatal River Drowning: The Identification of Research Gaps Through a Systematic Literature Review

Peden AE, Franklin RC, Leggat PA (2016) Fatal river drowning: the identification of research gaps through a systematic literature review. *Injury Prevention* 22: 202-209: doi:10.1136/injuryprev-2015-041750

Introduction: Drowning is a leading cause of unintentional death. Rivers are a common location for drowning. Unlike other location-specific prevention efforts (home swimming pools and beaches), little is known about prevention targeting river drowning deaths.

Methods: A systematic literature review was undertaken using English language papers published between 1980 and 2014, exploring gaps in the literature, with a focus on epidemiology, risk factors and prevention strategies for river drowning.

Results: Twenty-nine papers were deemed relevant to the study design including 21 (72.4%) on epidemiology, 18 (62.1%) on risk factors and 10 (34.5%) that proposed strategies for prevention. Risk factors identified included age, falls into water, swimming, using watercraft, sex and alcohol.

Discussion: Gaps were identified in the published literature. These included a lack of an agreed definition for rivers, rates for fatal river drowning (however, crude rates were calculated for 12 papers, ranging from 0.20 to 1.89 per 100 000 people per annum), and consensus around risk factors, especially age. There was only one paper that explored a prevention programme; the remaining nine outlined proposed prevention activities. There is a need for studies into exposure patterns for rivers and an agreed definition (with consistent coding).

Conclusions: This systematic review has identified that river drowning deaths are an issue in many regions and countries around the world. Further work to address gaps in the published research to date would benefit prevention efforts.

Paper 2 – The Hidden Tragedy of Rivers: A Decade of Unintentional Fatal Drowning in Australia

Peden AE, Franklin RC, Leggat PA (2016) The Hidden Tragedy of Rivers: A decade of unintentional fatal drowning in Australia, *PLoS ONE* 11(8): e0160709 doi: 10.1371/journal.pone.0160709

Objective(s) – Describe unintentional drowning deaths in rivers, creeks and streams (rivers) in Australia and identify risk factors to inform prevention.

Design & Setting – This study is a cross-sectional, total population audit of all unintentional fatal drownings in Australian rivers between 1-July-2002 and 30-June-2012 using Australian coronial data. A modified Bonferroni test has been applied, deeming statistical significance p<0.04.

Results –Rivers (n=770; 26.6%) were the leading location among the 2,892 people who died from unintentional fatal drowning. This is a rate of 0.37/100,000 persons / annum. Within river drowning deaths common groups include; males (80.4%), adults (85.3%), adults who have consumed alcohol (28.8%), people who fell into the river (21.3%), people involved in non-aquatic transport incidents (18.2%) and locals (74.0%). Children were 1.75 times more likely than adults (p<0.04) to drown in rivers as a result of a fall and adults 1.50 times more likely to drown in rivers as a result of watercraft incidents when compared to children (p<0.04). When compared to males, females were 2.14 and 4.47 times respectively more likely to drown in rivers as a result of incidents involving non-aquatic transport (p<0.04) and being swept away by floodwaters (p<0.04). Males were 2.66 and 4.27 times respectively more likely to drown in rivers as a result of watercraft incidents (p<0.04) and as a result of jumping in (p<0.04) when compared to females.

Conclusion(s) – While rivers are the leading location for drowning in Australia, little is understood about the risks. This study has identified key groups (males, adults, locals) and activities. While males were more likely to drown, the risk profile for females differed.

Paper 3 – Alcohol and Its Contributory Role in Fatal Drowning in Australian Rivers, 2002-2012

Peden AE, Franklin RC, Leggat PA (2016) Alcohol and its contributory role in fatal drowning in Australian rivers, 2002-2012, *Accident Analysis and Prevention*, 2017, 98: 259-265. doi: 10.1016/j.aap.2016.10.009

Objective: Examine the prevalence of alcohol and its contributory role in unintentional fatal river drowning in Australia to inform strategies for prevention.

Methods: Cases of unintentional fatal river drowning in Australia, 1-July-2002 to 30-June-2012, were extracted from the NCIS. Cases with positive alcohol readings found through autopsy or toxicology reports were retained for analysis. Discrete analysis was conducted on cases with a BAC of ≥0.05% (0.05 grams of alcohol in every 100 millilitres of blood).

Results: Alcohol was known to be involved in 314 cases (40.8%), 279 recorded a positive BAC, 196 (70.3%) recorded a BAC of ≥0.05%. 40.3% of adult victims had a BAC of ≥0.20%. Known alcohol involvement was found to be more likely for victims who drowned as a result of jumping in (X^2= 7.8; $p < 0.01$), identify as Aboriginal and Torres Strait Islander (X^2= 8.9; $p < 0.01$) and drowned in the evening (X^2= 7.8; $p < 0.01$) and early morning (X^2= 16.1; $p < 0.01$) hours.

Discussion: The number of people who drown with alcohol in their bloodstream is concerning and challenging for prevention. To assist with the prevention of alcohol-related river drowning improved data quality, as well as a greater understanding of alcohol's contribution and consumption patterns at rivers (especially those <18 years of age) is required.

Conclusion: Alcohol contributes to fatal unintentional drowning in Australian rivers. Although prevention is challenging, better data and exposure studies are the next step to enhance prevention efforts.

Paper 4 – Analysis of Causal Pathways of Flood-Related River Drowning Deaths

Peden AE, Franklin RC, Leggat PA, Aitken P. Causal Pathways of Flood Related River Drowning Deaths in Australia. *PLoS Currents Disasters*. 2017 May 18. Edition 1. doi: 10.1371/currents.dis.001072490b201118f0f689c0fbe7d437

Introduction: Globally, flooding is the most common of all natural disasters and drowning is the leading cause of death during floods. In Australia, rivers are the most common location of drowning and experience flooding on a regular basis.

Methods: A cross-sectional, total population audit of all known unintentional river flood-related fatal drownings in Australia between 1-July-2002 and 30-June-2012 was conducted to identify trends and causal factors.

Results: There were 129 (16.8%) deaths involving river flooding, representing a crude drowning rate of 0.06 per 100,000 persons per annum. Half (55.8%) were due to slow onset flooding, 27.1% flash flooding and the type of flooding was unknown in 17.1% of cases. Those at an increased risk were males, children, driving (non-aquatic transport) and victims who were swept away ($p<0.01$). When compared to drownings in major cities, people in remote and very remote locations were 79.6 and 229.1 times respectively more likely to drown in river floods. Common causal factors for falls into flooded rivers included being alone and a BAC ≥0.05% (for adults). Non-aquatic transport incident victims were commonly the drivers of four wheel drive vehicles and were alone in the car, whilst attempting to reach their own home or a friend's.

Discussion: Flood-related river drownings are preventable. Strategies for prevention must target causal factors such as being alone, influence of alcohol, type/size of vehicle, and intended destination. Strategies to be explored and evaluated include effective signage, early warning systems, alternate routes and public awareness for drivers.

Paper 5 – Exploring Visitation at Rivers to Understand Drowning Risk

Peden AE, Franklin RC, Leggat PA (2018) Exploring visitation at rivers to understand drowning risk, *Injury Prevention*, doi: http://dx.doi.org/10.1136/injuryprev-2018-042819

Introduction: Globally, rivers are a common drowning location. In Australia, rivers are the leading location for fatal drowning. Limited information exists on exposure and impact on river drowning risk.

Methods: Australian unintentional fatal river drowning data (sourced from coronial records) and nationally representative survey data on river visitation were used to estimate river drowning risk based on exposure for adults (18 years and older). Differences in river drowning rates per 100,000 (population and exposed population) were examined by sex, age group, activity prior to drowning, alcohol presence and watercraft usage.

Results: Between 1-January-2014 and 31-December-2016, 151 people drowned in Australian rivers; 86% male and 40% aged 18-34 years. Of survey respondents, 73% had visited a river within the last 12 months. After adjusting for exposure: males were 7.6 times more likely to drown at rivers; female drowning rate increased by 50% (0.06 to 0.09 per 100,000); males aged 75+ and females aged 55-74 years were at highest risk of river drowning; and swimming and recreating pose a high risk to both males and females. After adjusting for exposure, males were more likely to drown with alcohol present (RR=8.5;CI:2.6-27.4) and in a watercraft-related incident (RR=25.5;CI:3.5-186.9).

Conclusions: Calculating exposure for river drowning is challenging due to diverse usage, time spent and number of visits. While males were more likely to drown, the differences between males and females narrow after adjusting for exposure. This is an important factor to consider when designing and implementing drowning prevention strategies to effectively target those at risk.

Paper 6 – Breathalysing and Surveying River Users in Australia to Understand Alcohol Consumption and Attitudes Toward Drowning Risk

Peden, AE., Franklin, RC and Leggat, PA. (2018). Breathalysing and surveying river users in Australia to understand alcohol consumption and attitudes toward drowning risk. *BMC Public Health* 18(1): 1393.

Background: Little is known about people's river usage, a leading drowning location. This study examines alcohol consumption patterns of river users and their attitudes to drowning risk.

Methods: A convenience sample of adult (18+ years) river users were surveyed at four river locations. The survey covered eight domains: demographics; river attendance frequency; frequency of engaging in water activities; drinking patterns; alcohol and water safety knowledge; alcohol and water safety attitudes; alcohol consumption; and BAC. For BAC, participants were asked to record time since their last alcoholic drink and were then breathalysed to record an estimate of their BAC. BAC was examined by BAC reading (negative, positive, ≥0.050%). Hazardous lifetime drinking levels were calculated and their impact on drowning risk evaluated. Univariate and chi square analysis (95% confidence interval) was conducted.

Results: Six hundred eighty four people participated (51.6% female; 49.0% aged 18–34 years). Sixteen percent (15.9%) had a positive BAC (Mean + BAC = 0.068%; SD ± 0.08; Range = 0.001–0.334%), with 7.2% ≥0.050% (Mean BAC ≥0.050% =0.132%; SD ± 0.06). Those significantly more likely to record a BAC ≥0.050% at the river were: aged 18–34 years, resided in inner regional and low socio-economic areas, visited the river in the afternoon, with friends, on days with higher maximum air temperatures, frequent river users (11+ times in the last 30 days) and those who spend longer in the water (301+ minutes). River users who recorded a BAC ≥0.050% were more likely to self-report engaging in risky activities (i.e. diving into water of unknown depth and jumping into the river from height). River users on Australia day (a national public holiday) were significantly more likely to drink heavily (Mean BAC ≥0.05% = 0.175%; SD ± 0.09).

Conclusions: Despite males accounting for 85% of alcohol-related river drowning deaths, similar numbers of males and females were consuming alcohol at the river. This study has addressed a gap in knowledge by identifying river usage and alcohol consumption patterns among those at increased drowning risk. Implications for prevention include delivering alcohol-related river drowning prevention strategies to both males and females; at peak times including during hot weather, afternoons, public holidays and to river users who swim.

Paper 7 – Observing Patterns of River Usage

Peden AE, Franklin RC, Leggat PA, Lindsay D (Under Review) Observing patterns of river usage

Objective: Rivers are a leading location for drowning, yet little is known about people's usage of these waterways. This study aimed to test the use of direct observations to calculate river visitation.

Methods: Direct observations were conducted at regular intervals within defined zones at four river drowning locations in Australia (including weekends and the Australia Day national public holiday).

Data recorded were date and time of observation, total people (including males, females, children and adults), and number of people on, in and beside the water. Univariate analysis with mean (SD), and range was conducted. Interrater reliability for observations was determined using the intraclass correlation coefficient (ICC) (one-way random-effects, average measures model), with a 95% confidence interval (CI).

Results: Across 149 time points, 309 observations were conducted, resulting in 13,326 river interactions observed by multiple observers. There was an average of 39 people (M=39.4, SD= 29.4, range =0-137) per observation, 44 people (M= 44.2, SD= 32.7, range=0-137) on an average weekend and 97 people (M= 96.8, SD= 58.1, range=20-190) on Australia Day. More females (M=20.6, SD=16.0, range=0-83) than males (M=18.3, SD=14.5, range=0-68) were observed. More people were observed in water (M=20.6, SD=20.4, range=0-84) than beside or on the water. Interrater reliability was excellent, consistently above 0.900 for all variables collected (apart from beside the river).

Conclusion: Despite males accounting for 80% of river drowning fatalities, more females than males were observed. Increased visitation on the Australia Day public holiday may link to increased drowning risk.

Practical Applications: This study detailed a simple approach to data collection exploring exposure within a defined zone at river locations. River usage is dynamic with people's movement in and out of the water changing their risk exposure. Observational-based data collection for drowning, particularly for rivers, is an important yet highly neglected area of research.

Paper 8 – Preventing River Drowning Deaths: Lessons From Coronial Recommendations

Peden AE, Franklin RC, Leggat PA. Preventing river drowning deaths: Lessons from coronial recommendations. *Health Promot J Austral*. 2017;00:1–9. doi: 10.1002/hpja.24

Issue addressed: Coronial data provide rich information on drowning causal factors. Coroners may make recommendations to prevent future drowning events. Rivers are the leading drowning location in Australia. This study examines coronial recommendations associated with unintentional fatal drowning in Australian rivers from an injury prevention perspective.

Methods: All river drowning cases in Australia between 1 July 2002 and 30 June 2012 were extracted from the National Coronial Information System (NCIS). Recommendations were thematically analysed. Using a deductive process, each unique recommendation was coded to a category aligned to the Hierarchy of Control's six levels. An inductive process was used for those not categorised. Recommendations were also coded against a modified SMART principle.

Results: Of the 730 river drownings, 58 cases (7.9%) resulted in 71 unique recommendations. Victorian cases ($X2 = 32.1$; $P < .01$) and multiple fatality events ($X2 = 41.9$;$P < .01$) were more likely to have recommendations. Common categories of recommendations were administrative (39.4%) and signage-related (18.3%). Recommendations were often low on the Hierarchy; namely administrative (67.6%) and behaviour (19.1%). Half (50.7%) satisfied 4 of 6 modified SMART principle components.

Conclusion: Coronial recommendations associated with river drowning in Australia are reasonably rare. Recommendations provide opportunities for organisations to enact change, however, they could be strengthened with a specified time period and higher order control strategies recommended.

So what? SMART coronial recommendations may be more successful in achieving the behavioural, social and societal change required to prevent future river drownings. The recommendations examined in this study can be used as a benchmark for what could be considered appropriate safety actions.

Paper 9 – Developing Drowning Prevention Strategies for Rivers

Peden AE, Franklin RC, Leggat, PA (2019) Developing Drowning Prevention Strategies for Rivers Through The Use of a Modified Delphi Process, *Injury Prevention.* Published Online First: 30 March 2019. Doi: 10.1136/injuryprev-2019-043156

Introduction: Internationally, rivers are a leading drowning location, yet little evidence exists evaluating river drowning prevention strategies. This study aims to use expert opinion to identify strategies more likely to be effective.

Methods: Using a modified Delphi process, a virtual panel of 30 experts from 12 countries considered, grouped and prioritised strategies for river drowning prevention. Proposed strategies were assessed against known evidence and suitability in high-income countries (HICs), as well as low-and middle-income countries (LMICs) using expert opinion. The final phase, consolidated a list of strategies whose effectiveness was assessed against 10 evidence-based river drowning scenarios.

Results: An initial list of 424 prevention strategies was refined to 22. After being assessed against the 10 scenarios, a final list of 13 strategies was derived. Strategies addressed alcohol consumption around rivers, flood mitigation, improving child supervision, learning to swim, increased lifejacket wear, and achieving community-wide resuscitation skills.

Discussion: While all 13 strategies were assessed as being effective in both LMICs and HICs by at least 60% of respondents, further work is required to define river drowning at a country level, and therefore allow for effective solutions to be developed, particularly in LMICs. No strategy will be effective in isolation and must be implemented alongside policy and behaviour change, public awareness and education. Evaluation should be incorporated as part of any future implementation of strategies.

Conclusion: This Delphi process identified 13 drowning prevention strategies for rivers. Further research is required to validate the efficacy of these findings through implementation and evaluation.

Short Research Articles

Short Research Article 1 – The Flood-Related Behaviour of River Users in Australia

Peden AE, Franklin RC, Leggat P. The Flood-Related Behaviour of River Users in Australia. *PLoS Currents Disasters.* 2018 Jun 14 . Edition 1. doi: 10.1371/currents.dis.89e243413a0625941387c8b9637e291b.

Introduction: Flooding is a common natural disaster affecting 77.8 million people and claiming the lives of 4,731 people globally in 2016. During times of flood, drowning is a leading cause of death. Flooding is a known risk factor for river drowning in Australia. With little known about river usage in Australia, this study aimed to examine the links between person demographics and self-reported participation in two flood-related behaviours, driving through floodwaters and swimming in a flooded river.

Methods: A self-reported questionnaire was administered to adult river users at four high-risk river drowning locations; Alligator Creek, Townsville, Queensland; Murrumbidgee River, Wagga Wagga, New South Wales; Murray River, Albury, New South Wales; and Hawkesbury River, Windsor, New South Wales. Univariate and chi square analysis was undertaken with a 95% confidence interval ($p<0.05$). All river users surveyed, were also breathalysed to record an estimate of their BAC on their expired breath.

Results: 688 river users responded to the questionnaire; 676 (98.3%) answered the driving question and 674 (98.0%) answered the swimming in floodwaters questions. Of the respondents, 35.7% stated they had driven through floodwater and 18.7% had swum in a flooded river. Males were more likely ($p<0.001$) to report having undertaken both activities. Australian-born respondents were more likely to report having driven through floodwaters ($p=0.006$). Those aged 18-24 years old and those residing in outer regional areas were more likely ($p<0.001$) to have swum in a flooded river. Those who self-reported participating in both driving through floodwaters ($p=0.001$) and swimming in a flooded river ($p<0.001$) were significantly more likely to record contributory levels of alcohol (i.e. a BAC ≥0.05%) when breathalysed at the river.

Discussion: Ensuring the safe movement of people during floods is difficult, particularly for those living in regional Australia, due in part to long distances travelled and reduced investment in infrastructure such as bridges. With males and females equally exposed, more effective prevention strategies must target both sexes and may include improved education on when it is safe to drive through (low depth, still water, stable road base) and when it is not (e.g. deep water, moving water and unstable road base). This study identified one in five respondents had swum in a flooded river, most commonly young people aged 18-24 years, with participants significantly more likely to have recorded contributory levels of alcohol when breathalysed. Further research should examine the reasons behind participation in this behaviour, including the role of alcohol.

Conclusion: Preventing drowning in floodwaters is an international challenge, made more difficult by people driving through or swimming in floodwaters. Strategies for driving through floodwaters should educate both males and females on when it is safe to drive through floodwaters and when it is not. Further research is required to improve knowledge of the poorly understood behaviour of swimming in flooded rivers.

Short Research Article 2 – Cardiopulmonary Resuscitation and First-aid Training of River Users in Australia: A Strategy For Reducing Drowning

Peden AE, Franklin RC, Leggat PA. Cardiopulmonary resuscitation and first-aid training of river users in Australia: A strategy for reducing drowning. *Health Promot J Austral*. 2018;00:1–5. https://doi.org/10.1002/hpja.195

Issue addressed: Rivers are a leading location for fatal drowning worldwide; often geographically isolated from timely medical assistance. Cardio-pulmonary resuscitation (CPR) benefits drowning victims and those who suffer cardiac arrests. This study explored CPR and first aid training of river users in Australia.

Methods: Adult river users (18+ years) were surveyed at four high-risk river drowning sites. Respondents were asked the last time they undertook CPR (responses converted into: 'CPR ever undertaken' -yes/no; and 'CPR training current' -yes/no (training undertaken ≤12 months ago). Responses were explored by demographics and social determinants of health.

Results: Of those surveyed (N=688), 98.4% responded regarding CPR. Seventy-five percent (74.9%) had undertaken CPR training previously. Females and 35-44 year olds were more likely to have undertaken training ($p<0.05$). Males and older people (65+ years) were less likely to hold a current qualification ($p<0.05$). Major city residents reported a longer mean time (5.4 years) since last trained than remote and very remote locations (2.0 years). People in low socio-economic areas had a shorter time since qualification current (5.8 years) than those in areas deemed high (7.2 years).

Conclusion: Current CPR qualifications are important, particularly among those visiting high-risk river drowning locations. System-level, upstream strategies that should be explored include compulsory CPR training in secondary schools and linking CPR updates to motor vehicle licence renewals.

So what? CPR is a vital component of multi-faceted river drowning prevention. Social determinants of health, such as socio-economic disadvantage and geographical isolation, were not barriers to participation or currency of qualification.

List of Papers Completed During Enrolment Related to River Drowning But Not Included in Thesis

I have published 21 papers during my PhD enrolment which, although not included in this thesis, relate to the issue of river drowning. The full reference for each of the papers can be found below and the abstract for each paper can be found in Appendix 3.

1. **Peden AE**, Franklin RC, Leggat PA (2016). "International travelers and unintentional fatal drowning in Australia - a 10 year review 2002-12." *Journal of Travel Medicine* 23(2): 1-7.

2. Hamilton, K., **Peden, A.E.**, Pearson, M., & Hagger, M.S. (2016). Stop there's water on the road! Identifying key beliefs guiding people's willingness to drive through flooded waterways. *Safety Science*, 86, 308-314. doi:10.1016/j.ssci.2016.07.004

3. Mahony AJ, **Peden AE**, Franklin RC, Pearn JH, Scarr J (2017) Fatal, unintentional drowning in older people: Pre-existing medical conditions, *Healthy Aging Research*, 6: 1-8

4. Franklin RC, Pearn JH, **Peden AE**. Drowning fatalities in childhood: the role of pre-existing medical conditions. *Archives of Disease in Childhood* 2017;102(10):888-893.doi: 10.1136/archdischild-2017-312684

5. **Peden, Amy E.**; Franklin, Richard Charles; and Scarr, Justin (2017) "Measuring Australian Children's Water Safety Knowledge: The National Water Safety Quiz," *International Journal of Aquatic Research and Education*: Vol. 10: No. 2, Article 4. Available at: https://scholarworks.bgsu.edu/ijare/vol10/iss2/4

6. **Peden AE**, Franklin RC, Mahony AJ, et al Using a retrospective cross-sectional study to analyse unintentional fatal drowning in Australia: ICD-10 coding-based methodologies verses actual deaths *BMJ Open* 2017;7:e019407. doi: 10.1136/bmjopen-2017-019407

7. **Peden AE**, Franklin RC, Queiroga AC Epidemiology, risk factors and strategies for the prevention of global unintentional fatal drowning in people aged 50 years and older: a systematic review. *Injury Prevention* 2018;24:240-247. doi: 10.1136/injuryprev-2017-042351

8. Hamilton, K., S. Price, J. J. Keech, **A. E. Peden** and M. S. Hagger (2018). Drivers' experiences during floods: Investigating the psychological influences underpinning decisions to avoid driving through floodwater. *International Journal of Disaster Risk Reduction* 28: 507-518. doi.org/10.1016/j.ijdrr.2017.12.013.

9. Hamilton K, **Peden AE**, Keech JJ, Hagger, MS (2018) Changing people's attitudes and beliefs toward driving through floodwaters: evaluation of a video infographic, *Transportation Research Part F: Psychology and Behaviour,* 53(2018): 50-60

10. **Peden, A. E.,** Demant, D., Hagger, M. S., & Hamilton, K. (2018). Personal, social, and environmental factors associated with lifejacket wear in adults and children: A systematic literature review. *PLoS ONE*. 13(5): e0196421. https://doi.org/10.1371/journal.pone.0196421

11. Hamilton, K., Keech, J. J., **Peden, A. E**. and Hagger, M. S. (2018), Alcohol use, aquatic injury, and unintentional drowning: A systematic literature review. *Drug Alcohol Rev*., 37: 752-773. doi:10.1111/dar.12817

12. Keech JJ, Smith SR, **Peden AE**, Hagger MS, Hamilton K. The lived experience of rescuing people who have driven into floodwater: Understanding challenges and identifying areas for providing support. *Health Promot J Austral*. 2018;00:1–6. https://doi.org/10.1002/hpja.181

13. Barnsley, PD., **AE. Peden** and J. Scarr (2018). Calculating the economic burden of fatal drowning in Australia. *Journal of Safety Research* 67: 57-63. doi: 10.1016/j.jsr.2018.09.002

14. **Peden, AE**., Barnsley, PD., and Queiroga, AC. (2018) The association between school holidays and unintentional fatal drowning among children and adolescents aged 5–17 years. *J Paediatr Child Health*. doi:10.1111/jpc.14235

15. Barnsley PD, **Peden AE**. A Retrospective, Cross-Sectional Cohort Study Examining the Risk of Unintentional Fatal Drowning during Public Holidays in Australia. *Safety*. 2018; 4(4):42. doi.org/10.3390/safety4040042

16. **Peden AE**, Mahony AJ, Barnsley PD, et al. Understanding the full burden of drowning: a retrospective, cross-sectional analysis of fatal and non-fatal drowning in Australia. *BMJ Open* 2018;8:e024868. doi: 10.1136/bmjopen-2018-024868

17. Hamilton K, **Peden AE**, Keech JJ, Hagger MS (2018) Driving through floodwater: exploring driver decisions through the lived experience, *International Journal of Disaster Risk Reduction*. Available online 26 December 2018

18. Cenderadewi, M., Franklin RC., **Peden, AE**,. Devine, S. (2019) Pattern of intentional drowning mortality: A total population retrospective cohort study in Australia, 2006-2014, *BMC Public Health*, 19:207. doi: 10.1186/s12889-019-6476-z

19. Hamilton, K., Keech, JJ., **Peden AE**., Hagger, MS. (2019) Testing a novel implementation imagery e-health intervention to change driver behaviour during floods: A randomised controlled trial protocol, *BMJ Open*,9(2):e025565. doi: 10.1136/bmjopen-2018-025565

20. Pearn JH, **Peden AE**, Franklin RC (2019) The influence of alcohol and drugs on drowning among victims of senior years, *Safety*, 5(1), 8. doi: 10.3390/safety5010008

21. Franklin RC, Peden AE, Leggat PA, Brander R (2019) Who rescues who? Understanding aquatic rescues in Australia using coronial data and a survey, *Australian and New Zealand Journal of Public Health,* Published Online First 10 June 2019*,* doi:10.1111/1753-6405.12900

List of Abbreviations

ABC	Australian Broadcasting Corporation
ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
AIPN	Australasian Injury Prevention Network
am/AM	Ante Meridiem (before midday)
ANOVA	Analysis of Variance
ANZSBEG	Australia and New Zealand Safe Boating Education Group
ASD	Autism Spectrum Disorder
ASGC	Australian Standard Geographical Classification
ATSI	Aboriginal and Torres Strait Islander
ATVs	All-Terrain Vehicles
AUDIT	Alcohol Use Disorder Identification Test
AWSC	Australian Water Safety Council
Avg	Average
AVCC	Australian Vice Chancellor's Committee
AYAD	Australian Youth Ambassador for Development
BA	Bachelor of Arts
BAC	Blood Alcohol Concentration
BBC	British Broadcasting Corporation
BBQ	Barbeque
BMC	Biomed Central
BOM	Bureau of Meteorology
°C	Degrees Celsius
CATI	Computer-Assisted Telephone Interviewing

CCTV	Closed Circuit Television
CI	Confidence Interval
CPR	Cardiopulmonary Resuscitation
CQU	Central Queensland University
CRED	Centre for Research on the Epidemiology of Disasters
DALYs	Disability Adjusted Life Years
ED	Emergency Department
g	Grams
GBD	Global Burden of Disease
GRS	Graduate Research School
HaPI	Health and Psychology Innovations
HDR	Higher Degree by Research
HDRES	Higher Degree Research Enhancement Scheme
HH:MM	Hour Hour: Minute Minute
HICs	High-Income Countries
HREC	Human Research Ethics Committee
IBM SPSS	International Business Machines Statistical Package for the Social Sciences
ICC	Intraclass Correlation Coefficient
ICD	International Classification of Diseases
ICECI	International Classification of External Causes of Injury
ID	Identification
IQR	Interquartile Range
IRSAD	Index of Relative Socio-economic Advantage and Disadvantage
JCU	James Cook University
JHREC	Justice Human Research Ethics Committee

LMICs	Low- and Middle-Income Countries
Ltd	Limited
M	Mean
MFE	Multiple Fatality Event
ml	Millilitres
MPP	Master of Public Policy
N/A	Not Applicable
NCIS	National Coronial Information System
NHMRC	National Health and Medical Research Council
NP	Not Presented
NS	Not Shown
NSS	National Social Survey
NSW	New South Wales
NT	Northern Territory
p	p value
PhD	Doctor of Philosophy
PHAA	Public Health Association of Australia
PLoS	Public Library of Science
pm/PM	Post Meridiem (after midday)
PPE	Personal Protective Equipment
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PRL	Population Research Laboratory
QLD	Queensland
RAND	Research and Development
RDD	Random Digit Dialling

RLSSA	Royal Life Saving Society - Australia
RR	Relative Risk
SA	South Australia
SD	Standard Deviation
SDH	Social Determinants of Health
SMART	Specific, Measurable, Achievable, Relevant and Time Bound
SMART (modified)	Specific organisation, Specific action, Measurable, Achievable, Relevant & Time Bound
SPSS	Statistical Package for the Social Sciences
SRA	Short Research Article
TAS	Tasmania
THC	Tetrahydrocannabinol
TTM	Transtheoretical Model
UI	Uncertainty Interval
UK	United Kingdom
US	United States
USA	United States of America
UTBC	Unable To Be Calculated
UQ	University of Queensland
VIC	Victoria
VSLY	Value of a Statistical Life Year
WA	Western Australia
WHO	World Health Organization
WCDP	World Conference on Drowning Prevention
X^2	Chi square

4WD	Four Wheel Drive

List of International Classification of Diseases (ICD) Codes Relevant to Drowning

T75.1	Unspecified effects of drowning and nonfatal submersion
W65-74	Accidental drowning and submersion
W65	Drowning and submersion while in a bathtub
W66	Drowning and submersion following fall into bathtub
W67	Drowning and submersion while in a swimming pool
W68	Drowning and submersion following fall into swimming pool
W69	Drowning and submersion while in natural water
W70	Drowning and submersion following fall into natural water
W73	Other specified drowning and submersion
W74	Unspecified drowning and submersion
X37	Cataclysmic storm
X38	Flood, sequela
X71	Intentional self-harm by drowning and submersion
X92	Assault by drowning and submersion
V01-V99	Transport accidents
V90	Drowning and submersion due to accident to watercraft
V92	Drowning and submersion due to accident on board watercraft, without accident to watercraft
Y21	Drowning and submersion, undetermined Intent

Note this thesis only explore unintentional drowning.

Explanation of Terms

This thesis uses a range of terms that the reader may be unfamiliar with or would benefit from further explanation. Below, key terms are presented in alphabetical order and are explained in further detail to enhance readability of the thesis.

Aboriginal and Torres Strait Islanders

As per the Aboriginal and Torres Strait Islander Guide to Terminology recently released by the Public Health Association of Australia (PHAA), the preferred terminology to use when referring to this group is Aboriginal and Torres Strait Islander people [1]. Such terminology has been used throughout the thesis.

Blood Alcohol Concentration (BAC)

A blood alcohol concentration or BAC is what the level of alcohol in a person's bloodstream is referred to [2]. A person's BAC can be influenced by many things including body size, whether a person has eaten or not, the amount of body fat a person has, how fast a person's body processes alcohol, whether a person is male or female and how often a person drinks [2]. In Australia, a BAC of 0.05% is the upper legal limit for operating a motor vehicle, and a powered vessel in many states and territories [2]. This equates to 0.05 g of alcohol in every 100ml of blood. This limit means a driver must have a BAC of 0.049% or lower to legally be able to operate the vehicle or vessel. In this thesis, a BAC of ≥0.05% at time of autopsy or toxicology test was deemed to be a level of alcohol contributory to the drowning, due to the known effects on the body and the impact this has on drowning risk [3].

Breathalysing

Breathalysing is the process of estimating a person's BAC indirectly, by measuring the alcohol on the breath [4]. While self-reported surveys provide an indication of the amount of alcohol consumed, breathalysing is a robust [5], objective measure of alcohol concentration, which has been shown to give a reliable estimation of BAC [6]. Two articles from this thesis [4 7] report the results of data collection in the field, where river users were surveyed and breathalysed at four river drowning locations. BAC readings were captured using LION Alcometers (LION SD400 ™).

Computer Assisted Telephone Interviewing (CATI)

A Computer-Assisted Telephone Interviewing (CATI) survey is a telephone surveying technique in which the interviewer follows a script provided by a software application [8]. The interviewer makes a phone call to the number that is displayed on the screen. If the respondents was to join the survey, the interviewer starts reading questions displayed on the screen and selecting the respondents' answers. The CATI software will automatically proceed to the next question following the logic path. At the end of the questionnaire, the interviewer will display a new respondent to call [8].

A CATI survey was utilised in paper 5 of this thesis [9] to examine river visitation and usage to refine river drowning rates from a calculation per 100,000 head of population to a calculation per 100,000 persons exposed to rivers.

Delphi Process

A Delphi Process is a structured communication technique or method using a panel of experts to undertake a systematic, interactive forecasting method [10]. A Delphi process uses questionnaires, and after each round a facilitator provides an anonymised summary of the group's responses back to the group, which allows the expert panel to revise previous answers based on responses from the other members of the panel [10]. The intent of the process is that as the rounds continue, the range of answers will decrease and the group will converge towards the "correct answer". The process is stopped after a predefined stop criterion, (be it number of rounds, achievement of consensus, stability of results), and the mean or median scores from the final rounds are used to determine the results [11].

Drowning

In a *Bulletin of the World Health Organization* (WHO) released in 2005, a new definition of drowning was adopted: "Drowning is the process of experiencing respiratory impairment from submersion/immersion in liquid" [12]. Drowning outcomes were defined in the same document as being classified as death, morbidity, and no morbidity [12]. This definition was necessitated due to surveillance being hampered by the lack of a uniform and internationally accepted definition that permitted all relevant cases to be counted. As such in proposing the revised definition, the *Bulletin* also states that the terms wet, dry, active, passive, silent and secondary drowning should no longer be used [12].

This thesis adopts this definition of drowning, focusing solely on the epidemiology of fatal drowning (mortality) in rivers. However risk factors and prevention strategies are acknowledged as being relevant both to fatal and non-fatal drowning in rivers.

International Classification of Diseases (ICD)

The International Statistical Classification of Diseases and Related Health Problems (ICD) provides a common vocabulary for recording, reporting and monitoring health problems around the world [13]. The initial classification was developed by French statistician Jacques Bertillon in the late 19th century, and was called the Bertillon Classification of Causes of Death [13]. The WHO took over the system in the 1940s and expanded it to include statistics on causes of injury and disease, including causes of death. Today, the ICD is used widely in healthcare, from understanding what people get sick from, their cause of death, mapping disease trends and epidemics, deciding how to programme health services, allocate health care spending and investment in research and development [13].

The global estimates of unintentional fatal drowning are generally defined as ICD codes W65-74 (accidental drowning and submersion) and exclude drowning as a result of flooding (X38), transport accidents (V01-V99), water transport accidents (V90, V92) and undetermined intent (Y21). This has implications on global estimates, with use of the narrow definition of drowning (W65-74) shown to under-report drowning in Australia by 40% [14]. Additional challenges are posed by ICD codes W65-74, with respect to isolating river drowning deaths. Drowning locations are classified as bathtub, swimming pool, natural water and other or unspecified location. Without further breakdown, it is extremely difficult to extract rivers from a natural waterway code that also includes, lakes, oceans, and beaches.

Rivers

With respect to rivers (i.e. rivers, creeks and streams), the following definitions from the Australian context were used. River was defined as '…a natural waterway that may be fed from other rivers or bodies of water draining water away from a 'catchment area' to another location…' [15]. 'Rivers can vary in water flow, length, width and depth' [16]. A creek was defined as 'a water body that may be fed by rivers and other creeks. A creek is generally smaller in size than a river and is often characterised by intermittent water flow. Creeks can be prone to more extreme conditions of stasis in drought and flash flooding after rainfall' [16]. A stream was defined as 'a body of flowing water generally smaller than a river. May also be seasonal but may not always contain water' [16].

Chapter 1: Introduction

1.0 Overview

Drowning has been described as a global public health threat by the WHO, with rivers thought to be a leading contributor to the global burden [17]. Across nine original articles and two short reports, this research uses a public health approach to examine the epidemiology and risk factors for unintentional fatal drowning in rivers in Australia and builds an evidence base to further the development, implementation and evaluation of prevention strategies.

This chapter situates the thesis research within the issue of drowning globally and drowning in Australia. The chapter examines the definition of drowning, the outcomes of drowning (being both fatal and non-fatal), and outlines the rationale for the research, the aim and the research questions.

1.1 Definition of Drowning

In 2005, a new definition of drowning was proposed through an international consensus procedure. The procedure adopted the following definition "Drowning is the process of experiencing respiratory impairment from submersion/immersion in liquid." Drowning outcomes should be classified as: death, morbidity, and no morbidity" [12]. Consensus was also reached that terms such as wet, dry, active, passive, silent, and secondary drowning should no longer be used [12] as the terms are misleading and confusing to the public.

Prior to 2005, various definitions for drowning had been used. Most commonly, different definitions were used for fatal (referred to as drowning) and non-fatal cases (referred to as near-drowning), with further distinction between cases with aspiration or without [12]. Moving forward, definitions proposed by Modell [18 19] that defined drowning based on the presence (or not) of aspiration were deemed too difficult to use in surveillance when conducting epidemiological research [12]. Separating drowning into different definitions based on whether the drowning was fatal or non-fatal, was recognised as leading to continued underestimation, such as in Global Burden of Disease (GBD) studies [20], if two separate definitions were used. Incomplete surveillance may make the identification of risk factors difficult, thus impacting the development of effective programmes and policies which address these risk factors [12].

A consistently used definition for drowning is also of benefit in educating the public, including drawing attention to the full burden of drowning (i.e. both fatal and non-fatal) [21]. So too, is refraining from terms such as wet, dry, active, passive, silent and secondary drowning which may confuse and misinform the public, leading to further burden on the health system and a further misclassification of drowning [12].

Where possible the 2005 definition of drowning has been used throughout the thesis. There may be instances where some information included in the thesis (in particular from the literature which was published prior to 2005) does not conform to this definition.

1.2 Drowning Globally

Drowning has been described by the WHO as a threat to global public health [17]. In 2012, it was estimated that 372,000 people around the world die from drowning annually, making drowning the word's third leading unintentional, injury-related cause of death [17]. Globally, over half of all drowning deaths are among those aged under 25 years, males are twice as likely to drown as females and drowning disproportionately impacts low- and middle-income countries, where drowning rates are over three times higher than rates in high-income countries [17].

In 2014, this estimate of the global burden of drowning was subsequently revised down to 360,000 people in the WHO's second drowning report, which focused on implementation of drowning prevention strategies [22]. The WHO reports quantify the burden of drowning through the use of data from the WHO Global Health Estimates, which cover the International Classification of Diseases (ICD)-10 categories of W65-74 only, which do not include drowning due to natural disasters, intentional drowning or those due to aquatic transport [17].

Data was only presented from vital registration systems with coverage of at least 70% of drowning deaths. Cases where the age and sex of the deceased were not known, were proportionally re-distributed across age groups and sex based on the distribution of drowning deaths in the population. Statistics are presented for countries/areas where the proportion of the total deaths from all causes reported to WHO represented at least 70% of all deaths that occurred in the respective countries/areas [17].

By contrast, the GBD study, which uses a method of estimating injury mortality from the GBD mortality database which includes data from the 21 GBD world regions, from vital registration, verbal autopsy, mortality surveillance, censuses, surveys, hospitals, police records and mortuaries, estimated the global burden of drowning to be 368,000 in 2013, with a uncertainty interval (UI) of between 311,000 and 515,000 [20]. The study also identifies the impact of non-fatal drowning using disability adjusted life years (DALYs) and finds that drowning related DALYs have decreased by 45.1% (UI: -53.6% to +3.2%) between1990 and 2013 [20].

While the GBD and the WHO estimates are comparable in that they both exclude intentional drowning, the GBD method is more complete as it includes data from a variety of sources and is therefore able to look at the morbidity impact of non-fatal drowning, as well as fatalities. However there is a wide variation in the UI for both the global estimate of drowning deaths and the DALY decrease over time. Similarly, both methods use the ICD-10 codes of W65-74 which has its limitations [14].

1.3 Factors Impacting Accurate Global Drowning Estimates

The current global fatal unintentional drowning estimate of 360,000 deaths per year, is likely to be higher due to under-reporting, given the restrictive definition used [17 22]. This estimate is derived by using ICD-10 codes of W65-74 (accidental drowning and submersion) only, which excludes drowning incidents related to natural disasters (X38 - victim of flood), water transportation (V90 - drowning and submersion due to accident to watercraft, V92 - drowning and submersion due to accident on board watercraft, without accident to watercraft). And drowning deaths with undetermined intent (Y21 - drowning and submersion, undetermined intent) [23].

This estimate also classifies deaths based on a single underlying cause of death [14]. Therefore, cases where drowning was a secondary or contributory cause of death (e.g. Cause 1a ischaemic heart disease and 1b drowning) are excluded from an estimate of drowning deaths and instead coded to the cardiac condition. This is problematic as strategies used to prevent drowning may have been relevant to such a case. Cases, such as the example given, highlight the importance of medical checks prior to undertaking aquatic activity, particularly among the elderly, and have led to research examining the role of pre-existing medical conditions on drowning risk among children [24] and older people [25].

Methods used to calculate the burden of drowning in countries without death registry or where people who drown are not hospitalised (disproportionately impacting low- and middle-income countries) [26] is extremely difficult and estimates often rely on modelling [17], a method of unknown accuracy for calculating drowning fatalities.

1.4 Unintentional Fatal Drowning

The discussion on drowning in this thesis so far, focuses heavily on drowning which is unintentional in nature leading to death. While the author acknowledges, intentional drowning is an issue (and occurs in rivers), with 450 intentional drowning deaths between 2006 and 2014 [27], the prevention strategies needed may be different [28]. This thesis focuses on unintentional fatal river drowning in Australia and its prevention, including those cases with undetermined intent, as ruled by the coroner. The focus of this research is unintentional drowning. Intentional drowning in rivers, remains an area worthy of further research.

1.5 Unintentional Fatal Drowning in Australia

In Australia, there are two processes of data collection on fatalities; a medico-legal process of death investigation [29] with data available on the National Coronial Investigation Systems (NCIS) and vital registration system, with data available through the Australian Bureau of Statistics (ABS). All sudden and unexpected deaths, of which drowning is considered one, must be investigated by a coroner to determine the cause of death, identify if any criminal culpability exists and, in some instances, to explore if coronial recommendations can be made to prevent future similar deaths from occurring [30].

Investigation of drowning typically involves a police report, autopsy and toxicology reports and either a coronial finding indicating cause, as well as place and time of death, or in some instances, a coroners' inquest report where an inquest is convened to examine the death, or a series of deaths, and recommendations are made.

Investigation of drowning is undertaken at the state and territory level in Australia, with information fed into the national system. Such information is made available to researchers under ethical approval in the interests of prevention of future similar events through the [Australia] NCIS [31]. When a case closes (i.e. is no longer under coronial investigation) the above mentioned reports are made available to those with privileged access, to read. Data available on the NCIS is rich in detail and researchers can derive information from a coronial finding and autopsy, toxicology and police reports. If a death or a series of deaths go to coronial inquest, a more detailed coronial inquest report will outline the proceedings of the inquest and often make recommendations associated with preventing future similar deaths. This allows for rich detail on fatal drowning, however the same level of detail is not available for cases of non-fatal drowning.

These data have been used in the preparation of the Australian Water Safety Strategy [32], which outlines goal areas, derived from the data, where reductions will be required in order to achieve the aspirational target of an overall 50% reduction in drowning by the year 2020.

Data are also available on causes of death through the ABS [33]; these data use the ICD-10 codes to assign cause of death. Drowning related ICD-10 codes include unintentional drowning-related codes (W65-74), as well as other drowning related codes (T75.1, X37, X38, X71, X92, V90, V92,Y21)) To ensure all cases of drowning were captured, a data triangulation process (outlined further in the methods) of media reports, police and lifesaving organisation reports and data from the NCIS, is preferred to ensure more complete capture of fatal unintentional drowning cases in Australia [14].

In the academic literature, two seminal papers have examined the burden and causal factors of unintentional fatal drowning in Australia [34 35]. Mackie's 1999 [34] study, using ABS cause of death data, examined drowning in Australia between 1992 and 1997. The study reported an accidental non-boating drowning rate of 1.44 per 100,000 persons per year and boating-related drowning rate was 0.29 per 100,000 persons for the study period. Indigenous drowning was recorded as being much higher than the general population and the drowning rate among children under five remained the highest of all age groups (4.6 per 100,000 persons per year) during the study period, most commonly drowning in home swimming pools and bathtubs [34].

Franklin et al. examined unintentional fatal drowning in Australia between 1 July 2002 and 30 June 2007, in their study published in 2010 [35]. This study reported a drowning rate of 1.43 per 100,000 population per year and identified rivers as the leading location for drowning (20.3%), followed by beaches (18.3%) and private or public swimming pools (13.3%). The 0-4 years age group continued to record the highest drowning rate at 2.63 per 100,000 population, followed by the 80-84 years age group (2.00 / 100,000 persons) and 65-69 years age group (1.97 / 100,000 persons). Swimming/leisure activities (21.2%), fishing (11.4%) and watercraft use (10.4%) were the leading activities prior to drowning, with alcohol implicated in 21.6% of cases, with information on alcohol involvement missing in a further 35.4% of cases [35].

Between 2003 and 2017, Royal Life Saving Society – Australia (RLSSA) reports a total of 4216 cases of unintentional fatal drowning in Australia, a crude rate of 1.22 drowning deaths per 100,000 persons [36]. The ABS, over the same period, report a total of 2910 drowning deaths, a difference of 1306 drowning deaths or 31.0%. Table 1 shows the difference between RLSSA figures for unintentional drowning fatalities in Australia and statistics reported by the ABS by year. Although RLSSA, reports drowning data on a financial year basis (July to June), these figures have been converted to a calendar year (January to December) in order to be able to be compared to ABS data which is reported on a calendar year basis.

To date, drowning prevention research and interventions have largely focused on beaches and drowning prevention among children [37-40], predominately children under five and the risk posed by home swimming pools [41], and to a lesser extent, bathtubs [42]. Rivers, by contrast, have received little attention.

Table 1: Difference between RLSSA and ABS data on fatal unintentional drowning in Australia

Year	RLSSA Unintentional Fatal Drowning Figures	ABS Unintentional Fatal Drowning Figures	Difference	
			N	%
2003	304	201	103	33.9
2004	290	197	93	32.1
2005	240	192	78	28.9
2006	274	209	65	23.7
2007	294	191	103	35.0
2008	251	184	67	26.7
2009	314	200	114	36.3
2010	291	222	69	23.7
2011	271	167	104	38.4
2012	273	194	79	28.9
2013	287	214	73	25.4
2014	267	194	73	27.3
2015	263	185	78	29.7
2016	301	200	101	33.6
2017	266	160	106	39.8
TOTAL	**4216**	**2910**	**1306**	**31.0**

1.6 Non-Fatal Drowning in Australia

In section 1.1 of this chapter, the revised definition of drowning acknowledges that drowning is a process that may or may not result in death [12]. Highlighting the full burden of drowning (both fatal and non-fatal) is a vital part of educating the public and ensuring adequate resourcing and direction of prevention interventions [21].

Non-fatal drowning is an area where little research has been undertaken, particularly at a population level, and there remains a lack of agreement as to what constitutes a non-fatal drowning [21]. In previously published studies, a range of methods have been used to attempt to quantify non-fatal drowning including: school-based surveys, household surveys, hospital discharge data, emergency department visits and data from injury surveillance systems [21]. In Australia, a non-fatal drowning has been defined by RLSSA as someone who is admitted and subsequently discharged (alive) from hospital [21]. Research conducted by Wallis et al on drowning among children and adolescents (aged 0-19 years) in the Australian state of Queensland (QLD) used linked data to examine fatal and non-fatal drowning from pre-hospital (ambulance) through to emergency department presentation and hospital admission [43].

In Australia, an average of 717 people are hospitalised per year due to a non-fatal drowning, representing a fatal to non-fatal drowning ratio of 1 fatal to 2.71 non-fatal drownings. Hospital separations due to non-fatal drowning (where subsequent fatalities have been removed) have been as high as 823 in 2013/14 and in the most recent financial year, 551 people were hospitalised due to non-fatal drowning in 2017/18 [36]. When combining the total number of fatal and non-fatal drowning incidents, an average of 996 drowning incidents occur each year in Australia, representing a crude rate of 4.38 per 100,000 persons [36].

The Wallis et al study examined 1299 cases from 2002-2008 inclusive among QLD children. The study determined a drowning death to survival ratio of 1:10, with two out of three who survived the drowning incident, being admitted to hospital [43]. Children 5-9 years and 10-14 years recorded the lowest incidence rates per 10,000 population at 6.38 and 4.62 respectively, whereas children 0-4 years recorded the highest rates (all drowning events 43.90; fatal 4.04; non-fatal 39.85 – comprising admission 26.69 and non-admission 13.16) [43]. Wallis and colleagues also specifically examined drowning among Aboriginal and Torres Strait Islander children aged 0-19 years in Queensland across the same time period (2002-2008) [44]. This study identified that Aboriginal and Torres Strait Islander children record a combined fatal and non-fatal drowning incidence rate of 16.8 per 100,0000 persons per annum, a rate that is 44% higher than non-Aboriginal and Torres Strait Islander children. A ratio of 1:9 was seen, where for each fatality, a further nine Aboriginal and Torres Strait Islander children were rescued and sought medical treatment [44].

In Australia, this restrictive definition of drowning as outlined earlier (ICD-10 codes W65-74 and a single underlying cause of death only), impacts non-fatal drowning statistics as well as those for fatal drowning [14 21]. The above figures are estimates derived from mapping the fatal drowning under-report to non-fatal to ensure a methodology of inclusive capture for both fatal and non-fatal drowning in Australia.

1.6.1 Non-Fatal Drowning in Rivers, Creeks and Streams in Australia

The challenges with ICD coding of location of drowning incident, make it challenging to define rivers. Drowning locations under ICD-10 coding are defined as swimming pool, natural water, bathtub and other or unspecified locations [23]. Within the natural waterway code, it is possible to further refine this broad location grouping into the following categories: area of still water, stream of water, large area of water, beach and all other specified place of occurrence. Challenges around coding drowning location to this level of specificity may be hampering further research specifically focused on rivers.

Research into non-fatal drowning in Australia has used ‘stream of water’ within the natural waterway code, to loosely correlate to the fatal drowning category of rivers, creeks and streams. Drowning in areas coded as ‘stream of water’ has been found to have a negative fatal to non-fatal drowning ratio. Where the overall fatal to non-fatal drowning rate has been estimated at 1:2.71, the stream of water location category has a fatal to non-fatal drowning ratio of 1:0.48 [45]. This means that drowning is more often fatal, than non-fatal in rivers [45]. This compares to a ratio of 1.06 for beaches and 1:4.34 for swimming pools. This may indicate that rivers are more deadly than other locations due to a lack of bystanders able to assist, as may be seen in the home environment, or the fact they are unpatrolled, unlike some beaches. These assumptions needs further validation.

1.7 Fatal Drowning in Rivers, Creeks and Streams in Australia

For many years, the issue of drowning in rivers, creeks and streams in Australia has not been examined. Prior to this present research, one study identified rivers as the leading location for drowning in Australia, accounting for 20.3% of unintentional fatal drowning in Australia between 1 July 2002 and 30 June 2007 [35]. Aside from analysis in annual RLSSA National Drowning Reports on the yearly burden of drowning in rivers, within the broader context of all cases of fatal unintentional drowning in Australia in a particular year, there has been a lack of longitudinal focus on river drowning including trends over time and the identification of risk factors.

For many years, drowning in rivers have been grouped within a category of inland waterways [46 47]. This term refers to the grouping of the river, creek, stream category and the lake, dam, lagoon category. For example, the Australian Water Safety Council (AWSC) in its Australian Water Safety Strategies [46-48] has identified inland waterways (rivers, creeks, streams, lakes, dams and lagoons) as a key priority location where reductions in drowning are necessary to achieve an overall 50% reduction in Australia's annual drowning toll by the year 2020. This hides the complexity of drowning and its prevention in rivers with (often) moving water, compared to the still water of lakes and dams.

As opposed to such areas of drowning research such as child drowning prevention, in particular in swimming pools, which has benefited from many years of research [39 41] and beach drowning prevention, which has, on the whole, been well-resourced, the prevention of river drowning deaths had not experienced the same focus.

1.8 Rationale for Thesis

Reducing river drowning in Australia will be a key contributor to reducing drowning rates overall and in achieving the AWSC's aspirational target of a 50% reduction in drowning by the year 2020 [32]. Rivers have been identified for many years in the RLSSA annual national drowning estimates and Australian Water Safety Strategies as being an aquatic location of concern, often reported as the leading location for drowning[32 35 36 46]. Given the large burden of drowning deaths in rivers, creeks and streams [32 35 36 46 49] and the limited work to date to isolate this category of aquatic location, there is a need for focused effort in this space to identify the epidemiology, risk factors and strategies for prevention in order to reduce the associated drowning burden.

1.9 Scope

While the author acknowledge that drowning is a process that doesn't always end in death, this thesis and the publications within it focus on unintentional fatal drowning only. The risk factors identified are likely to be similar for non-fatal drowning in rivers; so too prevention strategies discussed are likely to be suitable in preventing both fatal and non-fatal drowning in rivers. Intentional drowning deaths (e.g. drownings as a result of suicide, homicide, assault, infanticide) are excluded. Drowning deaths where a coroner has ruled intent is 'undetermined' are included.

1.10 Thesis Structure

This is a thesis by publication. The thesis is organised around three themes, epidemiology of unintentional fatal river drowning (Results Part 1), exposure and the risk of river drowning (Results Part 2) and strategies for prevention (Results Part 3). The flow chart below can be found at the beginning of each chapter. The figure depicts the position of the current chapter of the thesis as well as the academic papers produced within the thesis and the chapter within which they fit. The flow chart also depicts if the paper is published or under review.

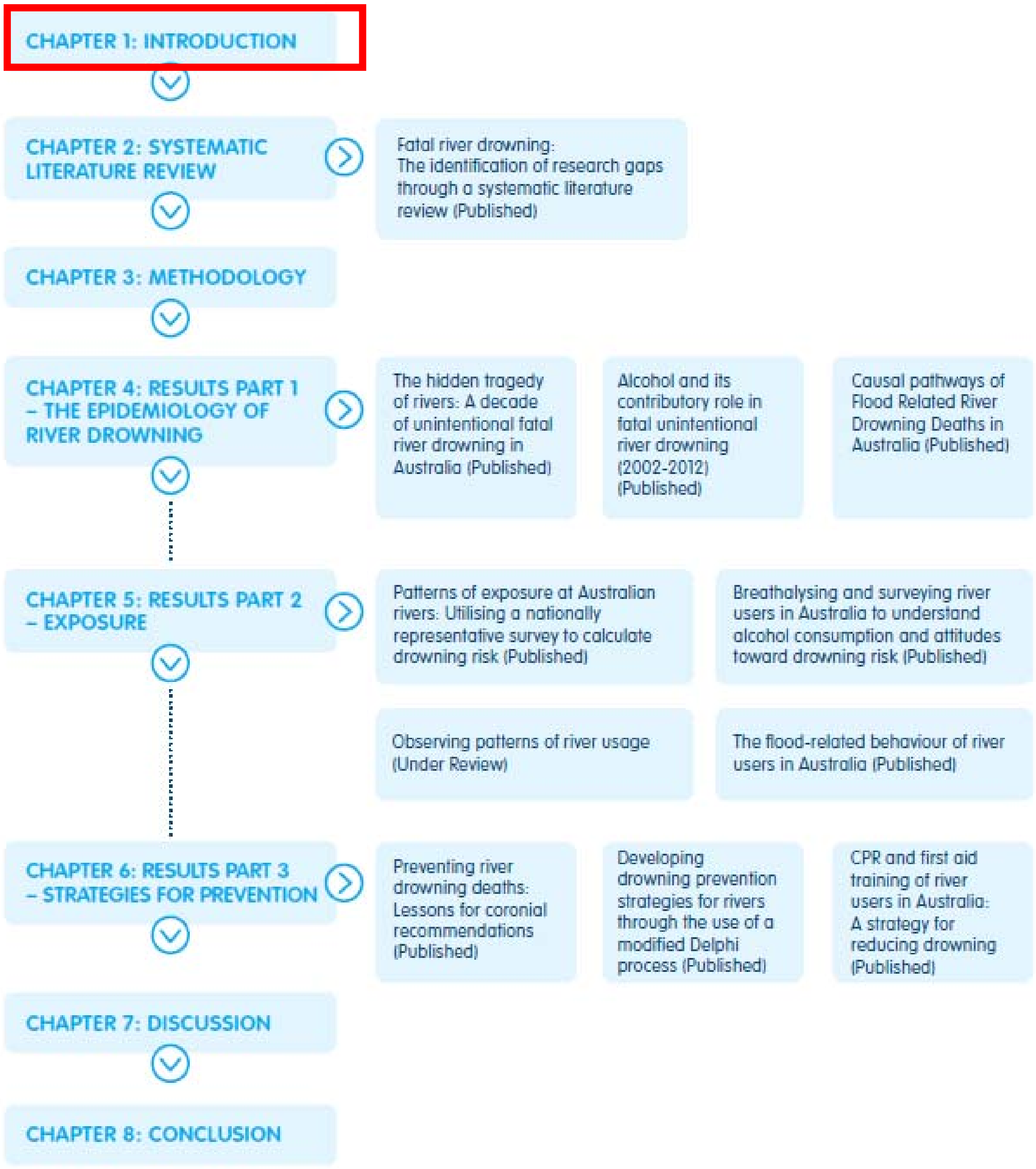

Figure 1: Chapter 1 position within thesis structure

1.11 Aims

To understand the epidemiology, risk factors, attitudes and behaviour of river users, and strategies for the prevention of unintentional fatal drowning in rivers in Australia.

The overarching questions this project will aim to answer include:

- Who drowns in rivers?
- What are the risk factors for drowning in rivers?
- What is currently known about prevention of river drowning deaths?
- What is the role of alcohol in river drowning deaths?
- Who is recreating at river locations in Australia? What do they do when they are there? How long do they spend?

Chapter 2: River Drowning Literature

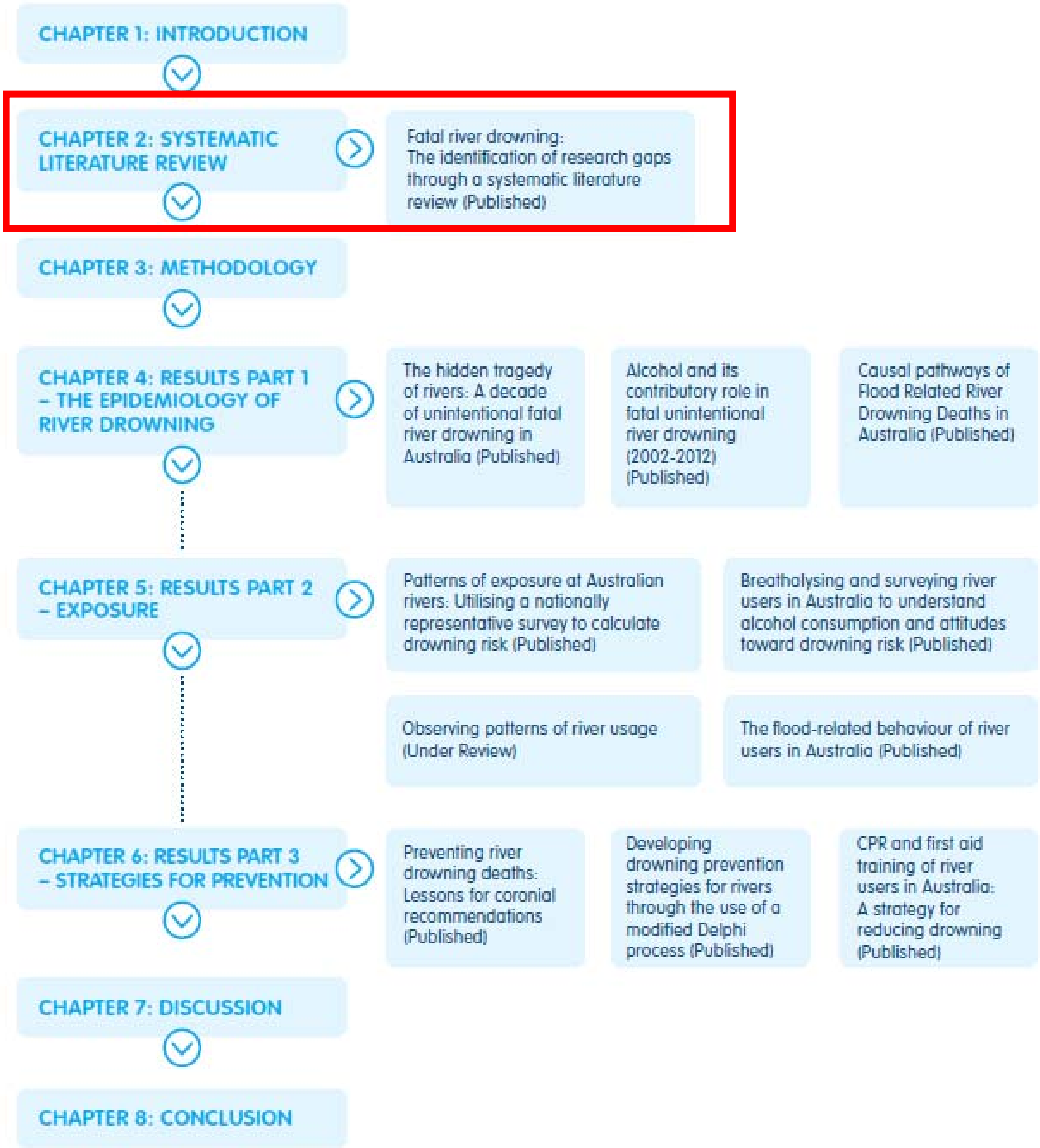

Figure 2: Chapter 2 position within thesis structure

2.0 Overview

Chapter 2 explores the peer reviewed literature on river drowning and its prevention. Chapter 2 is split into two sections, Part A and Part B. Part A outlines the findings of the systematic literature review completed and published in 2016 examining peer-reviewed published literature on the epidemiology of river drowning, risk factors and strategies for prevention (including whether any strategies have been implemented and evaluated) between 1980 and 2014. The systematic literature review was framed from the perspective of identifying research gaps associated with the small amount of literature published on the topic. The paper featured in this chapter is a reproduction of the peer-reviewed article published as open access in the journal Injury Prevention [50]. For the printed version of the paper, as it appeared in the journal, please see Appendix 1.

The reference for the published literature review is as follows:

Peden, AE., Franklin, RC., Leggat, PA. (2016). Fatal River Drowning: Identification of Research Gaps through a Systematic Literature Review. *Injury Prevention* 22: 202-209 [50].

Part B of the chapter provides an update to the initial study and covers the period January 2015 and December 2018 (inclusive). This review used the same methodology as the paper [50] and found 16 papers over the study period, excluding papers that were produced as part of this thesis.

Both the original literature review and the update assess literature identified against the National Health and Medical Research Council (NHMRC) Levels of Evidence An explanation of the levels of evidence are detailed below (Table 2).

Table 2: National Health and Medical Research Council (NHMRC) Levels of Evidence

Level of evidence	Study design
I	Evidence obtained from a systematic review of all relevant randomised controlled trials
II	Evidence obtained from at least one properly designed randomised controlled trial
III-1	Evidence obtained from well-designed pseudo-randomised controlled trials (alternative allocation or some other method)
III-2	Evidence obtained from comparative studies (including systematic reviews of such studies) with concurrent controls and allocation not randomisation, cohort studies, case-control studies or interrupted time series with a control group

III-3	Evidence obtained from comparative studies with historical control, two or more single arm studies, or interrupted time series without a parallel control group
IV	Evidence obtained from case series, either post-test or pre-test/post-test
V	Non-analytical studies (case reports), expert opinion, and formal consensus documents (position statements)

Part A – Fatal River Drowning: The Identification of Research Gaps Through a Systematic Literature Review (Paper 1)

Peden, AE., Franklin, RC., Leggat, PA. (2016). Fatal River Drowning: Identification of Research Gaps through a Systematic Literature Review. *Injury Prevention* 22: 202-209.

2.1 Introduction

Drowning prevention interventions based on site-specific locations are likely to have a greater impact and prove more successful than general strategies aimed at preventing drowning.[51] A significant reduction in the number of drowning deaths among young children in private swimming pools has been achieved through over 30 years of focused work on the epidemiology and risk factors for drowning in private swimming pools among young children. [35 37 41 52 53]

A focus on beaches has also seen prevention efforts in that space be successful.[54-56] Strategies which target specific aquatic locations may also prove to be successful, as they allow ownership of the issue. In Australia for example, local councils are responsible for beaches and publicly owned swimming pools, and individuals are responsible for private swimming pools.

The ICD-10 [23] currently divides aquatic locations into the subsets of 'bathtub', 'swimming pool' and 'natural waterway'. The category of 'natural waterway' is broad and includes rivers, creeks, beaches, oceans, harbours, lakes and dams, thus not providing the fidelity to extract rivers. In 2004, the International Classification of External Causes of Injury (ICECI) Coordination and Maintenance Group articulated a classification for 'body of water' that allows the identification of river, stream (15.02.25).[57] This information is needed to undertake site-specific research and develop targeted interventions.

To date, there has been limited research that has explored drowning in locations other than beaches and swimming pools. Inland waterways such as rivers, creeks, streams, lakes and dams regularly account for large proportions of drowning deaths,[58-60] particularly in LMICs. In LMICs, drowning often occurs as a result of the activities associated with daily life [61] rather than the recreational undertakings often being conducted before drowning in high-income countries (HICs). [62-64]

In Australia, rivers routinely claimed the largest number of lives in annual national drowning reports between 2011 and 2014, [65-68] and rivers accounted for 20.3% of unintentional fatal drowning in the 5 years between 2002 and 2007.[35] Inland waterways (rivers, creeks, streams, lakes, dams and lagoons) have been deemed a key priority location by the Australian Water Safety Council (AWSC) where sustained action is required to achieve the aim of a 50% reduction in national drowning deaths by the year 2020. [46 48]

Proposed contributory factors for drowning in rivers include a lack of barriers controlling access to water, an absence of adult supervision for young children, poor swimming skills, minimal awareness of the dangers, the consumption of alcohol, transportation on water, a lack of safe water supply, and disasters related to flooding.[17] Some proposed river prevention strategies include: community-based prevention; provision of safe places such as crèches for young children; basic swimming instruction for older children; increased public awareness of the vulnerability of children; legislation for safe boating; mitigation of flood risk; and continued research into priority areas. [17]

2.1.1 Aims

There is a need for a better understanding of the burden of river drowning as well as related risk factors to assist in the development of targeted and evidence-based strategies for prevention. This systematic review of peer-reviewed literature for fatal unintentional river drowning aims to:

- describe the epidemiology of fatal river drowning;
- describe risk factors for drowning in rivers;
- identify and critically analyse strategies for prevention; and
- identify gaps in research to date and propose priority areas where further work is required.

2.2 Methods

This systematic literature review explored literature published in the English language between 1980 and 2014 using the databases Medline, Scopus, ScienceDirect, PsychInfo, SportDiscuss, the Cochrane Central Register for Controlled Trials, and SafetyLit.

For this study, the internationally accepted definition of drowning has been used; [12] however, as this study explored papers over a 35-year period, not all papers used this definition. Any papers which used the words 'river', 'creek' or 'stream' (i.e. those papers that said they were exploring unintentional fatal drowning in these locations) were included.

Initial search terms used were 'drown*' limited to English language, human and a published date range between 1 January 1980 and 31 December 2014. Searches were then refined to include 'drown*' and 'river*' or 'creek*' or 'stream*' or 'fresh water' limited to peer-reviewed publications (Table 3).

Table 3: Search methodology including databases used, search terms used and results

Search Number	Search Term	Number Found
MEDLINE		
1	Drown* (no limits)	4803
2	Drown* with limits of English language, human, 1980-2014	2904
3	River* (no limits)	37555
4	Stream* (no limits)	33389
5	Creek* (no limits)	1947
6	Fresh water (no limits)	27018
7	Combined 2-6 OR	92345
8	Combined 7 AND 2	**195**
SCOPUS		
	TITLE-ABS-KEY (drown*) AND PUBYEAR > 1979 AND PUBYEAR < 2015 AND (TITLE-ABS-KEY (river*) OR TITLE-ABS-KEY (stream*) OR TITLE-ABS-KEY (creek*) OR TITLE-ABS-KEY (fresh water)) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO(SUBJAREA, "MEDI") OR LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "NURS") OR LIMIT-TO (SUBJAREA, "PHAR") OR LIMIT-TO (SUBJAREA, "HEAL") OR LIMIT-TO (SUBJAREA, "MULT") OR LIMIT-TO(SUBJAREA, "PSYC"))	**376**
PSYCHINFO		
	Drown* and river* OR steam* OR creek* OR fresh water (no limits)	1784
	Drown* and river* OR steam* OR creek* OR fresh water (limited to Peer reviewed and 1 January 1980 to 31 December 2014)	1111
	Drown* and river* OR steam* OR creek* OR fresh water (limited to Peer reviewed and 1 January 1980 to 31 December 2014 and human and English language)	942
	OR Drown* AND (river* OR stream* OR creek* OR fresh water)	**14**
SCIENCEDIRECT		

	pub-date > 1979 and pub-date < 2015 and DROWN* and (RIVER* OR CREEK* OR STREAM* OR FRESH WATER) AND LIMIT-TO(topics, "child, patient, drowning, cardiac arrest, usa, climate change ,post mortem, south china, north atlantic, cpr, emergency medicine, estuary, salt marsh") AND LIMIT-TO(cids, "271258,271105,272873,272201,271781,272396,272456,271861,273471,273323,271742,271759","Forensic Science International, Resuscitation, Annals of Emergency Medicine, Legal Medicine, Marine Geology, Estuarine, Coastal and Shelf Science, The American Journal of Emergency Medicine, Quaternary Science Reviews, Encyclopedia of Forensic and Legal Medicine, Pediatric Clinics of North America, Ecological Engineering, Global and Planetary Change").	**159**
SPORTSDISCUSS		
	Drown* (TX All Text) AND river* OR stream* OR creek* (TX All Text) limits to (1 Jan 1980 to 31 Dec 2014). Language English. Search modes – BooleanPhrase	**50**
COCHRANE.ORG		
	The term river was entered which produced 4 papers, of which 1 was deemed relevant	**1**
SAFETY LIT		
	Textword + synonyms searched using terms Drown* and river* OR creek* OR stream*(limits 1980 to 2014, All publication types, limited to English language)	**100**

Two reviewers assessed the papers against the inclusion/exclusion criteria. Titles and abstracts were screened for these criteria by two reviewers (AEP, RCF). Where there was not consensus, there was the possibility of a third reviewer (PAL); however, this was not required. Review papers (i.e. papers that did not present primary data; n=1) [69] were excluded from this study. A hand search technique was used to identify any additional primary data sources in the paper's references. A manual search was completed for all references retained for data extraction excluding grey literature.

Papers were assessed according to the following inclusion/exclusion criteria: (1) the drowning event was unintentional; (2) the literature included reference to rivers and/or creeks and/or streams. Exclusions included: intentional drowning (suicide) or homicide as a result of drowning; the forensic investigation of drowning (e.g. autopsies and how to identify drowning in cases of fresh water drowning). Conference abstracts, even if published in the peer-reviewed literature, were excluded.

Papers where the main focus was flood-related drowning were excluded, as flooding differs from the normal river process with different risks and should therefore be dealt with separately to river drowning deaths during non-flooding periods. [70 71]

Risk factors were defined as an attribute (such as personal behaviour or lifestyle), environment (such as speed of water flow, depth of water, objects in the water) or an inborn or inherited characteristic (such as age, sex) that on the basis of evidence is known to increase the probability of a specified outcome, be it injury, death or disease. [72] Preventive strategies were defined as any activity aimed at reducing river drowning.

With respect to rivers (i.e. rivers, creeks and streams), the following definitions from the Australian context were used. River was defined as '…a natural waterway that may be fed from other rivers or bodies of water draining water away from a 'catchment area' to another location…'. [15] 'Rivers can vary in water flow, length, width and depth'. [16] A creek was defined as 'a water body that may be fed by rivers and other creeks. A creek is generally smaller in size than a river and is often characterised by intermittent water flow. Creeks can be prone to more extreme conditions of stasis in drought and flash flooding after rainfall'. [16] A stream was defined as 'a body of flowing water generally smaller than a river. A river may also be seasonal but may not always contain water'. [16]

To reduce the size of tables 5 and 6 and to present the information consistently, categories (data sources and risk factors) have been given a numeric value–for example, death certificate is coded as 1 in Table 3. These can be found at the bottom of tables 5 and 6. Coding was used for the different hazards presented by rivers—for example, currents and drop offs were coded together as 'river characteristics' in Table 4 and given the numeric code '10'.

Where data on populations of the country or region being analysed, as well as the number of river drowning deaths, were made available, a crude rate of river drowning per 100 000 population was calculated. Where a drowning rate was presented as well as the proportion of all drowning deaths that rivers accounted for as a percentage, this proportion was used on the overall drowning rate to calculate a crude river drowning rate per 100 000 population.

The methodological quality of the papers that proposed strategies for prevention included in the review were assessed using the National Health and Medical Research Council (NHMRC) Levels of Evidence. [73]

2.3 Results

A large number of papers were excluded because of a lack of specificity around unintentional fatal drowning specific to rivers. Several papers were included because they mentioned rivers as a category of location and their burden within the overall number of drowning deaths, but any further analysis, including identifying risk factors, could not be extracted from the broader grouping of 'freshwater'. [74-78]

Others were excluded because they did not focus on unintentional drowning. Papers where unintentional drowning in rivers could not be separated from fatal river drowning as a result of suicide and/or homicide were also excluded. [77-82]

Papers were excluded from the systematic review if they focused on both fatal and non-fatal drowning, such as hospital admissions due to drowning, without making distinction between the two by location, [83 84] as the present study expressly focused on fatal river drowning.

Initial search results returned 895 papers, and all papers were extracted into EndNote (Figure 3) [85]. Duplicate papers (n=224) were removed leaving 671 references. After a title search, 417 papers were removed. Abstracts were reviewed for 254 papers, and 116 papers were removed. The full text for 138 papers was assessed against the inclusion and exclusion criteria, and a further 114 papers were removed. Hand searches of the initial 24 papers included in the review were undertaken and identified a further five papers, resulting in 29 papers for review (Table 4). Of the 29 papers found, 21 (72.4%) included epidemiological information, 18 (62.1%) included information on risk factors for drowning in rivers, and 10 (34.5%) were identified as proposing prevention strategies.

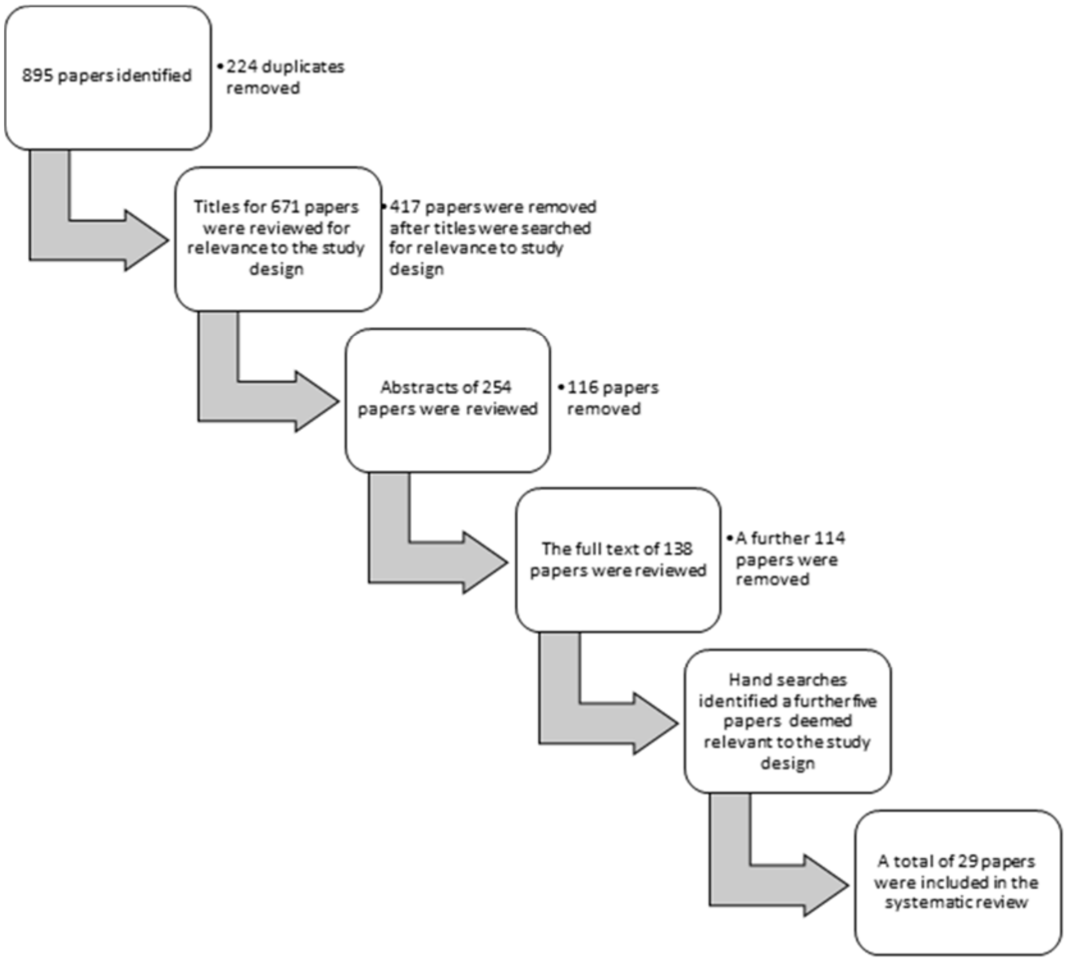

Figure 3:Modified PRISMA flow chart [85] – Process for extracting relevant papers (N=29)

Table 4: List of References Deemed Relevant to Study Design of Systematic Literature Review (N=29)

	Reference	**Reference number in text**
1	Ahmed MK, Rahman M, van Ginneken J. Epidemiology of child deaths due to drowning in Matlab, Bangladesh. International Journal of Epidemiology 1999;**28**(2):306-11.	86
2	Brenner RA, Trumble AC, Smith GS, et al. Where Children Drown, United States, 1995. Pediatrics 2001;**108**(1):85-89.	74
3	Byard RW, Lipsett J. Drowning deaths in toddlers and preambulatory children in South Australia. American Journal of Forensic Medicine & Pathology 1999;**20**(4):328-32.	87
4	Cass D, Ross F, Grattan-Smith T. Child drownings: a changing pattern. Medical Journal of Australia 1991;**154**(3):163-5.	88
5	Cass DT, Ross F, Lam LT. Childhood drowning in New South Wales 1990-1995: a population-based study. Medical Journal of Australia 1996;**165**(11-12):610-2.	89
6	Davis S, Ledman J, Kilgore J. Drownings of children and youth in a desert state. Western Journal of Medicine 1985;**143**(2):196-201.	71
7	Dietz PE, Baker SP. Drowning: Epidemiology and prevention. Am J Public Health 1974;**64**(4):303-12.	90
8	Fang Y, Dai L, Jaung MS, et al. Child drowning deaths in Xiamen city and suburbs, People's Republic of China, 2001-5. Injury Prevention 2007;**13**:339-43.	91
9	Fife D, Scipio S, Crane GL. Fatal and nonfatal immersion injuries among New Jersey residents. American Journal of Preventive Medicine 1991;**7**(4):189-93.	92
10	Franklin RC, Mitchell RJ, Driscoll TR, et al. Non-work-related farm fatalities in Australia, 1989-1992. J Agric Saf Health 2001;**7**(4):229-39.	93
11	Franklin RC, Scarr JP, Pearn JH. Reducing drowning deaths: the continued challenge of immersion fatalities in Australia. Medical Journal of Australia 2010;**192**(3):123-6.	35
12	Howland J, Mangione T, Hingson R, et al. A pilot survey of aquatic activities and related consumption of alcohol, with implications for drowning. Public Health Reports 1990;**105**(4):415-9.	94
13	Iqbal A, Shirin T, Ahmed T, et al. Childhood mortality due to drowning in rural Matlab of Bangladesh: magnitude of the problem and proposed solutions. J Health Popul Nutr 2007;**25**(3):370-6.	95
14	Kauffman RB. The drowning trap: on the Potomac River most people drown well below flood levels. Trends 1992;**29**(1):39-47.	96
15	Kemp A, Sibert JR. Drowning and near drowning in children in the United Kingdom: lessons for prevention. BMJ 1992;**304**(6835):1143-6.	83
16	Kiakalayeh AD, Mohammadi R, Ekman DS, et al. Unintentional drowning in northern Iran: a population-based study. Accid Anal Prev 2008;**40**(6):1977-81	97

17	Lunetta P, Smith GS, Pentilã A, et al. Unintentional drowning in Finland 1970-2000: a population-based study. International Journal of Epidemiology 2004;**33**(5):1053-63.	75
18	Moran K. Jumping to (fatal) conclusions? An analysis of video film on a social networking web site of recreational jumping from height into water. Int J Inj Contr Saf Promot 2014;**21**(1):47-53.	98
19	Nakahara S, Ichikawa M, Wakai S. Drowning deaths among Japanese children aged 1-4 years: different trends due to different risk reductions. Injury Prevention 2004;**10**(2):125-26.	99
20	Newman LM, Diekema DS, Shubkin CD, et al. Pediatric wilderness recreational deaths in western Washington State. Annals of Emergency Medicine 1998;**32**(6):687-92.	100
21	Nixon J, Pearn J, Wilkey I, et al. Fifteen years of child drowning- A 1967-1981 analysis of all fatal cases from the Brisbane drowning study and an 11 year study of consecutive near-drowning cases. Accident Analysis and Prevention 1986;**18**(3):199-203.	37
22	O'Hare D, Chalmers D, Arnold NA, et al. Mortality and morbidity in white water rafting in New Zealand. Inj Control Saf Promot 2002;**9**(3):193-8.	101
23	Patetta MJ, Biddinger PW. Characteristics of drowning deaths in North Carolina. Public Health Reports 1988;**103**(4):406-11.	76
24	Rahman A, Mashreky SR, Chowdhury SM, et al. Analysis of the childhood fatal drowning situation in Bangladesh: exploring prevention measures for low income countries. Injury Prevention 2009;**15**(2):75-79.	59
25	Riley MD, Larson A, Langford J. Drowning fatalities of children in Tasmania: differences from national data. Aust N Z J Public Health 1996;**20**(5):547-9.	102
26	Sorey WH, Cassidy LD, Crout J, et al. River tree rope swing injuries. Southern Medical Journal 2008;**101**(7):699-702.	103
27	Tan RMK. The epidemiology and prevention of drowning in Singapore. Singapore Medical Journal 2004;**45**(7):324-9.	104
28	Wentworth P, Croal AE, Jentz LA, et al. Water-related deaths in Brant County 1969-1992: A review of fifty-seven cases. J CAN SOC FORENSIC SCI 1993;**26**(1):1-18.	105
29	Wintemute GJ, Anton A, Andrada E, et al. Compliance with an ordinance requiring the use of personal flotation devices by children in public waterways. West J Emerg Med 2013;**14**(2):200-03.	106

2.3.1 Epidemiology

Of the 21 papers, seven (33.3%) examined drowning data at a national level, and 14 at a sub-national level. The time periods ranged from a single year [59 74 90 97] to 35 years. [87] Nine studies (42.9%) focused on all ages, and 10 (47.6%) focused on children. Two papers focused on specific populations (farm environment [93] and recreational river rafting [101]. Eight papers (38.1%) included information on activity prior to drowning. Falls were the most common activity, followed by swimming and watercraft (Table 5).

The three most common data sources used were death certificates (33.3%), country level statistics organisations (19.0%) and autopsy reports (9.5%). Three papers used multiple data sources, two used a combination of coronial records and country level statistics organisations, [35 93] and the other a combination of a surveillance system, death certificates and household surveys [97] (Table 5).

The burden of drowning in rivers ranged from 3.8% of all drowning deaths among children 0–14 years in the Australian state of New South Wales [89] to 52.0% in the USA state of Maryland in 1972. [90] The crude rate of river drowning per 100 000 population varied from 0.38 [91] to 1.89 [97] in LMICs and from 0.20 [104] to 1.56 [90] in HICs (Table 5).

Table 5: Relevant papers identifying prevalence of fatal drowning in rivers (n=21)

Reference	Country / Area of Country	Study Country Income Level	Year(s)	Population	Data Source / ICD 8,9,10, None, Unknown	Terminology	Population-based (Y/N)	Number of Riverine Drowning Deaths	% of Riverine drowning deaths	Rate / 100,000 persons	Activity prior to drowning
Brenner et al 2001 [74]	United States of America (USA)	HIC	1995	Children aged <20 years	1 (ICD 9)	River, creek	Y	235	17	UTBC	Not discussed
Byard and Lipsett 1999 [87]	Australia (South Australia)	HIC	Mar 1963-Feb 1998	Children < 2 years of age	3 (None)	River	N - Case Series	3	9	UTBC	Not discussed
Cass et al 1991 [88]	Australia (New South Wales)	HIC	1987-1990	Children less than 15 years	5 (None)	Rivers and creeks	N - Case Series	10	16	UTBC	70% wading near shore (caught by current or lost footing)
Cass et al 1996 [89]	Australia (New South Wales)	HIC	1990-1995	Children aged 0-14 years	2 (None)	Rivers	Y	5	4	UTBC	100% playing or swimming in the water
Davis et al 1985 [71]	USA (New Mexico)	HIC	1975-1980	People aged 0-24 years	1 (None)	Rivers	Y	63	19	0.82^	"Most victims involved in activities near but not in the water"
Dietz and Baker 1974 [90]	USA (Maryland)	HIC	1972	All accidental drowning deaths	6 (None)	Rivers or creeks	Y	61	52	1.56^	37.7% Boating 31.1% Swimming 24.6% Fell or stepped into deep water
Fang et al 2007 [91]	China (Xiamen city and suburbs)	LMIC	2001-2005	Children aged 1 to 14 years	1 (ICD9, 10)	River	Y	7	10	0.38^	Not discussed
Fife et al 1991 [92]	USA (New Jersey)	HIC	1981-1985	All immersion injuries leading to hospital admission or death	1 (ICD9)	River	Y	66	16	0.21^	Not discussed
Franklin et al 2001 [93]	Australia	HIC	1989-1992	Unintentional fatalities occurring in the farm environment	2, 8 (Unknown)	Rivers and creeks	Y	15	22	UTBC	Not discussed
Franklin et al 2010 [35]	Australia	HIC	1 Jul 2002-30 Jun 2007	All unintentional fatal drowning in Australia	2, 8 (None)	Rivers	Y	295	20	0.29^	20.7% Fall 20.3% Unknown 18.6% Other

Iqbal et al 2007 [95]	Bangladesh (Matlab)	LMIC	1985 - 2000	Children aged 1-4 years	7 (None)	Rivers	Y	44	4.4	UTBC	Not discussed
Kiakalayeh et al 2008 [97]	Iran (Guilan and Mazandran)	LMIC	20 Mar 2005-20 Mar 2006	Resident (R) and tourists (T)	7, 1, 4 (ICD10)	River	Y	85 (75 R 10 T)	25% (88.2% R 11.8% T)	1.89 *	Not discussed
Lunetta et al 2004 [75]	Finland	HIC	1998-2000	All ages	8 (ICD8,9,10)	River	Y	92	13.1	0.58^	Not discussed
Newman et al 1998 [100]	USA (five counties of Washington State)	HIC	1987 to 1996	Individuals > 12 months to 19 years who died of injuries sustained while involved in recreational wilderness activity	6 (None)	River	N- Case Series	15	37.5	UTBC	46.7% Swimming 33.3% Falls 20.0% Watercraft
Nixon et al 1986 [37]	Australia (Brisbane (Queensland))	HIC	1967-1981	Childhood (0-15 years)	99 (None)	Creeks, rivers	Y	20	15.0	0.53^	Not discussed
O'Hare et al 2002 [101]	New Zealand	HIC	1983-1995	Deaths as a result of recreational river rafting	8 (ICD9)	Rivers	N - Case series	31	93.9	UTBC	100% Watercraft
Patteta and Biddinger 1988 [76]	USA (North Carolina)	HIC	1980-1984	All people	1 (None)	River or Creek	Y	309	29.4	0.94^	Not discussed
Rahman et al 2009 [59]	Bangladesh (rural and urban communities)	LMIC	2003	Children 0-17	4 (None)	River	Y	96	5.2	1.42^	Not discussed
Riley et al 1996 [102]	Australia (Tasmania)	HIC	1981-1993	Children <15	2 (None)	Rivers	Y	7	20.6	1.01^	Not discussed
Tan 2004 [104]	Singapore	HIC	1992-2001	All ages	1 (None)	Rivers	Y	74	15.1	0.20*	Not discussed
Wentworth et al 1993 [105]	Canada (Brant County)	HIC	1969-1992	All ages	3 (None)	River, creek	Y	16	33.3	UTBC	37.5% Falls 18.8% Watercraft 18.8% Swimming

* Rate calculated using available population and drowning data in respective paper ^ Rate calculated using overall drowning rate and proportion of river drowning within overall drowning UTBC = Unable to be calculated. Data source: 1 – Death certificates, 2 – Coronial records, 3 – Autopsy reports, 4 – Household surveys, 5 – Hospital medical records, 6 – Medical records (e.g. Records at the office of the Chief Medical Examiner), 7 – Surveillance system, 8 – Country level statistics organisations (e.g. Statistics Finland, Australian Bureau of Statistics (ABS)) & New Zealand Health Information System, 99- Unknown Rate.

2.3.2 Risk Factors

Risk factors identified included: age (33.3%); activity prior to drowning (33.3%), of which falls into water (16.7%), swimming (16.7%) and using watercraft (11.1%) were identified; being male (22.2%); alcohol (27.8%). Where age was a risk factor, the age groups identified were children (5–14 years), [102] adolescents, [71] teenagers (12–18 years), [100] young people (under 39 years), [105] adults (18–49 years) [35] and older people (70+ years). [97] Common groupings of risk factors included age and falls [51 71 105] and age, being male and swimming [100 102] (Table 6).

Table 6: Relevant papers discussing risk factors for fatal drowning in rivers (n=18)

Reference	**Country / Area of Country**	**Risk Factors**	**Type of Study**
Ahmed et al 1999 [86]	Bangladesh (Matlab)	1,2	Population-based
Byard and Lipsett 1999 [87]	Australia (South Australia)	4	Case Series
Cass et al 1991 [88]	Australia (New South Wales)	8, 10, 18	Case Series
Cass et al 1996 [89]	Australia (New South Wales)	2, 9, 4	Case Series
Davis et al 1985 [71]	USA (New Mexico)	6, 12	Population-based
Fang et al 2007 [91]	China (Xiamen city and suburbs)	11	Population-based
Franklin et al 2010 [35]	Australia	12, 6, 7, 99	Population-based
Howland et al 1990 [94]	USA (Massachusetts)	3	Telephone survey
Kauffman 1992 [97]	USA (Potomac River - West Virginia, Maryland, Virginia, Washington, D.C.)	10, 3, 13, 18	Case studies
Kiakalayeh et al 2008 [97]	Iran (Guilan and Mazandran)	17, 12	Population-based
Lunetta et al 2004 [75]	Finland	3	Population-based
Newman et al 1998 [100]	USA (five counties of Washington State)	4, 12, 1, 5, 7, 14	Case series
Nixon et al 1986 [37]	Australia (Brisbane (Queensland))	16	Unknown
O'Hare et al 2002 [101]	New Zealand	14, 17	Case series
Patetta and Biddinger 1998 [76]	USA (North Carolina)	3	Population-based
Riley et al 1996 [102]	Australia (Tasmania)	12	Case series
Sorey et al 2008 [103]	USA	15	Case series
Wentworth et al 1993 [105]	Canada (Brant County)	4, 12, 3, 6,7	Population-based

Risk Factors Coding: 1 – Summer months, 2 – Exposure, 3 – Alcohol, 4 – Being male, 5 – Daylight hours, 6 – Falls into water, 7 – Swimming, 8 – Rurality, 9 – Risk-taking behaviour, 10 – River characteristics (e.g. caught in current, lost footing due to steep/sharp drop offs), 11 – Lack of swimming ability, 12 – Age, 13 – Not wearing lifejackets, 14 – Using watercraft, 15 – River tree rope swings, 16 – Lower survival rates / more likely to experience a bad outcome, 17 – Resident of the area they drowned in (as opposed to a tourist), 18 – Lack of river knowledge, 19 – Monsoon period, 20 – Absence of supervision, 99 – Unknown activity

2.3.3 Strategies for Prevention

There were nine papers proposing prevention strategies (Table 7), and only one paper that explored the effectiveness of a river drowning prevention strategy. This paper observed the use of lifejackets by children at three popular local river beaches in Sacramento County, California. [106] Of the nine papers which proposed prevention strategies, education was mentioned in six (66.7%). Other proposed strategies included fencing, [89 97 99] signage, [96] depth gauges, [96] grills, [97] covers, [99] lifejackets,[74 96 100 103 106] legislation and enforcement, [106]and supervision. [100 83]

Proposed education-based prevention strategies included targeting education at older boys who were deemed more likely to be risk takers [89] and young men on the risks of jumping from a height into water. [98] Education on river conditions (depth of the river, velocity and deceptiveness) through the use of public service announcements was suggested. [96] Encouraging river users to recognise water conditions such as currents and the impact on personal swimming ability [100] was also recommended, as well as education for users of river tree rope swings about the potential risk of injury and for land managers about associated liabilities. [103] Evidence for papers citing proposed strategies for prevention was generally low, classified as level IV in 90.0% of papers, with only one paper being classified as level III-3. [106]

Table 7: Relevant papers discussing proposed prevention strategies for fatal river drowning (n=10)

Reference	**Country / Area of Country**	**Prevention Strategy(ies)**	**Level of Evidence**
Wintemute et al 2013 [106]	USA (Observation sessions at 3 popular local river beaches in Sacramento County (California)	Lifejackets made available for use without charge by swimmers at popular local river beaches. Statutory requirements – ordinances making it unlawful for parents or guardians to allow children under 13 to enter rivers without lifejackets Enforcement – higher lifejacket use is likely if enforced	III-3 Observational study & expert opinion
Reference	**Country**	**Proposed Prevention Strategy(ies)**	**Level of Evidence**
Brenner et al 1995 [74]	United States	Lifejackets (when boating or playing near rivers)	IV Population-based study
Cass et al 1996 [89]	Australia (New South Wales)	Education (targeted at older boys who are prone to risk-taking behaviour) Engineering (fencing house to separate from hazard)	IV Expert opinion & case series
Kauffman 1992 [96]	USA (Potomac River - West Virginia, Maryland, Virginia, Washington, D.C.)	Education (public service announcements of river conditions) Engineering (river depth gauges with interpretive signs) Administrative (signage on risks of river) Lifejackets as a prevention strategy	IV Expert opinion & case series
Kemp and Sibert 1992 [83]	United Kingdom	Supervision Engineering - Restrict Access for Swimming Education - Youth organisations not to organise swimming parties in rivers	IV Expert opinion & case series
Kiakalayeh et al 2008 [97]	Iran (Guilan and Mazandran)	Engineering – fences and grills	IV Expert opinion
Moran 2014 [98]	Australia & New Zealand	Education - young males about safe behaviours and inherent risks of jumping from height into water.	IV Expert opinion
Nakahara et al 2004 [99]	Japan	Engineering – fences or covers for rivers	IV Population-based study
Newman et al 1998 [100]	USA (five counties of Washington State)	Education - Recognition of water conditions such as currents & personal swimming ability Basic water safety instruction for children Supervision and lifejacket use should be emphasized when children are around water	IV Case series
Sorey et al 2008 [103]	USA	Education – Awareness of injuries or liabilities Lifejackets – especially for non-swimmers	IV Expert opinion & case series

2.4 Discussion

There is currently no clear consistent definition of 'river', making this review challenging. Consideration was given to the types of terms used to classify rivers as well as whether any papers attempted to define river, creek and stream locations. No papers included in this systematic review included information as to how rivers were defined. As such, in this paper it is the first time that a definition of the aquatic location of 'river' has been provided.

The exploration of river drowning is also challenging given the use of ICD coding that does not allow the isolation of studies associated with rivers. [23] Being unable to quantify the burden of drowning in rivers makes the identification of river-specific risk factors difficult. This impedes the development of location-based strategies for prevention. For example, in Australia, 64.3% of drowning deaths would occur in the ICD10-coded natural waterways of beach, ocean, lake and river. [68]

2.4.1 Epidemiology

While rivers were found to be the leading location for drowning in several papers, [35 79 107] the majority of papers focused on the burden of drowning generally—of which river drowning may be a component—rather than national population-level epidemiological studies on the prevalence of river drowning. No papers provided a rate for drowning deaths in rivers; however, 12 papers provided sufficient information to calculate a crude fatal drowning rate, which ranged from 0.20 [104] to 1.89 [97] per 100 000 population.

Future studies of fatal drowning should provide rates based on location to allow comparison between papers. It should be noted that population-based rates do not take exposure into account. Future studies should also aim to identify exposure at river locations to calculate more accurate drowning rates.

Age groups found to be at risk ranged from children (5–14 years) [102] to older people (70+ years). [97] Further work needs to be undertaken to determine which age groups are at risk and why there is such variance. We postulate that this variance is due to exposure.

Exploration of common activities prior to drowning was rare, with only seven papers including information of this type. Activities included falls into water, [35 71 105 108] swimming, [35 100 105] using watercraft [100 101] and river tree rope swings. [103] Two papers also identified unique considerations for the prevention of fatal river drowning, namely the farm environment [93] and those who drown as a result of recreational river rafting. [101] These papers identify the need for epidemiological studies to isolate the different causal factors for fatal river drowning in order to identify applicable prevention strategies.

2.4.2 Risk Factors

Rivers have been identified as being a particularly risky location, with drownings more likely to result in a fatal outcome. [37] Being male was highlighted as a risk factor, [87 89 100 105] as was age (although consensus was lacking).[35 71 90 102 100 105] Teenagers and young adults, most commonly male, and their propensity towards risk-taking behaviour were identified in several papers. [71 98 100]

Other risk factors included: a lack of swimming ability; [91] underestimating the risk that river conditions can pose; [96] local residents (rather than tourists); [97 101] rurality of river location; [86 88 102] use of tree rope swings; [103] and reluctance to use lifejackets. [96] Children who play in and around rivers without adult supervision were also recognised as being at increased risk of drowning, [109] although adult supervision may still not be effective in preventing river drowning deaths in children in some circumstances. [100]

Alcohol was acknowledged as a risk factor for drowning in rivers in a number of papers, [75 76 94 96 105 108] with one paper finding 74.0% of all river drowning deaths to be alcohol-related. [75]

Much of the evidence to support the proposed risk factors for river drowning is based on population-based studies or case series. Several risk factors identified for river drowning are known risk factors for drowning, such as being male, the consumption of alcohol, and exposure to the hazard. Evaluations of proposed prevention strategies are needed to determine if strategies addressing general drowning risk factors are successful in the specific context of river drowning prevention. Other risk factors for river drowning identified in this systematic review may warrant further testing, such as lack of swimming ability, lack of knowledge of rivers as a hazard, and river characteristics.

Exposure studies will also assist in identifying if a lack of consensus based on age as a risk factor is due to the variety of activities being undertaken prior to drowning in rivers. We postulate that rivers are multipurpose settings, which poses a challenge for prevention.

2.4.3 Strategies for Prevention

There was only one study that discussed the evaluation of a prevention strategy for fatal river drowning through the use of lifejackets; however, the strategy was found to increase lifejacket use rather than prevent drowning. [106] Five papers made reference to strategies proposed in the WHO Global Report on Drowning, [17] most commonly restricting access to water through barriers, [83 89 97 99] and basic swimming instruction for children; [100] however, none had been evaluated. Engineering solutions to restrict access such as grills [97] and covers [99] were not well explained in the literature and are unlikely to be successful in open water environments such as rivers. There were nine other papers which discussed possible strategies and these were grouped around education, restricting access, lifejackets, signage, depth gauges, swimming skills and adult supervision of children.[74 83 89 96-100 103]

While supervision was commonly mentioned as a prevention strategy, one study stated that none of the victims were on their own when they drowned, teenagers usually were with peers and younger children with adults. [100] This has important implications for drowning prevention in rivers, as the presence of a 'supervisor' may not necessarily ensure supervision. Supervision as a prevention strategy should be clearly explained to include elements of responsibility (adult, sober), proximity, attention, continuity [53 110 111] and preparedness. [53] There would be benefit in a consistently applied universal definition for supervision. [53]

There are a range of contributory factors that lead to drowning in rivers. Any interventions designed to be successful in preventing drowning in such aquatic locations must be evidence-based and take into account factors such as exposure. [112] Further research is required to determine if strategies that are in place at other aquatic locations, such as lifeguard patrols at beaches, would be successful at river locations.

Ninety per cent of papers proposing strategies for the prevention of river drowning were classified as level IV, which represents a low level of quality. Well-designed and executed studies evaluating proposed strategies for prevention of river drowning are needed.

2.4.4 Additional Research Gaps

National population-based studies that specifically focus on the prevalence of river drowning among all age groups are urgently required. These studies should focus on the burden of river drowning as well as quantifying proposed risk factors such as age, sex, alcohol and activity prior to drowning among others. There is a need for more accurate exposure data (based on visitation information) to allow more sophisticated rates of river drowning per 100,000 visitations to be calculated. Most papers identified through this review focused on drowning overall, with only a small subsection of the paper including data and risk factors specific to rivers.

The sphere of river drowning prevention would also benefit from the use of an agreed definition to allow comparison across studies. Further specificity is required within coding mechanisms for location that go beyond the current coding structures within the ICD codes for location of drowning.

2.4.5 Limitations

- No papers identified in this systematic review included a rate per 100,000 for river drowning. Where a general rate of drowning per 100,000 and a proportion of drowning deaths in rivers was included in the paper, we were able to calculate a crude rate of river drowning per 100,000 persons. These crude drowning rates are not age adjusted and may not be as accurate if calculated from primary data. It does, however, for the first time provide a comparison between papers.

- Although the English language limit was used, the search did identify papers (three) where the abstract was in the English language, but the full paper was in a language other than English (Portuguese, Chinese and Turkish). Of these, only one paper identified the burden of river drowning, accounting for 6.3% of drowning in a tourism region of Turkey between 2002 and 2006. [113] These three studies were found as part of the overall 895 papers, but were excluded on the basis of not being in the English language.
- The majority of the papers included in this review are from HICs, with only four papers from three LMICs (China, Iran and Bangladesh) being deemed to fit the inclusion criteria.
- This systematic review excluded grey literature (i.e., non-peer-reviewed literature such as research published by international, government and non-governmental organisations) and may not have identified all studies in the area, thus publication bias may be present.

2.5 Conclusion

This review found that the crude rate of river drowning ranged from 0.20 to 1.89 per 100,000 population and that common risk factors were being male, age, alcohol and rurality of river locations. Data coding limitations that restrict our ability to extract river drowning deaths from within the ICD code of natural waterways makes identifying location-specific burden almost impossible.

This systematic review has identified that river drowning deaths are an issue in many regions and countries around the world. Further research is warranted, as well as the development, implementation and evaluation of prevention strategies. Future work should focus on the gaps identified in the research including: the development of an agreed definition; national population level studies into the prevalence of fatal river drowning; studies that quantify risk factors; studies that explore exposure; and studies that provide evidence for effective prevention.

Part B - Papers Published Since Literature Review Conducted

2.6 Introduction

An update to the systematic literature review, was conducted, using the same criteria and search terms, to cover the period 1 January 2015 to 31 December 2018 (4 years). Papers produced as part of this thesis were excluded. The searches were run on 20-01-2019.

Between 1 January 2015 and 31 December 2018, a total of 16 papers were identified that satisfied the inclusion criteria originally utilised in Part A of this chapter (Figure 4).

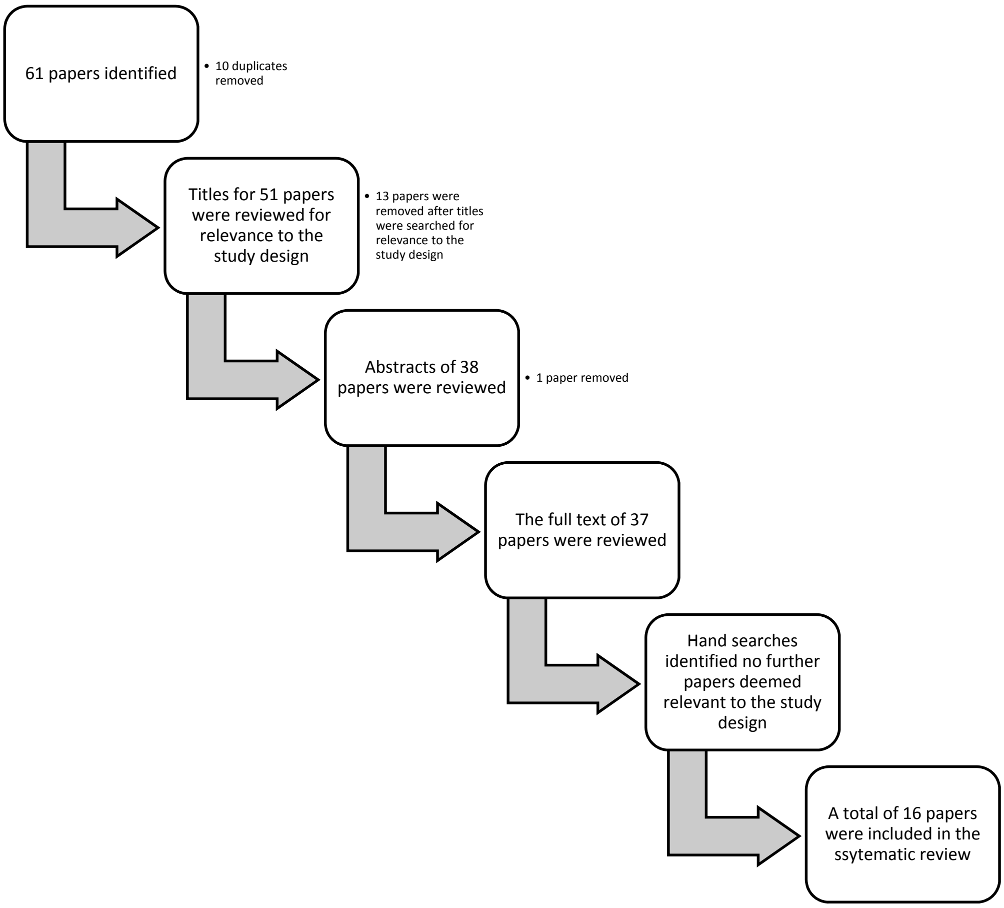

Figure 4: Modified PRISMA[85] flow chart depicting process of updated literature review (N=16)

Ten papers (62.5%) examined the epidemiology of river drowning, 11 (68.8%) papers examined risk factors and nine papers (56.3%) proposed prevention strategies. (Table 8)

Table 8: Relevant literature published since the original systematic literature review (N=16)

#	Reference	Country/area of country	Epidemiology	Risk Factors	Strategies for Prevention
1	Barnsley et al., 2018 [114]	Australia	√		
2	Chowdhury and Gulhan., 2016 [115]	Bangladesh		√	
3	Dandona et al., 2018 [116]	Bihar, India	√	√	√
4	Dirlik and Bostancioglu, 2015 [117]	Aydin province, Turkey	√	√	
5	Franklin et al., 2017 [24]	Australia	√	√	
6	Girasek et al., 2015 [118]	Yosemite National Park, California, United States of America		√	√
7	Girasek et al., 2016 [119]	Yosemite National Park, California, United States of America		√	√
8	Guan and Li., 2017 [120]	United States of America	√	√	
9	Hamilton et al., 2016 [121]	Australia			√
10	Morris et al., 2016 [122]	Pretoria, South Africa	√	√	
11	Murdoch and Kelly, 2018 [123]	El Paso County, Colorado	√	√	√
12	Phad and Dhawane., 2018 [124]	Central India	√		
13	Quan et al., 2018 [125]	Washington State, United States of America			√
14	Radosavljevic et al., 2017 [126]	Obrenovac, Serbia	√		√
15	Spitzer et al., 2018 [127]	United States of America (30 states)		√	√
16	Yang et al., 2017 [128]	China	√	√	√

2.7 Epidemiology

Ten studies met the inclusion criteria for the reporting of epidemiology of river drowning. Forty percent were conducted in HICs and 60.0% in countries classified as LMICs. Over half (60.0%) were conducted at the sub-national level. The most common data sources used were coronial records (used in 40.0% of studies) [24 84 114 122 123], followed by autopsy reports (20.0%) [117 124]. Other data sources included verbal autopsies [116], hydro meteorological data [126], newspaper reports [120] and records of rescues [128]. None of the studies used ICD coding to classify drowning cases. Of the studies which included epidemiology of river drowning, two included all ages [114 122 124], four focused only on children [24 116 117 120] one on flood-related fatalities [126] , one on a maritime incident [128] and one on white water rafting and kayaking deaths [123]. (Table 9)

The burden of drowning in rivers, ranged from 100% in studies on canoeing and kayaking drowning deaths [123], a maritime disaster on a river in China [128] and assessment of a river flood event [126] to 9% in a study of drowning deaths among all ages in central India [124]. In only one study, was a rate of river drowning presented, representing a rate of 5.9 per 100,000 persons in Bihar India among those aged 1 to 14 years [116]. In three studies, information on activity prior to drowning in the river was included, being watercraft activities [123], boating [128] and swimming [24]. (Table 9).

Table 9: Relevant papers identifying prevalence of fatal drowning in rivers (n=10)

Reference	Country/area of country	Study country income level	Year(s)	Population	Data source/ ICD8,9,10, none, unknown	Terminology	Population based (Y/N)	Number of river drowning deaths	% of all drowning deaths	Rate / 100,000 population	Activity prior to drowning
Barnsley et al., 2018 [114]	Australia	HIC	July 2002-June 2017	All ages	1 / none	River/Creek/ Stream	Y	1113	26%	UTBC	Not discussed
Dandona et al., 2018 [116]	Bihar, India	LMIC	Jan 2012-March 2014	1-14 year olds	2 / none	River	N	28	48%	5.9	Not discussed
Dirlik and Bostancioglu, 2015 [117]	Aydin province, Turkey	LMIC	2002-2012	0-18 years	3 / none	River	N	6	15%	UTBC	Not discussed
Franklin et al., 2017 [24]	Australia	HIC	July 2002-June 2012	0-14 years with pre-existing medical conditions	1 / none	River/Creek/ Stream	Y	10	19%	UTBC	20% Swimming
Guan and Li., 2017 [120]	USA	HIC	Jan 200 – May 2017	0-14 year olds with ASD	5 / none	River, creek	N	5	22%	UTBC	Not discussed
Morris et al., 2016 [122]	Pretoria, South Africa	LMIC	2002-2011	All ages	1 / none	Rivers	Y	43	15%	UTBC	Not discussed
Murdoch and Kelly, 2018 [123]	El Paso County, Colorado	HIC	2014-2017	White water rafting or kayaking drowning deaths	1 / none	Arkansas River	N	11	100%	UTBC	100% Watercraft (kayaking; white

											water rafting)
Phad and Dhawane., 2018 [124]	Central India	LMIC	Dec 2013-Nov 2015	All ages	3 / none	Rivers	N	15	9%	UTBC	Not discussed
Radosavljevic et al., 2017 [126]	Obrenovac, Serbia	LMIC	14-18 May 2014	Those prone to river flooding	4 / none	River flood	N	13	100%	UTBC	Not discussed
Yang et al., 2017 [128]	China	LMIC	1 June 2015	Victims of a marine disaster	6 / none	Changjiang River	N	442	100%	UTBC	100% Boating

Data sources: 1, coronial records; 2, verbal autopsy; 3, autopsy reports; 4, hydro meteorological data; 5, newspaper reports; 6, rescue records. Abbreviations: USA=United States of America; ASD=Autism Spectrum Disorder.

2.8 Risk Factors

Eleven studies included information on risk factors. The type of study most commonly identifying risk factors was case series (36.4%) and observational study (27.3%). Risk factors identified included location of household [115], age group [116-119 122 128], sex [116 118 119 123], rurality [116], epilepsy [24], inexperience [123], autism spectrum disorder [120], cardiomegaly [123], obesity [123], alcohol and drug use [123], and lifejacket non-use [127]. Age as a risk factor varied from 5-9 year olds [116], 15-18 year olds [117], people aged under 28 years [118], those older than 12 years [119], adults [122], and the elderly [128]. (Table 10)

Newly identified river drowning risk factors not previously found in the original literature review included factors impacting the individual such as: being female [128], medical conditions such as epilepsy [24], Autism Spectrum Disorder (ASD) [120], and cardiac conditions [123] as well as the impact of being overweight or obese [123], use of cannabis (THC) [123], previous experience using a riverside national park trail [118], recreating alone [119] and inexperience in white water rafting or kayaking [123]; location related factors such as: location of household [115], urban residence [116], and unfenced or unguarded water bodies [120]; activity related factors such as: bathing [116], being observed at the top of a waterfall [119], and cabin sailboaters [127]; and environmental related factors such as: warmer water temperature [127] and severe weather [128], and benign river conditions [127]. (Table 10)

Table 10: Relevant papers discussing risk factors for fatal drowning in rivers (n=11)

Reference	**Country/area of country**	**Risk Factors**	**Type of study**
Chowdhury and Gulhan., 2016 [115]	Bangladesh	1	Household survey
Dandona et al., 2018 [116]	Bihar, India	2, 3, 4, 5, 6	Population-based
Dirlik and Bostancioglu, 2015 [117]	Aydin province, Turkey	3, 7	Case series
Franklin et al., 2017 [24]	Australia	8	Case series
Girasek et al., 2015 [118]	Yosemite National Park, California, United States of America	3, 9, 10	Observational study and survey
Girasek et al., 2016 [119]	Yosemite National Park, California, United States of America	3, 11, 12, 13, 14	Observational study
Guan and Li., 2017 [120]	United States of America	15, 16	Case series
Morris et al., 2016 [122]	Pretoria, South Africa	17	Population-based
Murdoch and Kelly, 2018 [123]	El Paso County, Colorado	3, 18, 19; 20, 21	Case series
Spitzer et al., 2018 [127]	United States of America (30 states)	22, 23, 24	Observational study
Yang et al., 2017 [128]	China	25; 26; 27	Case study

Risk factor coding: 1, location of household; 2, monsoon season; 3, males, 4, 5-9 year olds; 5, bathing; 6, urban residence; 7, 15-18 year olds; 8, swimming with epilepsy; 9, People aged under 28 years; 10, Previous experience in using the riverside trail; 11, older than 12 years; 12, recreating alone; 13, observed at the top of the waterfall; 14, warmer temperature; 15, Autism Spectrum Disorder (ASD); 16, unfenced or unguarded water bodies; 17, adults; 18, cardiac conditions; 19, THC (Tetrahydrocannabinol) use; 20, no or minimal white water rafting or kayaking experience; 21, being overweight or obese; 22, cabin sail boaters; 23, warmer water temperature; 24, benign river conditions; 25, elderly age; 26, severe weather; 27, females.

2.9 Strategies for Prevention

There were nine papers which proposed prevention strategies. No studies had implemented or valuated the proposed prevention strategies. Newly proposed strategies not previously identified in the original systematic review included: Preventing river drowning among hikers (increasing search and rescue presence around high-risk rivers and developing safety messages with males in mind [119]), floods (targeting social influences when developing messaging aimed at discouraging people driving into floodwaters [121] and the use of a predictive model for flood evacuations[126]), regular training to enhance responses to large-scale maritime incidents [128] and exclusion of those under the influence of alcohol or drugs, implementing more stringent health requirements and setting an upper limit of difficulty of rapids based on an individual's previous experience for kayaking and white water rafting [123]. (Table 11)

Prevention strategies that reinforced the findings of the initial systematic review included: those strategies aimed at children (barriers to control access to water, supervised safe places and teaching swimming and water safety skills [116]), and lifejackets (including promotion of use and increased education on suitability of different styles [125]). None of the included studies which examined proposed prevention strategies, reviewed a drowning prevention program. (Table 11)

Table 11: Relevant papers discussing proposed prevention strategies for fatal river drowning (n=9)

Reference	Country/area of country	Proposed prevention strategies	Level of evidence
Dandona et al., 2018 [116]	Bihar, India	Engineering: Barriers controlling access to water Supervised safe spaces Education: Teaching swimming and water safety skills	IV Population-based study
Girasek et al., 2015 [118]	Yosemite National Park, California, United States of America	Tailoring risk communications to the different ways males and females perceive risk and interpret warnings.	III-3 Observational study and expert opinion
Girasek et al., 2016 [119]	Yosemite National Park, California, United States of America	Increase Preventive Search and Rescue presence at sites and times associated with higher numbers of visitors entering a river drowning risk zone.	III-3 Observational study and expert opinion
Hamilton et al., 2016 [121]	Australia	Targeting social influences when developing messaging aimed at discouraging people driving into rivers in flood.	III-3 Observational study and expert opinion
Murdoch and Kelly, 2018 [123]	El Paso County, Colorado	Excluding those who may be under the influence of alcohol or drugs from white water rafting or kayaking. More stringent health requirements. Setting an upper limit of difficulty of rapids based on an individual's previous experience.	IV Expert opinion and case series
Quan et al., 2018 [125]	Washington State, United States of America	Promoting of use of in-water lifejacket use for 15-64 year olds in open water. Educational messages to counter the perception that lifejackets are not needed by those who know how to swim or used only for boating.	III-3 Observational study and expert opinion
Radosavljevic et al., 2017 [126]	Obrenovac, Serbia	The issuing of general evacuation warnings during a rapid river flood when scores for a tool reach a particular level.	IV Expert opinion and case series
Spitzer et al., 2018 [127]	United States of America (30 states)	Education: Safety promotion efforts to recommend adult lifejacket use in all boating situations.	III-3 Observational study and expert opinion
Yang et al., 2017 [128]	China	The introduction of more automated and intelligent systems for maritime safety.	IV Expert opinion and case study

2.10 Key Findings

When comparing the findings of this update to the original systematic literature review, there remains a lack of population level studies on river drowning, particularly among LMICs. However, it is pleasing to note that LMICs make up almost half (43.8%) of the included studies in this update, compared to 17.2% in the original systematic literature review [50]. This may indicate an increase in research on river drowning in LMICs which are known to experience a high burden of drowning and, likely a high burden of river drowning [17].

When examining the epidemiological studies included in the updated literature review none relied on the use of ICD codes to classify drowning cases for inclusion in their study, with many using the outcome of coronial or medico-legal investigation. This may be due to the limitations previously identified in the original systematic literature review, outlining challenges in ICD coding structures for isolating rivers from other categories or natural waters [50]. It is hoped that the forthcoming iteration of ICD (ICD-11) will help addressed this issue.

As seen in the original systematic literature review [50], there remains a lack of consensus on risk factors, in particular sex and age group. Five studies [116-119 123] identified males as being at increased risk of river drowning, however in the context of a maritime disaster, females were identified as being at increased risk [128]. Similarly, the age groups identified as being at increased risk varied in the included studies, from children (ranging from 5 to 9 year olds [116] to 15 to 18 year olds [117]) to adults [122] and the elderly [128]. Several studies also pointed to broad age groupings being at increased risk of river drowning, such as people aged under 28 years [118] and those older than 12 years [119]. Further research is required to better clarify risk factors for river drowning at a population level, including age and sex, to best guide the development of prevention strategies.

With respect to prevention strategies, there appears to be a slight improvement in the levels of evidence used to prioritise prevention strategies, with 55.6% of studies included in this update being assessed as III-3 evidence and the remaining 44.4% as IV, compared to 10.0% III-3 and 90.0% IV in the original review [50]. However, similar to the findings of the original systematic literature review [50], there remains a dearth of evidence examining the implementation and evaluation of proposed prevention strategies, with only one study [106] providing this analysis in the original literature review and no studies in the update. This remains a gap in the river drowning prevention evidence base.

Chapter 3: Methodology

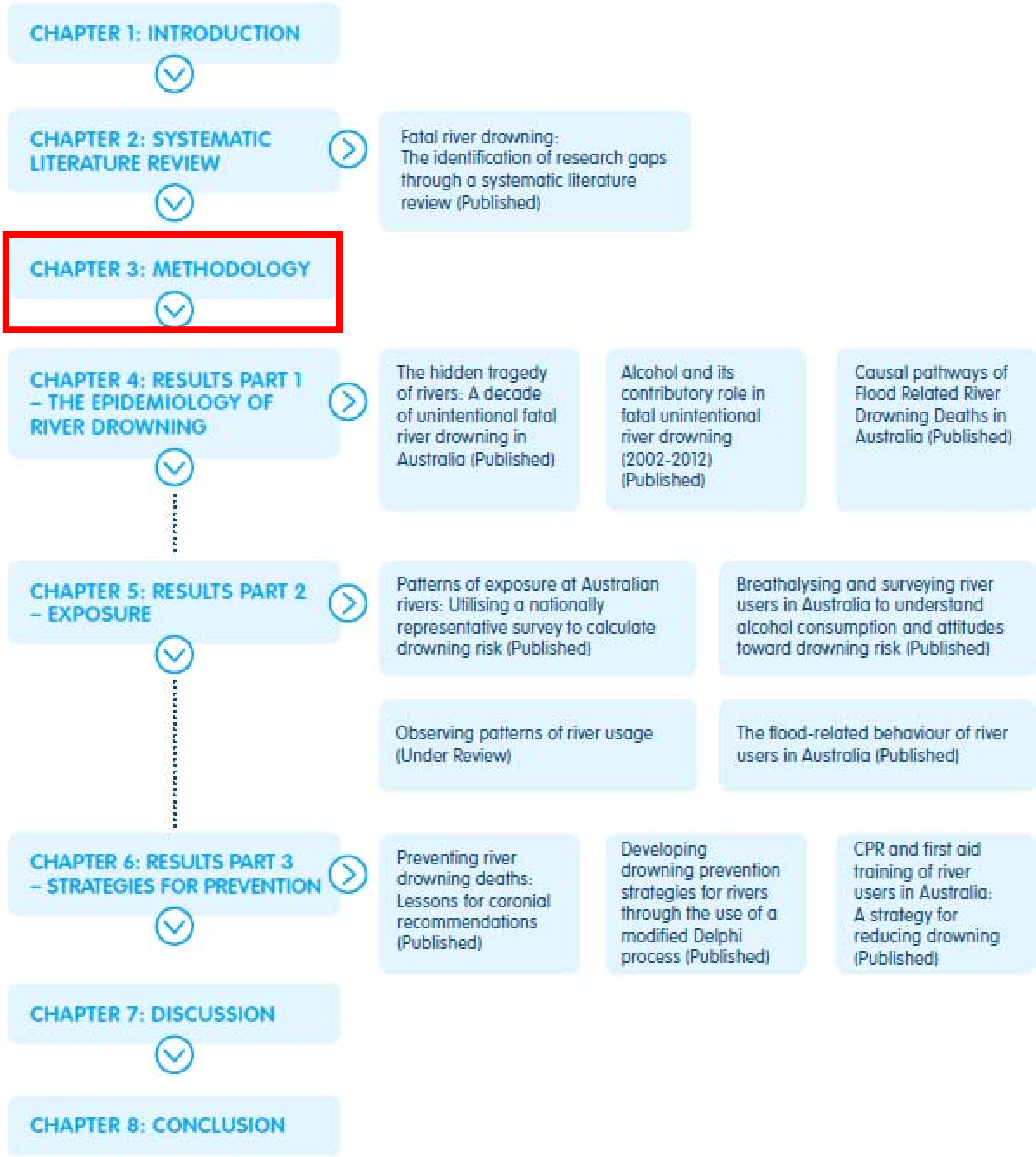

Figure 5: Chapter 3 position within thesis structure

3.0 Overview

This chapter discusses the methodologies used within this study. There were 11 different methods used to help explore, describe and assess river drowning and its prevention. The systematic literature found little prior research on river drowning, risk factors and strategies for prevention. This study therefore employed a public health approach to build an evidence base for river drowning prevention in Australia, including the need for stronger epidemiological studies, in-depth examination of risk factors and the development of prevention strategies which consider both.

Methods used in this study include: a data triangulation methodology to formulate a fatal unintentional river drowning set of data that was used for the epidemiological studies and the investigation of associated coronial recommendations; the use of a computer assisted telephone interviewing (CATI) survey as a means to explore exposure by developing river drowning rates per 100,000 population; data collection in the field at four popular river recreation locations (three of which are in the top 10 river drowning blackspots nationally [129]), including a face-to-face community survey (which included an examination of CPR skills and prior river flood-related behaviour), breathalysing of adult (18 years and over) river users, and a direct observation study. Finally, a modified Delphi process was used to identify, refine and prioritise strategies more likely to be effective in preventing river drowning. The methods used are discussed in detail in this chapter as well as addressing the theories discussed in this thesis.

3.1 Theories Used in Thesis

There were several theories utilised in the studies within this thesis. These include taking a Public Health Approach, the Transtheoretical Model of Behaviour Change, the Hierarchy of Control, and Social Determinants of Health.

3.1.1 Taking a Public Health Approach

The overall scope of the thesis and the publications within it, took a public health approach to drowning prevention. This approach involves four steps to improve the health and safety of all individuals by identifying and addressing underlying risk factors to reduce an individual's risk of a particular outcome [130]. The four steps of a public health approach are outlined in Figure 6, with the red box indicating the steps covered by the scope of this thesis.

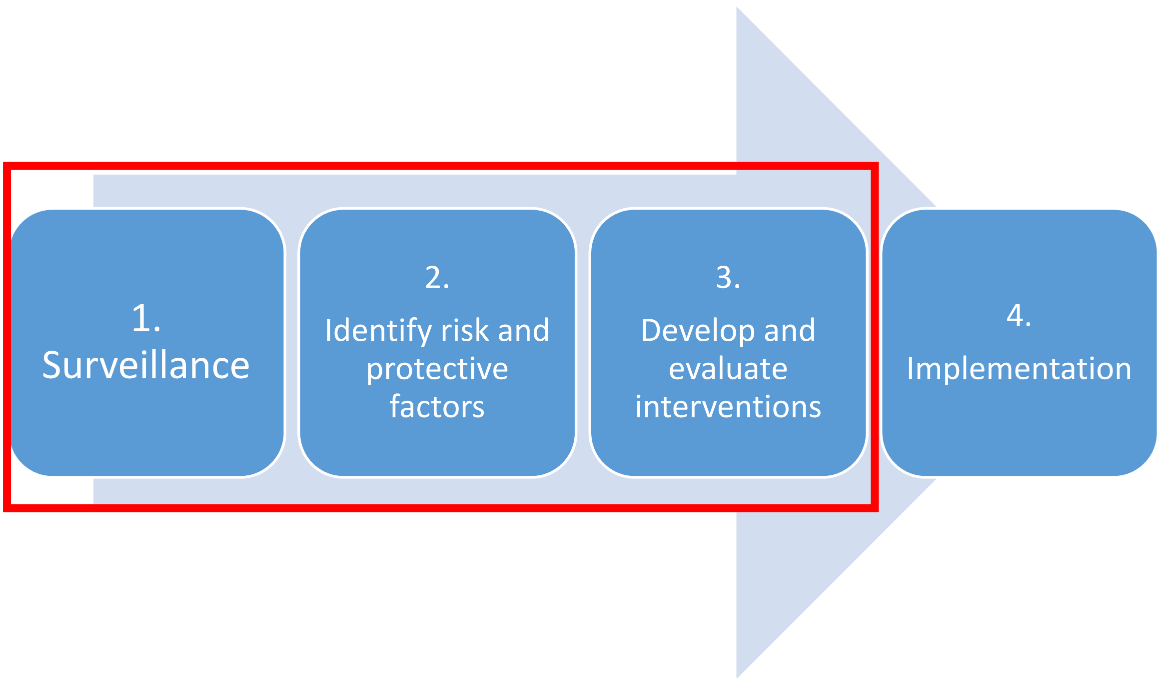

Figure 6: The public health approach and the steps covered in this thesis [131]

Given river drowning prevention is an issue in its infancy, with a dearth of population level research into the epidemiology and risk factors, and with virtually no drowning prevention interventions implemented and evaluated [50], a public health approach (in particular defining the problem through steps 1-2) was a useful way to frame the body of research used within this thesis.

Three of the four steps apply to the studies within this thesis as follows:

1) Surveillance – Using systematic data collection to define the problem of unintentional fatal drowning in rivers in Australia. This approach was used in the epidemiological study of river

drowning fatalities as presented in Chapter 4: Results Part 1: The Epidemiology of River Drowning [132 133 134]).

2) Identify risk and protective factors – Using the data to conduct research to identify why fatal unintentional drowning in rivers occurs and who is most at risk. This approach was used in the studies of river exposure (papers 5 [9], 7 [135]) and SR1 [7]. This approach was also used to explore alcohol consumption patterns at rivers and attitudes towards alcohol-related river drowning risk (paper 6 [4]).

3) Develop and evaluate interventions – Design, implement and evaluate interventions to determine what works. A systematic literature review methodology was used to explore current evidence and gaps in this knowledge base (paper 1 [50]). An in-depth analysis of river drowning related coronial recommendations using the Hierarchy of Control and SMART theories was utilised (paper 8 [136]). A modified Delphi process methodology was used to identify, develop and refine strategies for preventing drowning in rivers through the use of an expert panel, (paper 9 [137]). Finally, the theory of the social determinants of health were used to explore barriers or facilitators for river users in participating in CPR training and maintaining a current qualification was explored in Chapter 6 of this thesis and published in a short report (SR2) [138] in the *Health Promotion Journal of Australia*. It should be noted this thesis explored interventions that may reduce river drowning, however developing, piloting and evaluating interventions was beyond the scope of this thesis.

4) Implementation – Scaling up effective policy and programs. This approach was not covered in the thesis, however the information from the study is being used by RLSSA and is described in more detail in the discussion.

A public health approach focuses at a population level, rather than on the individual, which is vital given the burden of drowning in rivers and the diversity of those at risk [50]. Such an approach will be vital to achieving a sizeable reduction in the number of people drowning in rivers. The studies within Results Part 3 of the thesis (i.e. those papers which examine drowning prevention strategies for rivers [50 136-138]), also begin to touch on Step 3 of the public health approach, namely considering drowning prevention interventions. Further work is required to develop, implement and evaluate river drowning prevention interventions, which are beyond the scope of this thesis.

It should be noted that the public health approach is an iterative process (and not necessarily linear as depicted above in Figure 6). In this thesis the public health approach was used as a framework to structure the research. This was done as there was little known about river drowning, as such this research had to start at the beginning. After understanding the epidemiology, we moved onto identifying risk factors and thinking more deeply about some of these (in particular exposure and alcohol). The public health approach guided us in framing the issue to start addressing the "wicked problem" of river drowning and its prevention.

3.1.1.1 Strengths and Limitations of Taking a Public Health Approach

The strengths of a public health approach are the focus on well-being at a population level, the strong emphasis placed on prevention rather than treatment and it takes a systematic approach to identifying and preventing risk factors and strengthening preventative and enabling factors [139].

There are however, limitations with this approach. While there is evidence to support the efficacy of a public health approach, Wessells states there remain limitations [139]. It can be hard to reach a majority of the population for this approach to be effective. For something which is considered a process, such as drowning [12], a categorisation of interventions into primary, secondary and tertiary may not be entirely effective.

3.1.2 Theories of Behaviour Change

There are a number of approaches to explain / explore health behaviour and health behaviour change. These include the health belief model, theories of reasoned action and planned behaviour, social cognitive theory and the transtheoretical model of behaviour change [140-142]. The transtheoretical model of behaviour change was chosen for use in the breathalysing study [4], to explore the attitudes of river users, in particular, those who consume alcohol at the river, with a view to assessing their readiness their readiness to changing behaviour with respect to reducing alcohol consumption when at the river, to ultimately reduce drowning risk.

In particular those who consume alcohol at the river, place themselves at increased risk of drowning. Through the community survey, self-reported data was collected on the number of days in a month river users consumed alcohol, how many alcoholic beverages they consumed on an average day and on how many occasions they drank at risky levels. Data was used to determine hazardous lifetime alcohol use calculated by using the Alcohol Use Disorder Identification Test (AUDIT). River users were also breathalysed to record an objective measure of alcohol consumption at the time of completing the survey. These data identified many river users who drank as being risky drinkers in daily life, with the paper arguing, these river users are at the precontemplation stage and any interventions or attempts at behaviour change must take this into account.

3.1.2.1 Transtheoretical Model of Behaviour Change (Stages of Change)

The transtheoretical model of behaviour change conceptualises the way in which people move through steps in a process of change, i.e. the readiness of the individual to change their behaviour [140]. It was developed by Prochaska and Di Clemente in 2005 [143] to describe and explain the different stages that appear to be common to most behaviour change processes. The model describes both the stages and processes of change. Change is conceptualised as a process rather than an event, with individuals having varying levels of motivation or readiness to change.

The basic stages of change are outlined in Figure 7 and discussed below:

- Precontemplation – describing the individuals who are not even considering changing their behaviour, as well as those who are consciously intending not to change;
- Contemplation – describing the stage at which a person considers making a change to a specific behaviour;
- Preparation (or determination) – describing the stage at which a person makes a serious commitment to change;
- Action – describing the stage at which behaviour change is initiated;
- Maintenance – describing the stage at which the change is sustained, and also outlines the achievement of predictable health gains. Relapse may also be the fifth stage [144].

A sixth stage 'termination' has been added to describe those people who show no desire to return to their unhealthy behaviours and are sure they will not relapse. This stage is not often reached, with people therefore, tending to remain in the maintenance stage.

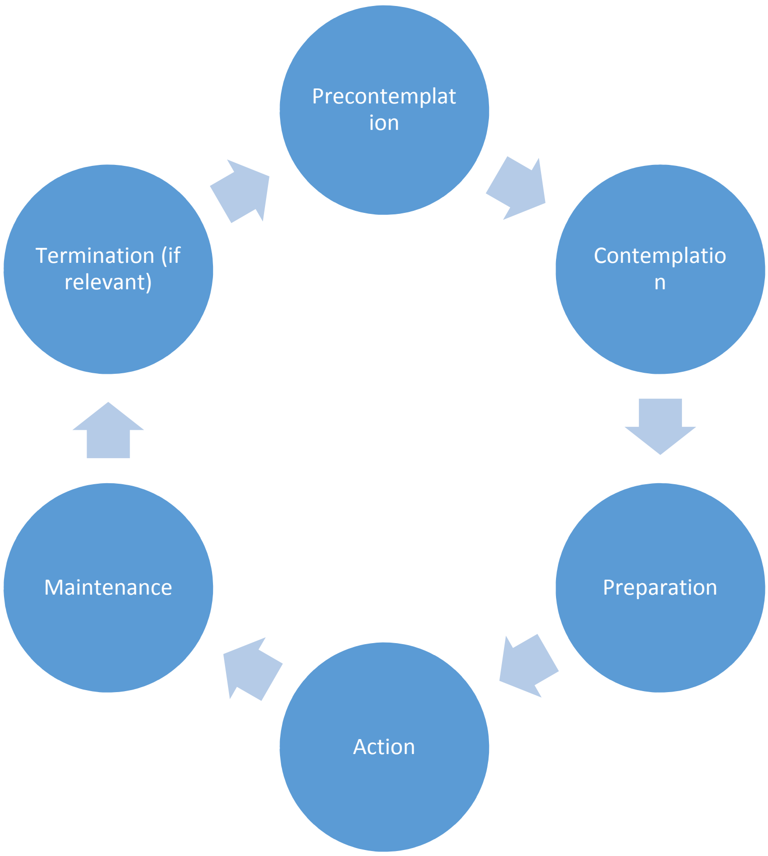

Figure 7: Stages of change in the Transtheoretical model of behaviour change [144]

3.1.3 Theories Which Aid in Injury Prevention

There are a range of theories which are used in injury prevention. These include: the Hierarchy of Control [145]; the five E's of injury prevention [146 147]; primary, secondary and tertiary prevention [148]; and the SMART principle [149]. The Hierarchy of Control and a modified SMART principle were the key theories in this section which were used in the thesis and are discussed in detail below.

3.1.3.1 The Hierarchy of Control

The Hierarchy of Control is a system used to minimise or eliminate exposure to hazards. The Hierarchy is commonly used in workplace health and safety as well as injury prevention [145].

The Hierarchy of Control was first proposed by William Haddon Jnr in his 1970 editorial entitled "On the Escape of Tigers: An Ecological Note" [145]. In this article, Haddon Jnr argued that physical hazards and their interaction with man have received scant attention and proposed ten strategies for reducing losses incurred from interaction with such hazards. These ten strategies were:

1. Preventing the hazard from being generated;

2. Reduce the size of the hazard;

3. Prevent the release of the hazard;

4. Modify the release of the hazard;

5. Separation of the hazard in space or time;

6. Separation of the hazard through the use of a barrier;

7. Environmental modification to reduce the impact of the hazard;

8. Strengthening the structure that may be impacted by the hazard;

9. Moving to detect and evaluate damage caused by the hazard; and

10. All steps from the emergency period following the damage caused by the hazard, to final stabilisation.

Over the years, these strategies have been condensed to the five hazard controls, used in order of decreasing effectiveness, we are currently familiar with: Elimination, Substitution, Engineering controls, Administrative controls and Personal Protective Equipment (PPE). (Figure 8)

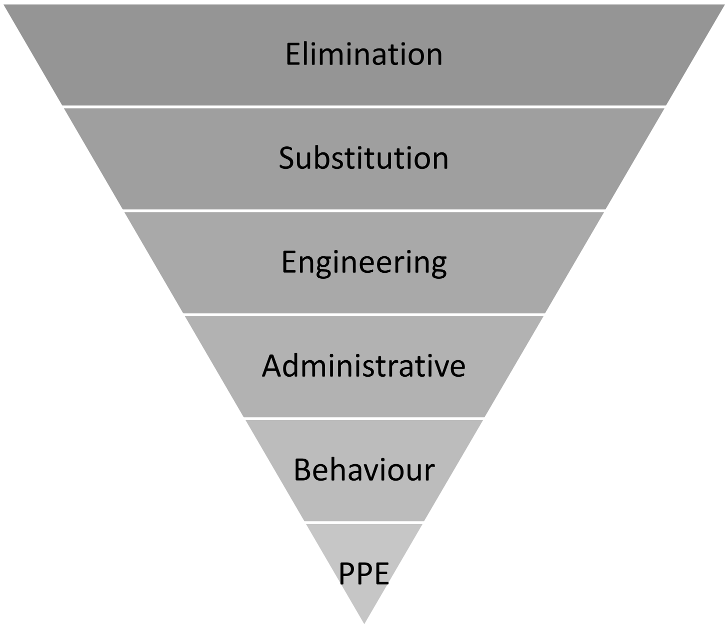

Figure 8: Hierarchy of Control [150]

The Hierarchy of Control is embedded in workplace health and safety legislation in Australia [151]. In a drowning prevention context, elimination can often be challenging due to the difficulty in removing the hazard and the recreational nature of use (particularly for a natural body of water). Therefore elimination may need to be thought of differently, i.e. remove particular activities from the river (e.g. remove jet-ski and powered boating use in areas designated for swimmers).

The management of safety at rivers can be challenging, often with multiple organisations in charge, for example the river bank, the water and the river bed may be owned and controlled by varying organisations. Rivers may be on public and/or private land, as well as in some instances, owned and operated by National Parks.

The Hierarchy of Control was used to examine if river drowning prevention strategies, either recommended by coroners (Paper 8 [136]) or by an expert panel (Paper 9 [137]), were likely to be effective in reducing river drowning deaths.

3.1.3.2 The SMART Principle

Also used in the study of coronial recommendations (Paper 8 [136]), was the SMART principle. The SMART principle gives criteria to the setting of objectives. The acronym stands for: Specific, Measurable, Achievable, Relevant and Time bound) [149]. The principle is commonly used in project management to ensure that objectives set are as clear as possible to ensure the achievement of such objectives and therefore overall success of projects. The principle is believed to have first appeared in an article published in a November 1981 issue of *Management Review*. The article examined the importance of objectives and the difficulty in setting them, with respect to business management [152].

The coronial recommendations were assessed against the aspects of the modified SMART principle with respect to whether it satisfied each component, to provide a score of how effective within a SMART principle context, the recommended action was. The SMART principle was modified to include two aspects to the Specific component, namely was the recommended action specified and was an individual or organisation charged with enacting the recommendation also specified as well, to ensure there was ownership over the issue, both important aspects in enhancing the likelihood of recommendations being enacted. Coronial recommendations were assessed against the modified SMART principle as it was hypothesised that the more SMART components a recommendation satisfied, the more likely the recommendations were to be enacted and therefore have an impact on reducing river drowning risk in the future.

Coronial recommendations were indexed against the Hierarchy of Control (see section 3.1.3.1), to examine the frequency and nature of coronial recommendations associated with cases of unintentional fatal river drowning in Australia, to guide future preventative efforts.

3.1.4 The Social Determinants of Health

There are multiple factors which impact society and therefore may impact their exposure to risk. The Social Determinants of Health (SDH) helps to describe these underling factors which include the conditions in which people are born, grow, live, works and play, which influence health [153]. Factors impacting inequities associated with the social determinants of health are defined as: i) the socioeconomic, political and cultural context; ii) daily living conditions and iii) individual health-related factors [154]. The theory of the social determinants of health, in particular socioeconomic context and daily living conditions, was chosen as a basis for examining the potential barriers and/or facilitators to participation in CPR training and possession of a current CPR qualification [138]. Knowing the impact of SDH on accessing CPR training can assist in the development of strategies to address any barriers posed to ensure all river users possess this important skill. The theory of SDH were also used to examine impact on likelihood of consuming alcohol (and amount consumed) at popular river usage locations [4] in order to be able to identify those individuals more at risk of alcohol-related river drowning and develop strategies to combat this.

By identifying the relevant SDH impacting river drowning risk, their impact on the likely effectiveness of river drowning prevention strategies can be identified and addressed in the future development and implementation of such strategies [153].

3.2 Epidemiological Approaches

The systematic literature review identified a dearth of population level epidemiological studies on fatal unintentional river drowning around the world, including in Australia. Therefore the epidemiological component of this study aimed to build the evidence base around the number and incidence of river drowning in Australia, as well as identify the risk factors to inform prevention. In Australia, data on causes of death is available from the ABS (www.abs.gov.au/causes-of-death) and coroners; while separate, these two are related.

3.2.1 Causes of Death Data in Australia- ABS

The ABS hold data on the causes of all deaths registered in Australia. Data are available on a national level, state and territory level, as a time series (year of occurrence) and on areas of specific focus, namely deaths among Aboriginal and Torres Strait Islanders and Perinatal Deaths [155].

In order for a death to be registered, the death must be certified by either a doctor using the Medical Certificate Cause of Death, or by a coroner. In 2017, 88.1% of deaths were certified by a doctor, with the remaining 11.9% certified by a coroner [155].

The registration of deaths is the responsibility of the eight individual state and territory Registrars of Births, Deaths and Marriages. As part of the registration process, information about the cause of death is supplied by the medical practitioner certifying the death or by a coroner. Other information about the deceased is supplied by a relative or other person acquainted with the deceased, or by an official of the institution where the death occurred. The information is provided to the ABS by individual Registrars for coding and compilation into aggregate statistics. In addition, the ABS supplements these data with information from the NCIS**.** The following diagram shows the process undertaken in producing cause of death statistics for Australia [155].

Figure 9 outlines the Australian Cause of Death Statistics System. Each death is certified by either a doctor or coroner and the resultant information is provided to the ABS through the Registrar of Births, Deaths and Marriages in each state or territory. Information is also provided via the NCIS for those deaths certified by a coroner. The ABS processes, codes and validates this information, which is then provided in statistical outputs [155].

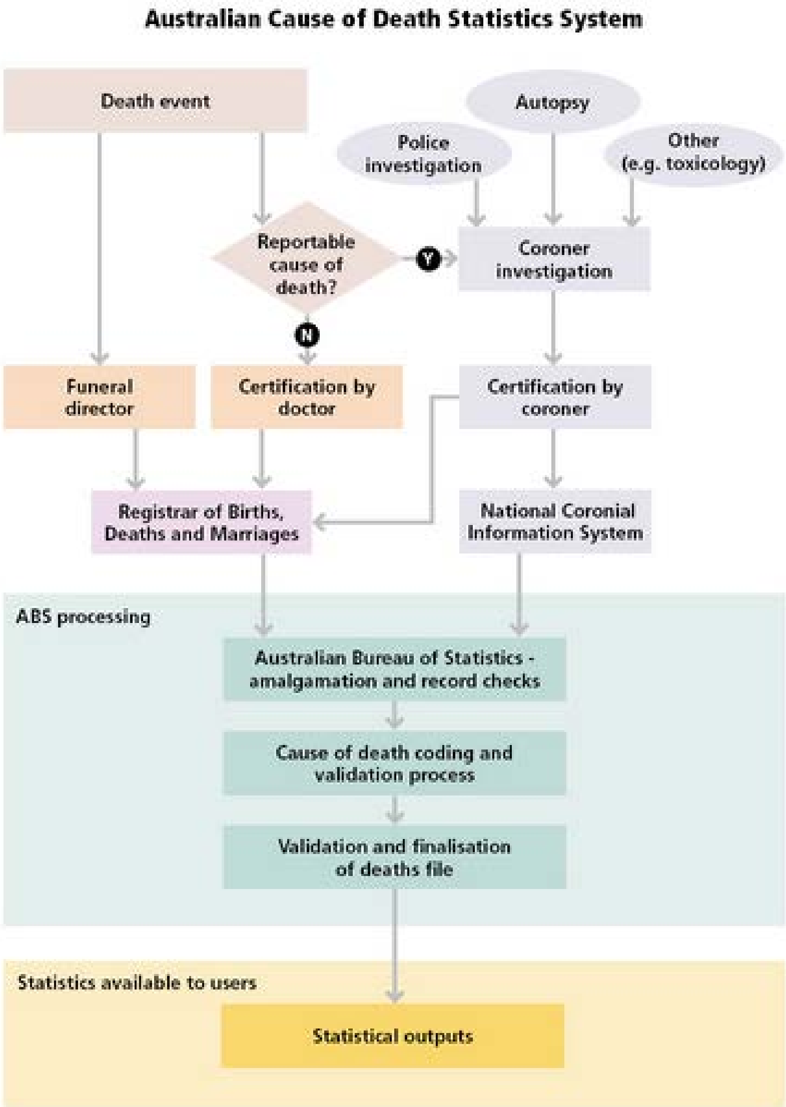

Figure 9: Australian Cause of Death Statistics System [155]

The ABS Causes of Death collection includes all deaths that occurred and were registered in Australia, including deaths of persons whose usual residence is overseas. Deaths of Australian residents that occurred outside Australia may be registered by individual Registrars, but are not included in ABS deaths or causes of death statistics [155].

The current scope of the statistics includes:

- all deaths being registered for the first time;
- deaths in Australia of temporary visitors to Australia;
- deaths occurring within Australian Territorial waters;
- deaths occurring in Australian Antarctic Territories or other external territories (including Norfolk Island);

- deaths occurring in transit (i.e. on ships or planes) if registered in the State of 'next port of call';
- deaths of Australian Nationals overseas who were employed at Australian legations and consular offices (i.e. deaths of Australian diplomats while overseas) where able to be identified; and
- deaths that occurred in earlier reference periods that have not been previously registered (late registrations) [155].

The scope of the statistics excludes:

- repatriation of human remains where the death occurred overseas;
- deaths overseas of foreign diplomatic staff (where these are able to be identified);
- stillbirths / foetal deaths (these are included in perinatal counts. In 2007-2009 these were published separately in Perinatal Deaths, Australia (cat. no. 3304.0), but are now included in this publication [155].

3.2.2 Cause of Deaths in Australia - The National Coronial Information System (NCIS)

The NCIS is an online data repository containing information about deaths reported to a coroner in Australia and New Zealand. The NCIS was established as a resource for coroners, and was launched in 2000 with the objective to securely share case information beyond state and territory borders for the purpose of coronial investigation and death prevention [31]. It was the first of its kind anywhere in the world [156].

The NCIS contains medico-legal data about all deaths reported to a Coroner in Australia and New Zealand. This includes demographic information about the deceased, contextual information about the nature of the fatality and full text reports of coronial findings, post mortem and toxicology reports and police notification of death reports. The data contained in the NCIS provides an invaluable resource for those working towards safer communities through injury and death prevention. These data are utilised by coroners, police, all levels of government, community and advocacy groups, researchers and the media as an evidence base for awareness raising and death prevention initiatives [31]. As the NCIS was the first such repository in the world it remains a leading example of the role of data as evidence to inform research, policy development and coronial investigation. Accessible online, the NCIS is available to researchers who satisfy strict ethical approvals, as was undertaken by PhD candidate Peden and primary supervisor Franklin in order to be able to access these data for the epidemiological section of this thesis (see section 3.5 of this chapter for more information about the ethics approvals gained for this research).

Information available on the NCIS includes: coronial finding (or an inquest report with recommendations if the case is taken to inquest); autopsy report; toxicology report; and police report. A coronial finding or inquest report, will confirm the identity of the person who drowned, the date of death and the cause(s) of death. An autopsy report will identify the cause of death from a forensic pathology perspective, as well as identifying any pre-existing medical conditions or injuries that were present when the victim died. A toxicology report will identify blood and urine concentrations of alcohol and other drugs (both prescription medications and/or illicit drugs). This includes where prescription medication is consumed at a sub-therapeutic, therapeutic and toxic level. Finally, the police report contains a narrative of the circumstances of the drowning incident, and will often include the perspective of witnesses to the event (if relevant). All documentation on the NCIS is used to collate the variables used for analysis within this thesis. See section 3.2.4.3 in this chapter about the process used to build the dataset.

3.2.3 International Classification of Diseases (ICD)

The ICD is the international standard classification for epidemiological purposes and is designed to promote international comparability in the collection, processing, classification, and presentation of causes of death statistics [13]. The classification is used to classify diseases and causes of disease or injury as recorded on many types of medical records as well as death records. The ICD has been revised periodically to incorporate changes in the medical field. Currently the ICD 10th revision is used for Australian causes of death statistics [155].

The ICD-10 is a variable-axis classification meaning that the classification does not group diseases only based on anatomical sites, but also on the type of disease. Epidemiological data and statistical data are grouped according to:

- epidemic diseases;
- constitutional or general diseases;
- local diseases arranged by site;
- developmental diseases; and
- injuries [155].

ICD codes used to define drowning (W65-74 only) have been shown to underreport drowning in Australia by 40% [14]. While cases of child drowning and those in swimming pools and bathtubs are largely unaffected, the use of ICD codes and the narrow codes to define drowning have a big impact on the accurate collation of cases of river drowning. This is due to non-inclusion of flood-related drownings (ICD code - X38) and boating and watercraft-related drowning deaths (ICD codes - V90, V92), which are key factors associated with drowning in rivers in Australia.

3.2.4 Data Triangulation Process

As a means of overcoming the limitations of ICD coding structures for the identification of river drownings, a data triangulation process was used consisting of the NCIS, media monitoring and reports from lifesaving organisations and child death review teams, rather than relying on ICD codes alone.

3.2.4.1 Media Monitoring

Monitoring of print, broadcast (radio and television) and online news media is conducted by a third party media monitoring company and provided to RLSSA in the form of email bulletins. Keywords used to identify relevant media reports on drowning/water-related death cases can be found in Figure 10. While the authors acknowledge 'near drowning' is not the accepted terminology within the drowning prevention community it is still a common term used [12].

Drowning/s OR drowned OR drowns AND death OR die OR died OR life OR pulled from water [exact phrase] OR pulled out of the water [exact phrase] OR swimming pool OR river Drowning OR water-related death cases [Australian focus] AND boating accidents OR ferry/boat capsizing OR inquests OR coronial findings AND rivers OR swimming pools OR beach OR ocean OR surf Near drowning AND serious injury OR brain injury OR hypoxia OR paralysis

Figure 10: Keywords used in media monitoring for fatal drowning incidents

Media monitored is print, broadcast (radio and TV), internet and social media, monitored at the time of being published. Print and internet email alerts are sent once a day, with broadcast emails 3-4 times as day as related content is broadcast. Social media alerts are obtainable through logging into the online media monitoring portal. A summary, as compiled by an Isentia team member, is provided for broadcast, while the full text of print and internet reports are available to be read via a direct link in the emails. The full social media posts can be accessed via the portal.

Media monitor emails are read by a researcher at RLSSA, who then transfer the relevant information for each suspected drowning death into an Access database. The information collected from media reports for each individual suspected fatal drowning is: Australian state or territory of incident, age of victim, sex of victim, if the victim was a tourist or the location of their residence, date of drowning incident, date of death (if different from date of incident in the case of initial non-fatal incidents), geographical location of incident, category of aquatic location of drowning incident, time of day of the incident, free text notes about the incident, name of victim (if released), media date, media type and name of media outlet. An ID number for each case is created automatically in access.

A drowning which is indicated by media as suicide is not logged. Drowning incidents where intent is not clear are logged for further examination against the NCIS. Although this study examines drowning during the summer months only, this process is undertaken by RLSSA all year round. Drowning deaths in Australia are reported on a financial year (1-July to 30 June) basis [36]. At the end of the financial year, searches are run on the NCIS to match cases in the Access database to coronial files and to identify those cases of unintentional fatal drowning not reported in the media.

3.2.4.2 Cross Referencing with NCIS Searches

Searches of NCIS are then undertaken for the Australian financial year period (1 July to 30 June). Financial years are used to allow for as much time possible to pass for the almost half (~42%) of drowning cases that occur in summer (in Australia spanning the months December to February inclusive) to be investigated by a coroner.

Searches are undertaken using query design to identify those cases with drown* in any of the attached documents (police, autopsy, toxicology reports or coronial finding). A query design is also undertaken for location code ‘countryside’ which includes ‘area of still water’, ‘stream of water’, ‘large area of water’ and ‘beach, shore, bank of a body of water’ among others or activity code which includes the categories of ‘sport and exercise during leisure time’, ‘leisure or play’ and ‘travelling not elsewhere classified’ among others. A mechanism of injury can also be searched, namely ‘threat to breathing’, followed by ‘drowning/near drowning’. An object can also be searched, for incidents occurring in a ‘building, building component or fitting’ such as ‘in-ground swimming pool’, ‘above ground swimming pool, external spa or hot tub’ and ‘wharf, jetty, pier’ among others.

Searches on the NCIS are also undertaken using the cause of death field, searching ‘drown*’, ‘hypox*’, ‘immers*’ and ‘submers*’ on causes 1a-3, 2 and 3. If a particular media case in question is still unable to be matched, a more general search of all incidents in a particular jurisdiction (i.e. Australian state or territory where the drowning incident occurred) by sex and date range around the drowning incident or death when the NCIS would have been notified of the death can be undertaken. Using media reported postcode of the incident and, if known, postcode of the deceased’s residential location, as well as date of the incident and the nearest case court to where the incident occurred, can be used to match the media reported case. This often occurs when there is no cause of death, location or activity coding to conduct a query design keyword search on.

3.2.4.3 Building the Database

Once confirmed as an unintentional fatal river drowning, cases were transferred from the NCIS into an SPSS V20 dataset [157]. As cases in the Access database are matched, the NCIS case file number is added to a field in Access against the entry. This process led to a database of cases of unintentional fatal drowning in Australia for the 10 financial year period 1 July 2002 to 30 June 2012.

Variables collected included NCIS number, age, sex, country of birth, Aboriginal and/or Torres Strait Islander status and residential postcode of the person who drowned. Other variables included geographical location and aquatic category of location of drowning death, activity being undertaken prior to drowning, if the incident was flood-related, if the victim recorded a positive BAC (and the reading), if a pre-existing medical condition was involved and the time of day, day of week, season and both calendar and financial year of the drowning.

Case status (i.e. open or closed) was also collected. Cases on the NCIS are open (i.e. under coronial investigation) until the investigation is completed and a coroner can rule on cause of death and a death certificate is issued. At this time, the case is closed on the NCIS and the full details and attached case files are made available to researchers. The time taken to close a case can vary based on state or territory jurisdiction, whether the case court is in a metropolitan or regional location and also if the case goes to inquest or not. If an inquest is held, the case, or a series of cases, are taken to inquest where multiple witnesses are called and the coroner deliberates over the circumstances before delivering a finding and handing down recommendations to prevent future similar deaths. For the study that examined coronial recommendations associated with river drowning deaths [136], the presence of coronial recommendations were recorded as a yes/no, with the closed cases with a yes for coronial recommendations retained for analysis.

3.2.4.4 Method Used in Papers in the Epidemiology Section of this Thesis

A range of statistical methods were used in the epidemiology papers featured in part one of the results of this thesis. Univariate and chi square [158] analysis were utilised in several studies in this thesis [132-134]. Where multiple categories within the one variable were tested, a modified Bonferonni as suggested by Keppel [159] was utilised to set a statistically significant p value at the appropriate level. Non-parametric chi square analysis was also conducted using the proportional basis of the population as the assumed outcome numbers [158].

Relative risk (with a 95% confidence interval) for risk factors among river drowning victims was also calculated [158]. The groups with the lowest numbers and/or rate, were used as the control groups. Both relative risk and chi square analysis were conducted without the unknown variable as it was assumed no bias was present among the unknown cases.

Crude drowning rates were also calculated per 100,000 persons, as well as by sex, age group, and state or territory of drowning incident [160]. Rates of non-aquatic transport flood-related drowning deaths were calculated per 100,000 registrations and vehicle type [134], using a 10 year average of registrations from the ABS Motor Vehicle Census [161]. Drowning rates for Aboriginal and Torres Strait Islanders were calculated using national population estimates [162]. Rates for country of birth (Australia and other), and Australian Standard Geographical Classification (ASGC) [163] of remoteness were calculated using a three yearly average from population data available from the three Australian Census years 2001 [164], 2006 [165] and 2011 [166]. The average BAC with a confidence interval, as well as the range, was calculated by age group.

3.2.4.5 Strengths and Limitations

A strength of the approach used is the total population nature of the dataset, which uses a data triangulation method, rather than rely on ICD coding structures which have shown to have a detrimental impact on case capture for river drowning fatalities [14]. Similarly, the data able to be derived from the NCIS is rich in causal detail and is geared towards examining incidents to prevent future similar deaths [156]. Known statistical methods were used to analyse the data and where possible, population data was used to determine highest risk within sub-groups, as opposed to relying only on incidence.

However, the epidemiological approaches utilised are not without limitations. Variables with unknown information were removed from the analysis and it was assumed no bias was present in the unknown cases. This may or may not be accurate. Case documentation (i.e. coroners, autopsy, toxicology and police reports are not available if cases are open within the NCIS). Cases that are open within the NCIS are subject to change depending upon the outcome of coronial investigations. The data presented within this thesis represents the best known available at the time of analysis and the proportion of cases closed does change over the papers published (i.e. 93.1% closed in the 10 year epidemiological study [132], increasing slightly to 93.4% for the papers on alcohol and flooding-related deaths [133 134]).

3.2.5 Analysis of Coronial Recommendations

All sudden and unexpected deaths (of which drowning is considered one) are investigated by a coroner to determine the circumstances and cause(s) of death. If deemed relevant, a coroner may take a case, or a series of cases to inquest, to deliver recommendations for the prevention of future similar deaths [30].

3.2.5.1 Method Used

Utilising the database built using the above epidemiological approach, an exploration of closed coronial cases was undertaken to examine the frequency with which coronial recommendations were made for river drowning deaths, as well as the nature of cases that were more likely to result in coronial recommendations was undertaken. The exploration described the kinds of strategies recommended for the prevention of deaths in rivers, how effective they are against the Hierarchy of Control (section 3.1.3) and the SMART principle (section 3.1.4), as well as the frequency with which similar recommendations were made.

3.2.5.2 Strengths and Limitations of Approach

A strength of this approach was the use of a total population dataset to analyse the coronial recommendations, as well as the application of those recommendations against agreed and well-known frameworks for assessing effectiveness (the SMART principle and the Hierarchy of Control). However there were limitations around the approach taken. The SMART principle had to be modified to suit the examination of coronial recommendations (specific reframed as specific action outlined and specific person with responsibility to enact it identified). The assessment of the text of the coronial recommendations against the modified SMART principle may have been subjective in nature, although both authors of the paper [136] AEP and RCF had to come to an agreement on assessment against SMART using a thematic, inductive approach [167].

3.3 Exposure

Several methods were used in the second part of the results section of this thesis, which considered exposure to river drowning. These methods included using the results of a CATI survey about river exposure to modify fatal river drowning rates from per 100,000 population to per 100,000 exposed population; a community survey with breathalysing at river drowning locations; a direct exposure study at the same locations using headcounts.

3.3.1 Computer-Assisted Telephone Interviewing (CATI) Survey

3.3.1.1 Introduction

A Computer-Assisted Telephone Interviewing (CATI) survey is a telephone surveying technique in which the interviewer follows a script provided by a software application [8]. The interviewer makes a phone call to the number that is displayed on the screen. If the respondents was to join the survey, the interviewer starts reading questions displayed on the screen and selecting the respondents' answers. The CATI software will automatically proceed to the next question following the logic path. At the end of the questionnaire, the interviewer will display a new respondent to call [8].

The study on exposure in this thesis, discussed in Chapter 5 – results part 2 and published in a paper in *Injury Prevention* [9] utilised the National Social Survey (NSS) to gather data. The NSS is a cost-sharing survey aimed at obtaining public opinion on a range of topics held by a random sample of Australian residents. It is based on an omnibus model that affords researchers the opportunity to collect high quality data from a sizeable national sample at a far lower cost than an independent survey. Researchers are able to pay to have seven questions asked of the representative sample as well as gather responses to 63 demographic and core health questions that are asked of all participants.

The CATI survey was run by the Population Research Laboratory (PRL) of Central Queensland University (CQU).

3.3.1.2 The Sample

For sampling purposes Australia was delineated into state and territory areas for telephone interviewing. A random selection of mobile telephone numbers was also included, in order to capture respondents from the growing proportion of the population without landline telephones (approximately 48% of the sample were contacted on a mobile telephone) [168].

The target population designated for telephone interviewing was all persons 18 years of age or older who, at the time of the survey, were living in a dwelling unit in Australia that could be contacted by direct-dialled, land-based telephone service or direct-dialled mobile telephone service [168].

A random selection approach was used to ensure that all respondents had an equal chance to be contacted. Geographically proportionate landline samples were drawn to cover each state and territory. The PRL utilises reputable research sample provider, Sampleworx Pty Ltd to randomly generate landline telephone numbers which are selected using postcode parameters and washed to remove known non-residential and non-working numbers where possible. Mobile telephone numbers are randomly generated and pre-validated (there is no associated geographical marker for mobile random digit dialling (RDD) numbers) [168].

The sample was drawn from the telephone database by using a computer program to select, with replacement, a simple random sample of telephone numbers. For each record, one eligible person was selected as the respondent for the interview. When dialling mobile telephone numbers the eligible respondent was deemed to be the person who received the phone call, if this person confirmed they were 18 years of age or older [168].

In the case of landline telephone numbers, a respondent within each household was selected on the basis of gender using the following selection guidelines to ensure an equal yet random selection of male and female participants.

a) The dwelling unit must be the person's usual place of residence and he/she must be 18 years of age or older.

b) Each household was randomly pre-selected as either a male or female household.

c) If there was more than one male/female in the household then the male/female that had the most recent birthday was selected.

d) If there was no-one of the pre-selected gender residing in the house then the house was designated not qualified.

3.3.1.3 The Survey Instrument

The survey instrument consisted of three components:

1. Standardized introduction,

2. Questions which reflected the specific research interests of the University and community researchers participating in the study,

3. Demographic and core health questions.

The questionnaire was pilot-tested by trained interviewers on a total of 40 randomly-selected households. Interviewer comments (e.g. confusing wording, inadequate response categories, question order effect, etc.) and pre-test frequency distributions were reviewed before modifications were made to the 2015 NSS questionnaire. The 2015 NSS received approval by the Human Ethics Research Review Panel at CQUniversity before administration to the general public. Project: H14/09-203, NATIONAL SOCIAL SURVEY 2015 [168].

3.3.1.5 The Data

The data was tabulated and cleaned using SPSS version 22 [169]. The resultant 2015 NSS data set contains 1,318 cases with a total of 257 variables for each case (partial data for a further 36 cases has not been included in the final data set) [168].

3.3.1.6 Data Collection

The 2015 NSS was administered through the twenty-station CATI system installed on a local area network at the PRL. This system facilitates the exchange of information among interviewing PC stations and supervisor stations linked via a file server during the data collection period. Supervisors monitor call dispositions, field edit, validate and accumulate data for analysis. Following the pre-test, an electronic questionnaire was modified for the main data collection. The sample database was loaded into the CATI system that allocates telephone numbers to the interviewing stations. The question text and instructions were presented on the computer screen to the interviewer who asked the questions to the respondent over the telephone and entered the given responses into the computer. CATI features such as the automatic routing of questions and built-in checks for inconsistencies eliminated additional field editing. Continual monitoring of the closed-ended responses was undertaken [168].

The interviewing began on Monday 6 July, 2015 and was completed on Friday 14 August, 2015. All of the data collection was conducted from the Population Research Laboratory at CQU. Interviews were conducted between the hours of 10:30am to 2:30pm Monday, Wednesday and Friday, 4:30 pm to 8:30pm, Monday through to Friday and between the hours of 12:00pm and 4:00pm on Saturday and Sunday. If the interviewers were unsuccessful in establishing contact on their first call, a minimum of five callback attempts was made. Upon making contact, interviewers identified themselves and then asked the screening questions for selecting the respondent. The average interview length was 33 minutes [168].

3.3.1.7 Piloting and Quality Assurance

Prior to the commencement of data collection the survey instrument was trialled and the data examined. All PRL staff involved in the study were required to sign statements of confidentiality and privacy before the commencement of data collection. Feedback was sought on the final version of the survey instrument from the survey sponsors. Data and document backup procedures were implemented. The data was regularly monitored during the data collection period. Regular data backups were made and the data was stored at two secure locations. Regular assessments were made of the data collection progress. A Supervisor's electronic log book was maintained in order to facilitate discussion and permit prompt action of any potentially adverse situations that arose. A quality assurance study was conducted concurrently by the Supervising staff of the PRL of a randomly selected proportion (approximately 10%) of survey participants [168].

3.3.1.8 Response Rate

The response rate is a calculated percentage representing the number of people participating in the survey either with a completed or partially completed interview divided by the number of eligible people contacted for the survey. The response rate for the 2015 NSS was 33% [168].

Response rates for general household surveys have been on the decline in recent years [170, 171]. Respondents in urban areas are increasingly subject to telephone solicitation for fundraising, market research, sales or politically-related calls, including polling. As a result, some householders are reluctant to participate in telephone surveys. A perceived barrier to contacting respondents is increased use of call display to screen telephone calls. Also, although direct data was not obtained, anecdotally a number of respondents expressed that the length of the survey (average 33 minutes) was a deterrent for participation [168].

3.3.1.9 Estimated Sampling Error

The sampling error is a measure of the validity of the descriptive statistics that are observed in a sample. The estimated sampling error, at the 95% confidence level, for the sample of 1,318 respondents and a 50/50 binomial percentage distribution is plus or minus 2.7 percentage points [168].

3.3.1.10 How the NSS Data Was Used

The CATI exposure study, published in *Injury Prevention* [9] and discussed in Chapter 6, asked respondents seven questions about frequency and nature of river usage including frequency of visitation, activities undertaken, use of lifejackets and consumption of alcohol at rivers. The study in question, then used these data, by sex and age group to revise the population exposed to river drowning and calculate improved river drowning rates using the population exposed, rather than calculate rates per 100,000 population [168].

3.3.1.11 Strengths and Weaknesses of CATI

There are strengths and limitations to this approach. The strengths are the CATI survey was that it was nationally representative with a sizeable sample size of respondents (N=1,318). Limitations are that the survey is self-reported [172]. Respondents were asked at a single point in time to reflect on their river usage in the past 12 months, which may have introduced recall bias [173]. The survey was administered in winter, which may have impacted the participants' responses regarding river usage [168].

3.3.2 Direct Observation

In order to further explore the self-reported findings from the CATI survey, a process of river exposure was undertaken using a process of direct observation. Direct observation is the process of active acquisition of information from a primary source. Observations can be qualitative or quantitative in nature [174].

Observational studies are defined as an empiric comparison of treated and control groups in which the objective is to elucidate cause-and-effect relationships [… in which it] is not feasible to use controlled experimentation, in the sense of being able to impose the procedures or treatments whose effects it is desired to discover, or to assign subjects at random to different procedure [175].

3.3.2.1 Method Used

The direct observation study [135] used a method of headcounts at four key river usage locations (three of which are situated on rivers which feature in the national top 10 river drowning blackspots [176]). The locations were: Alligator Creek, Townsville, QLD; the Murrumbidgee River, Wagga Wagga, NSW; the Murray River, Albury, NSW; and the Hawkesbury River, Windsor, NSW (Figure 211 found on page 204).

At each location a zone of interest was identified, within which data collection was conducted. The zone was explained to data collectors ahead of time and used natural landmarks as boundary points. The zones included both the water surface (on the water), the river itself (in the water) and the river bank (beside the water) on which the researchers were standing. The far bank of the river was not used.

Data was collected using headcounts of total number of people observed, total males, total females, total adults and total children; as well as total in the water, on the water and beside the water. There was always a minimum of two data collectors recording data, generally on the half hour of each hour at the river. Data was consistently collected on Friday, Saturday and Sunday between 10:30am and 4:30pm at all sites, with a Monday-Sunday period of data collection (7 days) conducted at the Murray River, including the Australia Day public holiday. Data collection occurred during January and February, Australian summer, day light savings (longer daylight hours) and school holidays (January).

Data was collected using a pre-drafted data collection sheet which had space for river location and data collectors' name, date and time of data observation, total number, total males, females, adults, children and total number of people in, on and beside the river. Observers stood beside each other in the middle of the zone, or a location with clear visibility for the entire zone, but did not confer with each other.

3.3.2.2 Data Analysis

Results were analysed using the mean number for all observations with a minimum of two observers. Data was examined using univariate analysis, with mean (Standard Deviation [SD]), range and median (interquartile range [IQR]) calculated. ANOVA and T-tests were used to calculate statistical differences in average people observed, males and females observed, adults and children observed and differences in people observed by time of day, day of week, public holidays and weekends. Statistical significance was deemed $p<0.01$. Interrater reliability for observations was determined using the Intraclass correlation coefficient (ICC), with a 95% confidence interval (CI) reported. As per the guidelines outlined for ICC use in Hallgren [177], a one-way random-effects, average measures model examining absolute agreement was the ICC method chosen for this study. This model was chosen because different raters were used across observations, all observations in the study were performed by multiple raters, and the agreement between values of the raters was of interest to the study [177].

Days on which data was collected spanned Australia Day, a national public holiday in Australia. As it was an outlier, this was removed from the analysis and dealt with separately. As it is a day when most people are not at work or school, data collected on Australia Day was compared to an average weekend day. Data on headcounts was also compared to the findings of the CATI survey [9] and the epidemiological analysis of river drowning [132], and can be found in Chapter 5, section 5.4

3.3.2.3 Strengths and Limitations

The methodology utilised was a low-resource method which relied on data collectors, pens, data collection sheets and clipboards only. It was a transferrable design, which showed a high degree of reliability between observers. Data was collected firsthand, as opposed to relying on self-reported responses regarding river usage, derived from surveys.

Although the exposure counts were reasonably quick to undertake, the method used was labour intensive, relying on a minimum of two data collectors to record counts of exposure every hour. Although a high degree of reliability between observers was seen, this method is subject to error due to fatigue.

The fluid nature of the data collection zones (and river environments in general) and natural obstructions to vision (slopes and gullies on river banks and trees) may be more suited to the use of still or closed circuit television (CCTV) cameras to record exposure data. Similarly collecting data from river users through diaries or online ‘apps’ may also be viable options for more wide-scale data collection. Such electronic options for the collection of exposure data may negate additional limitations in the method used around social desirability bias (due to media coverage the research generated in areas local to the research sites) as well as the presence of researchers, potentially influencing river user behavior. Due to ethical and safety constraints, data was not able to be collected during the late night and early morning hours, and such electronic or technological options may overcome some of these constraints.

3.3.3 Community Survey and Breathalysing

Breathalysing is the process of estimating a person's BAC indirectly, by measuring the alcohol on the breath [4]. It provides a robust, objective measure of alcohol concentration, as opposed to self-reported surveys which provide an indication of the amount of alcohol consumed subject to the truthfulness of the respondent and susceptible to recall bias [173].

Adult (18 years and over) river users at four known river drowning and popular river recreation locations were surveyed and breathalysed. The community survey featured questions across the following eight domains: demographics; river attendance frequency; frequency of engaging in water activities; drinking patterns; alcohol and water safety knowledge; alcohol and water safety attitudes; alcohol consumption; and BAC. The results from this study are presented in results section 5.3 and published in *BMC Public Health* [4], as well as the short reports in sections 5.5 (flood-related behaviour of river users) and 6.4 (CPR training of river users) which were published in *PLoS Currents Disasters* [7] and the *Health Promotion Journal of Australia* [138] respectively.

3.3.3.1 Strengths and Limitations of the Community Survey and Breathalysing Approach

A strength of this approach was the subjective measure of alcohol consumption (recorded through the community survey), paired with the objective measure of BAC through breathalysing. There are however limitations associated with the use of breathalysing. Those who had consumed alcohol were free to refuse to participate in the research. Due to ethical constraints, the study was only able to survey and breathalyse adults (i.e. those aged 18 years and over). Therefore data on adolescents consuming alcohol at rivers was not able to be collected, despite adolescents being represented in river drowning fatalities in Australia where alcohol was known to have been consumed [133]. The sample was one of convenience and therefore data collected only represents the four locations visited and the views and BACs of river users during the times of day when data collection was undertaken. Time of day of data collection was coded to the broad times of day the fatality data was coded to (i.e. morning, afternoon and evening) recognising data collection often ceased within the evening time band for fatalities (e.g. data collection continued until approximately 20:30 with the evening time band for fatalities ending at 12:00am or midnight).

3.4 Delphi Process

A Delphi Process is a structured communication technique or method using a panel of experts to undertake a systematic, interactive forecasting method [10]. A Delphi process uses questionnaires, and after each round a facilitator provides an anonymised summary of the group's responses back to the group, which allows the expert panel to revise previous answers based on responses from the other members of the panel [10]. The intent of the process is that as the rounds continue, the range of answers will decrease and the group will converge towards the "correct answer". The process is stopped after a predefined stop criterion, (be it number of rounds, achievement of consensus, stability of results), and the mean or median scores from the final rounds are used to determine the results [11]. (Figure 11)

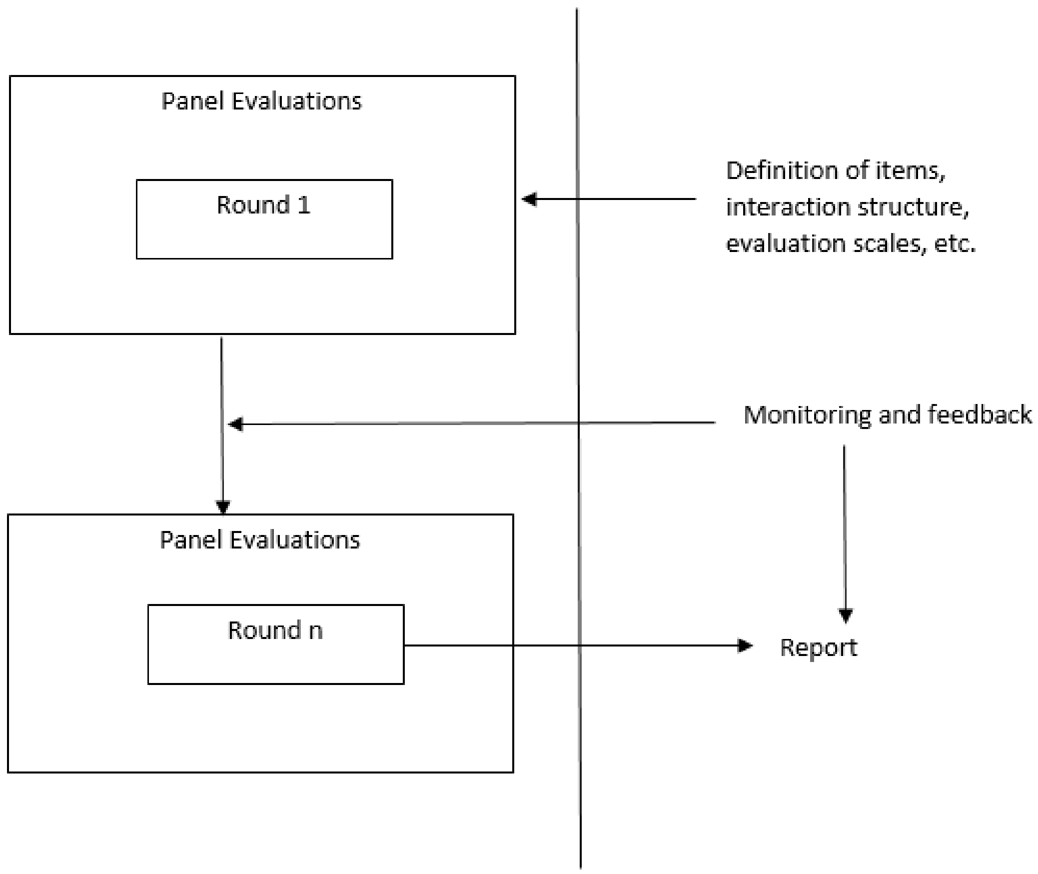

Figure 11: The Delphi method communication structure

Note: Image originally developed by Czkssa and recreated here under the CC BY-SA 3.0 license which can be viewed here: https://creativecommons.org/licenses/by-sa/3.0/legalcode

The name 'Delphi' is derived from the Oracle of Delphi [178], and the Delphi method is based on the assumption that group judgements are more valid than individual judgements. The process was first used during the 1950s by workers at the Research and Development (RAND) Corporation while involved on a U.S. Air Force sponsored project [11]. The aim of the project was the application of expert opinion to the selection of an optimal U.S. industrial target system, with a corresponding estimation of the number of atomic bombs required to reduce munitions output by a prescribed amount, from the point of view of a Soviet strategic planner [11].

Key characteristics of a Delphi process include: anonymity of the participants, structuring of information flow to control interactions among participants, regular feedback, and the role of the facilitator in running the rounds and analysing responses to provide summaries back to the panel prior to the start of each subsequent round [11].

3.4.1 Strengths and Limitations of a Delphi Process

The strengths of a Delphi process are that it is believed that decisions from a structured group are more accurate than those from unstructured groups. A Delphi also avoids the negative effects of face to face panel discussions and solves the usual problems of group dynamics [11]. Delphi processes have been criticised in that some query whether a reduction in variance over rounds reflects 'true consensus' and been accused of being a method of reducing group pressures to conform [179]. Delphi processes are also seen as a low level of evidence (i.e. expert opinion) [73].

With an absence of data on river drowning prevention interventions and their effectiveness, a modified Delphi process was used in section 6.3 of Chapter 6 of this thesis and published in Injury Prevention [137] to develop, refine and prioritise drowning prevention strategies more likely to be effective in river drowning. The Delphi process was modified in that participants assessed the effectiveness as well as relevance of strategies both through the use of surveys and evidence-based scenarios.

3.5 Ethics Approvals

A series of ethics approvals were sought and gained for this research. For the epidemiological research a three stage ethics approval was conducted. Firstly, ethical access for the data held on the NCIS was applied for and granted by the Victorian Department of Justice and Regulation Justice Human Research Ethics Committee (Reference: CF/15/13552). Secondly, separate ethics approval had to be sought (and was granted) by the Western Australia Coronial Ethics Committee, in order to be able to access data on deaths which occurred in Western Australia (WA) (Reference EC20/2015). Lastly, ethics approval was received from the James Cook University (JCU) Human Research Ethics Committee (HREC) - Approval number H6282. These ethics approvals cover the epidemiological studies presented in Chapter 4 of this thesis, as well as the analysis of coronial recommendations found in section 6.2. These ethics agreements were then amended to include access to the coronial data to be able to conduct the revision of crude river drowning rates per 100,000 exposed [9] (found in section 5.2.

Ethics approval for the community survey and direct observations studies was sought, and granted, from JCU HREC (Approval number H7249). Outputs covered by this agreement include the breathalysing study (found in section 5.3 of the thesis), the direct exposure study (found in section 5.4) and the short reports on flood-related behaviour of river users (found in section 5.5) and the CPR training of river users (found in section 6.4).

Ethics approval for the modified Delphi process (which can be found in section 6.3 of this thesis) was sought, and granted, from JCU HREC (Approval number H7166).

Copies of the ethics approvals can be found in Appendix 2.

The systematic literature review (Chapter 2), did not require ethics approval. The CATI survey used to refine river drowning rates per 100,000 persons (section 5.2) was administered by the Central Queensland University. Prior to being administered, the survey received ethics approval from the Central Queensland University Human Research Ethics Committee (H14/09-203).

Chapter 4: Results Part 1: The Epidemiology of River Drowning

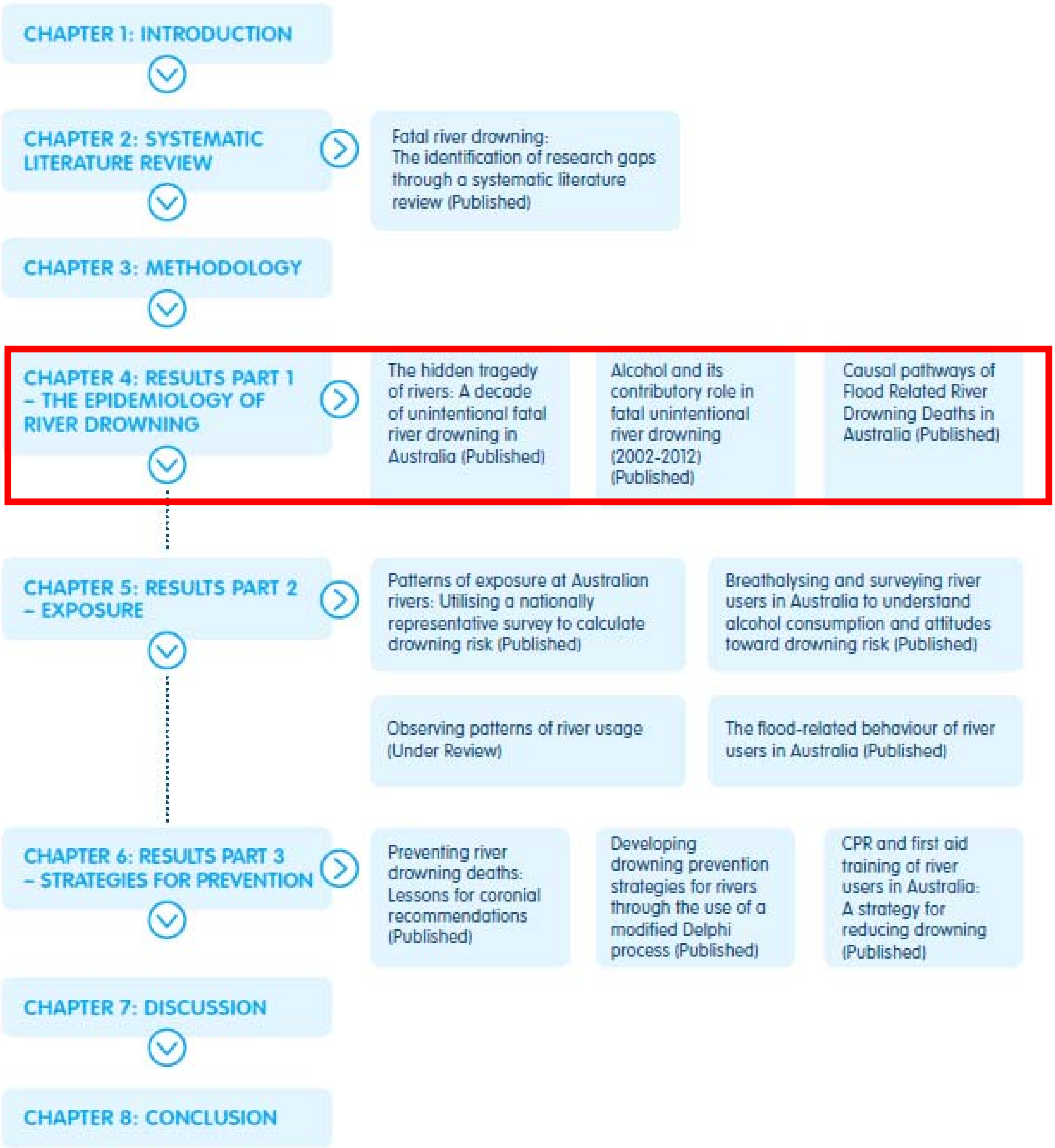

Figure 12: Chapter 4 position within thesis structure

4.1 Overview

Chapter 4 examines the epidemiology and risk factors of unintentional fatal drowning in rivers in Australia. It was clear from the systematic literature review in chapter 2 that there was a dearth of published literature on the epidemiology and risk factors for river drowning, and therefore little evidence to inform the development, implementation and evaluation of prevention strategies. The three studies in this chapter set out to fill a gap on the evidence surrounding unintentional fatal river drowning in Australia. These studies represent the first step in a public health approach to preventing river drowning by defining the problem through a situational analysis of the issue using systematically collected data. The three papers featured in this chapter are reproductions of the peer-reviewed articles.

The first study (Paper 2) is a 10 year total population analysis of all river drowning deaths in Australia between 2002/03 and 2011/12 [132]. This study was published open access in *PLOSONE* in August, 2016. The full reference for the study is as follows:

> Peden AE, Franklin RC, Leggat PA (2016) The Hidden Tragedy of Rivers: A decade of unintentional fatal drowning in Australia, *PLOS ONE* 11(8): doi: 10.1371/journal.pone.0160709

The second study (Paper 3) is an examination on the specific issue of alcohol involvement in unintentional fatal river drowning in Australia across the same time period [133]. This study was published in *Accident Analysis and Prevention* in October, 2016. The full reference for this study is as follows:

> Peden AE, Franklin RC, Leggat PA (2017) Alcohol and its contributory role in fatal drowning in Australian rivers, 2002-2012, *Accident Analysis and Prevention*, 98: 259-265. doi: 10.1016/j.aap.2016.10.009

The third study (Paper 4) focuses specifically on the issue of flood-related fatal river drownings in Australia across the same time period as the two studies above. This study used flow charts to display causal pathways leading to flood-related river drowning as a result of the top three activities: non-aquatic transport-related incidents, being swept away by floodwaters and falls into flooded rivers [134]. This study was published open access in *PLOS Currents Disasters* in May, 2017. The full reference for this study is as follows:

> Peden AE, Franklin RC, Leggat PA, Aitken P. Causal Pathways of Flood Related River Drowning Deaths in Australia. *PLOS Currents Disasters*. 2017 May 18. Edition 1. doi: 10.1371/currents.dis.001072490b201118f0f689c0fbe7d437.

4.2 The Hidden Tragedy of Rivers: A Decade of Unintentional Fatal Drowning in Australia (Paper 2)

Peden AE, Franklin RC, Leggat PA (2016) The Hidden Tragedy of Rivers: A decade of unintentional fatal drowning in Australia, *PLOS ONE* 11(8): doi: 10.1371/journal.pone.0160709

4.2.1 Introduction

Drowning is a neglected public health issue, with an estimated 372,000 lives lost worldwide per annum [17]. The majority occur in low- and middle-income countries as a result of activities associated with daily life [180]. This is in contrast to drowning deaths in high-income countries which generally occur recreationally [17].

Until now drowning prevention research has focused on young children (particularly those under five). This has been successful in reducing drowning deaths of young children in private swimming pools predominantly through improved pool fencing [51]. In contrast, a systematic review of literature published between 1980 and 2014 found there had been little research that specifically focused on drowning in rivers, creeks and streams (henceforth referred to as rivers), nor is the profile of river drowning victims well understood [50]. In studies published to date internationally, the crude death rate per 100,000 persons for fatal river drowning varied from a low of 0.20 to a high of 1.89 [50].

Since the completion of the systematic literature review, the WHO published a global report on drowning, identifying it as a world-wide issue [17]. Subsequent to the release of this report, studies have continued to be published on the issue of drowning prevention [181 182]. Little research has been published on the issue of drowning in rivers, however several papers identify natural waterways (which includes rivers) as common drowning locations [26 183 184]. One of these studies modelled unintentional drowning mortality rates in Thailand (2000-2009), finding most drowning deaths occurred in rural areas, however did not explore specific drowning locations [183]. A Chinese study exploring drowning of migrant children found they were at an increased risk of non-fatal drowning, often in natural waterways, however they did not specifically separate out drowning location [184]. A third study exploring unintentional drowning mortality rates across 60 countries identified that natural waterways were high (e.g. 93% in Finland, 87% in Panama and 85% in Lithuania), again not identifying specific aquatic locations within the broad grouping of natural waterways [26]. These studies continue to highlight the challenges around understanding river specific drowning [50].

Factors that have been found to increase the likelihood of fatal drowning in rivers include: being male, alcohol, swimming and the use of watercraft and a range of ages, with no consistency between publications [50]. A recent systematic literature review identified gaps in the published literature including the need for a consistent definition, national population level studies focusing solely on rivers, clarity on risk factors for river drowning and evidence for the effectiveness of proposed prevention strategies to reduce fatal river drowning [50].

To date there has been little epidemiological research into drowning deaths in rivers, due in large part to the difficulty in identifying the specific location of rivers within the coding (e.g. ICD) utilised for location of drowning in hospital and causes of death data [50]. Research has highlighted the shortcomings of the ICD coding framework which leads to underestimation of overall drowning [185 186]. A lack of specificity for location of drowning within the ICD framework sees location of drowning segmented into swimming pool, bathtub and natural waterway (a catch-all code that includes beach, ocean, river, lake etc) [23]. In Australia coronial data provides the most comprehensive and accurate opportunity to explore the casual factors of drowning deaths in detail [187].

Nationally, rivers have been identified as accounting for a fifth (20.3%) of all unintentional drowning deaths in Australia between 2002-2007 [35], making rivers the leading location for drowning in Australia. The prevention of unintentional river drowning deaths is of concern and has been identified by the Australian Water Safety Council (AWSC) as a key priority area for the drowning prevention sector in their bid to achieve a 50% reduction in drowning by the year 2020 [46]. There is a need for in-depth epidemiological analysis to identify risk factors to inform strategies for prevention. As such this paper aims to, for the first time, undertake a total population study from Australia describing unintentional fatal drowning in rivers.

4.2.2 Methods

Data for the 10 year period 1 July 2002 to 30 June 2012 was sourced through privileged access to the Australian NCIS (JHREC - CF/15/13552). Ethical approval for the project was also provided by James Cook University (HREC - H6282). Cases in the NCIS remain open (i.e. under investigation) until such time as the Coroner makes a ruling as to cause of death and the case is closed. This specific 10 year period has been chosen to minimise the number of cases still under coronial investigation and therefore strengthen the data presented. At the time of analysis, 93.1% of cases were closed. For open cases, data were correct as at 1 October, 2015.

Data relates to unintentional fatal drowning only. This is because different prevention strategies would need to be considered for intentional (i.e. self-harm, homicide, infanticide) injuries (including drowning) [188]. Deaths as a result of crocodile attack were also excluded. Cases where intent was unlikely to be known or where the coroner has made an open finding were included. Cases were included where the primary medical cause of death was drowning, or drowning was a contributing factor. Cases where the victim was found in the river but the cause of death did not mention drowning (e.g. multiple drug toxicity or blunt force trauma) were not included.

Rivers, creeks and streams were defined as "…A natural waterway that may be fed from other rivers or bodies of water draining water away from a 'catchment area' to another location…" [15 50] and "…can vary in water flow, length, width and depth…" [16]. Non-aquatic transport relates to means of transport not primarily designed or intended for aquatic use such as motor vehicles, motorbikes, tractors, bicycles and aeroplanes among others. A pre-existing medical condition was defined as a disease or injury that was present prior to the drowning event that was documented in either the pathology/autopsy report or coronial finding. Categories of medical conditions were coded using the International Statistical Classification of Diseases and Related Health Problems (ICD) 10th Revision [23].

Variables collected included age, sex, activity prior to drowning, time of day of drowning, day of the week and season of drowning, alcohol involvement, geographical location of incident, residential and incident postcode, remoteness classification of incident postcode, visitor status and Indigenous status [15]. Indigenous status refers to those known to be Aboriginal, Torres Strait Islander or both Aboriginal and Torres Strait Islander. Where Indigenous status was unknown, this was assumed to be 'no' for the purposes of analysis.

Due to difficulties around interpreting BAC for drowning victims [189], alcohol involvement was deemed where a BAC was available (either in the autopsy or toxicology report) and was ≥0.05% (that is 0.05 grams of alcohol in every 100 millilitres of blood). Cases where alcohol was known to be consumed but no BAC was available were deemed Unknown for alcohol involvement.

Time of incident was coded into four groupings for analysis: morning (6:01am to 12pm), afternoon (12:01pm to 6pm), evening (6:01pm to 12am) and early morning (12:01am to 6am). For the time of incident variable, where time could not be determined a coding of 9999 (Unknown) was used.

The remoteness classification of an incident postcode is calculated based on a range of factors including distance and isolation from major services. The remoteness classification was coded to the Australian Standard Geographical Classifications (ASGC) and calculated using the Doctor Locator website, a site which provides ASGC classification by inputting a postcode [190]. Drowning rates per 100,000 persons were calculated using population data from the ABS [191] and excluded international tourists. Drowning rates by remoteness of incident location (for Indigenous and non-Indigenous people) were calculated using Census population data by remoteness classification for the years 2001 [164], 2006 [165] and 2011 [166] and averaged out to determine average population and yearly drowning rate.

Visitor status was calculated by determining the distance, in kilometres, between the residential and incident postcodes using Google Maps [192]. A distance of 100 km or less was classified as 'Not A Visitor'; those who resided within the same State or Territory with a distance greater than 100 km, were classified as an 'Intrastate Visitor'; those who drowned in a different State or Territory and were greater than 100 km from where they resided were classified as 'Interstate Visitors'. Those with a residential postcode of 7777 (i.e. live overseas) were classified as 'International Tourists'. Children were defined as aged 0-17 years and adults were defined as aged 18 years and over. In Australia, 18 years is the age a child reaches adulthood for the purposes of the criminal law [193].

Data coding and analysis was conducted in IBM SPSS V20 [157]. Descriptive statistics and chi squared analysis were utilised. A modified Bonferroni test suggested by Keppel [159] has been applied and therefore statistical significance was deemed $p<0.03$ (Table 12) and $p<0.04$ (Table 13). Non-parametric chi squared analysis was also conducted using the proportional basis of the population as the assumed outcome numbers.

Relative risk for risk factors within river drowning victims was calculated, along with a 95% Confidence Interval (CI). When calculating relative risk, females and children were used as the control groups. Relative risk and chi squared analysis were conducted without the 'unknown' variable – e.g. presence of alcohol was calculated using the 'yes' and 'no' variables only. Where variable analysis presents cases of four or less, the term NP (not presented) has been used for both numbers and percentages in Table 12 and Table 13.

4.2.3 Results

During the study period 2,892 people died as a result of unintentional fatal drowning. Of these, 770 people drowned in rivers (26.6%), 487 in Ocean / Harbour locations (16.8%) and 440 at Beaches (15.2%), making rivers the leading location for drowning in Australia.

Annual crude drowning rates per 100,000 persons have remained steady across the study period ranging from a high of 0.48 in 2010/11 (the year of the QLD floods which claimed the lives of 22 people [194]) to a low of 0.27 in 2004/05. (Figure 13)

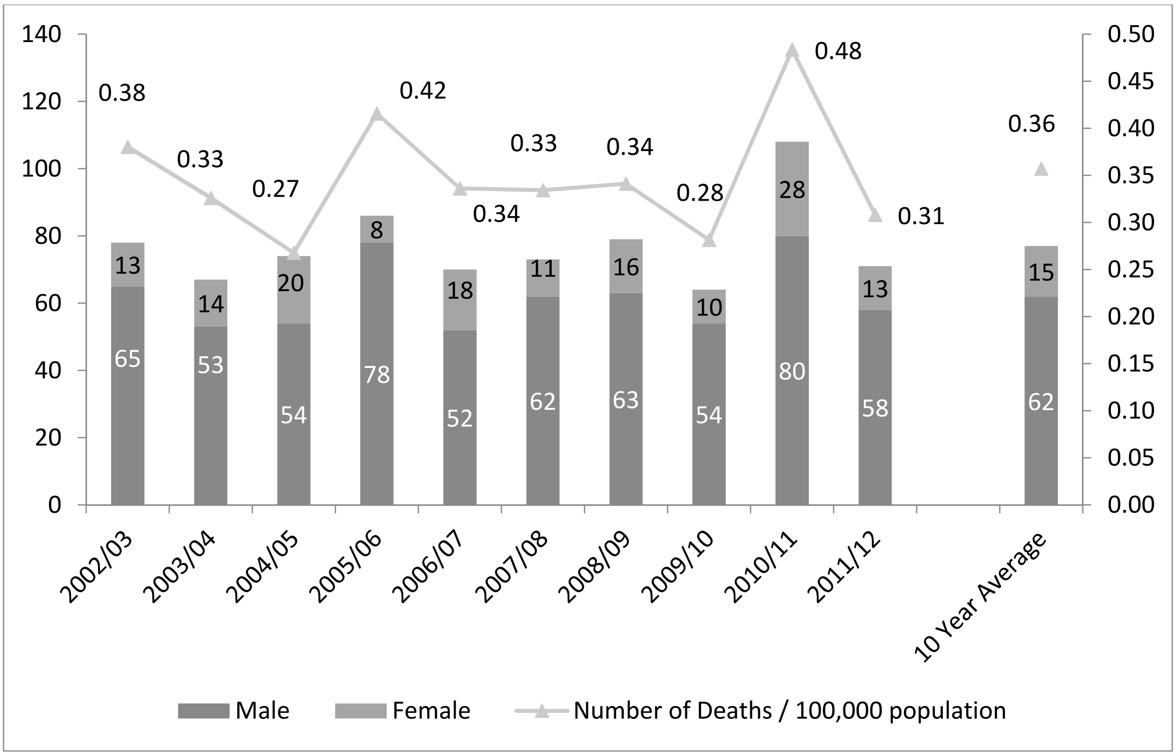

Figure 13: Drowning deaths in rivers by financial year, number by sex and crude rate per 100,000 persons, Australia, 2002/03 to 2011/12 (N=770)

Males accounted for 80.4% (a rate of 0.59 per 100,000 persons) of drowning fatalities in rivers. When compared to females drowning in rivers, males drown in rivers at a rate that is 4.15 times higher (X^2=284.4; $p<0.001$) (Table 12).

Table 12: Drowning deaths in rivers by sex, age group, state or territory of incident, Aboriginal and/or Torres Strait Islander status and remoteness classification of incident location, crude drowning rate per 100,000 persons and relative risk, Australia, 2002/03 to 2011/12 (N=770)

	Total	Crude rate / 100,000 population	Relative Risk (CI) comparing drowning deaths in rivers to the relevant population	X^2 (p value) [a]
Total	770	0.36		
Sex				
Male	619	0.59	4.15 (3.47-4.95)	284.4 (p<0.001)
Female	151	0.14	1 [b]	
Age Group				
0-4 years	32	0.23	1	56.6 (p<0.001)
5-9 years	26	0.19	0.82 (0.49-1.38)	
10-14 years	28	0.20	0.86 (0.52-1.43)	
15-17 years	27	0.32	1.37 (0.82-2.28)	
18-24 years	91	0.44	1.87 (1.25-2.79)	
25-34 years	110	0.37	1.57 (1.06-2.33)	
35-44 years	106	0.34	1.47 (0.99-2.19)	
45-54 years	105	0.36	1.55 (1.04-2.30)	
55-64 years	103	0.44	1.89 (1.27-2.81)	
65-74 years	64	0.43	1.82 (1.19-2.78)	

75+ years	78	0.60	2.55 (1.69-3.85)	
State or Territory of Incident Location				
Australian Capital Territory (ACT)	5	0.14	1	260.6 (p<0.001)
New South Wales (NSW)	268	0.39	2.69 (1.11-6.52)	
Northern Territory (NT)	43	1.98	13.73 (5.44-34.66)	
Queensland (QLD)	217	0.52	3.62 (1.49-8.79)	
South Australia (SA)	34	0.21	1.49 (0.58-3.81)	
Tasmania (TAS)	35	0.70	4.90 (1.92-12.50)	
Victoria (VIC)	107	0.20	1.42 (0.58-3.49)	
Western Australia (WA)	61	0.28	1.96 (0.79-4.88)	
Aboriginal and/or Torres Strait Islander Status [c]				
Yes	82	1.32	3.93 (3.12-4.94)	164.2 (p<0.001)
No	688	0.34	1	
Remoteness Classification of Incident Location [d]				
Major Cities	217	0.16	1	1333.4 (p<0.001)
Inner Regional	226	0.58	3.62 (2.58-5.09)	
Outer Regional	196	1.01	6.37 (4.47-9.06)	
Remote	49	1.58	9.95 (5.65-17.53)	
Very Remote	82	4.57	28.76 (18.08-45.73)	

[a] A modified Bonferroni test has been applied meaning statistical significance is deemed at 0.03; [b] Where relative risk was calculated, the group with the lowest rate was used as the reference point; [c] Where Indigenous status was unknown, this was assumed to be 'no' for the purposes of analysis; [d] Population data are only available for three population census years (2001, 2006 and 2011), therefore a 12 year average for deaths and a 3 year average for population have been used to calculate crude rates.

The mean age of river drowning victims was 42.0 years (males 41.7 years; females 43.5 years) (Table 13). Over half (55.1%) of all deaths occur between 25-64 years. People aged 75+ years recorded the highest age-specific drowning rate per 100,000 population in rivers at 0.60, with the lowest rate seen in the 5-9 years age group (0.19). (Figure 14)

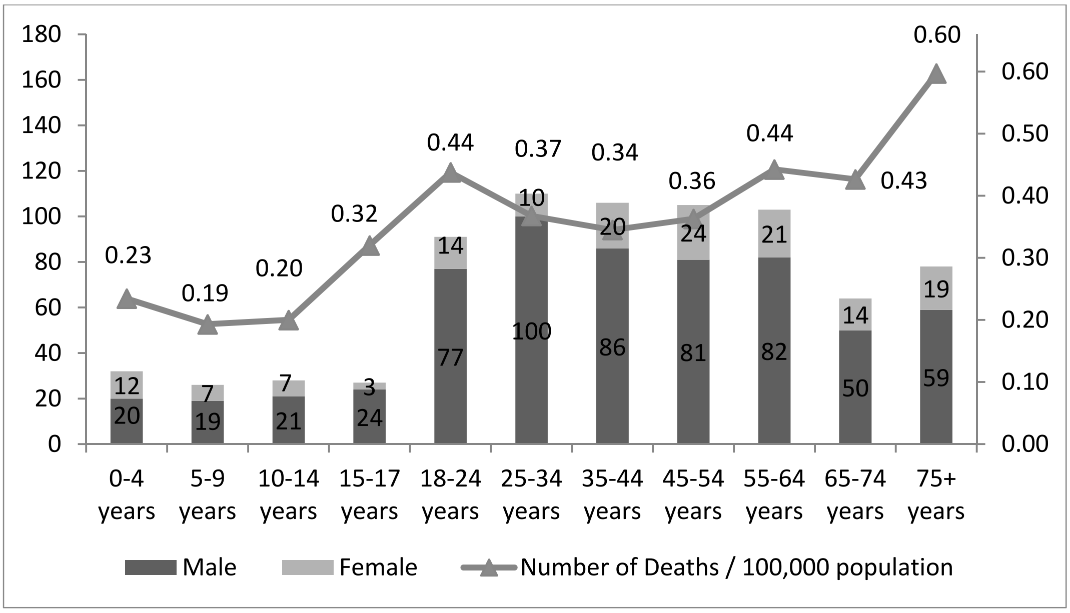

Figure 14: Drowning deaths in rivers by age group and sex, and crude rate by age group per 100,000 persons, Australia, 2002/03 to 2011/12 (N=770)

People aged 75 years and over drown in rivers at a rate that is 2.55 (CI: 1.69-3.85) times that of children aged 0-4 years. This was followed by 55-64 year olds at 1.89 times (CI: 1.27-2.81) and 18-24 year olds at 1.87 times (CI: 1.25-2.79). Age was found to be statistically significant for drowning in rivers (X^2=56.6; p<0.001). (Table 12)

Aboriginal and Torres Strait Islanders drown in rivers at a rate that is 4.62 (CI: 3.67-5.83) times that of non-Indigenous people in rivers (Table 12). Indigenous river drowning victims also recorded a younger mean age (31.5 years) when compared to non-Indigenous victims (43.2 years) (Table 13).

The prevalence of male drowning was most pronounced in the 25-34 years age group (90.9%) male followed by the 15-17 years age group (88.9% male). (Figure 14)

A fall into water was the leading activity prior to drowning in rivers (21.3%), followed by incidents involving non-aquatic transport (18.2%) and swimming (16.2%). Activity immediately prior to drowning was unknown in 16.0% of cases. (Table 13)

Table 13: River drowning deaths by mean age, sex and children or adults by activity immediately prior to drowning, presence of alcohol, pre-existing medical condition and Aboriginal and/or Torres Strait Islander status, and relative risk, Australia, 2002/03 to 2011/12 (N=770)

	Total		Mean Age (CI)	Male		Female [a]		RR (CI) comparing females to males for river drowning deaths	X^2 (p value) [c]	Children [a]		Adults		RR (CI) comparing children to adults for river drowning deaths	X^2 (p value) [c]
	N	%		N	%	N	%			N	%	N	%		
	770	100	42.0 (40.4-43.6)	619	80.4	151	19.6			113	14.7	657	85.3		
Activity Immediately Prior to Drowning															
Falls	164	21.3	44.5 (40.1-48.8)	123	75	41	25	0.99 (0.72-1.36)	3.3 (p=0.069)	38	23.2	126	76.8	0.57 (CI: 0.42-0.77)	6.3 (p=0.012)
Non-aquatic Transport	140	18.2	44.8 (40.9-48.6)	92	65.7	48	34.3	0.47 (CI: 0.35-0.63)	22.4 (p<0.001)	24	17.1	116	82.9	0.83 (CI: 0.56-1.23)	0.0 (p=0.916)
Swimming	125	16.2	31.6 (28.9-34.3)	109	87.2	16	12.8	1.66 (CI:1.01-2.72)	5.1 (p=0.023)	23	18.4	102	81.6	0.76 (CI: 0.51-1.14)	0.3 (p=0.606)
Watercraft	107	13.9	41.4 (37.7-45.1)	98	91.6	9	8.4	2.66 (CI: 1.37-5.13)	10.9 (p=0.001)	11	10.3	96	89.7	1.50 (CI: 0.83-2.71)	4.0 (p=0.047)
Jumped In	37	4.8	26.3 (22.1-30.5)	35	94.6	NP [b]	NP	4.27 (CI: 1.04-17.55)	5.3 (p=0.022)	9	24.3	28	75.7	0.54 (CI: 0.26-1.10)	1.6 (p=0.211)

Swept Away	23	3	48.3 (38.3-58.3)	11	47.8	12	52.2	0.22 (CI: 0.10-0.50)	15.3 (p<0.001)	NP	NP	20	87	1.15 (CI: 0.35-3.80)	0.3 (p=0.620)
Other	51	6.6	43.6 (38.5-48.8)	49	96.1	NP	NP	5.98 (CI: 1.47-24.30)	9.0 (p=0.003)	NP	NP	50	98	8.60 (CI: 1.20-61.63)	8.8 (p=0.003)
Unknown	123	16	49.8 (46.4-53.2)	102	82.9	21	17.1			NP	NP	119	96.7		
Presence of Alcohol (≥0.05)															
Yes	196	25.5	41.7 (39.4-44.0)	166	84.7	30	15.3	1.35 CI: 0.96-1.91)	2.7 (p=0.098)	7	3.6	189	96.4	4.64 (CI: 2.24-9.61)	33.4 (p<0.001)
No	321	41.7	41.3 (38.5-44.0)	253	78.8	68	21.2			72	22.4	249	77.6		
Unknown	253	32.9	43.3 (40.5-46.1)	200	79.1	53	20.9			34	13.4	219	86.6		
Pre-existing Medical Condition															
Yes	288	37.4	53.5 (51.1-55.8)	234	37.8	54	35.8	1.06 (CI: 0.83-1.34)	0.2 (p=0.668)	14	4.9	274	95.1	3.37 (CI: 2.04-5.54)	72.6 (p<0.001)
No	211	27.4	26.8 (24.3-29.3)	169	27.3	43	28.5			72	34.1	139	65.9		
Unknown	271	35.2	41.8 (39.4-44.3)	216	34.9	54	35.8			27	10	244	90		
Aboriginal and/or Torres Strait Islander Status															
Yes	82	10.6	31.5 (28.0-35.0)	66	80.5	16	19.5	1.01 (CI: 0.60-1.69)	0.0 (p=0.912)	20	24.4	62	75.6	0.53 (CI: 0.34-0.85)	5.0 (p=0.025)
No	584	75.8	43.2 (41.3-45.0)	467	80	117	20			86	14.7	498	85.3		
Unknown	104	13.5	44.1 (40.1-48.0)	86	82.7	18	17.3			7	6.7	97	93.3		

[a] Females and children have been used as the control groups; [b] NP = not presented for variables where cases amounted to 4 deaths and under; [c] A modified Bonferroni test has been applied meaning statistical significance is deemed at 0.04.

When examining activity prior to drowning in rivers by sex of the victim, females were 2.14 and 4.47 times more likely respectively to drown as a result of incidents involving non-aquatic transport (χ^2= 22.4; p<0.04) and being swept away by floodwaters (χ^2=15.3; p<0.04). When compared to females, males were 2.66 more likely to drown in rivers as a result of watercraft incidents (χ^2= 10.9; p<0.04) and 4.27 times more likely as a result of Jumping in (χ^2= 5.3; p<0.04). (Table 13)

When comparing activity prior to drowning in rivers between children and adults, children were 1.75 times more likely to drown as a result of a fall into water (χ^2= 6.3; p<0.04) and adults were 8.60 times more likely to drown in rivers when participating in an activity coded as other when compared to children (χ^2= 8.8; p=0.04). (Table 13)

Aboriginal and Torres Strait Islanders accounted for 10.6% of all drowning deaths in rivers, of these 24.4% were children and 75.6% adults. (Table 13) Almost three quarters (74.0%) of all river drowning victims were local to the area where they drowned, a further 20.3% were intrastate or interstate travellers. Just 2.7% of all river drowning victims were international tourists (of which all were adults). (Table 14)

Table 14: River drowning deaths by sex and children or adults by visitor status, remoteness classification of incident, season of drowning incident and time of day of drowning incident and relative risk, Australia, 2002/03 to 2011/12 (N=770)

	Total		Male		Female [a]		RR (CI) comparing females to males for river drowning deaths	X^2 (p value) [d]	Children [a]		Adults		RR (CI) comparing children to adults for river drowning deaths	X^2 (p value) [d]
	N	%	N	%	N	%			N	%	N	%		
	770	100.0	619	80.4	151	19.6			113	14.7	657	85.3		
Visitor Status														
Not a Visitor	570	74.0	454	79.6	116	20.4	0.95 (CI: 0.86-1.05)	0.4 (p=0.508)	87	15.3	483	84.7	0.95 (CI: 0.85-1.07)	0.1 (p=0.711)
Visitor – Intrastate	110	14.3	87	79.1	23	20.9	0.92 (CI: 0.60-1.41)	0.1 (p=0.755)	21	19.1	89	80.9	0.73 (CI: 0.47-1.12)	1.7 (p=0.192)
Visitor - Interstate	46	6.0	40	87.0	6	13.0	1.63 (CI: 0.70-3.76)	1.4 (p=0.234)	NP [b]	NP	42	91.3	1.81 (CI: 0.66-4.94)	1.5 (p=0.217)
Visitor - Overseas	21	2.7	18	85.7	NP	NP	1.46 (CI:0.44-4.90)	0.4 (p=0.519)	0	0.0	21	100.0	UTBC [c]	3.8 (p=0.051)
Unknown	23	3.0	20	87.0	NP	NP			NP	NP	22	95.7		
Remoteness Classification of Incident Location														
Major Cities	217	28.2	183	84.3	34	15.7	1.31 (CI: 0.95-1.81)	3.0 (p=0.084)	26	12.0	191	88.0	1.26 (CI: 0.88-1.81)	1.8 (p=0.186)

Inner Regional	226	29.4	171	75.7	55	24.3	0.76 (CI: 0.59-0.97)	4.5 (p=0.033)	33	14.6	193	85.4	1.01 (CI: 0.74-1.37)	0.0 (p=0.970)
Outer Regional	196	25.5	161	82.1	35	17.9	1.12 (CI: 0.82-1.54)	0.5 (p=0.474)	29	14.8	167	85.2	0.99 (CI: 0.70-1.39)	0.0 (p=0.956)
Remote	49	6.4	39	79.6	10	20.4	0.95 (CI: 0.49-1.86)	0.0 (p=0.884)	7	14.3	42	85.7	1.03 (CI: 0.48-2.24)	0.0 (p=0.937)
Very Remote	82	10.6	65	79.3	17	20.7	0.93 (CI: 0.56-1.54)	0.1 (p=0.787)	18	22.0	64	78.0	0.61 (CI: 0.38-0.99)	3.9 (p=0.049)
Season of Drowning Incident														
Summer	295	38.3	239	81.0	56	19.0	1.04 (CI: 0.83-1.31)	0.1 (p=0.730)	53	18.0	242	82.0	0.79 (CI: 0.63-0.98)	4.1 (p=0.042)
Autumn	145	18.8	112	77.2	33	22.8	0.83 (CI: 0.59-1.17)	1.1 (p=0.289)	18	12.4	127	87.6	1.21 (CI: 0.77-1.91)	0.7 (p=0.393)
Winter	157	20.4	128	81.5	29	18.5	1.08 (CI: 0.75-1.55)	0.2 (p=0.687)	16	10.2	141	89.8	1.52 (CI: 0.94-2.44)	3.1 (p=0.075)
Spring	173	22.5	140	80.9	33	19.1	1.03 (CI: 0.74-1.45)	0.0 (p=0.840)	26	15.0	147	85.0	0.97 (CI: 0.67-1.40)	0.0 (p=0.881)
Time of Day of Drowning Incident														
Morning	147	19.1	123	83.7	24	16.3	1.25 (CI: 0.84-1.86)	1.1 (p=0.306)	23	15.6	124	84.4	0.93 (CI: 0.62-1.38)	0.0 (p=0.944)
Afternoon	321	41.7	254	79.1	67	20.9	0.92 (CI: 0.76-1.13)	1.0 (p=0.331)	65	20.2	256	79.8	0.68 (CI: 0.56-0.82)	10.3 (p=0.001)
Evening	160	20.8	128	80.0	32	20.0	0.98 (CI: 0.69-1.38)	0.1 (p=0.796)	16	10.0	144	90.0	1.55 (CI: 0.96-2.49)	4.7 (p=0.030)
Early Morning	76	9.9	63	82.9	13	17.1	1.18 (CI: 0.67-2.09)	0.3 (p=0.571)	5	4.4	72	94.7	2.48 (CI: 1.02-6.00)	5.3 (p=0.021)
Unknown	66	8.6	51	77.3	15	22.7			5	7.6	61	92.4		

[a] Females and children have been used as the control groups; [b] NP = not presented for variables where cases amounted to 4 deaths and under; [c] UTBC = unable to be calculated; [d] A modified Bonferroni test has been applied meaning statistical significance is deemed at 0.04.

The largest proportion of river drowning deaths occurred in inner regional locations (29.4%). Proportionally, compared to population distribution, very remote areas recorded the highest crude rate of fatal drowning with an average rate of fatal drowning at 4.57 per 100,000 persons, with people in very remote areas drowning in rivers at a rate of 28.76 (CI: 18.08-45.73) times that of people who drown in rivers in major cities. Over half (χ^2= 107.3; $p<0.05$) of Indigenous victims drowned in rivers in very remote areas. (Table 14)

The crude rate of drowning by remoteness classification for Indigenous river drowning victims was higher across all remoteness classifications when compared to non-Indigenous river drowning victims, with the exception of remote areas. Indigenous people drowned at a rate of 0.33 in major cities, compared to 0.16 for non-indigenous people, 1.29 compared to 0.56 for inner regional, 2.12 compared to 0.95 for outer regional, 1.31 compared to 1.62 for remote and 5.12 compared to 4.20 for very remote areas. Over a third of all river drowning victims (37.4%) were known to have a pre-existing medical condition (95.1% adults) (Table 13). The most common categories of medical conditions were diseases of the circulatory system (such as ischemic heart disease, hypertension and cardiomyopathy) (14.8% of all drowning victims in rivers), followed by mental and behavioural disorders (such as dementia, autism and depression) (11.4%) and diseases of the nervous system (such as epilepsy and multiple sclerosis) (4.4%).

Almost half of all river drowning cases (41.7%) occurred in the afternoon. (Table 13) The time of day of the drowning incident was not found to be significant for adults, however children were more likely (χ^2= 10.3; $p<0.04$) to drown in rivers in the afternoon (Table 14).

Alcohol was known to be present (BAC readings of ≥0.05%) in 25.5% of cases (6.2% children; 28.8% adults), however was missing in 32.9% of cases. The mean age of river drowning victims who recorded positive readings for alcohol was 41.7 years (male 40.7 years; female 46.9 years). The mean BAC recorded was 0.21% (male 0.21%; female 0.20%). (Table 13)

4.2.4 Discussion

Preventing drowning in rivers is a significant challenge due to the number and locations of rivers, diversity of activity prior to drowning and a lack of known prevention strategies [50]. Seven areas have been identified where further work in developing prevention strategies might help in reducing river drowning deaths, noting that further work is required to understand exposure as this influences potential risk.

4.2.4.1 Identifying River Drowning

Drowning in rivers is a little explored area, compounded by the lack of a specific location code within the ICD coding framework which is used internationally to categorise cause of death [50]. This study, for the first time, describes the epidemiology of river drowning deaths at a country level as its sole focus. There is a need for a greater understanding of river drowning in Australia given the burden, and we hypothesize that rivers may represent similar burden internationally [26]. Further research on river drowning deaths is needed as rivers have a different morphology from other aquatic locations [195]. Alternative coding mechanisms need to be employed [57] to better identify rivers as a location for drowning and develop more effective prevention strategies.

Further research is also required around exposure. Exposure is one of the significant challenges for understanding risk around drowning in general [50] (and river drowning specifically) and is a challenge to collect at the macro level (i.e. how often they visit a river location in a given time period) but especially at the micro level (i.e. what was the person doing at the location and for how long, ignoring the challenges around water depth, speed, temperature etc).

To our knowledge two Australian studies have explored river exposure. Using a population health survey, the first study compared drowning mortality and hospitalised morbidity rates by population rates of exposure by location and activity [196]. It should be noted that this study only examined people in one Australian state (New South Wales) and grouped rivers into broader exposure to water (e.g. swimming pools, beach, lake, river, creek, stream or dam). The second study, which also utilised a community survey, only looked at the activity of swimming in a river (albeit nationally), which found that the majority of people (80%) had not swum in a river over the previous 12 months [197]. Thus rates based on exposure are likely to be higher than what is reported for the whole population in this paper.

4.2.4.2 Role of Alcohol in River Drowning
Alcohol is known to be a risk factor for drowning [187]. This study has found high blood alcohol levels in river drowning victims, an average BAC of 0.20%, four times the legal driving limit in Australia. Such significant levels of alcohol are likely to increase one's risk of drowning. Proposed strategies such as greater enforcement [198] (more active breathalysing of skippers, the establishment of no drinking zones around popular river locations and associated penalties) as well as increased public education and awareness of the role of alcohol in river drowning should be explored. Any preventative strategies employed must be evaluated to determine effectiveness [50].

4.2.4.3 Pre-existing Medical Conditions
Two in five adult river drowning victims were known to have a pre-existing medical condition, however it is unknown if this contributed to their death. Further work is required to compare the prevalence of particular pre-existing medical conditions within the river drowning cohort and the Australian population to determine risk. A medical check-up, particularly for those who go diving [199-

[201], has been recommended and, as such, should be tested to see if it may be a viable strategy for the prevention of river drowning.

4.2.4.4 Males and Females

Males made up the majority of river drowning deaths, however the profiles differed. Females were proportionately more likely to drown as a result of incidents involving non-aquatic transport (2.14 times) and being swept away by floodwaters (4.47 times) and males as a result of watercraft incidents (2.66 times) and jumping in (4.27 times). Males have been identified as greater risk takers, including for drowning [202] and lessons from other areas [203 204] may be transferable to the prevention of drowning deaths. This is an area that needs to be explored in greater detail.

There is a need for better understanding of river usage by gender (exposure studies) to inform prevention. Further work is needed to understand the nature of watercraft drowning incidents in rivers. For example a study by Smith identified the need to target alcohol and boating safety campaigns to both skippers and passengers and to broaden the prohibition of drinking to not only being while the boat is under way [198].

4.2.4.5 Children and Adults

Adults and children have different profiles when it comes to drowning in rivers. Children were more likely to drown as a result of falls (unintended access) (33.6%) and to drown in the afternoon (57.5%), whereas, when compared to children, adults were at an increased risk of drowning in rivers if alcohol was known to be involved (28.8%).

Supervision has been recommended as a strategy for the prevention of drowning in children [83 205 206], however there is little evidence about this being an effective strategy for river drowning, nor information around how this strategy should be communicated [53 207]. Lifejackets have also been proposed as another prevention strategy [100 106]. However all recommended strategies need to be validated for effectiveness at a river setting.

4.2.4.6 Visitor Status

While the media [199 208] may more commonly highlight the drowning of a tourist, the majority (74.0%) of river drowning victims are locals. Prevention strategies targeted at local people are likely to have the greatest impact, however this is a challenge in Australia based on the size and population distribution. Other challenges in communicating safety information as there may be a familiarity or perceived ‘local knowledge’ that may lead to people underestimating their drowning risk. This should be explored further through exposure and attitudinal studies.

4.2.4.7 Remoteness of Incident Location

As river drowning locations became more remote, the relative risk based on the population residing in those areas increased, with very remote locations recording fatal unintentional drownings in rivers at a rate (4.57) that is 28.76 times higher than river drowning deaths in major cities (0.16). Almost half (45.1%) of all Indigenous victims drowned in rivers in very remote areas, recording a rate of 5.12 drowning deaths per 100,0000 population compared to 4.20 for non-Indigenous people within the same remoteness classification. Strategies for the prevention of drowning in isolated areas will be a major challenge due to the dispersion of the population over large areas as well as the difficulties and costs in reaching large numbers of people efficiently [112 209 210]. Indigenous specific river drowning prevention strategies must be developed in partnership with Indigenous communities [211].

It has been argued that all adults [212 213] should be equipped with cardio-pulmonary resuscitation (CPR) skills. There is a lack of information on CPR with respect to river drowning victims. Therefore it was not included and further research is required into the use of CPR and its effectiveness in the prevention of river drowning deaths. Such skills may improve bystanders' response in locations where timely medical assistance may be difficult due to remoteness. Further research is required to determine if CPR was performed in these cases, if the victim was alone when they drowned, whether emergency services were called, and if any of these variables would have varied the fatal outcome.

Any strategies which are delivered need to include an evaluation component, as there is a lack [50] of evidence to show what works and does not work to prevent drowning in rivers. Understanding drowning in rivers may also help prevent drowning internationally, as rivers are a common location for drowning across the world [17 50].

4.2.5 Limitations

Cases where intent was unlikely to be known or where the coroner has made an open finding were included. This may overestimate the number of unintentional fatal drownings in rivers as 10.1% of closed cases recorded an intention of 'unlikely to be known' and a further 2.5% of cases were coded 'undetermined intent' as cases were under investigation within the NCIS. However this information is also cross checked with media and other reports so the numbers should not change significantly.

Information for some variables may be limited due to 6.9% of cases being open (i.e. under investigation) within the coronial system at the time of publishing. This limits the access of the researcher to case files such as coronial finding and autopsy, toxicology and police reports. This affects variables such as pre-existing medical condition, activity prior to drowning and presence of alcohol.

Access to toxicology and autopsy reports is not available in all cases (e.g. case files not electronically uploaded or autopsy or toxicology testing is not performed, or the case is under investigation), thus impacting our understanding of the involvement of alcohol and drugs. Data on the BAC level was unknown in 32.9% of cases.

Calculations for crude fatal drowning rates by population of remoteness classifications uses an average from three years 2001, 2006 and 2011 (Australian Census years) for population and drowning data from 2002/03 to 2011/12. This may produce rates that are not as accurate as if population data was available for each year of drowning data.

There is limited exposure data available around drowning in general and river drowning specifically. Therefore, calculations of relative risk include only people in the study (i.e. those people who died as a result of an unintentional drowning in a river) and do not take into account the total exposed population.

Cadavers that have been submerged in water for a period of time naturally produce alcohol [189]. Therefore due to a lack of reliable information on the amount of time between death and autopsy/toxicological testing, BACs represented in this dataset may be artificially inflated due to decomposition.

Where Indigenous status was unknown, for the purposes of calculating rates, the ‘unknown’ group were included with the ‘no’. In this circumstance this may underestimate the number of Indigenous people within the population. However we note that the average age of the ‘unknown’ group was similar to that of the ‘no’ group (Table 13).

4.2.6 Conclusion

Rivers were the leading location for unintentional fatal drowning in Australia between 2002 and 2012. This study has highlighted the differences in river drowning deaths between males and females, adults and children. Locals, adults who consume alcohol, those who fall in or use watercraft, and those in very remote locations were common groupings of drowning deaths in rivers in Australia. There is a need for the development, implementation and evaluation of strategies to prevent further drowning in Australian rivers.

4.3 Alcohol and its contributory role in fatal drowning in Australian rivers, 2002-2012 (Paper 3)

Peden AE, Franklin RC, Leggat PA (2017) Alcohol and its contributory role in fatal drowning in Australian rivers, 2002-2012, *Accident Analysis and Prevention*, 98: 259-265. doi: 10.1016/j.aap.2016.10.009

4.3.1 Introduction

Internationally, alcohol has been identified as a risk factor for injuries [214] including drowning [75 76 94 96 105 108]. Drinking whilst engaging in activities in or near the water is common [215] and alcohol use is known to result in a lack of coordination, greater risk-taking behaviour, impaired reaction time and impaired judgement among other effects [216].

Alcohol has been identified as a key challenge for the prevention of drowning, particularly drowning deaths as a result of recreational activities [187 217]. Estimates of the proportion of drowning cases known to involve alcohol vary from 22% to 25% of recreational aquatic activity related drownings in Australia [35 218], 30%–40% of unintentional fatal drowning in New Zealand [219], 47% of cases in an alcohol study group in Maryland, United States [90] and 63% of water traffic accident fatalities in Finland [220].

In Australia an average of 293 people per annum die due to unintentional drowning [32]. Alcohol has been previously identified as being present in 21.6% of cases of unintentional drowning in Australia between 2002 and2007 [35] and its involvement in drowning has prompted the Australian Water Safety Council (AWSC) to identify the reduction of alcohol and drug related deaths as a key priority for achieving an overall 50% reduction in drowning by the year 2020 [32 46].

More broadly, alcohol-related harm is a public health issue, with consumption a known risk factor for a range of health conditions [221], as well as mortality and morbidity due to injuries from falls, poisoning [222], suicide (particularly among Indigenous people) [223] and road traffic incidents [224]. The total cost per annum to the Australian society of alcohol-related problems in 2010 was estimated to be $14.352 billion [225], placing a huge strain on the health system [226]. To address this, public health approaches to prevention have been incorporated into several strategies including the National Binge Drinking Strategy which aims to address Australia's harmful binge drinking culture (with a particular focus on young people), through education, restricting availability and age or intoxication based restrictions on entering licensed venues [227 228]. Similarly, the National Drug Strategy 2010–2015 aims to reduce harm as a result of alcohol and other drugs through demand, supply and harm reduction [229]. These strategies may have an impact on drowning prevention through reduced supply and the promotion of a more responsible drinking culture, although to date this impact is unproven.

The involvement of alcohol poses challenges for the prevention of drowning such as: accessing quality data on the involvement of alcohol; the impact of decomposition and determining true levels of alcohol consumed prior to death [230]; exposure; risk factors; and effectiveness of prevention strategies [187 50 218 219 231]

Studies to date on alcohol and drowning have focused on BAC levels ranging from 0.05% to 0.10% as markers of a contributory role in fatal drowning [187].This study examines all river drowning deaths with positive readings for alcohol, with a particular focus on those deaths with a BAC of ≥0.05%. As a BAC of ≥0.05% has been shown to impact concentration, reaction times and risk-taking behaviour, as well as being legislated as the upper legal limit for driving a motor vehicle [232] in all Australian states and territories, this level has been deemed to be contributory to drowning for this study.

To develop more effective drowning prevention strategies, an understanding of the risk factors at specific aquatic locations and the role of alcohol is required [50]. Although rivers are known to be the location with the largest numbers of fatal drowning in Australia [132], this study represents the first population level analysis of the prevalence of alcohol involvement in river drowning [50].

This paper aims to:

- Identify the burden of alcohol-related unintentional fatal drowning in Australian rivers, creeks and streams between 2002 and2012.
- Explore the circumstances of drowning in rivers where alcohol was deemed to have been a contributory factor.
- Propose strategies for the prevention of alcohol-related drowning deaths.

4.3.2 Methods

Data on unintentional fatal drowning in Australian rivers, creeks and streams (henceforth referred to as rivers), was collected for a 10 Australian financial year period (1 July to 30 June). The data in this study spans 1 July 2002 to 30 June 2012 and was sourced from the Australian NCIS. The NCIS is an online registry which records information on all sudden and unexpected deaths in Australia. Due to a lack of specificity within ICD location codes [50], cases of unintentional fatal drowning in rivers were determined by using the location coding of 'stream of water' within the NCIS. Cases were also included if the location as discussed in the police report and/or finding document satisfied the following definition: "...a natural waterway that maybe fed from other rivers or bodies of water draining water away from a ‘catchment area’ to another location…” and “…can vary in water flow, length, width and depth…” [15 50].

Variables collected included age, sex, activity prior to drowning, time of day, day of the week, month and season of drowning, pre-existing medical conditions, involvement of alcohol and drugs, geographical location of residence and incident, tourist status and Indigenous status [15]. Indigenous status refers to those known to be Aboriginal, Torres Strait Islander or both Aboriginal and Torres Strait Islander.

Within the ‘activity prior to drowning’ variable; ‘swimming and recreating’ includes both competitive and unstructured swimming, wading, floating and paddling in water; and ’non-aquatic transport’ relates to vehicles not intended to be used in the water, such as cars, trucks, motorbikes, and bicycles etc.

Information on alcohol involvement was sourced from the toxicology and/or autopsy reports (where available) within the NCIS. Where a victim recorded a positive BAC reading, a ‘yes’ was recorded for alcohol involvement. Where known, the BAC level was recorded in a second variable. BAC readings were coded to two decimal places (rounding up at five – e.g. 0.015% was recoded as 0.02%). Alcohol involvement was deemed contributory to the drowning where the victim recorded a BAC of ≥0.05% (that is0.05 grams of alcohol in every 100 millilitres of blood) [233].

The season in which the drowning death occurred was categorised as: Summer (December, January, February), Autumn (March, April, May), Winter (June, July, August) and Spring (September, October, November). The time of drowning incident was coded into four broad groupings for analysis: early morning (12:01 am–6 am), morning (6:01 am–12 pm), afternoon (12:01 pm–6 pm) and evening (6:01 pm–12 am). Drowning rates per 100,000 persons were calculated using population data from the ABS [191].

Visitor status was calculated by determining the distance, in kilometres, between the residential and drowning incident post-codes. Distance was determined using Google Maps [192].A distance of 100 km or less was classified as ‘Not A Visitor’; those who resided within the same State or Territory with a distance greater than 100 km were classified as an ‘Intrastate Visitor’; those who drowned in a different State or Territory from where they resided were classified as ‘Interstate Visitors’ and overseas residents were classified as ‘International Tourists’.

The remoteness classification of an incident postcode is calculated based on a range of factors including distance and isolation from major services. Remoteness classification was coded using the

Australian Standard Geographical Classifications (ASGC) and calculated using the Doctor Locator website, which provides ASGC classifications by inputting a postcode [190].

For the analysis of children and adult river drowning deaths, children were defined as those aged 0–17 years and adults were defined as being aged 18 years and over. When examining the role of alcohol in victims with BACs of 0.05% or higher, only cases of adult drowning victims were utilised for analysis. For cases where children recorded positive readings for alcohol, case files were interrogated to record, in a new variable, whether alcohol was known to have been consumed or was likely to have been as a result of decomposition.

Data coding and analysis was conducted in SPSS V20 [157]. Descriptive statistics were utilised, as well as chi squared analysis. A modified Bonferroni test as suggested by Keppel [159] has been applied and therefore statistical significance was deemed $p < 0.04$. Chi squared analysis was conducted without the 'unknown' variable – e.g. presence of alcohol was calculated using the 'yes' and 'no' variables only. Where variable analysis presents cases of three or less, the term NP (not presented) has been used. Data included in this study is correct as at 15 June 2016. At the time of analysis, 93.4% of cases were no longer under coronial investigation (i.e. closed within the NCIS).

Ethical approval for the study was provided by both the NCIS (JHREC – CF/15/13552) and James Cook University (HREC – H6282).

4.3.3 Results

4.3.3.1 Alcohol Involvement as a Proportion of all Drowning Deaths in Rivers

There were 770 people who drowned in rivers in Australia. Alcohol was found in 314 cases (40.8%). There were 214 cases (27.8%) where alcohol involvement was unknown. For the 314 cases where alcohol was present, 279 (88.9%) recorded a BAC, of which 196(70.3%) registered a BAC of ≥0.05%. (Figure 15).

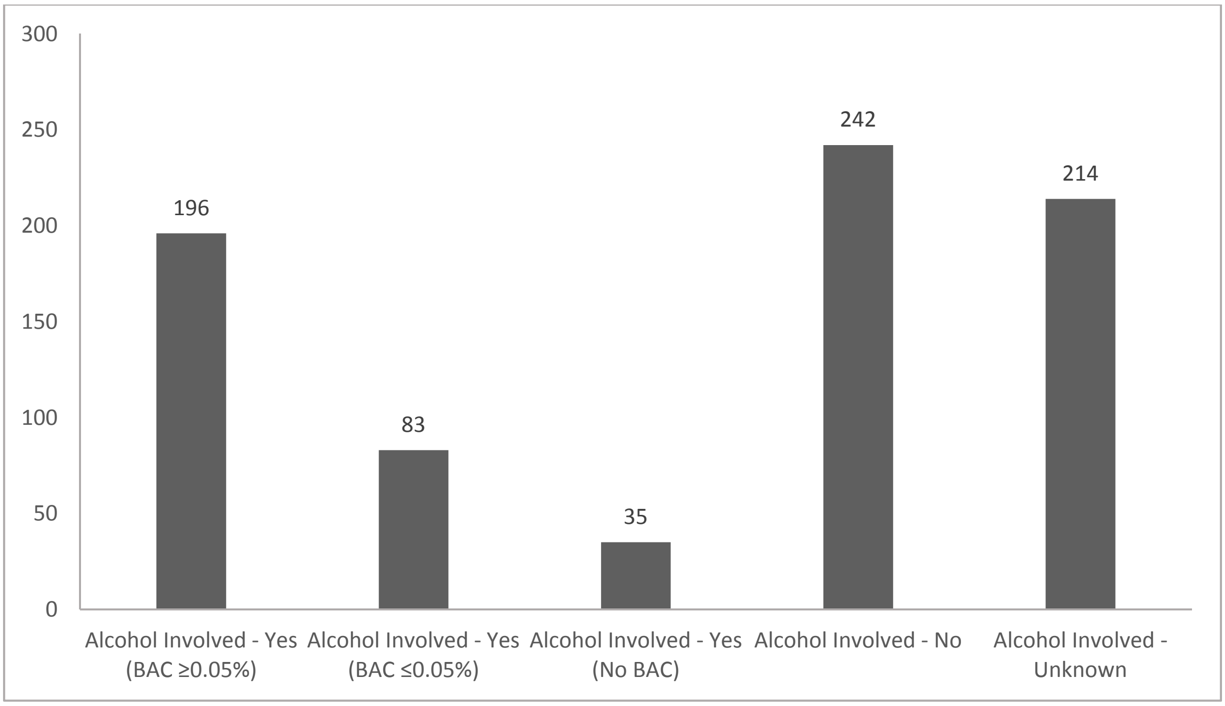

Figure 15: Unintentional fatal river drowning deaths by presence of alcohol (N=770)

Males recorded a higher proportion of drowning deaths with known alcohol involvement (41.8%), compared to females (36.4%). Adult river drowning victims were significantly more likely to have known positive alcohol involvement when compared to children (X^2= 36.0; $p < 0.01$). Over half (56.1%) of Aboriginal and Torres Strait Islander (ATSI) river drowning victims recorded known positive alcohol involvement and ATSI river drowning victims were significantly more likely (X^2= 8.9; $p < 0.01$) to record positive readings for alcohol when compared to non-Indigenous river drowning victims. (Table 15)

Table 15: River drowning deaths by alcohol presence by sex, age group, activity immediately prior, season of drowning incident, weekday or weekend and time of day of drowning incident, Chi squared (p value), Australia, 2002/03 to 2011/12 (N=770)

	Total		Alcohol Yes								Alcohol - No		Alcohol - Unknown		X^2 (p value) comparing alcohol yes to alcohol no
			Alcohol yes - no BAC		Alcohol yes - BAC ≤0.05%		Alcohol yes - BAC ≥0.05%		Total						
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	
Total (N)	770	100.0	35	11.1	83	26.4	196	62.4	314	40.8	242	31.4	214	27.8	
Sex															
Male	619	80.4	28	10.8	65	25.1	166	64.1	259	41.8	191	30.9	169	27.3	1.1 (p=0.290)
Female	151	19.6	7	12.7	18	32.7	30	54.5	55	36.4	51	33.8	45	29.8	
Age group															
Children	113	14.7	NP	NP	13	61.9	7	33.3	21	18.6	60	53.1	32	28.3	36.0 (p<0.01)
Adults	657	85.3	34	11.6	70	23.9	189	64.5	293	44.6	182	27.7	182	27.7	
Aboriginal and Torres Strait Islander status															
Yes	82	10.6	6	13.0	10	21.7	30	65.2	46	56.1	17	20.7	19	23.2	8.9 (p<0.01)
No	584	75.8	27	11.8	63	27.6	138	60.5	228	39.0	202	34.6	154	26.4	
Unknown	104	13.5	NP	NP	10	25.0	28	70.0	40	38.5	23	22.1	41	39.4	
Activity immediately prior to drowning															
Falls	164	21.3	NP	NP	12	20.7	44	75.9	58	35.4	64	39	42	25.6	4.1 (p=0.043)
Non-aquatic transport	140	18.2	9	16.4	12	21.8	34	61.8	55	39.3	41	29.3	44	31.4	0.2 (p=0.676)

Swimming and recreating	125	16.2	9	15	17	28.3	34	56.7	60	48.0	41	32.8	24	19.2	0.8 (p=0.362)
Watercraft	107	13.9	7	15.9	11	25.0	26	59.1	44	41.1	30	28	33	30.8	0.6 (p=0.444)
Jumped in	37	4.8	NP	NP	6	23.1	18	69.2	26	70.3	7	18.9	NP	NP	7.8 (p<0.01)
Other & unknown	74	9.6	NP	NP	9	37.5	13	54.2	24	32.4	32	43.2	18	24.3	0.7 (p=0.405)
Season															
Summer	295	38.3	9	7.9	31	27.2	74	64.9	114	38.6	99	33.6	82	27.8	1.2 (p=0.268)
Autumn	145	18.8	11	17.7	11	17.7	40	64.5	62	42.8	40	27.6	43	29.7	0.9 (p=0.331)
Winter	157	20.4	9	13.6	15	22.7	42	63.6	66	42.0	47	29.9	44	28.0	0.2 (p=0.643)
Spring	173	22.5	6	8.3	26	36.1	40	55.6	72	41.6	56	32.4	45	26.0	0.0 (p=0.953)
Weekday or weekend															
Weekday	502	65.2	19	9.5	56	28.1	124	62.3	199	39.6	161	32.1	142	28.3	0.6 (p=0.440)
Weekend	268	34.8	16	13.9	27	23.5	72	62.6	115	42.9	81	30.2	72	26.9	
Time of day															
Morning	147	19.1	7	19.4	14	38.9	15	41.7	36	24.5	66	44.9	45	30.6	21.6 (p<0.01)
Afternoon	321	41.7	7	5.7	46	37.4	70	56.9	123	38.3	110	34.3	88	27.4	1.5 (p=0.218)
Evening	160	20.8	16	18.8	13	15.3	56	65.9	85	53.1	43	26.9	32	20.0	7.8 (p<0.01)
Early morning	77	10	NP	NP	NP	NP	41	89.1	46	59.7	11	14.3	20	26.0	16.1 (p<0.01)
Unknown	65	8.4	NP	NP	7	29.2	14	58.3	24	36.9	12	18.5	29	44.6	

NP = not presented for variables where cases amounted to 3 deaths and under. A modified Bonferroni test has been applied meaning statistical significance is deemed p<0.04; ^ Compares alcohol yes to alcohol no

The 55–64 years age group recorded the highest proportion of drowning cases with known positive alcohol involvement (50.5%),followed by the 25–34 and 35–44 years age group (50.0% positive readings for alcohol respectively) however alcohol involvement was significant for those aged 35–44 years (X^2= 7.1; $p < 0.01$).

For activity immediately prior to drowning and known alcohol involvement, the activity category of 'jumping in' recorded the highest proportion of cases with positive readings for alcohol (70.3%) (X^2= 7.8; $p < 0.01$), followed by swimming and recreating (48.0%) and drowning deaths as a result of watercraft incidents (41.1%). (Table 15)

The highest proportion of river drowning deaths with known alcohol involvement occurred in summer (14.8%); however there was no significant difference in the proportion of deaths involving alcohol by season (Table 15). The largest proportion occurred on Fridays (50.0% known to involve alcohol), followed by Saturdays (45.2%) and Sundays (40.6%).

Alcohol-related river drowning deaths most commonly occurred during the early morning hours (59.7% known alcohol related) (X^2= 16.1; $p < 0.01$), followed by the evening (53.1%) (X^2= 7.8;$p < 0.01$). Those who drowned in rivers during the morning were significantly less likely to have recorded positive readings for alcohol (X^2= 21.6; $p < 0.01$) (Table 15).

When examining known alcohol involvement, neither the visitor status of the victim nor the remoteness classification of the incident location were found to be statistically significant.

4.3.3.2 Children

Of the 21 instances where positive readings for alcohol were found in fatal river drowning cases in children, 33.3% of victims were known to have consumed alcohol prior to drowning. In 52.4% of cases the positive reading for alcohol was deemed to be as a result of decomposition and alcohol consumption was not known in three cases. Of the children with BAC's available, the average age was 16 years and the median BAC was 0.170% (range 0.072%–0.232%). All victims were male, with deaths most commonly occurring in the early morning (57.1%) and afternoon (42.9%) hours. Incidents involving non-aquatic transport and watercraft accounted for 57.1% of the deaths. (Table 16)

Table 16: Blood alcohol concentration (BAC) readings by age group, sex, activity conducted immediately prior to drowning and time of day of drowning for child and adult drowning victims with an available BAC

Age	**Sex (%)**	**BAC**	**Activity immediately prior to drowning (ranked order)**	**Time of day (ranked order)**
Children (n=7)				
Average age: 16 years Range: 14-17 years	Male (100.0)	Av.: 0.168% (CI=0.126-0.210) Range: 0.072% – 0.232% Note: In one case the BAC was unknown	Non-aquatic transport (NP), Watercraft (NP), Falls (NP), Swimming and Recreating (NP), Jumped In (NP)	Early Morning (4), Afternoon (NP)
Adults (18+ with available BAC)				
18-24 years (n=32)	Male (88.1) Female (11.9)	Av.: 0.163% (CI=0.141-0.185) Range: 0.006%-0.259%	Jumped In (11), Watercraft (7), Falls (4), Non-aquatic transport (4)	Early Morning (16), Afternoon (9), Evening (4)
25-34 years (n=38)	Male (87.8) Female (12.8)	Av.: 0.210% (CI=0.178-0.242) Range: 0.009%-0.430%	Swimming and Recreating (12), Unknown (6), Non-aquatic transport (5)	Afternoon (11), Evening (9), Early Morning (7)
35-44 years (n=34)	Male (86.4) Female (13.6)	Av.:0.242% (CI=0.206-0.278) Range: 0.009%-0.523%	Swimming and Recreating (12), Falls (7), Watercraft (6)	Afternoon (17), Evening (12), Early Morning (NP)
45-54 years (n=37)	Male (83.7) Female (16.3)	Av.:0.247% (CI=0.213-0.281) Range: 0.005%-0.473%	Falls (10), Unknown (8), Non-aquatic transport (6)	Afternoon (18), Evening (12)
55-64 years (n=30)	Male (71.7) Female (28.3)	Av.:0.196% (CI=0.170-0.222) Range: 0.005%-0.330%	Falls (11), Non-aquatic transport (9), Unknown (7)	Evening (13), Early Morning (7), Afternoon (6)

65-74 years (n=12)	Male (83.3) Female (16.7)	Av.:0.188% (CI=0.137-0.238) Range: 0.009%-0.340%	Falls (NP), Non-aquatic transport (NP), Watercraft (NP), Unknown (NP)	Evening (4), Early Morning (NP), Afternoon (NP)
75+ years (n=6)	Male (75.0) Female (25.0)	Av.:0.145% (CI=0.107-0.183) Range: 0.010%-0.212%	Falls (NP), Fishing (NP), Non-aquatic transport (NP), Unknown (NP)	Afternoon (NP), Evening (NP),

Note: For children, all cases where alcohol was known to have been involved (e.g. positive BAC or coronial files stated the deceased was intoxicated or witnesses stated the deceased had consumed alcohol) were included for analysis; for variables that amounted to three cases or less; NP (Not Presented) has been used.

4.3.3.3 Blood Alcohol Concentration (BAC)

Blood Alcohol Concentration (BAC) readings for adult victims ranged from 0.006% to 0.528% (mean 0.16%). In over half (59.9%) of all drowning cases in adults where a BAC was available, victims recorded a BAC of 0.1% or higher (twice the legal limit in Australia) and 40.3% recorded a BAC of 0.2% (four times the legal limit). Overall 86.7% of all readings were ≥0.02%. Males recorded a slightly higher mean BAC at 0.16% compared to 0.15% for females.

4.3.3.4 Blood Alcohol Concentration (BAC) ≥0.05%

Of the 279 cases where BAC was known, 196 cases (70.3%) recorded a BAC ≥0.05%. Where BAC was recorded, 8.7% (n = 17) were ≥0.05% and ≤0.07%, 6.1% (n = 12) recorded BACs of ≥0.08%and <0.10%, and 85.2% (n = 167) of known BAC cases recorded a BAC of ≥0.10%. (Table 15)

Males accounted for 84.1% of all drowning cases, where the BAC was 0.05% or higher. Available BACs were ≥0.05% in 189 cases of adult drowning (28.8% of all adult river drowning deaths). Almost one fifth (18.6%) of children recorded positive readings for alcohol, compared to 44.6% of adults.

Those aged 45–54 years recorded the highest mean BAC at 0.247%. (Table 16) and recorded the highest proportion of cases with a BAC of 0.05% or higher at 54.4% (X^2= 9.1; $p < 0.01$). Almost three quarters (73.7%) of all Aboriginal and Torres Strait Islander river drowning victims recorded BACs that were ≥0.05% (X^2= 7.0;$p < 0.01$).

Over three quarters (77.3%) of drowning deaths as a result of jumping in were known to have contributory BACs. This was followed by Swimming and Recreating (45.2% of cases where the BAC was contributory) and non-aquatic transport incidents (44.6%).

Almost three quarters (72.5%) of alcohol-related drowning deaths in autumn were of victims with a BAC of 0.10% or higher (Table 15). A slightly higher proportion of drowning deaths with contributory alcohol levels occurred on the weekend (72.8%) compared to weekdays (68.9%). The largest number of drowning death with contributory levels of alcohol occurred in the afternoon (34.2%), followed by the evening (28.6%) and early morning (19.4%) (X^2= 36.1;$p < 0.01$). (Table 15)

4.3.4 Discussion

This study shows that at least 41% of people who drowned in rivers, had alcohol in their system at autopsy with almost two-thirds (62%) of these recording a BAC of ≥0.05%. It is unknown what level of intoxication impacts a person when in the water and potentially using ≥0.05% is too high with 86.7% of victims with a BAC recording levels of ≥0.02%. This research highlights key themes and challenges for drowning prevention practitioners.

4.3.4.1 Child Fatal Drowning and Alcohol

Underage consumption of alcohol is a challenge in Australia [234], with 91% of students having tried alcohol by the time they are 15 years of age [235].This study found 30% of child river drowning victims recorded a BAC of ≥0.10% (twice the legal limit) despite being under the legal age for alcohol consumption. In 57.1% of cases, alcohol-related river drowning deaths occurred in the early hours of the morning, raising questions regarding supervision and peer group influences. Further research should be conducted to explore children's drinking patterns around water, why they choose such locations, and what measures would be most effective in ensuring their safety.

The BAC levels of child river drowning victims link to the broader challenges of limiting supply and use of alcohol by those under the legislated drinking age. Recent research among adolescents has noted that these measures are often bypassed [227]. Education and increasing awareness of the risks of combining aquatic activity and alcohol may also contribute to prevention efforts but must be well entrenched prior to adolescents leaving high school. These challenges exist for those working in the field of drowning prevention as well as those more broadly working in injury prevention and public health.

4.3.4.2 Binge Drinking and BAC Levels of River Drowning Victims

The results of this research highlight the number of victims who have drowned in Australian rivers after consuming large amounts of alcohol. Over one third (40.3%) of all adult victims with a BAC recorded a blood alcohol level of 0.20% or higher (four times the legal driving limit or more).

At a population level, alcohol consumption has been estimated, with research showing one in four Australians aged 14 years and over consume alcohol at a level that puts them at risk of injury from a single drinking event at least once a month [236]. Less is known about consumption patterns of alcohol at river locations, with one survey finding rivers to be the category of aquatic location with the largest proportion of alcohol consumption with 36% of respondents consuming alcohol at rivers, compared to 29% at a lake or pond and 20% at a pool or the ocean [94]. Nationally representative population level epidemiological surveys [132] and exposure studies [50] may assist in addressing gaps in knowledge and better inform prevention strategies for the reduction of alcohol-related drowning deaths at rivers.

4.3.4.3 Alcohol and Activity Undertaken Immediately Prior to Drowning

A number of activities undertaken prior to drowning in rivers recorded a high proportion of alcohol involvement. Most notable was the activity of deliberately jumping into the water, where 62.5%of victims recorded a BAC of 0.10% or higher, 64.7% were aged 18–24years and 90.9% were male. This result highlights that further work around risk taking, alcohol use and river drowning needs to be conducted. Further research should also examine causal factors such as who the victim was recreating with (peers, family, alone) and the type of objects these victims are jumping from (e.g. bridges, trees etc).

A further 14.8% of river drowning victims whose activity prior to drowning was unknown, were known to record BACs of 0.05% or higher. This may indicate that the victim was on their own when they drowned and their activity prior to drowning was not witnessed. Prevention strategies should also highlight the dangers of recreating in and around water alone whilst under the influence of alcohol.

4.3.4.4 Challenges – Alcohol and its Contributory Role in Drowning

There is a lack of consensus among researchers as to a risky level of alcohol and how to determine its contributory role in a drowning [237]. Research conducted into the role of alcohol and drowning as a result of recreational swimming has examined cases that range from "under the influence' or where alcohol was 'mentioned as a cause' to reported BACs of 0.05%, 0.08%and 0.10% [187].

This study used a BAC of ≥0.05% (70.3% of those with a BAC) as a measure of contributory involvement of alcohol (due to known effects on the body); however people drown in rivers with a BAC lower than 0.05% (29.7% of those with a known BAC). It is not known if the risk of death and injury is higher on water than land and, therefore, whether aligning with BAC levels linked to road traffic incidents is a mistake (i.e. should the relevant BAC for drowning victims be lowered to 0.02%?). Further research (including information on length of time the body was submerged in water prior to removal) and exposure studies [50] are required to be able to support an appropriate BAC level with evidence.

4.3.4.5 Challenges – Data Quality and How to Improve It

Previous research has shown that it is important to minimise the number of cases with missing information on alcohol involvement [187] to determine true prevalence and impact. Data quality on the Australian NCIS is improving with the proportion of cases with unknown alcohol involvement reducing from a high of 55.1% in the first year of this study (2002/03) to a low of 18.8% unknown in 2009/10. However, with cases in more recent years more likely to be under investigation, it is unsurprising that cases with unknown alcohol involvement increase within more recent years of coronial data.

However, there remain challenges, even with a BAC, to determine whether alcohol had been consumed prior to drowning, and then, the amount of alcohol consumed, as it is possible that any alcohol present may be due at least in part to decomposition [230]. The other challenge is determining the contribution of alcohol to the drowning death, e.g. alcohol may have been consumed by the skipper of the boat, yet a passenger may be the victim of this alcohol-related incident.

Police, forensic pathologists and coroners should be encouraged to ensure toxicology reporting is mandatory for drowning victims and made electronically available on the NCIS across all jurisdictions and age groups (including children). Greater clarity is needed around the number of hours a body has been in the water and determinations by forensic pathologists around if alcohol readings are due to decomposition or consumption. Those investigating fatal drownings (commonly police) should prioritise detail around alcohol consumption in their reports to the coroner.

4.3.4.6 A Public Health Approach to Prevention

From a public health perspective, policies exist in all States and Territories that mandate upper legal limits for alcohol consumption, when operating a motor vehicle; however when it comes to watercraft jurisdictional differences apply [238]. The enforcement of such policies remain a challenge considering the top 10 longest rivers in Australia amount to a distance of 7,427 km [239], as well as the remoteness of many river drowning locations [132]. Improving awareness of the increased risk of drowning and injury when operating watercraft, as well as the risks of driving through floodwaters when intoxicated, may also enhance prevention efforts.

Breathalysing and 'don't drink and drive campaigns' have been successful in road traffic safety efforts, and, although the same legislation applies to operating watercraft as a motor vehicle with respect to the upper limit of the BAC, the likelihood of similar success may be low on rivers due to resourcing and the sheer amount of river space to patrol, as well as frequency of activity being undertaken. Exposure studies and an increased epidemiological focus on the geographical location of alcohol-related watercraft drowning deaths may help guide enforcement authorities; however this may not prove to be successful. A public health approach may include warnings of increased risk of injury (including drowning) as well as the health effects when counselling a patient on the risks of over-consumption of alcohol.

4.3.5 Limitations

The number of cases known to involve alcohol may be artificially inflated by decomposition [231]. Cadavers that have been submerged in water for a period of time naturally produce alcohol [189]. Cases which recorded a positive reading for alcohol in the bloodstream were included as 'yes' cases for alcohol involvement though cases with low BAC levels may have registered positive readings for alcohol due to decomposition and not as a result of consuming alcohol.

We have assumed in cases where the BAC was ≥0.05% that this contributed to the person's drowning. However, it is difficult to judge absolutely whether this level would have contributed to the drowning, or whether this is an appropriate level to base such an assumption on.

Just over a quarter (28.8%) of cases recorded an unknown for alcohol involvement, therefore the data presented in this study is likely to be an under-representation of alcohol-related drowning deaths in Australian rivers and may limit the accuracy of the analysis. The underrepresentation is due to several factors. Cases of river drowning that are under investigation do not allow electronic access to the autopsy and toxicology reports. Some jurisdictions may not upload the electronic documents for the autopsy and toxicology for the victim to the NCIS. In some cases, an autopsy and/or toxicology report may not have been conducted (body not recovered, family objection) and therefore it would not be possible to determine involvement of alcohol.

There is a lack of exposure data on alcohol usage among those who visit and recreate at river locations. This therefore limits the assumptions that can be made regarding risk of drowning when consuming alcohol prior to recreating at rivers. Further work is required.

4.3.6 Conclusions

This research, the first of its kind, identifies the role of alcohol in fatal river drowning, as well as the concerning levels of alcohol being consumed. There are many challenges associated with the successful prevention of alcohol-related fatal river drowning; however priorities for drowning prevention practitioners as well as those working more broadly in injury prevention and public health include: An increased focus on adolescents and the role of alcohol in river drowning, the development of population level strategies to curb risky drinking behaviours on and around rivers, conducting exposure studies to provide greater evidence around 'risky' BAC levels for aquatic activity and the development of strategies to improve data collection. It is hoped this work will contribute to a greater body of knowledge on risk factors for river drowning deaths and ultimately lead to the reduction of fatal drowning and the saving of lives.

4.4 Causal Pathways of Flood Related River Drowning Deaths in Australia (Paper 4)

Peden AE, Franklin RC, Leggat PA, Aitken P. Causal Pathways of Flood Related River Drowning Deaths in Australia. *PLOS Currents Disasters*. 2017 May 18. Edition 1. doi: 10.1371/currents.dis.001072490b201118f0f689c0fbe7d437

4.4.1 Introduction

Floods are the most common of all natural disasters, and the leading cause of natural disaster deaths worldwide [240].The World Health Organization (WHO) estimates that globally, between 1980 and 2009, floods have claimed the lives of over 500,000 people [17]. Drowning is the leading cause of death during flood events [241], accounting for two-thirds of all deaths, followed by trauma [70].

Drowning risk changes during floods due to characteristics [242] such as: water depth, flow velocities and the rate of rising waters [243 244]; roadways being covered or cut off by water and debris [245]; and an increased amount of water in storm water drains and irrigation channels [246 247]. There is a need for prevention strategies to minimise risk of drowning during times of flood. Strategies proposed include: engineering measures to restrict access to floodwaters, particularly by motorists [248] and the use of public awareness and education measures [248]; as well as predictive modelling and early warning and evacuation procedures [242].

Australia has experienced significant flood events. One of the most devastating recent events was the Queensland floods of 2010/11 which affected 78% of the state and resulted in the deaths of 33 people, 21 in one flash flood event [194]. In Australia, rivers are the leading location for drowning [132] and slow onset floods from inland rivers are the most common, however most deaths occur due to flash flooding, often as a result of thunderstorms [249].

Rivers, with their variable environments [244] and significant contribution to the fatal drowning toll [132], require attention in order to develop effective prevention strategies. Unlike coastal waters, specifically rip currents [250-252], which have benefited from much research, flood-related deaths (16.8% of all unintentional drowning deaths in rivers) have not benefited from such focus.

Population-based research examining risk factors has been identified as a gap in the published literature for river drowning [50]. With the likelihood of floods increasing [240 253] there is a need to examine the epidemiology of river flood-related drowning deaths in Australia. This paper represents the first total population cross-sectional study of all unintentional fatal river flood-related drowning in Australia using coronial data.

This study aims to: Describe the incidence of unintentional fatal drowning during periods of river flooding in Australia between 1 July 2002 and 30 June 2012; discuss risk factors associated with river flood-related drowning; and propose potential strategies for prevention.

4.4.2 Methods

Ethical approval for this study was provided by the Victorian Department of Justice and Regulation (Department of Justice and Regulation Human Research Ethics Committee – CF/15/13552) and James Cook University (James Cook University Human Research Ethics Committee – H6282). Informed consent has not been obtained as the human subjects involved in this research are deceased.

Unintentional fatal drowning in Australia is considered a 'reportable death' and cases of this nature are captured in the Australian NCIS, an internet based data storage and retrieval system for Australian coronial cases. All cases of unintentional fatal river drowning between 1 July 2002 and 30 June 2012 were extracted from the NCIS and collated in a database. This includes populating a range of variables for each victim including sex, age, geographic location of drowning incident, residential location of drowning victim, activity being undertaken prior to drowning, involvement of alcohol and/or drugs, the presence of pre-existing medical conditions and ethnicity of the drowning victim. Cases in the NCIS remain open (i.e. under investigation) until a cause of death has been ruled by the coroner. At time of analysis, 93.4% of cases were closed (i.e. no longer under coronial investigation). For the open cases, data was correct as at 16 July 2016.

All cases within this study are either cases where the primary cause of death (Level 1a) was drowning or where drowning was a contributory cause of death (Level 1b to Level 3). Where an initial non-fatal drowning occurred and the victim subsequently died in hospital from the related effects of the immersion, these cases were included (no such victims in the flood-related cohort). Cases relate to unintentional drowning deaths that occurred in Australian rivers, creeks and streams only. Rivers, creeks and streams were defined as "A natural waterway that may be fed from other rivers or bodies of water draining water away from a 'catchment area' to another location…" and "can vary in water flow, length, width and depth…" [132].

Flooding for the purposes of this study was defined as comprising slow onset floods from inland rivers [244] and rapid on-set flash floods as a result of intense rainfall associated with thunderstorms [249]. The involvement of flooding was determined through information presented in the cause of death text field or narratives of the police report and/or coronial report (if available). Where available, cases coded to ICD-10 were also identified as being flood-related if the external cause code X37.8 (other cataclysmic storms) and X38 (flood, sequela) was provided in the external data tab within the NCIS [23]. Data on the ICD10 code for deaths are identified by matching cases within the NCIS to the de-identified data provided through the ABS Causes of Death release [33]. Cases were identified as being flood-related with a 'yes' in the corresponding variable.

Drowning victims were coded into two groups (children or adults) based on their age. Children were defined as those aged 0-17 years and adults were defined as being aged 18 years and over. In Australia, 18 years is the age a child reaches adulthood for the purposes of the criminal law [193].

The remoteness classification of incident postcode was coded according to the Australian Standard Geographical Classification (ASGC) [254]. Postcodes are coded into one of five remoteness classifications based on a number of factors including distance from essential services [163].

Visitor status was calculated by determining the distance, in kilometres, between the residential and incident postcodes using Google Maps [192]. A distance of 100 km or less was classified as 'Not A Visitor'; those who resided within the same State or Territory with a distance greater than 100 km, were classified as an 'Intrastate Visitor'; those who drowned in a different State or Territory and were greater than 100 km from where they resided were classified as 'Interstate Visitors'; and those with a residential postcode in the NCIS of 7777 (i.e. live overseas) were classified as 'Overseas Tourists'.

Time of day of drowning incident was coded into four groupings for analysis: morning (6:01 am to 12 pm), afternoon (12:01 pm to 6 pm), evening (6:01 pm to 12 am) and early morning (12:01 am to 6 am). For the time of incident variable, where time could not be determined a coding of 9999 (Unknown) was used.

Crude drowning rates per 100,000 persons were calculated using population demographic data cubes from the ABS for the period June 2003 to June 2012 [160 191] and excluded international tourists. Drowning rates for people of Aboriginal or Torres Strait Islander descent were calculated using population estimates for 2002-2011 from the ABS [162]. Rates for country of birth and remoteness classification of incident location were calculated using a three yearly average from population data available from the three Australian population Census years 2001 [164], 2006 [165] and 2011 [166] and averaged to determine population and yearly drowning rate.

Due to difficulties around interpreting BAC for drowning victims [189], alcohol involvement was deemed where a BAC was available (either in the autopsy or toxicology report) and was ≥0.05% (that is 0.05 grams of alcohol in every 100 millilitres of blood). Cases where alcohol was known to be consumed but no BAC was available were deemed Unknown for alcohol involvement.

Data coding and analysis was conducted in SPSS V20 [157]. Descriptive statistics were utilised, as well as chi squared analysis. A modified Bonferroni test suggested by Keppel [159] has been applied and statistical significance is deemed p<0.03. Relative risk (RR) was calculated, along with a 95% Confidence Interval (CI). Relative risk and chi squared analyses were conducted without the 'unknown' variable as it was assumed that this information was missing and no systematic bias was likely – e.g. presence of alcohol was calculated using the 'yes' and 'no' variables only. Where variable analysis presents cases of four or less, the term NP (not presented) has been used in the tables. Non-parametric chi squared analysis was also conducted using the proportional basis of the population as the assumed outcome numbers.

Causal factor analysis was conducted for river flood-related drowning deaths as a result of the top three activities (falls, non-aquatic transport incidents, swept away; 83.7%). The narrative of the incident was analysed from the coronial finding. If the finding was unavailable, the police report narrative was used. If this was not available the autopsy report was used. The following new variables were added and coded from available data: For all cases – type of flood (flash or slow onset), if the victim was alone or with company and if the victim entered floodwaters intentionally or unintentionally. For drowning deaths due to falls into flooded rivers – what the victim fell from. For drownings as a result of being swept away by river floods – what the victim was swept from. For drowning deaths as a result of non-aquatic transport incidents involving river floods – if the victim was a driver or passenger, if the road was open or closed at the time of the incident, the victim's intended destination and the type of vehicle the victim was in when they drowned. The data was then visually depicted using flow charts developed with the assistance of a graphic designer. Initial coding was conducted by AEP, and then reviewed by RCF with cross-checking to ensure consistency by PAL.

Rates of non-aquatic transport flood-related drowning per 100,000 registered vehicles were calculated using Australian vehicle registration data. Using the ABS Motor Vehicle Census [161], a 10 year average of registrations by vehicle type was calculated using data from 1-March-2003 to 1-March-2012 inclusive. Rates were calculated for passenger vehicles (car, four wheel drives (4WD)), light commercial vehicles (utilities), rigid trucks (heavy vehicles, machinery) and motorcycles (motorbikes, All Terrain Vehicles (ATVs)).

4.4.3 Results

Between 1 July 2002 and 30 June 2012, there were 770 drowning deaths in rivers, of which 129 (16.8%) were river flood-related (Table 17). This represents a 10 year average drowning rate of 0.06 per 100,000 persons per year (Figure 16). The number of deaths vary from a low of five deaths in

2002/03 to a high of 45 deaths in 2010/11, of which 21 (46.7%) occurred in a single flash flooding incident in the state of Queensland.

Table 17: River drowning deaths and flood-related drowning deaths by sex, age group, people of Aboriginal and Torres Strait Islander descent, visitor status, activity immediately prior to drowning, remoteness classification of incident location, presence of alcohol (≥0.05%) and time of day of drowning incident, Chi Square (p value), Australia, 2002/03 to 2011/12 (N=770)

	Total		Flooding – Yes		Flooding – No		Flooding – Unknown		X^2 (p value) comparing flooding – yes to flooding – no
	N	%	N	%	N	%	N	%	
Total	770	100.0	129	16.8	485	63.0	156	20.3	
Sex									
Male	619	80.4	82	13.2	406	65.6	131	21.2	25.4 (p<0.001)
Female	151	19.6	47	31.1	79	52.3	25	16.6	
Age Group									
Children	113	14.7	30	26.5	65	57.5	18	15.9	7.6 (p=0.006)
Adults	657	85.3	99	15.1	420	63.9	138	21.0	
People of Aboriginal or Torres Strait Islander descent *									
Yes	82	10.6	15	18.3	46	56.1	21	25.6	0.5 (p=0.469)
No	688	89.4	114	16.6	439	63.8	135	19.6	
Visitor Status									
Not A Visitor	570	74.0	105	18.4	355	62.3	110	19.3	2.2 (p=0.140)
Visitor – Intrastate	110	14.3	21	19.1	68	61.8	21	19.1	0.3 (p=0.598)
Visitor – Interstate	46	6.0	NP	NP	29	63.0	15	32.6	4.4 (p=0.036)
Visitor – Overseas	21	2.7	0	0.0	16	76.2	5	23.8	-

Visitor Status - Unknown	23	3.0	NP	NP	17	73.9	5	21.7	-
Activity Immediately Prior to Drowning									
Falls	164	21.3	15	9.1	121	73.8	28	17.1	16.5 (p<0.001)
Non-aquatic Transport	140	18.2	71	50.7	47	33.6	22	15.7	110.0 (p<0.001)
Swept Away	23	3.0	22	95.7	0	0.0	NP	NP	73.3 (p<0.001)
Swimming and Recreating	125	16.2	9	7.2	91	72.8	25	20.0	14.9 (p<0.001)
Watercraft	123	13.9	5	4.1	84	68.3	18	14.6	19.5 (p<0.001)
Other	88	11.4	6	6.8	66	75.0	16	18.2	3.7 (p=0.054)
Unknown	107	16.0	NP	NP	76	71.0	46	43.0	-
Presence of Alcohol (BAC ≥0.05%)									
Yes	196	25.5	26	13.3	132	67.3	38	19.4	3.2 (p=0.073)
No	321	41.7	64	19.9	205	63.9	52	16.2	
Unknown	253	32.9	39	15.4	148	58.5	66	26.1	-
Time of Day									
Morning	147	19.1	26	17.7	91	61.9	30	20.4	0.6 (p=0.452)
Afternoon	321	41.7	52	16.2	220	68.5	49	15.3	0.1 (p=0.715)
Evening	160	20.8	27	16.9	95	59.4	38	23.8	0.6 (p=0.457)
Early Morning	77	10.0	8	10.4	53	68.8	16	20.8	1.9 (p=0.168)
Unknown	65	8.4	16	24.6	26	40.0	23	35.4	-

^ compares flooding yes to flooding no; * 'Persons of Aboriginal or Torres Strait Islander descent – unknown have been combined with 'persons of Aboriginal or Torres Strait Islander descent – no' for the purposes of analysis. A modified Bonferroni test has been applied meaning statistical significance is deemed at p<0.03.

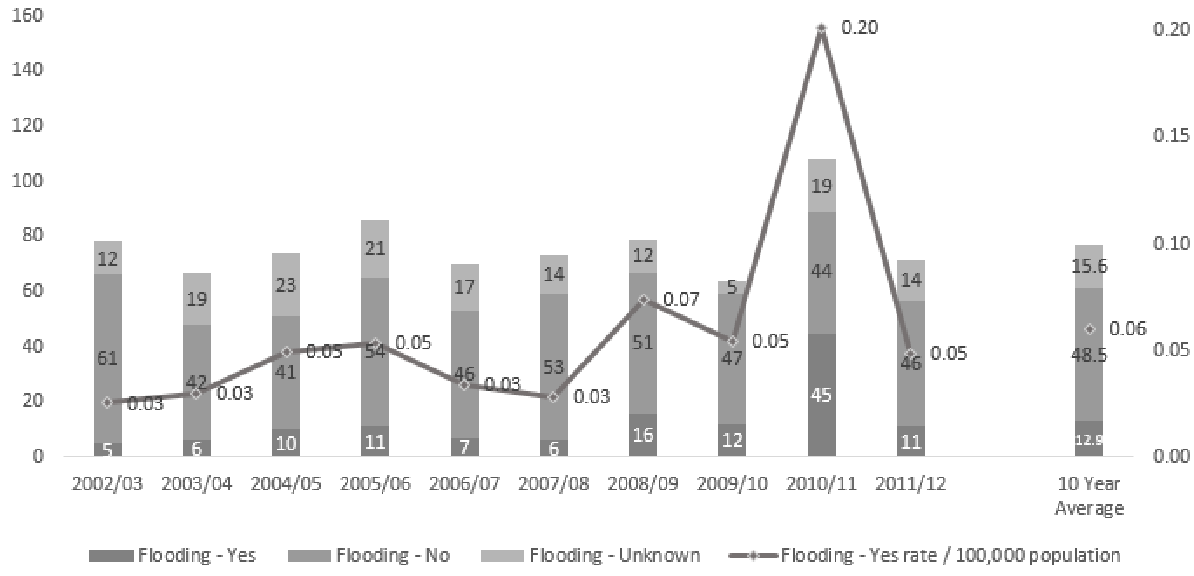

Figure 16: Unintentional fatal drowning in rivers by flood status and financial year, number and crude rate per 100,000 persons, Australia, 2002/03 to 2011/12 (N-770)

Slow onset flooding was involved in half (55.8%) of all river flood drowning deaths, 27.1% were as a result of flash flooding and type of flood was unknown in the remaining 22 cases. Males were significantly more likely to drown in river floods than females (χ^2 = 9.9; p=0.002), accounting for almost two-thirds (63.6%) of all drownings during river flooding (Table 18). Although a larger number of adults (n=99) drowned compared to children (n=30), children were significantly more likely to drown as a result of flooding (χ^2 = 7.6; p=0.006). (Table 17) The 55-64 years age group recorded the largest number of river flood-related drowning victims (n=20), however those aged 75+ years were 2.24 (CI: 0.13-38.24) times more likely to drown when compared to those aged 0-4 years. (Table 18)

Table 18: Flood-related drowning deaths average per annum and percentage, annual population and crude rate of drowning per annum by sex, age group, people of Aboriginal or Torres Strait Islander descent, state or territory of drowning death, country of birth and remoteness classification of incident location, relative risk (RR) and 95% confidence interval (CI), Chi Square (p value), Australia, 2002/03 to 2011/12 (n=129)

	Flooding - Yes		**Australian Population**		**RR (CI)**	**X^2 (p-value)**
	Average per annum (n)	%	Annual population per annum over 10 years	Crude rate per 100,000 persons per annum		
Total	12.9	100.0	21114977	0.06		
Sex						
Male	8.2	63.6	10498797	0.08	1.76 (0.57-5.48)	9.9 (p=0.002)
Female	4.7	36.4	10616180	0.04	1	
Age Group						
0-4 years	0.7	5.4	1365812	0.05	1	15.9 (p=0.104)
5-9 years	0.7	5.4	1347529	0.05	1.01 (0.04-27.84)	
10-14 years	1.1	8.5	1383490	0.08	1.55 (0.08-31.06)	
15-17 years	0.5	3.9	843606.2	0.06	1.16 (0.03-43.58)	
18-24 years	0.6	4.7	2079371	0.03	0.56 (0.02-17.70)	
25-34 years	1.4	10.9	2992752	0.05	0.91 (0.05-16.08)	
35-44 years	1.8	14.0	3073163	0.06	1.14 (0.07-18.07)	
45-54 years	1.4	10.9	2894025	0.05	0.94 (0.05-16.63)	
55-64 years	2.0	15.5	2328123	0.09	1.68 (0.11-25.49)	
65-74 years	1.2	9.3	1500780	0.08	1.56 (0.08-29.74)	
75+ years	1.5	11.6	1306326	0.11	2.24 (0.13-38.24)	
People of Aboriginal or Torres Strait Islander descent * ^						
Yes	1.5	11.6	532309	0.28	5.25 (0.94-29.24)	37.3 (p<0.001)
No	9.9	76.7	18447158	0.05	1	
State or Territory of Drowning Death						
ACT	0.0	0.0	347360			183.5 (p<0.001)
NSW	2.9	22.5	6920872	0.04	1	
NT	1.2	9.3	217595	0.55	13.16 (1.57-110.47)	
QLD	6.9	53.5	4160860	0.17	3.96 (1.00-15.60)	
SA	0.0	0.0	1583108			
TAS	0.4	3.1	496584	0.08	1.92 (0.07-52.43)	
VIC	1.0	7.8	5226474	0.02	0.46 (0.05-4.43)	
WA	0.5	3.9	2159441	0.02	0.55 (0.03-11.11)	
Country of Birth ** ^^						
Australia	9.5	73.6	15216855	0.07	2.60 (0.39-17.39)	10.5 (p=0.001)
Outside Australia	1.2	9.3	5003784	0.02	1	
Remoteness Classification of Incident location						
Major Cities	1.0	7.8	13700034	0.02	1	996.9 (p<0.001)
Inner Regional	4.2	32.6	3926730	0.36	14.65 (1.65-129.74)	
Outer Regional	2.9	22.5	1937273	0.50	20.51 (2.11-199.09)	
Remote	1.8	14.0	309826	1.94	79.59 (6.91-917.33)	
Very Remote	3.0	23.3	179434	5.57	229.05 (23.82-2202.06)	

Note: Population information is calculated from June 2003 to June 2012 and is sourced from the Australian Bureau of Statistics (ABS). Data on Aboriginal or Torres Strait Islander population, Country of Birth and Remoteness Classification of incident location is calculated as three year averages from Australian Census years from 2001, 2006 and 2011. *There were 15 flood-related drowning deaths across the 10 years where Aboriginal or Torres Strait Islander descent was unknown. **There were 22 flood-related drowning deaths across the 10 years where country of birth was not known. ^ ^^Population estimates drawn from different ABS data cubes.

People of Aboriginal or Torres Strait Islander descent were 5.25 times more likely to drown in floods than non-Indigenous flood victims (χ^2 =37.3; p<0.001). (Table 18) The state of New South Wales recorded the highest number of river flood-related drowning deaths (n=29) however those who drowned in the Northern Territory and Queensland were 13.16 (p<0.001; CI: 1.57-110.47) times and 3.96 (p<0.001; CI: 1.00-15.60) times more likely to drown in flooded rivers compared to non-flooded rivers. (Table 18)

People born in Australia, were 2.60 (χ^2 =10.5; p=0.001) times more likely to drown during river flooding, compared to those born outside of Australia. (Table 18) The majority of victims were not visitors to the drowning location (81.4%). Visitor status of the victim was not found to increase drowning risk. There were no flood-related drowning deaths among international tourists to Australia during the study period. (Table 17) There was an increased risk for those who drown in remote areas, with people in remote areas being 79.59 (p<0.001; CI: 6.91-917.33) times and those in very remote areas being 229.05 (p<0.001; CI: 23.82-2202.06) times more likely to drown during times of river flooding than those who drown in major cities. (Table 18)

River flood-related drowning deaths most commonly occurred in the summer months (December to February) (55.8%) (χ^2 = 20.4; p<0.001). Almost half of all flood-related drowning deaths occurred in the afternoon (40.3%), with a further fifth (20.9%) occurring in the evening, however time of day was not found to be statistically significant. (Table 17) Alcohol (i.e. a BAC ≥0.05%) was known to be present in a fifth (20.2%) of river flood-related drowning deaths, however the involvement of alcohol was not found to be statistically significant (Table 17). Males accounted for 76.9% of cases where alcohol was known to be present.

Non-aquatic transport incidents were the leading activity immediately prior to drowning, accounting for over half (55.0%) of all flood-related drowning deaths (χ^2 = 110.0; p<0.001), followed by being swept away by floodwaters 17.1% (χ^2 = 73.3; p<0.001). The third leading activity prior to drowning was a fall into water (11.6%), however a fall was found to be significantly less likely to occur during times of flood when compared to drowning deaths in rivers not in flood (χ^2 = 16.5; p<0.001). (Table 17) Males outnumbered females in all categories of activity immediately prior to drowning with the exception of the category of Swept Away (54.5% female), however sex was not found to be statistically significant by activity prior to drowning.

River flood-related deaths as a result of non-aquatic transport incidents were more likely in winter (χ^2 = 35.8; p<0.001) and more likely to occur on a Friday when compared to drowning as a result of other activities. For flood-related drowning deaths in rivers, Monday was the most common day (24.0%) (χ^2 = 9.1; p=0.002); however these were less likely to be related to non-aquatic transport incidents when compared to Friday (26.8% of all flood-related non-aquatic transport incidents).The largest proportion of flood-related non-aquatic transport drowning deaths occurred in afternoon (38.0%), however time of day was not found to be statistically significant. Alcohol was known to be present in just over a fifth (21.1%) of all flood-related non-aquatic transport incidents, however alcohol was not found to be statistically significant.

4.4.3.1 Causal Factors

There were three main activities prior to drowning in floods, those who fell into water, those who were swept away and those who drowned as a result of non-aquatic transport incidents. Deaths as a result of these activities represented 83.7% of all river flood-related drowning deaths.

4.4.3.1.1 Falls Into Water

There were 15 drowning deaths as a result of falls into water, 60.0% of which were adults, 73.3% were alone, 27.3% were children and alcohol was known to be involved in 26.7% (100.0% of whom were adults). Common scenarios were children who either fell into floodwaters from the creek/river bank (33.3%) or whilst wading in the water (50.0%). Interestingly, two children were alone when they drowned, whilst another two were with company, however supervision had lapsed. For adults, common scenarios were being alone (72.7%) and falling from the creek/river bank (36.4%), two cases of which involved alcohol (Figure 17).

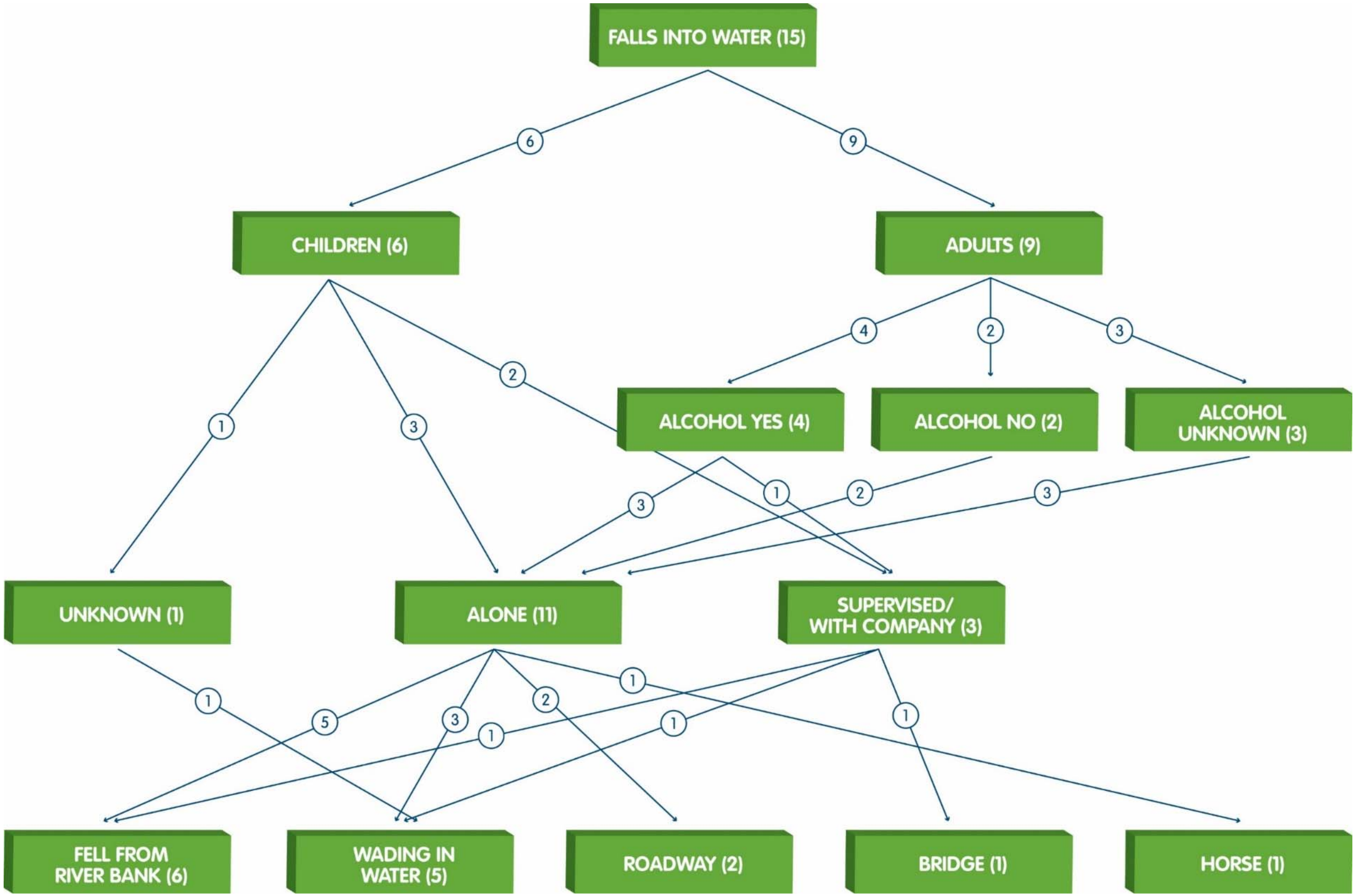

Figure 17: Flood-related drowning deaths as a result of falls into water (n=15)

4.4.3.1.2 Swept Away

Being swept away by floodwaters accounted for 22 drowning deaths between 2002/03 and 2011/12, of which 18 deaths (81.8%) were from one incident (the 2010/11 Queensland floods). In 72.7% of cases the person was unexpectedly swamped by water, commonly in their home (87.5%) and in all cases (100.0%) there was no prior warning of the inundation. For those who intentionally entered floodwaters (27.3%), all (100.0%) entered on foot, with 66.7% of these being swept away by floodwaters whilst crossing a flooded bridge, all of which occurred during periods of slow-onset flooding (100.0%) whilst the victims were trying to get home (100.0%) (Figure 18).

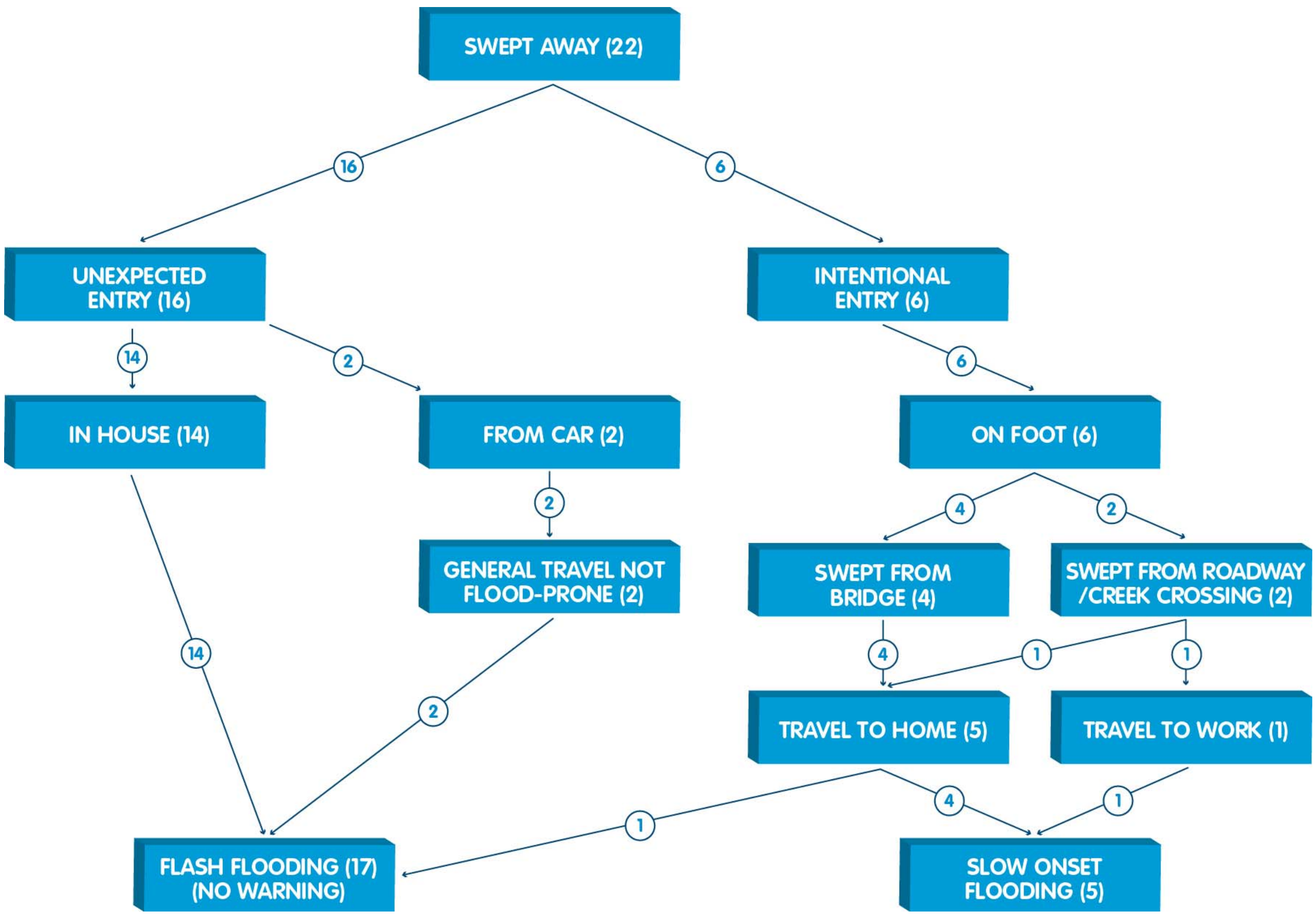

Figure 18: Flood-related drowning deaths as a result of being swept away (n=22)

4.4.3.1.3 Non-aquatic Transport Incidents

There were 71 drowning deaths due to non-aquatic transport incidents, the most common activity being undertaken prior to drowning in river floods. In almost two-thirds (60.0%) of cases those who drowned were the drivers and were alone in the car when they drove into floodwaters. Drivers were most commonly in 4WD vehicles and attempting to reach their home or a friend's home (60.0%). (Figure 19)

Almost two-thirds (60.6%) occurred on roads that were known to be open at the time of the incident. Drivers were alone in the vehicle in 58.3% of road open cases, the remaining 41.7% of drivers drove through floodwaters with passengers in the vehicle. Almost a third (30.2%) of non-aquatic transport victims on open roads were intending to travel to their own home or a friend's home, most commonly in cars (38.5%), utilities (30.8%) and 4WDs (23.1%). Just over a fifth (25.6%) of those who drowned on open roads were intending to travel to work/appointments. All victims driving heavy vehicles or machinery were undertaking paid employment at the time of their drowning. All incidents (100.0%) involving motorbikes/ATVs occurred when the victim was riding for recreation (Figure 19).

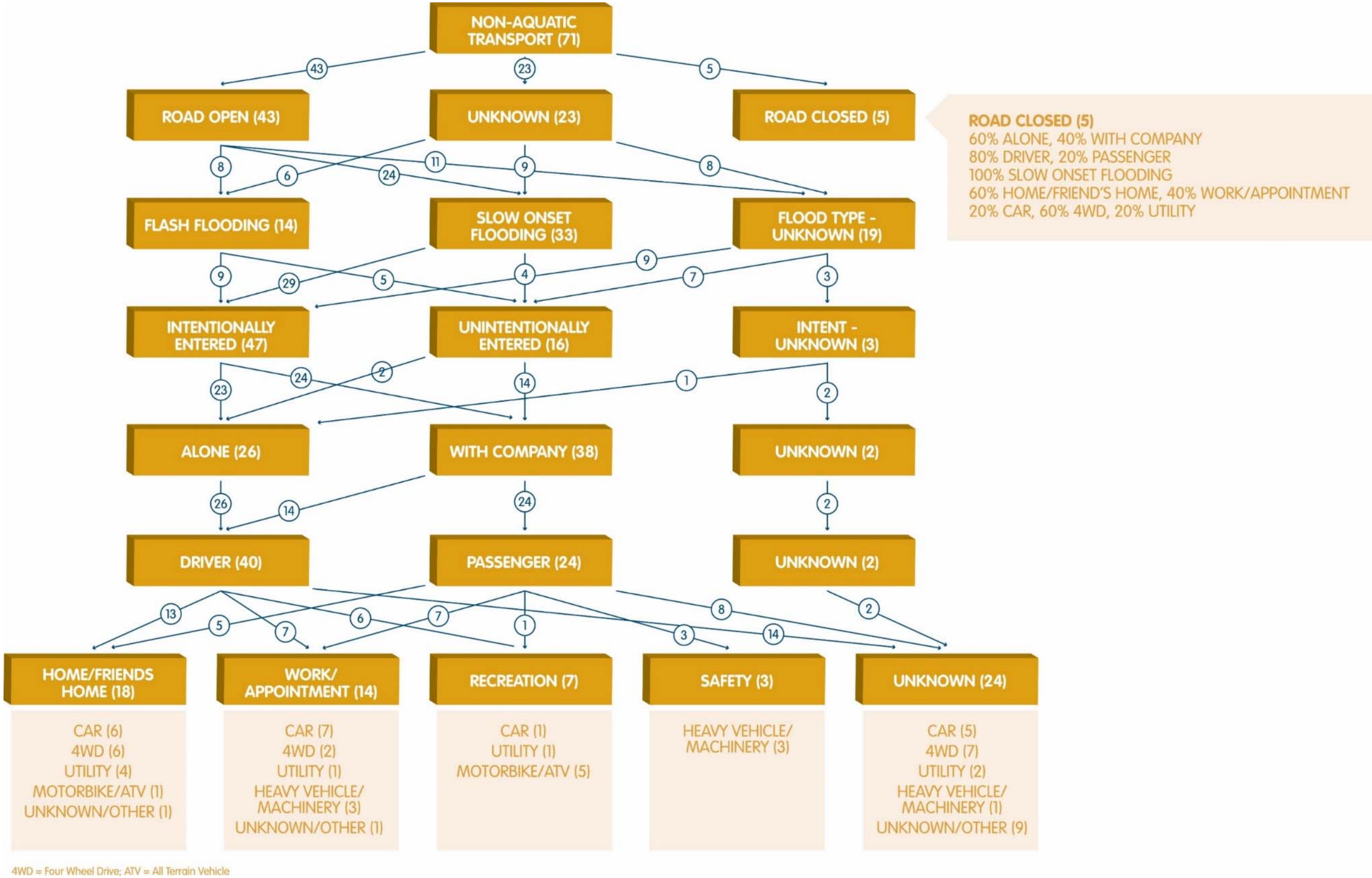

Figure 19: Flood-related drowning deaths as a result of non-aquatic transport incidents (n=71)

4.4.4 Discussion

River flood-related unintentional fatal drownings are a regular occurrence in many countries around the world [240 242 255]. This study, the first to analyse Australian river flooding deaths using coronial data, found those at an increased risk include: males, children and those residing in states prone to tropical rainfall patterns (Northern Territory and Queensland); and those involved in non-aquatic transport incidents or those swept away. Risk factor identification has been shown to be an important tool for developing successful prevention strategies [248 255-257].

4.4.4.1 Understanding Causal Pathways to Inform Prevention

This study uses causal pathway analysis to understand common scenarios leading to drowning and depicts these as flow charts. Similar work has been undertaken to understand causal pathways leading to drowning of young children in home swimming pools [258] and among divers [200].

While not the first to use flow charts to depict flood-related drowning deaths, this study expands on Fitzgerald's [259] work using a flow chart to depict circumstances of flood victims before death. Our study differs in that it uses coronial data (rather than newspaper reports or historical accounts) to examine causal factors for the three leading activities prior to drowning. Fitzgerald's study found almost half (43.8%) of flood fatalities in Australia between 1997 and 2008 were vehicle-related, with crossing a waterway the leading contributor, a finding that is mirrored in this study. Our research reported similar proportions of watercraft related flood drowning (4.4% in Fitzgerald, 4.1% in this study), but a higher proportion of victims being trapped and subsequently swept away by floodwaters (17.1%) with most being trapped in their home (63.6%). Fitzgerald reported zero flood fatalities of this type, with our study reflecting the 2011 mass casualty event in the State of Queensland [194].

Causal factor analysis provides important information about the chain of events leading to river flood-related drowning to inform prevention. The development and implementation of prevention strategies must also consider work beyond epidemiological studies, such as behavioural psychology, to determine motivations underpinning behaviour, such as the decision to drive through floodwaters [121].

4.4.4.2 Challenges Around Definitions of Flooding

A key challenge when conducting analysis of river flood-related drowning deaths is the lack of a consistent definition. This has previously been identified as a limitation in the published literature around defining and isolating river drowning statistics [50]. This study has classified river floods as slow onset or flash flooding; and while attempts have been made to define different types of flooding in the past [242 260], a lack of consistency in terminology and classifications has made the comparison of different studies difficult. This limits the ability to examine how risk differs between types of floods across a range of studies. A consistent set of definitions allows flood type and flood characteristics to be routinely collected at the time of death investigation (primarily by police). This information may then allow for opportunities to predict the severity [242] of flood events to develop and implement evidence based strategies for prevention.

Consistent terms that are then communicated to, and well understood by, those at increased risk, may increase the effectiveness of prevention strategies. Clearly communicated prevention strategies may increase recall and impact on behaviour [261 262] and therefore the likelihood that such activities will be effective in their aim of reducing flood-related drowning.

4.4.4.3 Falls Into Water

A fall into water, although statistically more common when rivers are not in flood, was the third leading category of activity prior to drowning in river floods. Causal factor analysis raises questions regarding the protective nature of supervision, with a third of all children drowning due to falls into flooded rivers whilst with company. In order to be effective, supervision must be focused, continuous and proximate [53]. Drowning prevention strategies aimed at parents and carers of young children must highlight the key elements of effective supervision, including around floodwaters. Floodwater risks to children must be communicated prior to the traditional risk-taking teenage years with the average age of child victims being 8.2 years.

Almost half (44.4%) of all adults who fell into flooded rivers were known to have consumed alcohol prior to drowning. With the contributory role of alcohol having been identified in river drowning deaths in Australia [133], this study highlights the need to ensure flooding is considered in any strategies developed to address alcohol-related river drowning deaths.

4.4.4.4 Swept Away

While being swept away was a significant cause of death, 21 people (17.1% of all river flood-related drowning deaths) in this study drowned in a single flood event in the state of Queensland in 2011 [194]. Victims from this event accounted for 81.8% of all deaths as a result of being swept away. Events such as these are worthy of further examination with extreme weather predicted to increase the likelihood of such events in the future [257]. It is therefore vital that prevention efforts focus on those most at risk during such events.

Half (50.0%) of those who drowned as a result of being swept away were aged 55 years and over, identifying the vulnerability of older people. Almost all (90.9%) of those aged 55 years and over who were swept away by floodwaters, were swept from their house when it was inundated as a result of flash flooding. The 2011 Queensland floods occurred during the day, when older victims, more likely to be retired from the workforce, were home. This event highlights the impact of age related reductions in mobility and chronic conditions on drowning risk during floods [25]. To reduce the risk, including for older people, the implementation and evaluation of prevention strategies such as predictive modelling, early evacuation, the relocation of flood prone communities and improved urban planning to avoid building on floodplains should be considered [194 263 264].

4.4.4.5 Non-aquatic Transport Related Fatal Drowning

Similar to previous studies on drowning deaths in flooded rivers, non-aquatic transport incidents were the most common activities being undertaken prior to drowning [243 259 265 266]. Males are consistently at an increased risk, postulated to be due to greater confidence to drive into floodwaters [267]. For prevention targeting males with effective education and awareness raising messages will be critical. As over half of all females who drowned as a result of non-aquatic transport incidents were passengers in the vehicle education strategies highlighting risk to life for both driver and passengers may be more effective [121].

While trucks and motorcycles accounted for a small proportion of vehicles driven through floodwaters (13.8%) in this study, rates per 100,000 registrations per annum [161] were 4.33 and 3.67 times that of cars (0.13 / 100,000 and 0.11 / 100,000 respectively). This is partially explained by Coles (2008) research where occupants of bigger vehicles are more likely to try to travel across floodwaters [268]. Although registration data are only a proxy for exposure, this highlights the need for education and prevention efforts to be targeted at drivers of such vehicles. Future research should focus on exposure studies [50] to identify those at an increased risk of drowning due to river floods.

Preventing drowning in floodwaters is a challenge and ultimately the most effective strategy is to prevent drivers from crossing flooded roads. In this study only 7% of all deaths were from people traveling on closed roads, as such timely road closures may save lives. Road closures which are automatically based on real time flood water data and are physical in nature (e.g. barriers) [248] are likely to be effective. Providing information about alternative routes and information prior to reaching the flood water to allow for a change of route may also help. Enforcement of closed roads is also important as this helps to reinforce the signage as a means of providing information and may enhance effectiveness.

Prevention may also encompass better urban design, including building infrastructure and bridges to enable safe travel across flood-prone locations. Further research is required to determine effectiveness, and implications for disobeying road closure signage and barriers must be considered. Further work is required to explore other prevention strategies such as enforcing the culpability of those who deliberately drive through floodwaters and put others at risk and the use of regulations to hold driver's liable for costs incurred during their rescue from floodwaters.

4.4.4.6 Prevention

This study has identified a number of risk factors where prevention strategies should be targeted. These include targeting males, those who drive through flooded rivers (particularly truck drivers and motorcycle riders) and those residing in the northern areas of Australia prone to tropical rainfall.

Unlike drowning deaths at coastal locations that commonly involve international tourists [199], all victims who drowned in river floods were Australian residents, the majority of which (83.3%) drowned within 100 km of their residential postcode. It could be postulated that these people were in areas where they are more likely to have "local knowledge" about normal conditions [269], or in the case of non-aquatic transport incidents, on roads they had driven on many times in the past. This mirrors research conducted by Hamilton et al into the key beliefs underpinning people's decisions to drive through floodwaters, which found that people regularly ignore road closed and flood warning signs if they had previous experience of driving on roads that regularly flooded [248 270]. Further qualitative studies that focus on people who reside in flood-prone areas and who have driven through floodwaters may assist in the development of effective prevention strategies for this group that account for the majority of river flood-related drowning victims.

Those who drowned in the Northern Territory and Queensland were at a significantly increased risk for river flood-related drowning, which is related to their tropical climate and wet season. Prevention strategies must consider rainfall patterns and climate differences in order to be better tailored, and therefore relevant, for those at an increased risk. This is evidenced by permanent signage, used in parts of northern Queensland, which shows open and closed roads 50 to 100 km ahead to allow motorists to make decisions about which route to take. This signage is particularly important during the wet season, however the effectiveness of this method has yet to be evaluated.

There is limited evidence regarding the effectiveness of prevention strategies for those who drive through floodwaters. Key prevention strategies currently utilised are low order strategies [145 271], such as signage (road closed and depth markers) and barriers. This study also shows signage appears to be ineffective, with 63.6% of non-aquatic transport incidents in remote and very remote areas known to have occurred on roads that were open at the time of the drowning incident. Signage and detour routes are reactive strategies and hard to enact if authorities do not know if there is water on the road in such isolated locations [272]. Further work is needed to explore how to make signage more effective.

In Australia, the use of the "If it's flooded, forget it" slogan, to discourage people from deliberately entering floodwaters, be it in a car, on foot or for swimming, has been recommended [194]. However this campaign has yet to be evaluated. The motivational factors behind people's decisions to drive through floodwaters must be considered when developing prevention strategies.

There are many challenges associated with effective prevention of river flood drowning deaths. One such challenge is these deaths are reasonably rare in any given location as they are geographically dispersed across the country. Slow onset flooding moves long distances and can affect river systems hundreds and thousands of kilometres from where rainfall occurred, potentially leading those in flood-prone locations to underestimate risk to self and others [141]. Gathering evidence that particular strategies are effective is an ongoing challenge.

4.4.5 Limitations

There may be limitations associated with this study. Firstly, not all flood-related drowning deaths may have been identified. Relying on ICD codes has been found to under-report drowning deaths as a result of flooding [50] and boating accidents [75]. Just over one fifth (20.3%) of cases in this study recorded an unknown for the involvement of flooding. Where the case remained open (i.e. under investigation within the coronial system) there is limited information available on the circumstances of the drowning. A case that is open will also not be coded to ICD 10 coding. With 6.9% of drowning cases open within the coronial system, this paper may under-report the number of drowning deaths as a result of flooding in Australia during this period.

As this study uses data for cases where a coroner must investigate, there is a period of time where there is limited information about the case. Until the case is officially closed by the coroner (i.e. no longer under investigation and a cause of death has been determined) there is minimal data available about the circumstances surrounding the drowning death. The period under analysis has been chosen to minimise incomplete data, however 6.9% of river drowning cases remain open (i.e. under investigation) within the coronial system.

Calculations for crude fatal drowning rates by population of remoteness classifications uses an average from three years 2001, 2006 and 2011 (Population census years in Australia) for population and drowning data from 2002/03 to 2011/12. This may produce rates that are not as accurate as if population data was available for each year of drowning data. These rates were calculated using the 'yes' variable only and therefore some of the unknown cases may be flood-related and this may underestimate the rate.

Alcohol involvement was unknown in 27.9% of river flood-related drowning deaths. This study may therefore underestimate the involvement of alcohol in incidents of fatal drowning during river flooding. The difficulty with retrieving bodies during times of flood may also artificially inflate BAC readings due to rapid decomposition in water [231].

The chi squared analysis in Table 17 was calculated using the yes and no variables for flooding only. The authors are therefore making the assumption that the unknowns would be evenly distributed between the known categories. Relative risk was calculated on only the yes variable for flooding and as such may be impacted by the unknown cases.

The relative risk calculations based on remoteness of drowning location use census population data by remoteness classification for a victim's residential location. It is possible that a victim may have drowned in one remoteness classification but resides (and is therefore counted in population data) in a different remoteness classification. This may therefore have an impact on the accuracy of the relative risk calculations.

4.4.6 Conclusion

Although periods of drought and flood may well be inevitable in many countries, including Australia, fatal drowning does not have to be a by-product of such weather events. Prevention strategies are vital to reducing the needless loss of life during flood disasters. This study identifies key risk factors that must be considered when developing prevention strategies such as communicating the risk of floodwaters to children prior to the teenage years, highlighting the dangers of driving through floodwaters, the need to target people in rural and remote areas with prevention messages, drivers of trucks and motorcycles and those in tropical areas prone to periods of seasonal increased rainfall.

By implementing and evaluating a range of prevention strategies based on evidence, it is hoped that the number of drowning deaths occurring in Australia due to flooding, can be minimised, and ultimately prevented.

Chapter 5: Results Part 2 – Exposure

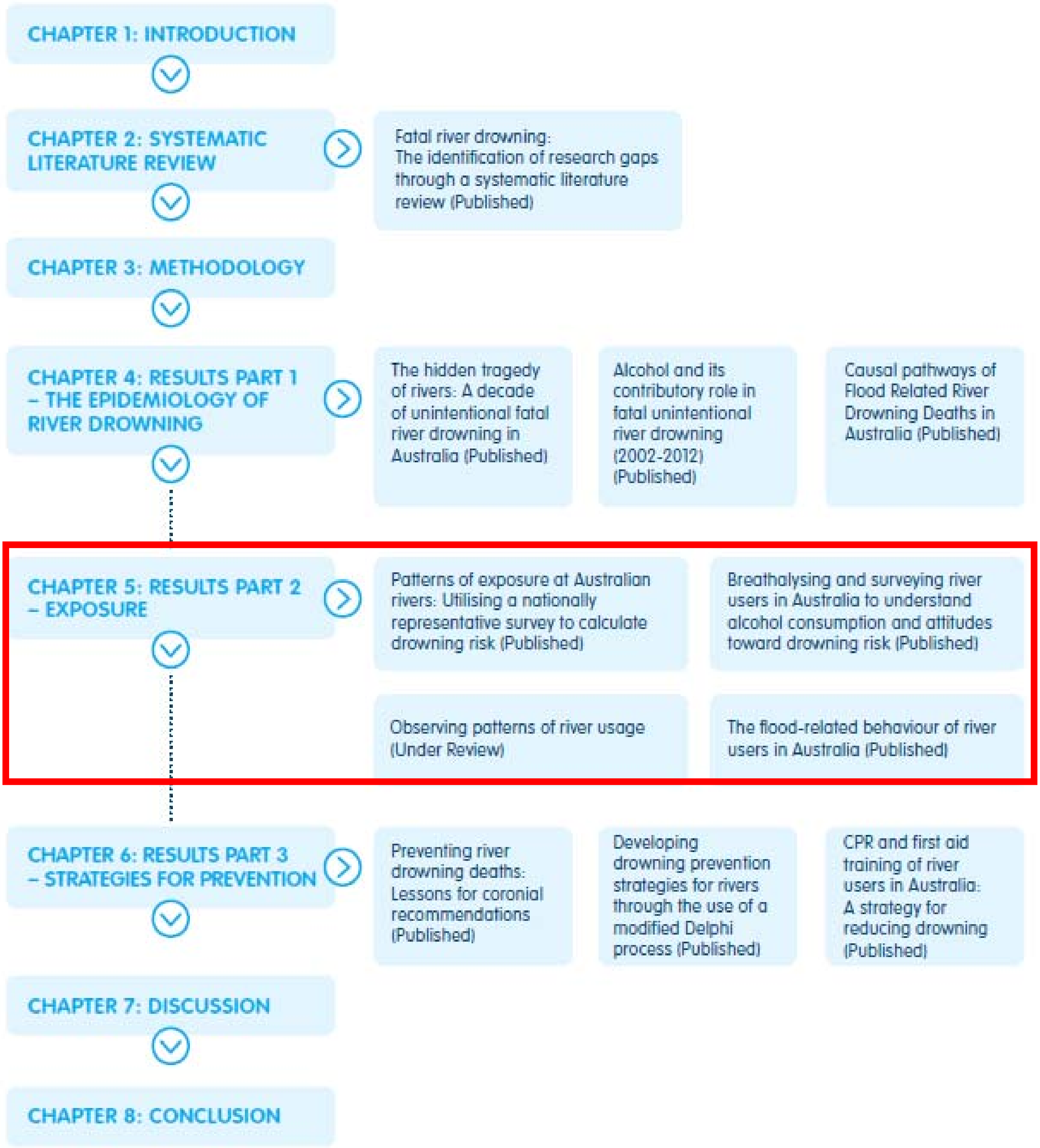

Figure 20: Chapter 5 position within thesis structure

5.0 Overview

Chapter 5 examines the issue of river exposure, including a focus on alcohol consumption at the river and interactions with flooded rivers. Another gap in the published literature, identified by the systematic literature review, was a lack of consideration for the impact of exposure on river drowning risk, with all of the included epidemiological studies publishing rates per 100,000 persons. Building the evidence base on how river drowning risk varies based on exposure, will ensure those at highest risk of drowning in rivers are targeting when developing, implementing and evaluating prevention strategies. These studies continue to build on the public health approach taken by identifying who is at risk and any risk and protective factors. The three papers and one short research article featured in this chapter are reproductions of the peer-reviewed articles.

The first study in this chapter (Paper 5) revises rates per 100,000 persons for river drowning by taking into account river exposure, using nationally representative population level data on river visitation and usage. This study was published in *Injury Prevention* in June, 2018. The full reference for this published study is as follows:

> Peden AE, Franklin RC, Leggat PA (2018) Exploring visitation at rivers to understand drowning risk, *Injury Prevention*, Published Online First: 06 June 2018. doi: 10.1136/injuryprev-2018-042819

The second study in this chapter (Paper 6) details the findings of community surveillance work (comprised of a community survey and breathalysing) of adult river users at four river drowning locations in two Australian states. The study was published open access in *BMC Public Health* in December 2018. The full reference for this published study is as follows:

> Peden AE, Franklin RC, Leggat PA (2018) Breathalysing and surveying river users in Australia to understand alcohol consumption and attitudes toward drowning risk, *BMC Public Health* 18:1393. doi: 10.1186/s12889-018-6256-1

The third study in this chapter (Paper 7) uses data derived from direct observations at the same river locations where the above study was conducted, to examine river visitation and usage by total number of people, total number of males and females, total number of adults and children and total number of people in, on, and beside the water. The reference for this study which is currently under review is as follows:

> Peden AE, Franklin RC, Leggat PA, Lindsay, D (Under Review) Observing patterns of river usage

The fourth study in this chapter (Short Research Article [SRA] 1) uses data collected during the community survey and breathalysing study. This particular short research article examines the flood-related behaviour of river users, in particular examining driving into floodwaters and swimming in flooded rivers. This short research article was published open access in *PLOS Currents Disasters* in June 2018.

The full reference for this published study is as follows:

> Peden AE, Franklin RC, Leggat P. The Flood-Related Behaviour of River Users in Australia. *PLOS Currents Disasters.* 2018 Jun 14 . Edition 1. doi: 10.1371/currents.dis.89e243413a0625941387c8b9637e291b.

5.2 Exploring Visitation At Rivers To Understand Drowning Risk (Paper 5)

Peden AE, Franklin RC, Leggat PA (2018) Exploring visitation at rivers to understand drowning risk, *Injury Prevention*, Published Online First: 06 June 2018. doi: 10.1136/injuryprev-2018-042819

5.2.1 Introduction

Accurately calculating exposure is an important, yet challenging aspect of injury prevention [196]. Using exposure to estimate risk would allow for the development and monitoring of more effective prevention strategies [273]. Determining suitable and accurate methods for calculating exposure is difficult [274]. In road traffic research [275], a range of exposure methods have been used including distance travelled, type of vehicle, number of vehicles on the road, number of trips taken and time spent travelling [276 277]. Such methods can broaden our understanding of different means of calculating and considering exposure. These challenges have, in part, been addressed (for drowning and other injuries) via the use of ad hoc survey data [278-280] and direct observation [281].

The WHO Global Report on Drowning estimates drowning claims 372 000 lives annually [17]; however, the methodology used is likely to underestimate the actual number of deaths [14]. While the epidemiology and risk factors for drowning are increasingly being described, exposure to risk and how that varies based on location is an area where research is lacking [50 273]. Previous studies have attempted to calculate exposure and drowning risk at beaches [279 281 282], for boaters [198], rivers in King County (USA) [283] and as a result of various activities including fishing, rock fishing and swimming [196]. Methods used include qualitative telephone surveys [94 196 282-284], observations [281 283], aerial surveys [283], remote camera observations[283] and one-on-one interviews [198 283 285].

Surveys have been used to explore alcohol consumption patterns around water [280], the role of different activities in non-fatal drownings of young adults [285] and to explore visitation at different categories of aquatic location for residents of rural and remote areas in the Australian state of New South Wales [112]. A recently proposed alternative method of calculating exposure has been to compare drowning rates per 100,000 persons with rates per 100,000 km^2 of water [286].

Despite such studies at Australian beaches, there have been no specific exposure studies into drowning at Australian rivers, regardless of the fact that rivers claim over one-quarter of all lives lost to drowning, more than any other location [50 132]. While the risk profile for unintentional fatal drowning in rivers is becoming increasingly understood [133 134], there is a need for exposure studies [50] to better inform much needed strategies for prevention. This study aims to examine how river drowning death rates vary when adjusted for exposure.

5.2.2 Methods

5.2.2.1 Data Collection and Analysis

5.2.2.1.1 Drowning Deaths in Rivers

Data on unintentional fatal drowning in Australian rivers, creeks and streams (henceforth referred to as rivers) among people aged 18 years and over between 1 January 2014 and 31 December 2016 were sourced through privileged access to the Australian NCIS. The process for identifying cases of unintentional fatal river drowning in Australia has been previously outlined [132-134]. Drowning deaths as a result of flooding were excluded as were not related to recreational activities undertaken in, on or beside rivers for the purposes of calculating exposure-based rates. Drowning deaths of international tourists (i.e., no residential address in Australia) and children (aged 0–17 years) were removed as they were not surveyed.

Drowning data on sex, age group, activity prior to drowning, alcohol involvement and watercraft usage were used to calculate drowning rates. Alcohol involvement was coded as a 'yes' if the victim's BAC was ≥0.05%. As BAC readings of river drowning victims may be impacted by decomposition, [189] this marker (≥0.05% the upper legal limit for operating a motor vehicle in all Australian states and territories and powered watercraft in most states and territories) was used to account for this. Where there was no BAC available (no body found, toxicology test not undertaken or toxicology report not attached to case file on the NCIS), this was deemed unknown.

5.2.2.1.2 River Exposure Data

Data on people's exposure to rivers were sourced through a national computer-assisted telephone instrument (CATI) survey administered by Central Queensland (CQ) University [168]. Based on an omnibus model, this survey uses cost-sharing participation, allowing researchers to embed a set of questions based on their specific research interests into a survey which collects data from a sizeable national sample. Researchers receive responses to their questions, as well as the core dataset of demographic and health variables.

The survey represents the geographical dispersion of the population of Australia, based on state and territory of respondent's residence. The final sample contained a reasonably equal number of males and females (54.3% female). The sampling error for the total sample (n=1318) at a 95% CI was 0.027. The survey was conducted between 6 July 2015 and 14 August 2015.

The river usage questionnaire was developed specifically for this study by authors AEP and RCF. Respondents were asked if they had visited a river, creek or stream location within the last 12 months. If yes, the respondent continued on to the remaining questions about frequency of visitation, time spent at rivers, main activities being undertaken, alcohol consumption and watercraft usage. The question pertaining to watercraft usage categorises watercraft as any of the following: powered boat, canoe, jet-ski, kayak, paddleboard, water skiing, tubing, houseboat, etc. The questionnaire was pilot tested by trained interviewers on a total of 40 randomly selected households prior to broader data collection. Interviewer comments (such as confusing wording, inadequate response categories and question order effect) and pre-test frequency distributions were reviewed before modifications were made. There were no modifications required for the river usage question set. Face validity was not confirmed.

De-identified responses were provided to the authors in an SPSS database. The main activities undertaken at rivers were provided via an open response question. These were initially coded into 11 categories or recorded as other/text (n=214) by CATI interviewers. This information was then recoded (by consensus by authors AEP and RCF) into five categories to match those used to describe drowning deaths. These activities prior to fatal drowning were non-aquatic activities (i.e., those activities which did not involve interaction with the water such as walking beside the water, having a picnic, etc); fishing; swimming and recreating; watercraft and other. There remained 38 (17.8%) responses from the initial 'other' category that could not be recoded to the four groups. The activity prior to drowning categories and corresponding CATI survey activity categories can be seen in Table 19.

Table 19: Drowning death activity categories and corresponding Computer-Assisted Telephone Instrument (CATI) survey activity categories

Fatal river drowning data categories for activity immediately prior to drowning	**CATI survey activity at river categories**
Falls	Recreating near water, walking beside the water, picnic, riding a bike beside the water
Fishing	From a boat, from water's edge, from water's edge and wading in water
Swimming and Recreating	Swimming, wading, diving and general recreation in water
Watercraft	Jet ski, water ski, canoe and kayaking
Other (Other)	Other
Unknown	-

5.2.2.1.3 Statistical Methods

This study used descriptive, retrospective, population-based analysis. River drowning rates per 100,000 adult (aged 18 years and older) population were calculated using the total number of drowning deaths between 2014 and 2016 as the numerator and the total population during 2014–2016 as the denominator. This 3-year period was chosen as being the year the CATI survey was conducted (2015) as well as a year either side of this to account for yearly variations in fatalities.

For river drowning rates based on exposure, the numerator remained the same and the proportional basis of the population (as determined by the CATI survey results) were used as the denominator. These rates were also stratified by sex, sex and age group, activity undertaken and activity by sex, alcohol presence by sex and age group and watercraft usage by sex and males by age group only. Population data were sourced using the ABS population data cubes for the month of June for 2014, 2015 and 2016 [160].

Data coding and analysis was conducted in SPSS V.20 [157]. Univariate and X^2 analysis (with 95% CI) were used. A modified Bonferroni test suggested by Keppel [159] has been applied ($p<0.01$). Non-parametric X^2 analysis was also conducted using the proportional basis of the population as the assumed outcome numbers. Relative risk (RR) was calculated using the MedCalc statistical software

[287]. Variable analysis which produced less than four cases will be concealed using 'not presented' in adherence with ethical requirements.

5.2.3 Results

5.2.3.1 River Drowning Deaths

There were 195 drowning deaths in rivers in Australia during the study period. Of these, 16 (8.2%) were children (0–17 years of age) and 28 (14.4%) were international tourists. Once removed, 151 drowning deaths of adults aged 18 years and older with an Australian residential postcode remained (86.4% male). Male to-female ratio remains constant by age group, activity and blood alcohol presence. Twenty-nine per cent of all river drowning deaths involved alcohol (Table 20). In a further 23.2% of cases (n=35), alcohol involvement was unknown.

Table 20: Fatal adult river drowning victims by sex, age group and activity immediately prior to drowning, 2014-2016 (N=151)

	Total		Male		Female		X^2 (p value)
	N	%	N	%	N	%	
Total	151	100.0	133	86.4	18	11.7	89.438 (p<0.001)
Age Group							
18-34 years	60	39.7	56	93.3	4	6.7	2.617 (p=0.106)
35-54 years	48	31.8	41	85.4	7	14.6	0.475 (p=0.491)
55-74 years	32	21.2	25	78.1	7	21.9	3.832 (p=0.050)
75+ years	11	7.3	11	100.0	0	0.0	1.606 (p=0.205)
Activity immediately prior to drowning #							
Falls	31	20.5	29	93.5	2	6.5	0.046 (p=0.831)
Fishing	2	1.3	2	100.0	0	0.0	0.161 (p=0.689)
Swimming and Recreating	37	24.5	32	86.5	5	13.5	2.996 (p=0.083)
Watercraft	31	20.5	30	96.8	1	3.2	1.023 (p=0.312)
Other *	22	14.6	21	95.5	1	4.5	0.303 (p=0.582)
Unknown	28	18.5	19	67.9	9	32.1	-
Alcohol (BAC ≥0.05%) #							
Yes	44	29.1	41	93.2	3	6.8	0.088 (p=0.767)
No	72	47.7	66	91.7	6	8.3	
Unknown	35	23.2	26	74.3	9	25.7	-

* Please note: The 'Other' category of aquatic activity being undertaken immediately prior to drowning includes activities such as non-aquatic transport (all excluding bicycles), swept away and jumped in. # Analysis excludes the Unknown variable.

5.2.3.2 Survey Findings

Of the 1318 survey responses, 73.3% of respondents had visited a river within the last 12 months. Males (74.7%) and females (72.2%) visited a river in similar proportions, with people aged 35–54 years reporting the highest visitation numbers. Activities that were non-aquatic in nature were the most commonly undertaken activities (71.4%). A higher proportion of females participated in non-aquatic activities (X^2=19.0; p<0.001), whereas males were more likely to fish (X^2= 11.5; p=0.001) (Table 21).

Forty-five per cent of respondents visited a river once in the last 12 months, or once every 3 months. When visiting a river, 51.3% spent between 1 and 5 hours at the river. Nine per cent (9.5%) of visitors stayed 24 hours or more (overnight). Those who reported visiting the river everyday most commonly spent <1 hour (X^2= 83.1; p<0.001). Those aged 75+ years were more likely to stay at a river for <1 hour (X^2= 21.5; p=0.001). Approximately one-quarter (25.6%) of those attending rivers used watercraft.

Males were significantly more likely to consume alcohol at rivers (X^2= 9.2; p=0.002) (Table 21). Those who reported consuming alcohol were more likely to use watercraft (X^2=60.1; p<0.001) and stay 24 hours or more at rivers (i.e., overnight) (X^2= 85.7; p<0.001).

Table 21: CATI Survey results by sex and visitation at a river, creek or stream, frequency of visitation, duration of visit, main activity being undertaken, use of watercraft and consumption of alcohol, Chi Square (p value), 18+ years, Australia, 2015 (N=1,318)

	Total			Male		Female		X^2 (p value)by sex
	N		%	N	%	N	%	
Total	1,318		100.0	602	45.7	716	54.3	6.928 (p=0.008)
Have you visited a river, creek or stream within the last 12 months? (n=1,316)*								
Yes	965		73.3	449	46.5	516	53.5	1.078 (p=0.299)
Visitation at river, creek or stream within the last 12 months by age group (n=1,304) *#								
18-34 years (n=253)	Yes	185	73.1	97	52.4	88	47.6	0.303 (p=0.582)
35-54 years (n=405)	Yes	316	78.0	142	44.9	174	55.1	4.343 (p=0.037)
55-74 years (n=523)	Yes	393	75.1	171	43.5	222	56.5	0.691 (p=0.406)
75+ years (n=123)	Yes	64	52.0	36	56.3	28	43.8	1.822 (p=0.177)
How often did you visit a river, creek or stream in the last 12 months? (n=960)								
Once to once every three months	436		45.4	200	45.9	236	54.1	0.111 (p=0.740)
Once a month to once a week	344		35.8	169	49.1	175	50.9	1.536 (p=0.215)
Twice a week or more	180		18.8	77	42.8	103	57.2	1.206 (p=0.272)
When you visited a river, creek or stream, how many hours on average did you stay there? (n=961)								
Less than one hour	330		34.3	150	45.5	180	54.5	0.324 (p=0.569)
One to five hours	493		51.3	231	46.9	262	53.1	0.007 (p=0.932)
Six to twenty three hours	47		4.9	23	48.9	24	51.1	0.097 (p=0.755)
Twenty four hours or more	91		9.5	45	49.5	46	50.5	0.301 (p=0.584)
What was the main activity you undertook whilst visiting a river, creek or stream? (n=963)***								
Non-aquatic activities	688		71.4	290	42.2	398	57.8	18.991 (p<0.001)
Fishing	112		11.6	69	61.6	43	38.4	11.534 (p=0.001)
Swimming and Recreating	62		6.4	28	45.2	34	54.8	0.052 (p=0.819)
Watercraft	72		7.5	43	59.7	29	40.3	5.418 (p=0.020)
Other	29		3.0	19	65.5	10	34.5	4.318 (p=0.038)
In the past 12 months when you visited a river, creek or stream did you consume any alcoholic beverages? (n=961)								
Yes	154		16.0	89	57.8	65	42.2	9.201 (p=0.002)
In the past 12 months when you visited a river, creek or stream have you used any sort of watercraft? (n=962)								
Yes	246		25.6	126	51.2	120	48.8	2.872 (p=0.090)

* Please note: total excludes those responses (n=2) that stated they didn't know. ** Please note total excludes responses (n=5) where people did not specify how often they visited a river. ***Please note total excludes those responses (n=2), one male, one female, that did not specify the main activity they undertook when they visited a river. # Excludes the 12 people who did not specify their age.

5.2.3.3 Adjusting For Exposure

Males drown at a rate that is 7.6 times that of females, however females reported slightly lower exposure to rivers (72.1% compared with 74.6% for males) meaning the exposure adjusted rate of female drowning increased from 0.06 to 0.09). When adjusting for exposure, the fatal drowning rate for males aged 75+ years moves from 0.55 to 0.95, representing an RR that is slightly higher (RR=1.1; 95% CI 0.6 to 2.1) than that of males aged 18–34 years. Females aged 55–74 years recorded the highest rate of female river drowning (0.10), increasing to a rate of 0.13 per 100 000 exposed. This represents an RR one and a half times (RR=1.5; 95% CI 0.44 to 5.2) that of females aged 18–34 years (Table 22).

After adjusting for exposure, the RR for swimming and recreating increased from 1.2 to 12.4 when compared with the risk of a fall from a non-aquatic activity (RR=12.4; 95% CI 7.7 to 20.0). The RR for swimming and recreating increased by a factor of 9 for males (RR=1.10–10.59) and 11 times for females after adjusting for exposure (RR=2.50–28.00) (Table 23).

After adjusting for exposure, the male rate of alcohol-related river drowning increased from 0.15 to 1.00/100 000. Males were eight times (RR=8.5; 95% CI 2.6 to 27.4) more likely to drown with alcohol present in their bloodstream than females. For males aged 18–35 years, after adjusting for exposure, the rate of alcohol-related river drowning increases from 0.20 to 0.97 and from 0.11 to 0.76 per 100,000 exposed for males aged 55–74 years. Females aged 55–74 years had the largest change in alcohol-related river drowning rates after adjusting for exposure, 0.01–0.14 per 100 000 (Table 24).

The RR of drowning as a result of a watercraft-related incident when comparing males with females, decreased from 30 times (RR=30.0; 95% CI 4.1 to 220.0) to 25 times (RR=25.5; 95% CI 3.5 to 186.9) after adjusting for exposure (Table 25).

Table 22: River Drowning Deaths by sex, sex and age group, rate per 100,000 persons and relative risk (RR) with 95% confidence interval (CI)

	Unintentional drowning deaths 2014-2016 (N)	Australian Population 2014-2016 (N)	River drowning rate per 100,000 persons	Relative Risk (RR) *	Confidence Interval (CI)	Proportion of population who visit a river (%)	River drowning rate per 100,000 persons exposed	Relative Risk (RR)	Confidence Interval (CI)
Total	151	55,459,827	0.27	-	-	73	0.37	-	-
Total by sex									
Female	18	28,194,627	0.06	1	-	72	0.09	1	-
Male	133	27,265,200	0.49	7.64	4.67-12.50	75	0.65	7.34	4.48-12.00
Male by age group									
18-34 years	56	8,832,199	0.63	1	-	75	0.85	1	-
35-54 years	41	9,433,808	0.43	0.69	0.46-1.03	83	0.52	0.62	0.41-0.93
55-74 years	25	6,994,201	0.36	0.56	0.35-0.90	73	0.49	0.58	0.36-0.93
75+ years	11	2,004,992	0.55	0.87	0.45-1.65	58	0.95	1.12	0.59-2.14
Female by age group									
18-34 years	4	8,677,569	0.05	1	-	72	0.06	1	-
35-54 years	7	9,643,498	0.07	1.57	0.46-5.38	74	0.10	1.53	0.45-5.23
55-74 years	7	7,230,294	0.10	2.10	0.61-7.17	77	0.13	1.51	0.44-5.17
75+ years	0	2,643,266	0.00	UTBC	UTBC	46	0.00	UTBC	UTBC

* Females and the 18-34 years age group have been used as the reference groups when calculating relative risk.

Table 23: River drowning deaths by activity and sex, rate per 100,000 persons and relative risk (RR) with 95% confidence interval (CI)

	Unintentional drowning deaths 2014-2016 (N)	Australian Population 2014-2016 (N)	River drowning rate per 100,000 persons	Relative Risk (RR) *	Confidence Interval (CI)	Proportion of population who visit a river (%) and undertake this activity	River drowning rate per 100,000 persons exposed	Relative Risk (RR)	Confidence Interval (CI)
Total by activity being undertaken									
Non-aquatic activities	31	55,459,827	0.06	1	-	52	0.11	1	-
Fishing	2	55,459,827	0.00	0.06	0.02-0.27	8	0.05	0.42	0.10-1.75
Swimming & Recreating	37	55,459,827	0.07	1.19	0.74-1.92	5	1.33	12.41	7.70-20.00
Watercraft	31	55,459,827	0.06	1.00	0.61-1.65	5	1.12	10.40	6.32-17.11
Other	22	55,459,827	0.04	0.71	0.41-1.23	2	1.98	18.45	10.68-31.87
Unknown/No response	28	55,459,827	0.05	0.90	0.54-1.51	-	-	-	-
Male by activity									
Non-aquatic activities	29	27,265,200	0.11	1	-	48	0.22	1	-
Fishing	2	27,265,200	0.01	0.07	0.02-0.29	11	0.07	0.30	0.07-1.26
Swimming & Recreating	32	27,265,200	0.12	1.10	0.67-1.82	5	2.35	10.59	6.41-17.51
Watercraft	30	27,265,200	0.11	1.03	0.62-1.72	7	1.57	7.09	4.26-11.82
Other	21	27,265,200	0.08	0.72	0.41-1.27	3	2.57	11.59	6.61-20.32
Unknown/No response	19	27,265,200	0.07	0.66	0.37-1.17	-	-	-	-
Female by activity									
Non-aquatic activities	2	28,194,627	0.01	1	-	56	0.01	1	-
Fishing	0	28,194,627	UTBC	UTBC	UTBC	6	UTBC	UTBC	UTBC

Swimming & Recreating	5	28,194,627	0.02	2.50	0.49-12.89	5	0.35	28.00	5.43-144.32
Watercraft	1	28,194,627	0.00	0.50	0.05-5.51	4	0.09	7.00	0.63-77.20
Other	1	28,194,627	0.00	0.50	0.05-5.51	1	0.35	28.00	2.54-308.80
Unknown/No response	9	28,194,627	0.03	4.50	0.97-20.83	-	-	-	-

Note: Falls have been used as the reference group when calculating relative risk.

Table 24: Alcohol-related river drowning deaths by sex and age group, rate per 100,000 persons and rate per 100,000 persons exposed, relative risk (RR) with 95% confidence interval (CI)

	Unintentional drowning deaths involving alcohol (≥0.05%) 2014-2016 (N)	Deaths involving alcohol (≥0.05%) as proportion of total	Australian Population 2014-2016	Alcohol-related river drowning rate per 100,000 persons	Relative Risk (RR) *	Confidence Interval (CI)	% of people who consume alcohol when they visit a river	River drowning rate per 100,000 persons exposed to consuming alcohol at a river	Relative Risk (RR)	Confidence Interval (CI)
	Total									
	44	29	55,459,827	0.08	-	-	16	0.50	-	-
Total by sex										
Female	3	17	28,194,627	0.01	1	-	9	0.12	1	-
Male	41	31	27,265,200	0.15	14.13	4.38-45.64	15	1.00	8.48	2.63-27.38
Male by age group										
18-34 years	18	32	8,832,199	0.20	1	-	21	0.97	1	-
35-54 years	15	37	9,433,808	0.16	0.78	0.39-1.55	29	0.55	0.56	0.28-1.12
55-74 years	8	25	6,994,201	0.11	0.56	0.24-1.29	15	0.76	0.79	0.34-1.81
75+ years	0	0	2,004,992	0.00	UTBC	UTBC	6	0.00	UTBC	UTBC
Females by age group										
18-34 years	1	25	8,677,569	0.01	1	-	14	0.08	1	-
35-54 years	1	14	9,643,498	0.01	0.90	0.06-14.39	17	0.06	0.74	0.05-11.85
55-74 years	1	14	7,230,294	0.01	1.20	0.08-19.19	10	0.14	1.68	0.11-26.89
75+ years	0	0	2,643,266	0.00	UTBC	UTBC	4	0.00	UTBC	UTBC

* Females and the 18-34 years age group have been used as the reference groups when calculating relative risk.

Table 25: Watercraft-related river drowning deaths by sex and males by age group, rate per 100,000 persons and rate per 100,000 persons exposed, relative risk (RR) with 95% confidence interval (CI)

	Unintentional drowning deaths as a result of watercraft incidents 2014-2016 (N)	Deaths as a result of watercraft incidents as proportion of total	Australian Population 2014-2016	Watercraft related river drowning rate per 100,000 persons	Relative Risk (RR) *	Confidence Interval (CI)	% of people who visit a river and use watercraft	River drowning rate per 100,000 persons exposed through watercraft usage	Relative Risk (RR)	Confidence Interval (CI)
Total by sex										
Female	1	6	28,194,627	0.00	1	-	23	0.02	1	-
Male	30	23	27,265,200	0.11	30.00	4.09-219.99	28	0.39	25.48	3.48-186.87
Males by age group										
18-34 years	7	13	8,832,199	0.08	1	-	39	0.20	1	-
35-54 years	10	24	9,433,808	0.11	1.34	0.51-3.51	30	0.35	1.74	0.66-4.57
55-74 years	9	36	6,994,201	0.13	1.62	0.60-4.36	22	0.58	2.88	1.07-7.73
75+ years	4	36	2,004,992	0.17	2.52	0.74-8.60	22	0.91	4.46	1.31-15.24

* Females and the 18-34 years age group have been used as the reference groups when calculating relative risk.

5.2.4 Discussion

Exposure is complex and challenging to calculate [50 198 276 278], particularly in dynamic environments such as rivers [198], where people move in and out of the water and multiple activities are undertaken. This study explored river exposure by activity to establish improved estimates of drowning risk. In Australia, 73% of the adult population visits a river at least once in a 12-month period, most commonly for non-aquatic activities. Even after adjusting for exposure, males still have a higher rate of drowning in rivers than females, posing challenges for prevention.

5.2.4.1 Calculating Exposure

There are a multiplicity of factors which impact exposure at rivers including number and duration of visit and type and duration of activities undertaken. People spend different lengths of time undertaking activities in, out, near and away from the water, as well as a varying numbers of visits. CATI surveys are a popular option among researchers to gather population-level data [288], however they are not without their limitations [173]. In using a CATI survey to calculate river-exposed drowning risk, the authors found it was challenging for respondents to recall length of time spent performing an activity, especially when undertaking multiple activities. Respondents were asked to nominate the main activity they undertook; however, as people often undertook multiple activities, results present the minimum number of people who undertook that activity. This therefore means that activity-based rates presented represent the maximum possible due to only one activity being recorded. Similar issues were faced by other exposure-based research where self-reported visitation and activity data may suffer from recall bias [196 289]. Observational research, including novel strategies such as aerial surveys and remote camera observations [283], may add greater detail and overcome some of the methodological constraints, but is not without its own limitations [290].

Rivers present the challenge of having three types of exposure; namely beside the river (e.g. walking, picnicking and fishing from the river bank), in the river (e.g. swimming and recreating) and on the river (e.g. using watercraft). Questions remain regarding how activity and distance of activity from river (e.g. walking beside the river vs picnicking) impact risk. It is not known what a safe distance from the river is and how this differs based on type of river and geography of the location. Similarly, watercraft usage changes risk, so too does boat size [291], powered or unpowered [292], seat position in the boat [293], lifejacket wear [292 294] and alcohol consumption [133 198]. A constraint of this study is that watercraft usage was combined in the CATI survey and used to calculate rates. Further research, potentially in the form of observational studies, exploring watercraft usage at rivers, is warranted.

5.2.4.2 Exposure and Sex

Males make up 80% of drowning statistics worldwide [17], in Australia [35] and in Australian rivers [132]. There was no difference in visitation between males and females at rivers, however the female drowning rate increased by 50% when adjusting for exposure. While exposure explains a small amount of the variation in drowning rates between males and females, visitation alone based on any time in the last 12 months is not a predictor of drowning risk and further work needs to be undertaken in developing a more sensitive measure of self-reported exposure to rivers.

A rationale for the variation between males and females may be the activity undertaken and the location of that activity, males have been identified as undertaking risky behaviours [295 296] and visiting unsafe locations [132 297]. Even at a young age, males are identified as having lower levels of water safety knowledge [298] and poorer swimming skills [299] than their female peers. Further research is required to examine behaviours and attitudes towards safety of female river-goers and how this differs from males.

5.2.4.3 Alcohol

Alcohol is widely consumed across Australia (9.70 L of pure alcohol consumed per capita in 2016) [300] and is a known risk factor for drowning. Twenty-nine per cent of the deaths in this study had a BAC≥0.05% [133], whereas the proportion reporting drinking at rivers was 16%. Based on these findings, drinking at rivers appears to increase drowning risk by 1.8 times (RR=1.8; 95% CI 1.05 to 3.12). It should be noted that alcohol was present in 314 (41%) river drowning deaths [133], however this may also include a build-up of alcohol due to decomposition [189].

Alcohol consumption impacts the risk of injury or death due to the way people interact with the water and the physiological effects on the body [187]. The location of the river, as well as activity being conducted may also impact on alcohol consumption and risk. It is unclear if needing to drive a motor vehicle to the river (or operate watercraft once at the river) impacts on alcohol consumption, however even if the driver does not drink, passengers may consume alcohol, potentially at higher levels, although this assumption needs further testing in the field.

This study identified challenges associated with quantifying alcohol-related drowning risk; in particular understanding location- specific alcohol use, activities undertaken while or immediately after consuming alcohol and the self-reported nature of alcohol consumption. This may impact the accuracy of the exposure-adjusted alcohol-related river drowning rates presented in this study. Future research with different methodological approaches (such as population-based case-control studies [198]) will be required to help fully understand the role and impact of alcohol on drowning risk at rivers.

Alcohol has also been identified as a significant risk factor for drowning (both in rivers and other aquatic locations) in other high-income countries, such as Canada [301], Sweden [302], Finland [220], the

USA [280] and New Zealand [295]. Exposure studies in such countries should also be conducted in order to explore whether drinking alcohol at rivers increases drowning risk.

5.2.4.4 Future Research: Validating Findings in the Field

There are thousands of kilometres of rivers where people recreate and more work needs to be done in understanding how people are using these spaces. A river user may visit a particular river or spot on the river for boating or water skiing and a different location for swimming, for example, all of which impact risk. This study provides exposure information at a population level, noting the challenges associated with self-reporting [288].

Further community-based research in the form of prospective studies is required, such as using diaries or mobile applications to collect visitation and participation data direct from the community or validating this study's findings in the field at known river drowning locations [50]. Other technological solutions for conducting observational studies, such as aerial surveys and remote camera observations may also be explored [283]. Developing a set of common variables for river exposure studies will be important both in Australia and internationally, to allow for comparison between and across studies, to enhance our knowledge of river usage and safety.

5.2.4.5 Strengths and Limitations

This study is the first to examine river exposure on a national basis. The survey tool was nationally representative allowing for broader extrapolation to the Australian public. By combining survey data with a total population survey of fatalities in the year immediately before, during and after the survey was conducted, this study provides more accurate river drowning rates, both overall and by subpopulation, to better inform river drowning prevention efforts.

Given the high burden of river drowning internationally, and the lack of published data on river exposure, this study has global relevance, especially in high-income and middle-income countries, where there is significant recreational aquatic activity.

There are, however, limitations associated with this study. The CATI survey collects self-reported responses and has the limitations of self-reported data. The survey is cross-sectional in nature and therefore, different studies are needed to support causality. The survey also asks respondents to reflect on their behaviour within the last 12 months, which may introduce recall bias. The CATI survey data were collected between 6 July 2015 and 7 August 2015, being the winter season in Australia which may have impacted on the answers respondents gave. Information on race and ethnicity was not collected in the survey and is poorly reported in the coronial data placing further limitations on revising river drowning risk based on exposure for different ethnicities. This is an area that warrants further attention. Information on type of watercraft was not collected by the survey tool and therefore further refined fatal drowning rates based on different types of watercraft were not able to be calculated. As risk may differ based on watercraft type, this is also an area worthy of further research.

Analysis of activity by age group beyond watercraft incidents for males was not undertaken. Given the high exposure-adjusted rates of fatal river drowning for females aged 55–74 years and males 75 years and older, this warrants further research to better inform prevention efforts among these age groups.

Available data on unintentional drowning fatalities for the 3 years used to calculate risk ratios may not offer all details on the circumstances of the drowning. As 15.2% of cases remained open (i.e. under investigation), information may change pending the outcome of coronial investigations.

5.2.5 Conclusion

The findings of this study present, for the first time, nationally representative data on river exposure in Australia. When combined with data on unintentional fatal drowning in Australia, a clearer understanding of those at increased risk appears. This study has identified those at highest risk are males, in particular those aged 75 years and older and females aged 55–74 years. Such findings should be considered when developing prevention strategies and in undertaking advocacy for prevention among target groups.

5.3 Breathalysing and Surveying River Users in Australia to Understand Alcohol Consumption and Attitudes Toward Drowning Risk (Paper 6)

Peden AE, Franklin RC, Leggat PA (2018) Breathalysing and surveying river users in Australia to understand alcohol consumption and attitudes toward drowning risk, *BMC Public Health* 18:1393. doi: 10.1186/s12889-018-6256-1

5.3.1 Background

Alcohol is a known risk factor for drowning (both fatal and non-fatal) and aquatic-related injury [187 218 237 303] with up to 41% of river drowning deaths involving alcohol [133]. Alcohol disproportionately affects drowning risk in males [295 302 304], boating-related incidents [132 198 218 301], natural waters [301 302], and among Indigenous populations [133]. Globally, drowning is estimated to claim the lives of 372,000 people per annum [17], a statistic that is likely to under-report the true burden [14]. In Australia, an average of 281 people per year die from unintentional drowning. While the fatal drowning rate has reduced by 28% in Australia since 2002/03 [49], largely driven by reductions among children under five [305], the number of people drowning in rivers has stayed persistently high [35 132].

In Australia, between 2002/03 and2011/12, an average of 289 people died in Australia due to unintentional drowning [132]. Common fatal drowning scenarios in Australia include young children drowning unsupervised in bathtubs [306] and swimming pools [305] and adult males drowning in natural waterways such as beaches, oceans and in rivers [35] due to alcohol, pre-existing medical conditions [25] and not wearing a lifejacket [294]. Rivers are the leading location for drowning in Australia [132] with leading activities being undertaken prior to drowning including accidental falls into water (21.3%), non-aquatic transport incidents (commonly driving a motor vehicle into floodwaters) (18.2%) and swimming (16.2%). Alcohol is a known risk factor for unintentional fatal drowning in rivers in Australia, with the average adult drowning victim who had consumed alcohol prior to death recording a BAC of 0.200% [133], a figure which is four times the upper legal limit for operating a motor vehicle and powered vessel in Australia [232].

Australia is a country with widespread alcohol consumption [307]. In 2017, 37% of Australians reported drinking alcohol on a weekly basis, almost one in five (17%) exceed the lifetime alcohol risk guidelines (more than two standard drinks per day) and 16% drink at hazardous levels (i.e. usually consuming four or more standard drinks per day) [308]. Alcohol is second only to tobacco as a cause of drug-related death and hospitalisation, responsible for 5.1% of the total burden of disease and injury in Australia in 2011 [307]. Each week, on average, more than 100 Australians die and more than 3,000 are hospitalised as a result of excessive alcohol consumption [226]. People who drink regularly at higher levels place themselves at increased risk of chronic ill health and premature death [307-309], including due to injuries such as drowning [133].

Alcohol increases drowning risk due to its effects on cognitive processing, central nervous system processing, and physiological responses [187]. Alcohol is a vasodilator increasing the period of time someone may choose to remain in cold water thus increasing the risk of hypothermia [76]. Alcohol also causes labyrinthine dysfunction leading to decreased balance and impaired hearing and it also impairs judgement increasing the likelihood of exposure to high-risk situations [94]; all of which contribute to increased drowning risk [133 187 237 303]. In Australia, alcohol-related unintentional river drowning fatalities are significantly more likely as a result of jumping in, among those who identify as Aboriginal and Torres Strait Islander and those who drown in the evening (6:01pm to 12am) and early morning (12:01am to 6am) hours [133].

Previously published research on river drowning has identified the need for exposure studies [50 132 133] and real-time data collection in the field [9]. Given the role of alcohol in fatal river drowning, there is a need to understand alcohol consumption patterns of river users, as well as attitudes to alcohol consumption and aquatic activity. Breathalysers, which estimate a person's BAC indirectly by measuring the alcohol on the breath, have predominately been used in broader injury research [310 311], including road traffic-related injury [312 313]; however only one drowning-related study has been conducted using breathalysers at Australian beaches [314]. While self-reported surveys provide an indication of the amount of alcohol consumed, breathalysing is a robust, objective measure of alcohol concentration [5], which has shown to give a reliable estimation of BAC [6].

Little is known about those who visit rivers, including demographics, activities being undertaken and exposure to drowning risk [50 132 133]. One previously published study, which used a survey of self-reported river exposure to re-calculate fatal river drowning rates based on exposure in Australia, found that males and females visited the river in similar proportions in a year (males 74.7% and females 72.2%) albeit for different activities; females significantly more likely to visit the river for non-aquatic activities (55.6%; $p<0.001$) such as picnics and walking beside the river and males for fishing (11.9%; $p=0.001$) and watercraft-related activities (7.1%;$p=0.020$) [9]. Sixteen percent of those surveyed also reported consuming alcohol at the river [9].

Given the influence of alcohol in fatal river drowning, this study specifically focuses on the self-reported drinking patterns of river users as well as alcohol consumption on the day surveyed. This study aimed to describe the demographic profile of river users, explore attitudes toward river safety and alcohol use at rivers and measure the BACs of river users at a point in time. The study will also discuss considerations for the prevention of alcohol-related river drowning.

5.3.2 Methods

5.3.2.1 Study Design

A cross-sectional convenience sample of adult (18 years and older) river users were surveyed. People aged 18 years and over were chosen in accordance with ethical approval for the study design in that it only breathalysed adults. The survey featured a total of 34 questions across eight domains: demographics, frequency of river attendance, frequency of engaging in water activities, drinking patterns, knowledge (alcohol and water safety), attitudes (alcohol and water safety), alcohol consumption and BAC. The survey domains of demographics, frequency of attendance at an aquatic location, and alcohol consumption and BAC have been previously been used [314]. The survey questionnaire was piloted prior to use in the field by researchers AEP and RCF. It was then also piloted by three colleagues not part of the research team. Minor modifications between the pilot and final survey phases were made, mainly moving questions to enhance the flow of the survey and modifying response categories to ensure adequate options were provided.

Potential respondents were approached, or approached the researchers, and asked to participate. The project was verbally explained to potential respondents and they were then provided with an information sheet that described the study and the ethics approval granted. If they were willing to participate, respondents noted their informed consent (yes/no) in the first question of the survey. Respondents who completed the survey were invited to enter the draw for a $100 pre-paid credit card. Prize winner details were captured separately to survey responses. Four researchers collected data across the sites with predominately two collecting data at one time. The research team collaborated to ensure that a person was breathalysed or surveyed only once. Details on how the survey was administered (i.e. both electronically and on paper) have been published previously [7 138].

Each paper-based survey was linked to the identification (ID) number for the entry generated by SurveyGizmo ™ to allow for cross-referencing if required. The survey instrument collected time of day the survey was commenced and also the time of day the BAC reading was recorded. All data collected were de-identified. If any potential respondents were deemed too intoxicated to give informed consent and/or complete the survey, the interview was ended and the potential participant was not invited to participate. There were no people surveyed and breathalysed who were deemed too intoxicated to give informed consent. They were also advised not to enter the water due to being at increased risk of drowning and injury.

5.3.2.2 Study Setting

Surveys were conducted at four high-risk river drowning locations namely Alligator Creek, the Murrumbidgee, Murray and Hawkesbury Rivers (Figure 21). A detailed description of the research sites including site characteristics, data collection dates and weather data [315] (maximum air temperature and total daily rainfall) can be found in Table 26. This study forms part of a broader suite of work examining the epidemiology, risk factors and strategies for the prevention of river drowning in Australia [7 9 50 132-134 136 138].

Figure 21: Map of Australia depicting the four pilot research sites

Table 26: Characteristics of research sites, date of data collection, maximum air temperature and total daily rainfall

Name of site	**Remoteness classification of site**	**Description of site characteristics**	**Date of data collection (2018)**	**Maximum daily air temperature (degrees celsius) #**	**Total daily rainfall (mm)**
Alligator Creek, Townsville, Queensland	Outer Regional	Located within Bowling Green National Park, no gates or fee to enter. Carpark, BBQ facilities, covered tables for eating, public toilet block, boardwalk area, beach entry. One camping area with facilities and three camping areas without facilities. There is safety signage warning of previous death and injury at the site & disallowing glass.	Friday 12th January	31.7	0
			Saturday 13th January	31.5	0
			Sunday 14th January	33.5	0.2
Murrumbidgee River, Wagga Wagga, New South Wales	Inner Regional	Carpark, BBQ facilities, covered tables for eating, public toilets and a child's playground. A canoe club is located at the site. There is a grassed area with trees and a sandy beach entry to the river. Walkway past the beach entry and down further along the river. Safety signage was present warning of submerged objects, strong currents and deep water.	Friday 19th January	39.8	0
			Saturday 20th January	41.5	0
			Sunday 21st January	42.1	0
Murray River, Albury, New South Wales	Inner Regional	Carpark, large public reserve, child's playground, BBQ facilities, picnic tables, public toilets, public café (licensed – except for Australia Day). The river bank is grassed with concrete stairs and ramps to enter the river at certain points. There is safety signage warning about strong currents. The site was a designated 'alcohol free zone' on Australia Day.	Monday 22nd January	38.2	1.2
			Tuesday 23rd January	41.5	0
			Wednesday 24th January	33.5	1.8
			Thursday 25th January	35.8	0
			Friday 26th January (Australia Day Public Holiday)	37.3	0.6
			Saturday 27th January	34.2	3.4
			Sunday 28th January	36.8	0
Hawkesbury River, Windsor, New South Wales	Major Cities	Carpark, large public reserve, public toilets, a boat ramp and a boardwalk area adjacent to the boat ramp at the rivers edge. The boat ramp featured safety signage regarding paddle craft, shallow water, wearing a lifejacket and alcohol.	Friday 2nd February	24.7	0.8
			Saturday 3rd February	26.8	3.2
			Sunday 4th February	28.6	4.0

= Weather data sourced from climate data online from the Bureau of Meteorology (http://www.bom.gov.au/climate/data/index.shtml?bookmark=136) Access Date 20-03-2018].

Data was collected across a three day period for three sites (Friday, Saturday and Sunday) and across a seven day period (Monday to Sunday) at the Murray River. The Murray River data collection timeframe included Australia Day (Friday 26th January) which is a national public holiday in Australia. Due to the public holiday, the Murray River site was a designated 'alcohol free zone' by the local council and nominally enforced by police. At all other times and at all other sites, there was nothing in place regulating alcohol consumption beyond the requirement at Alligator Creek that no glass be taken onto the site.

Data collection occurred during the Australian summer (December-February inclusive) and during daylight savings (where the sun does not set until 8-9pm at night). Data collection at all sites except the Hawkesbury River occurred during school holidays. To examine how river visitation, usage and alcohol consumption varied due to air temperature and rainfall, weather data was captured retrospectively from the Australian Bureau of Meteorology for each site for the days of data collection. (Table 26)

5.3.2.3 BAC Testing

BAC readings were captured using LION Alcometers (LION SD400 ™), Lion Laboratories, United Kingdom (UK). Two devices were available to maximise data collection. Devices were calibrated by Pacific Data Solutions (Ltd) prior to data collection commencing.

The respondent was required to exhale into a straw attached to the device for a continuous period of time (generally 5-10 seconds) until a BAC was recorded. A clean straw was used for each participant. The BAC reading was recorded as a continuous variable to three decimal places (e.g. 0.123%). The researcher administered the breathalyser and recorded BAC reading and time of day of the reading. Those who were drinking alcohol when approached by the research team were instructed not to drink while completing the survey; thereby allowing for approximately a 10 minute period prior to being breathalysed where they did not consume alcohol. Those who recorded a BAC of ≥0.050% were advised by the researcher against going back in the water due to their increased risk due to intoxication.

5.3.2.4 Data Cleaning, Coding, Checking and Statistical Analysis

The final dataset of survey responses was downloaded from SurveyGizmo into IBMSPSS V20 [157] for data cleaning, coding, checking and analysis. The process of checking data transferred from paper-based surveys to the electronic database has been published previously [7 138]. The four responses where a BAC reading was not captured were excluded from the dataset. Two responses where age of respondent was not captured were also excluded.

Age in years of respondent was coded into the following age bands to allow for comparison with previously collected data [9 133]: 18-34 years; 35-54 years; 55-74 years and 75+ years. Time of day of BAC reading was recorded and BAC readings were cleaned to ensure consistency of format (e.g. time of day recoded into HH:MM using 24 hour time) prior to analysis. Information on how the remoteness classification [163] and relative socio-economic status [316] of the survey respondents' postcode was coded have been published previously [7 138]. The activity of 'recreate' beside water relates to activities undertaken for leisure purposes, such as picnics, reading a book, sun bathing etc. For the question regarding frequency of engaging in water activities at rivers in the last 12 months, answers were converted into a dichotomous variable with 'sometimes' and 'always' recoded as 'yes' and 'never' and 'N/A – Don't do this' recoded as no. Those with a blank response were removed prior to analysis.

Attitudinal questions required respondents to indicate their level agreement with statements on a five point Likert scale (strongly agree, agree, neither agree nor disagree, disagree, and strongly disagree) with a 'don't know' option. For ease of analysis, 'strongly agree' and 'agree' were combined into 'agree' and 'disagree' and 'strongly disagree' were combined into 'disagree'). This left four categories for analysis: agree, neither agree nor disagree, disagree and don't know. Attitudinal questions asked included" "It's okay to drink alcohol on a boat (as the skipper)" and "It's okay to drink alcohol before swimming". Knowledge based questions included: "When was the last time you undertook/updated first aid qualifications (including CPR)?"

Maximum daily air temperature were reported in quartiles as determined by IBM SPSS ™. For each upper end of the quartile (e.g. 24.7-31.5) this was rounded up to be displayed as (24.7-31.9). Temperature was recorded in degrees Celsius and was subsequently converted into degrees Fahrenheit. Both are displayed for ease of understanding for an international readership. Time of day of BAC reading was coded into morning (6:01 am to 12 pm), afternoon (12:01 pm to 6 pm) and evening (6:01 pm to 12 am).

This study examined the role of alcohol in two ways. Alcohol consumption on the day was measured using BAC and hazardous lifetime alcohol use was calculated using the Alcohol Use Disorder Identification Test (AUDIT) [317 318]. Using self-reported data on alcohol consumption, an audit score was calculated as follows:

a) Number of days in which you had at least one drink of any alcoholic beverage during the past 30 days. It was codified as 0=none; 1=1 day; 2=2-4 days; 3=5-15 days; 4=16-20 days; and 5=24+ days.

b) On the days when you drank, number of drinks on average during the past 30 days. Codified as 0=between 0 and 2 drinks; 1= between 3 and 4 drinks; 2=between 5 and 6 drinks; 3=between 7 and 9 drinks; and 4= if ≥10 drinks.

c) Considering all types of alcohol beverages, number of times in the past 30 days you have had 4 or more drinks (for females) or 6 or more drinks (for males) on a single occasion. Codified as 0=none/less than monthly; 2=between 1 and 7 times; 3=between 8 and 12 times; 4= if ≥13 times.

Hazardous alcohol use was calculated by adding the AUDIT scores as codified above (a+b+c). Alcohol use was considered hazardous if the resulting score was ≥3 in females and ≥4 in males [317 318].

A contributory level of alcohol was defined as a BAC of ≥0.050% due to known impacts on decision-making, motor skills and being the legislated upper limit for operating a motor vehicle and watercraft in most states and territories in Australia [187 232]. For the purposes of analysis BAC readings were divided into three categories: BAC – No (a BAC of 0.000%), BAC between 0.001% and 0.049%, and a BAC of ≥0.050%.

Univariate and chi-square analysis was undertaken with a 95% confidence interval. Non-parametric testing was undertaken using the proportional basis of the population as the assumed outcome numbers. Population data was sourced from the ABS using the most recent data available (September 2017) [160]. For cells with small counts (i.e. <5), a Fisher's Exact Test was used.

5.3.2.5 Ethics

Ethics approval for this study was granted by the James Cook University Human Research Ethics Committee (HREC – H7249).

5.3.3 Results

A total of 690 people were surveyed. After removing entries without BACs (n=4) and without age recorded (n=2), there remained a total of 684 responses included for analysis. Females accounted for 51.6% of the sample and 49.0% of the sample were people aged 18-34 years. Twelve (n=1.8%) survey respondents were international tourists. The largest number of respondents was recorded at the Murray River (n=278; 40.6%), followed by the Murrumbidgee River (n=174; 25.4%), Alligator Creek (n=120; 17.5%) and the Hawkesbury River (n=112; 16.4%). Those surveyed at the Hawkesbury River were significantly more likely to be male (X^2=46.0; p<0.001), whereas the cohort surveyed at the Murrumbidgee (X^2= 3.9; p=0.049) and Murray rivers (X^2= 5.9; p=0.016) were significantly more likely to be female. Age group and IRSAD of respondent's residential postcode did not vary by sex of respondent. (Table 27)

Table 27: Demographics of river users surveyed (N=684)

	Total		Male		Female		X^2 (p value)
	N	%	N	%	N	%	
Total	684	100.0	331	48.4	353	51.6	0.399 (p=0.527)
Age group							
18-34 years	335	49.0	162	48.4	173	51.6	0.000 (p=0.986)
35-54 years	251	36.7	120	47.8	131	52.2	0.054 (p=0.816)
55+ years	98	14.3	49	50.0	49	50.0	0.118 (p=0.731)
Remoteness classification of respondent's residential postcode							
Major Cities	123	18.0	81	65.9	42	34.1	17.308 (p<0.001)
Inner Regional	391	57.2	169	43.2	222	56.8	12.547 (p<0.001)
Outer Regional, Remote & Very Remote	146	21.3	73	50.0	73	50.0	2.343 (p=0.343)
Unknown/International	24	3.5	8	33.3	16	66.7	-
Country of Birth							
Australia	577	84.4	289	50.1	288	49.9	4.242 (p=0.039)
Outside Australia	107	15.6	42	39.3	65	60.7	
IRSAD classification of respondent's residential postcode							
Low	118	17.3	58	49.2	60	50.8	2.390 (p=0.122)
High	113	16.5	67	59.3	46	40.7	
Other/Unknown/International	453	66.2	206	45.5	247	54.5	-

Please note: Chi square analysis excludes the other/unknown variables.

The leading activities being undertaken at three of the sites (Alligator Creek, Murrumbidgee River and Murray River) were walk/sit/recreate beside the river (90.0% (n=108) of respondents at Alligator Creek; 89.1% (n=155) at Murrumbidgee River; and 93.2% (n=259) at the Murray River), followed by swimming (85.8% (n = 103) of Alligator Creek respondents; 87.9% (n = 153) of Murrumbidgee River respondents; and 75.9% (n = 211) of Murray River respondents). The Hawkesbury river site differed in that the top two activities were boating (82.1% (n=92) of respondents) and water skiing (54.5% (n=61)).

Sixteen percent (15.9%; n=109) respondents recorded a positive BAC reading when breathalysed (mean positive BAC=0.068%; SD± 0.08). A slightly higher proportion of females (16.1%) than males (15.8%) recorded positive BAC readings; however sex was not found to be statistically significant for consuming alcohol. People aged 18-34 years (X^2= 10.7; p=0.001) and those residing in areas classified as Inner Regional (X^2= 9.0; p=0.003) were significantly more likely to record a positive BAC reading; while those aged 55 years and older (X^2= 5.2; p=0.023) and those residing in major cities (X^2= 7.3; p=0.007) were significantly less likely to record a positive BAC. Australian-born respondents were more likely to record positive BAC readings (17.2% positive) compared to overseas born respondents (9.3% positive) (X^2= 4.1; p=0.043). Respondents from postcodes classified as being low IRSAD were significantly more likely to record positive BAC readings (X^2= 5.7; p=0.017), when compared to those residing in postcodes classified as high. (Table 28)

Table 28: Blood alcohol concentration (BAC) readings by demographics of survey respondents and time of day (N=684)

	Total		Alcohol Yes				Alcohol No		X^2 (p value) comparing alcohol yes to alcohol no	X^2 comparing over BAC <0.05% to BAC ≥0.05%
			BAC 0.001%-0.049%		BAC ≥0.050%					
	N	%	N	%	N	%	N	%		
Total	684	100.0	60	8.8	49	7.2	575	84.1	-	-
Sex										
Male	331	48.4	25	7.6	27	8.2	279	84.3	0.024 (p=0.876)	0.952 (p=0.329)
Female	353	51.6	35	9.9	22	6.2	296	83.9		
Age group										
18-34 years	335	49.0	36	10.7	33	9.9	266	79.4	10.649 (p=0.001)	7.128 (p=0.008)
35-54 years	251	36.7	17	6.8	15	6.0	219	87.3	3.006 (p=0.083)	0.841 (p=0.359)
55+ years	98	14.3	7	7.1	1	1.0	90	91.8	5.158 (p=0.023)	6.491 (p=0.006)*
Remoteness classification of respondent's residential postcode										
Major Cities	123	18.0	10	8.1	0	0.0	113	91.9	7.269 (p=0.007)	12.124 (p<0.001)*
Inner Regional	391	57.2	37	9.5	40	10.2	314	80.3	8.558 (p=0.003)	10.989 (p=0.001)
Outer Regional, Remote and Very Remote	146	21.3	11	7.5	9	6.2	126	86.3	0.872 (p=0.350)	0.433 (p=00.511)
Unknown/International	24	3.5	2	8.3	0	0.0	22	91.7	-	-
Country of Birth										
Australia	577	84.4	53	9.2	46	8.0	478	82.8	4.112 (p=0.043)	3.626 (p=0.065)*
Outside Australia	107	15.6	7	6.5	3	2.8	97	90.7		
IRSAD classification of respondent's residential postcode										
Low	118	17.3	13	11.0	16	13.6	89	75.4	5.659 (p=0.017)	16.462 (p<0.001)*
High	113	16.5	14	12.4	0	0.0	99	87.6		
Other/Unknown/International	453	66.2	33	7.3	33	7.3	387	85.4	-	-
Time of day										
Morning (6:01am to 12pm)	196	28.7	11	5.6	0	0.0	185	94.4	21.855 (p<0.001)	21.199 (p<0.001)*
Afternoon (12:01pm to 6pm)	476	69.6	49	10.3	42	8.8	385	80.9	11.831 (p=0.001)	6.484 (p=0.011)
Evening (6:01pm to 12am)	12	1.8	0	0.0	7	58.3	5	41.7	16.390 (p<0.001)	48.088 (p<0.001)*

Please note: Chi square analysis excludes the other/unknown variables. * p value reported is Fisher's Exact Test.

Seven percent (7.2%) of respondents recorded a BAC ≥0.05%. The mean BAC ≥0.05% was 0.132% (SD±0.06; Range 0.001%-0.334%). The mean BAC ≥0.05% for males was 0.129% (SD±0.09) and 0.136% (SD±0.08) for females. Respondents aged 18-34 years were significantly more likely to record a BAC ≥0.05% (X^2= 7.1; p=0.008), while those aged 55 years and older were significantly less likely to (X^2= 6.5; p=0.006).

Respondents residing in areas classified as major cities were significantly less likely to record a BAC ≥0.05% (X^2= 12.1; p<0.001) while respondents from inner regional areas were significantly more likely to record a BAC ≥0.05% (X^2= 11.0; p=0.001). Respondents from low IRSAD areas were more likely to record a BAC ≥0.05% (X^2= 16.5; p<0.001). (Table 3) Respondents at the Hawkesbury River site, were significantly less likely to record a positive BAC (X^2= 15.3; p<0.001) or a BAC ≥0.05% (X^2= 7.9; p=0.005). All BAC readings ≥0.05%, were recorded in the afternoon (X^2= 6.5; p=0.011) or evening (X^2= 48.1; p<0.001) with over half (57.1%) being recorded between 4pm and 6pm (Figure 22).

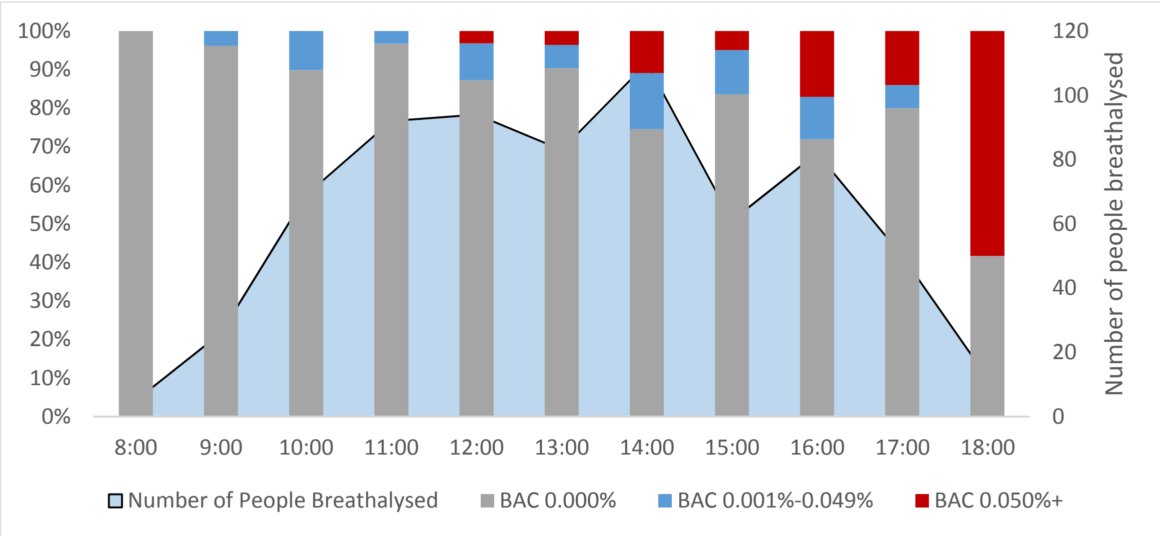

Figure 22: Blood alcohol concentration (BAC) ≥0.05% by time of day (n=49)

Respondents were significantly more likely to both record a positive BAC (X^2= 32.3; p<0.001) and a BAC ≥0.05% (X^2= 32.0; p<0.001) on the Australia Day public holiday. Twenty-six percent (26.4%) of river users breathalysed on Australia Day recorded a BAC ≥0.05% (Mean BAC ≥0.05% =0.175%; SD±0.09). The BACs recorded on Australia Day ranged from 0.000% to 0.308%.

Air temperature impacts alcohol consumption, with days recording cooler maximum air temperatures (<32.0 °C) significantly less likely to have respondents recording positive BACs (X^2=22.4; p<0.001) or BACs ≥0.05% (X^2= 11.3; p<0.001); whereas days with a higher maximum air temperature (36.8°C -39.9°C) being significantly more likely to have respondents with positive BACs (X^2= 9.1; p=0.003) and BACs ≥0.05% (X^2= 6.1; p=0.013). (Table 29)

Table 29: Blood alcohol concentration (BAC) readings of river users by daily maximum temperatures, river attendance information and self-reported swimming ability, chi square (N=684)

	Total		**Alcohol Yes**				**Alcohol No**		**X^2 (p value) comparing alcohol yes to alcohol no**	**X^2 comparing over BAC <0.05% to BAC ≥0.05%**
			BAC 0.001%-0.049%		**BAC ≥0.050%**					
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**		
Daily maximum air temperature degrees Celsius (Fahrenheit)										
<32.0 (<89.6)	182	26.6	6	3.3	1	0.5	173	95.1	22.361 (p<0.001)	11.343 (p<0.001)*
32.0-35.9 (89.6-96.6)	167	24.4	16	9.6	10	6.0	141	84.4	0.022 (p=0.882)	0.459 (p=0.498)
36.0-39.9 (96.8-103.8)	189	27.6	22	11.6	21	11.1	146	77.2	9.056 (p=0.003)	6.119 (p=0.013)
>40.0 (>104.0)	146	21.3	16	11.0	15	10.3	115	78.8	3.888 (p=0.049)	2.700 (p=0.100)
At river alone or with others										
Alone	41	6.0	2	4.9	0	0.0	39	95.1	3.981 (p=0.046)	3.366 (p=0.107)*
With friends	412	60.2	39	9.5	44	10.7	329	79.9	13.707 (p<0.001)	19.257 (p<0.001)
With family	317	46.3	22	6.9	11	3.5	284	89.6	13.466 (p<0.001)	12.120 (p<0.001)
Frequency of visiting any river in the last 30 days (month)										
1-2 times	248	36.3	19	7.7	21	8.5	208	83.9	0.004 (p=0.947)	0.946 (p=0.331)
3-5 times	166	24.3	15	9.0	6	3.6	145	87.3	1.838 (p=0.175)	4.215 (p=0.040)
6-10 times	128	18.7	10	7.8	8	6.3	110	85.9	0.443 (p=0.506)	0.211 (p=0.646)
11+ times	139	20.3	16	11.5	14	10.1	109	78.4	4.040 (p=0.044)	2.164 (p=0.141)
Unknown	3	0.4	0	0.0	0	0.0	3	100.0	-	-
Length of time spent in water (in minutes)										
0 minutes	152	22.2	15	9.9	3	2.0	134	88.2	2.445 (p=0.118)	7.915 (p=0.004)*
1-30 minutes	283	41.4	32	11.3	17	6.0	234	82.7	0.685 (p=0.408)	0.971 (p=0.324)
31-60 minutes	87	12.7	5	5.7	3	3.4	79	90.8	3.380 (p=0.066)	2.069 (p=0.184)*
61-120 minutes	53	7.7	4	7.5	7	13.2	42	79.2	0.996 (p=0.318)	3.155 (p=0.091)*
121-300 minutes	89	13.0	4	4.5	13	14.6	72	80.9	0.765 (p=0.382)	8.523 (p=0.007)*
301+ minutes	20	2.9	0	0.0	6	30.0	14	70.0	3.042 (p=0.081)	16.155 (p=0.002)*

Please note: Chi square analysis excludes the other/unknown variables. * p value reported is Fisher's Exact Test.

Respondents visiting the river alone were significantly less likely to report a positive BAC (X^2= 4.0; p=0.046). Respondents visiting the river with family were also significantly less likely to report a positive BAC (X^2=13.5; p<0.001) and a BAC ≥0.05% (X^2=19.3; p<0.001); whereas those visiting the river with friends were significantly more likely to both report a positive BAC (X^2=13.7; p<0.001) and a BAC ≥0.05% (X^2=12.1; p<0.001). (Table 29)

Thirty-six percent (36.3%) of respondents reported visiting a river 1-2 times in the last 30 days, with a further 24.3% visiting 3-5 times. Those visiting a river 3-5 times were significantly more likely to record a BAC ≥0.05% (X^2=4.2; p=0.040) whereas those visiting a river 11+ times were significantly more likely to record a positive BAC (X^2=4.0; p=0.044).

On average people spent 60.1 minutes in the water (SD±89.8) with 41% (41.4%) of river users surveyed stated they spent 1-30 minutes in the water per visit. Respondents who did not enter the water were significantly less likely to record a BAC ≥0.05% (X^2=7.9; p=0.004), whereas those spending 301+ minutes in the water were significantly more likely to record a BAC ≥0.05% (X^2=16.2; p=0.002). (Table 29)

River users were asked to indicate how frequently they participated in a range of activities at any river in the last 12 months. When compared to BAC reading, those who stated they had participated in the alcohol-related aquatic activities (e.g. swimming within 2 hours of consuming alcohol, boating within 2 hours of consuming alcohol, either as the passenger or the skipper) were significantly more likely to record a positive BAC; swimming (X^2=47.5; p<0.001) and boating (X^2=6.2; p=0.013). Those who self-reported swimming alone were also significantly more likely to record a positive BAC (X^2=6.1; p=0.013). (Table 30)

Sixty-four percent (63.6%) of river users surveyed were found to consume alcohol at hazardous levels. River users who self-reported participating in all activities were significantly more likely to be drinking at hazardous levels (p<0.05), with results most pronounced for the activities of swimming within 2 hours of consuming alcohol (X^2=69.3; p<0.001), boating within 2 hours of consuming alcohol (as passenger or skipper) (X^2=12.5; p<0.001) and jumping into a river from a height (X^2=17.3; p<0.001). (Table 30)

Thirty-five percent (34.8%) of respondents stated they sometimes (32.6%) or always (2.2%) consumed alcohol prior to visiting a river. Those who responded sometimes or always to this question were significantly more likely to record a positive BAC (sometimes X^2=30.0; p<0.001 and always X^2=28.4; p<0.001). Forty-eight percent (48.2%) of respondents stated they sometimes (45.1%) or always (3.1%) consumed alcohol while at the river. Those who responded both sometimes (X^2=25.7; p<0.001) and always (X^2=40.5; p<0.001) to this question were significantly more likely to record a positive BAC when breathalysed. Respondents with hazardous alcohol consumption levels were significantly more likely to self-report always (X^2=7.7; p=0.003) or sometimes (X^2=63.1; p<0.001) drinking alcohol prior to visiting a river and always (X^2=8.1; p=0.005) or sometimes (X^2=59.1; p<0.001) consuming alcohol when at the river. (Table 30)

Table 30: Self-reported frequency of undertaking risky/alcohol-related behaviours at rivers in the past 12 months and drinking alcohol prior to visiting and while at the river, by BAC and hazardous drinking levels, chi square

	Total		BAC 0.000		Positive BAC (0.001 and higher)		X^2 comparing BAC 0.000 to positive BAC (0.001 and higher)	Hazardous drinking levels - Yes		Hazardous drinking levels - No		Hazardous levels - Unknown		X^2 comparing hazardous drinking levels - yes to hazardous drinking levels - no
	N	%	N	%	N	%		N	%	N	%	N	%	
Swim within 2 hours of consuming alcohol (n=677)														
Yes	277	40.9	200	35.2	77	70.6	47.489 (p<0.001)	227	52.4	45	19.2	5	50.0	69.309 (p<0.001)
No	400	59.1	368	64.8	32	29.4		206	47.6	189	80.8	5	50.0	
Boat within 2 hours of consuming alcohol (as passenger or skipper) (n=676)														
Yes	166	24.6	129	22.8	37	33.9	6.183 (p=0.013)	124	28.6	38	16.3	4	40.0	12.508 (p<0.001)
No	510	75.4	438	77.2	72	66.1		309	71.4	195	83.7	6	60.0	
Swim alone (n=674)														
Yes	351	52.1	283	50.0	68	63.0	6.107 (p=0.013)	237	54.9	106	45.7	8	80.0	5.084 (p=0.024)
No	323	47.9	283	50.0	40	37.0		195	45.1	126	54.3	2	20.0	
Jump into a river from a height (e.g. from tree, bridge, rocks or using a rope swing) (n=677)														
Yes	232	34.3	193	34.0	39	35.8	0.132 (p=0.717)	173	40.0	56	23.9	3	30.0	17.297 (p<0.001)
No	445	65.7	375	66.0	70	64.2		260	60.0	178	76.1	7	70.0	
Swim in water that was too deep to touch the bottom (n=677)														
Yes	512	75.6	424	74.8	88	80.7	1.838 (p=0.175)	339	78.3	165	70.5	8	80.0	4.977 (p=0.026)
No	165	24.4	144	25.4	21	19.3		94	21.7	69	29.5	2	20.0	
Dive into water of unknown depth (n=676)														
Yes	155	22.9	124	21.9	31	28.4	2.234 (p=0.135)	114	26.4	39	16.7	2	20.0	8.108 (p=0.004)
No	521	77.1	443	78.1	78	71.6		318	73.6	195	83.3	8	80.0	
Camp (stay overnight) (n=677)														
Yes	293	43.3	240	42.3	53	48.6	1.512 (p=0.219)	203	46.9	84	35.9	6	60.0	7.477 (p=0.006)
No	384	56.7	328	57.7	56	51.4		230	53.1	150	64.1	4	40.0	
How often is alcohol consumed prior to visiting a river? (n=680)														
Never	429	63.1	391	68.5	38	34.9	49.655 (p<0.001)	227	52.3	199	84.3	3	30.0	75.033 (p<0.001)

Sometimes	222	32.6	161	28.2	61	56.0	30.035 (p<0.001)	187	43.1	30	12.7	5	50.0	63.114 (p<0.001)
Always	15	2.2	5	0.9	10	9.2	28.366 (p<0.001)	14	3.2	0	0.0	1	10.0	7.654 (p=0.003)*
Not Applicable	14	2.1	14	2.5	0	0.0	-	6	1.4	7	3.0	1	10.0	-
How often is alcohol consumed while at the river? (n=680)														
Never	343	50.4	322	56.4	21	19.3	52.839 (p<0.001)	169	38.9	171	72.5	3	30.0	75.559 (p<0.001)
Sometimes	307	45.1	233	40.8	74	67.9	25.696 (p<0.001)	244	56.2	58	24.6	5	50.0	59.136 (p<0.001)
Always	21	3.1	7	1.2	14	12.8	40.509 (p<0.001)	19	4.4	1	0.4	1	10.0	8.047 (p=0.005)*
Not Applicable	9	1.3	9	1.6	0	0.0	-	2	0.5	6	2.5	1	10.0	-

* p value reported is Fisher's Exact Test.

River users were also asked attitudinal questions related both to alcohol and driving a motor vehicle, as well as specific aquatic-related questions (alcohol and boating; alcohol and swimming). Those who recorded a positive BAC when breathalysed at the river were significantly more likely to agree that it's okay to drink alcohol on a boat as a passenger (X^2= 7.9; p=0.005), that it's okay to drink alcohol on a boat as the skipper (X^2= 10.0; p=0.002), and to drink alcohol before swimming (X^2= 13.3; p<0.001). (Table 31)

Those with hazardous drinking levels were significantly more likely to agree with the statements 'it's okay to drink alcohol on a boat as a passenger' (X^2= 28.5; p<0.001), 'It's okay to drink alcohol on a boat as the skipper' (X^2= 6.4; p=0.011) and 'it's okay to drink alcohol before swimming' (X^2= 9.4; p=0.002). (Table 31)

Table 31: Attitudinal questions related to alcohol by BAC and hazardous drinking levels, chi square (N=684)

	Total		BAC 0.000		Positive BAC (0.001 and higher)		X^2 comparing BAC 0.000 to positive BAC (0.001 and higher)	Hazardous drinking levels - Yes		Hazardous drinking levels - No		Hazardous levels - Unknown		X^2 comparing hazardous drinking levels - yes to hazardous drinking levels - no
	N	%	N	%	N	%		N	%	N	%	N	%	
Total	684	100.0	575	84.1	109	15.9	-	435	63.6	236	34.5	13	1.9	-
It's okay to drink alcohol and drive a motor vehicle														
Agree	49	7.2	38	6.6	11	10.1	1.663 (p=0.197)	31	7.1	17	7.2	1	7.7	0.000 (p=0.984)
Neither agree nor disagree	31	4.5	24	4.2	7	6.4	1.064 (p=0.302)	23	5.3	7	3.0	1	7.7	1.965 (p=0.161)
Disagree	597	87.3	507	88.2	90	82.6	2.900 (p=0.089)	377	86.7	211	89.4	9	69.2	0.789 (p=0.374)
Don't Know	7	1.0	6	1.0	1	0.9	-	4	0.9	1	0.4	2	15.4	-
It's okay to drink alcohol on a boat (as a passenger)														
Agree	287	42.0	228	39.7	59	54.1	7.873 (p=0.005)	213	49.0	67	28.4	7	53.8	28.508 (p<0.001)
Neither agree nor disagree	135	19.7	116	20.2	19	17.4	0.453 (p=0.501)	86	19.8	48	20.3	1	7.7	0.007 (p=0.932)
Disagree	248	36.3	219	38.1	29	26.6	5.366 (p=0.021)	126	29.0	119	50.4	3	23.1	29.061 (p<0.001)
Don't Know	14	2.0	12	2.1	2	1.8	-	10	2.3	2	0.8	2	15.4	-
It's okay to drink alcohol on a boat (as the skipper)														
Agree	68	9.9	48	8.3	20	18.3	10.028 (p=0.002)	52	12.0	14	5.6	2	15.4	6.409 (p=0.011)
Neither agree nor disagree	48	7.0	38	6.6	10	9.2	0.879 (p=0.349)	36	8.3	11	4.7	1	7.7	3.158 (p=0.076)
Disagree	557	81.4	479	83.3	78	71.6	10.021 (p=0.002)	340	78.2	209	88.6	8	61.5	10.426 (p=0.001)
Don't Know	11	1.6	10	1.7	1	0.9	-	7	1.6	2	0.8	2	15.4	-
It's okay to drink alcohol before swimming														
Agree	142	20.8	105	18.3	37	33.9	13.308 (p<0.001)	106	24.4	34	14.4	2	15.4	9.355 (p=0.002)
Neither agree nor disagree	133	19.4	104	18.1	29	26.6	4.041 (p=0.044)	99	22.8	33	14.0	1	7.7	7.592 (p=0.006)
Disagree	397	58.0	355	61.7	42	38.5	21.694 (p<0.001)	223	51.3	166	70.3	8	61.5	22.827 (p<0.001)
Don't Know	12	1.8	11	1.9	1	0.9	-	7	1.6	3	1.3	2	15.4	-

Please note: Chi square analysis excluded the 'don't know' variable.

5.3.4 Discussion

Alcohol is a leading risk factor for fatal unintentional drowning in rivers in Australia [133]. Sixteen percent of river users recorded a positive BAC, with 7% of these recording a contributory level of alcohol (BAC ≥0.05%). Sixty-four percent (63.6%) of river users surveyed were found to consume alcohol at hazardous levels, compared to 18% of the Australian population aged 18 years and over in 2016 [308].

River users residing in inner regional areas, areas defined as low IRSAD, who visit the river in the afternoon, with friends, on days with higher maximum air temperatures, frequent river users (11+ times in the last 30 days) and those who spend longer on average in the water (301+ minutes) were significantly more likely to have contributory levels of alcohol when breathalysed. Key findings with a focus on comparisons with previously published alcohol-related fatal drowning statistics and river exposure are discussed, as well as implications for river drowning prevention.

5.3.4.1 Alcohol Consumption

A previously conducted nationally representative computer-assisted telephone instrument (CATI) survey of river users found that 16% of people surveyed self-reported consuming alcohol at a river when they visit [9]. Similarly, this study found 16% of those surveyed recorded positive BACs at the river when breathalysed. When comparing the two studies by sex and age group, 9% of females and 15% of males self-reported consuming alcohol at the river, compared to 16% of males and females respectively when breathalysed, indicating females may under-report their alcohol consumption at rivers when asked to self-report [9].

There are inconsistencies in the drinking behaviour of river users when compared to the general population. This study found 13% of river users drink five or more alcohol drinks per day, compared with 7% of the Australian population [319]. With respect to river users who drink at risky levels, 24% of river users surveyed stated they did, similar to 26% of the Australian population [307]. These findings suggest river users surveyed are twice as likely to drink at heavier levels daily than the general population, but are not binge drinking as much as the general population. Reducing alcohol-related drowning risk among this cohort of river users will be challenging, and starts with behaviour change in daily life, far removed from river drowning risk. This behaviour is also carried into the river setting and this work is required to ensure that the activity of drinking and entering the water is avoided.

5.3.4.2 Sex Differences

Males continue to be the primary target of strategies aimed at reducing drowning at river locations in Australia [320]. This is warranted as males account for the vast majority (84%) of river drowning deaths where blood alcohol levels are known to be contributory [133]. The authors note, however, that the females surveyed in this study, are drinking at similar rates as males. Females accounted for 45%

of all river users with a BAC ≥0.05%, recorded a higher mean BAC ≥0.05% (0.139%) than males (0.129%) and a higher number of females (n=18) than males (n=15) recorded a BAC of ≥0.100% (double the contributory level). These findings are supported by recent research that identifies rates of alcohol use appear to be converging among males and females [321], with more females in younger cohorts increasingly likely to record higher levels of alcohol use and abuse [322]. Despite decreases among Australian males, exceeding lifetime alcohol risk guidelines in females has remained similar [308].

Further research is warranted to examine the differences in behaviour (and the factors underpinning this) that see males and females drink at equally risky levels, but predominately males represented in fatal river drowning statistics where alcohol is involved. With clear links identified between masculinity and risky drinking behaviours around water [296 323], the authors postulate that males may be pressured to go back into the water and engage in risky behaviours after consuming alcohol, whereas females may be more likely to stay on the bank when under the influence of alcohol. This assumption requires further testing to examine the different attitudes between males and females influencing this behaviour. Further research should also be conducted to test this study's findings of alcohol consumption (and BAC levels) among females at more river locations.

5.3.4.3 Time of Day

People who were surveyed and breathalysed at rivers in the afternoon and evening hours were significantly more likely to record BACs ≥0.05%. This mirrors analysis of fatal river drowning data in Australia that shows 64.3% of all fatal river drowning with a contributory level of alcohol occurred at such times. Evening hours show a link between fatal river drowning and contributory levels of alcohol [133], posing a challenge for data collection. The number of people at rivers in the evening hours is scarce, however the likelihood of recording a positive BAC increased, mirroring the number of alcohol-related drowning deaths at these hours [133]. Alcohol-related drowning deaths at rivers in the evening appear to be a rare yet regularly occurring event and as such, prevention of such drowning deaths will require upstream approaches to prevent the intoxicated person from drowning.

One-fifth (20%) of all fatal drownings in Australian rivers known to involve contributory levels of alcohol occurred in the early morning hours (i.e. 12:01 am to 6 am). It may be postulated that those more likely to consume alcohol in the afternoon and evening hours, be it at the river or not, are the ones who continue to drink alcohol into the early morning hours, increasing their risk of harm or injury, including drowning. While the link between risky drinking in everyday life and BACs ≥0.05% at the river was identified by this study, the assumption around time of day requires further testing to better illuminate the link between alcohol consumption, time of day and river drowning risk.

A limitation of this study was that survey and breathalysing data was not collected during the late evening and early morning hours, with the latest survey and breathalyser reading being recorded at 6:50pm. However, numbers of river users decreased later in the day with the authors postulating that there would be very few river visitors after 8pm at night. Alternative methods for collecting exposure and alcohol consumption-related data at rivers in both urban and regional areas during the late evening and early morning hours should be explored, and may include online surveys [9] and technological solutions such as remote camera observation [283]; however, the impact of time of year and season must be considered. Collecting BAC readings poses more of a challenge but remains worthy of further exploration.

5.3.4.4 Boating

Aquatic location, activity being undertaken and exposure are all factors that may impact the likelihood and level of alcohol consumption. Unlike the other three research sites where recreating beside the water and swimming were the two main activities being undertaken, the Hawkesbury River site's top two activities were boating (82%) and water skiing (55%). The Hawkesbury River site was also the only site where respondents were significantly less likely to record positive BACs (and therefore BACs ≥0.05%).

The potential link between participation in boating activity and decreased likelihood of alcohol consumption at rivers needs further examination. Length of stay at the river may be a factor. River users who self-reported participating in boating activities were significantly more likely to stay longer at the river (301+ minutes), however this study also found a link between staying longer at the river and likelihood of having a BAC ≥0.05% (121-300 minutes in the water X^2=8.523; p=0.004; 301+ minutes in the water X^2=16.155; p<0.001), which was not found among those participating in boating (X^2=0.368; p=0.544).

It may be that those participating in boating activities in the sample were less likely to drink due to needing to drive their motor vehicle to the boat ramp, the monetary value associated with their vessel and the impact of damaging it and also the perception of increased likelihood of breath tested by police either on roads or the river, given the Hawkesbury River is located in an area defined as major cities. Further investigation with this cohort is vital, given that 24% of all fatal drownings due to boating and watercraft incidents were known to involve a person with a BAC ≥0.05% [133].

5.3.4.5 Young Males and Risk-Taking

Drowning deaths of river users as a result of risk-taking behaviours (i.e. jumping into water from height) and alcohol are more likely to be young males [133]. This study did find a link between alcohol and self-reported risk-taking behaviour, with those who agreed it was okay to drink alcohol as the skipper of a boat or while swimming in a river significantly more likely to record positive BACs and to drink at hazardous levels. Further research is required to better understand the link between alcohol and risk-taking behaviour, particularly among the young male cohort. Are young males aware they are taking a risk, do they indeed engage in risky behaviour because they enjoy taking risks and would such behaviour continue without the influence of alcohol? Further research is required to understand the psychological factors impacting such behavioural choices, which in turn will influence the development of strategies that are more likely to be effective in changing such behaviour [296].

Adolescence is described as an age group of increased risk-taking and impulsivity [324] and the published literature often defines 16-21 year olds as the age group most likely to undertake risky behaviour [325] and to experience an escalation in alcohol use and misuse [326]. Due to ethical constraints, this study survey and breathalysed adults (18 years and over), and in reporting results, aggregated the 18-34 years age group to allow for comparison with previously published studies of alcohol-related river drowning and river exposure [9 133]. The potential limitation of combining such disparate experiences within a heterogeneous age group must be considered and disaggregated in future studies to identify the ages of peak risk-taking from an alcohol-related drowning prevention perspective. Further work is also required to examine underage drinking and the impact this has on drowning risk.

5.3.4.6 Public Holidays

It has long been postulated by drowning prevention researchers and practitioners that there may be increased risk of drowning on public holidays [327], due to opportunities for exposure to water as a result of more leisure time (adults not at work and children not at school) [199 328], the celebratory nature of the occasion, and the consumption of alcohol [329]. This study found a link between the Australia Day public holiday and increased alcohol consumption at rivers, with a mean BAC among those who were consuming alcohol on Australia Day being 0.114%.

The site where data was collected on Australia Day had been designated an ‘alcohol free zone’ by the local council. However, as the data presented in this study shows, alcohol continued to be consumed, sometimes to excessive levels (e.g. the highest BAC recorded on Australia Day was 0.308). The findings of this study have identified challenges around controlling safe alcohol consumption at public locations. Despite research showing public support for restrictions on alcohol consumption in public places [330], alcohol-free zones are unlikely to be effective without public awareness and enforcement of rules. Future questions to be answered include: Are alcohol-free zones likely to succeed in preventing all river users from drinking, or just those who do not drink at risky levels? Does it allow those who would drink to excess to ‘have the day off’ or does it move those who wish to drink to other, potentially less safe, locations to drink? What is the effect of such alcohol-free zones and are there other strategies to reduce alcohol consumption at rivers?

A limitation in being able to explore the link between public holidays, alcohol consumption and drowning risk, is that these data represent one public holiday at one aquatic location only. Further research is required to determine whether the phenomena is true of other public holidays, other rivers, and other types of aquatic location.

5.3.4.7 Air Temperature

The results of this study appear to indicate a link between hot weather and alcohol consumption. River users who were breathalysed on days with a maximum air temperature (36.8°C-39.9°C) being significantly more likely to record both positive BACs and BACs ≥0.05%. This finding may be used to guide the timing of prevention messages around alcohol risk and drowning in the lead-up to predicted high temperatures and the summer months.

The link between air temperature and drowning risk (not alcohol-related) has previously been explored. A study in Canada found a 69% increase in risk of outdoor drowning when temperatures exceeded 30 degrees Celsius [331]. While a study from Australia found air temperature did not impact beach visitation between genders, there was a slight impact on beach visitation by age group [281]. This impact of hot weather and alcohol-related drowning risk appears worthy of further testing, including the impact of temperature on both likelihood of consuming alcohol and amount of alcohol consumed at rivers, as well as other aquatic locations.

It must be noted that the maximum air temperatures reported in this study, do not take into account humidity. High humidity has the ability to dramatically increase how hot a day feels [332]. This is especially relevant to the Alligator Creek research site, which was located in northern Queensland. Capturing wet-bulb temperatures [333] to account for both air temperature and humidity should be incorporated into future studies examining alcohol consumption at rivers, although wet-bulb is not without its own limitations [334].

5.3.4.8 Attitudes, Behaviour and The Transtheoretical Model

River users were significantly more likely to record a positive BAC and to drink at hazardous levels if they showed support for attitudinal questions around drinking alcohol while the skipper of a boat and drinking alcohol before swimming. Achieving attitudinal and behaviour change among this cohort is likely to prove challenging. Using established models around behaviour change such as the Transtheoretical model (TTM) [140], a model of behaviour change that focuses on the readiness of the individual to change their behaviour, allow for a starting point at which to develop appropriate strategies. The authors postulate that river users who consume alcohol at hazardous levels in their daily life are likely at the precontemplation stage and are unaware of the potential increased risk of drowning their drinking may create. Such assumptions require further validation.

The consumption of alcohol (often to excess) and participation in recreational activities in and around the water appear to be an intrinsic part of Australian culture [296 335], meaning behaviours are deeply embedded and likely to take many years to change. A variety of strategies will be required to move people towards termination of consumption of alcohol at hazardous levels at rivers. Examining the psychological motivations underpinning such behaviours must form a vital component of any future research into river drowning and its prevention, to ensure appropriateness and efficacy of any intervention.

There were differences in attitudes towards acceptability of drinking and driving a motor vehicle and alcohol-related river usage among those surveyed. Of those surveyed, 7% agreed that it was okay to drink alcohol and drive a motor vehicle, 10% agreed it was okay to drink alcohol and operator a boat as skipper, 42% agreed it was okay to drink alcohol as a passenger on a boat and 21% agreed it was okay to drink alcohol before swimming. The authors posit such differences in attitude regarding alcohol use between road and river may be due to familiarity and understanding of the risks of drink-driving a motor vehicle due to exposure to advertising, as well as the visible police enforcement of legislation outlawing the behaviour through random breath testing, fines and prosecution [336]. While legislation already exists in seven of eight Australian states and territories (except the Northern Territory) regulating the operation of a powered vessel with a BAC ≥0.05%, enforcement is weak, in particular on rivers and outside metropolitan areas [133]. River drowning prevention practitioners should examine interventions that have been found to be successful in reducing injury due to alcohol in road traffic and explore if such strategies may be suitable for alcohol-related river drowning prevention.

5.3.4.9 Strengths and Limitations

Exposure around aquatic activity is challenging to capture. This study is the first of its kind and fills an important knowledge gap regarding exposure and consumption of alcohol at rivers. This study uses subjective measures (questionnaire) and objective measures (BAC reading) and cases of fatal unintentional alcohol-related river drowning to explore risk. While subjective measures have limitations, using the objective measure of a BAC reading confirmed a link between self-reported behaviour and a contributory level of alcohol. This study has identified river users at increased risk of alcohol-related river drowning and, therefore, targets for future interventions to change such risky behaviour.

Responses are self-reported and may be subject to recall bias [173], including questions on self-reported average daily alcohol consumption and alcohol consumption at 'risky levels' [337]. This is a limitation. Respondents may have also over-inflated their alcohol consumption when participating with their peers. As the research attracted media coverage (print, radio, television and online) the results may be subject to social desirability bias [338]. The survey was administered in English which may have impacted participation, particularly by those born outside Australia. The sample was a random convenience sample and therefore results represent the views of those attending the four river locations only. Caution should be used when extrapolating the results more broadly. Those in the study may have been subject to participation bias, with those more likely to drink, opting in; or those who didn't drink, thinking the study was not applicable to them. The BAC reading represents a single point in time only. Further research is required to validate these findings more widely. Although 3.6% of fatal drowning in rivers with contributory levels of alcohol occurred in children 17 years and younger [132], for ethical reasons, this study only included adults (18 years and older).

5.3.5 Conclusion

Rivers are the leading location for fatal unintentional drowning in Australia and alcohol has been identified as a risk factor. A triangulation approach was taken using fatal river drowning statistics, surveying and breathalysing, to identify those at increased risk of alcohol-related drowning. Those at increased risk are: rivers users aged 18-34 years, residents of inner regional and low socio-economic areas, those who visit the river in the afternoon, with friends, and on days with higher maximum air temperatures, frequent river users (11+ times in the last 30 days) and those who spend longer in the water (301+ minutes). Prevention efforts should include targeting both males and females, and consideration of the role of warm weather, time of day, public holidays and those who consume alcohol to hazardous levels in daily life. This study addresses a gap in the published literature around river exposure and alcohol consumption.

5.4 Observational Error and Challenges in Exploring Exposure to River Drowning Risk (Paper 7)

Peden AE, Franklin RC, Leggat PA, Lindsay, D (Under Review) Observing patterns of river usage

5.4.1 Introduction

Accurately calculating exposure is one of the significant challenges associated with understanding drowning risk [9 196 281]. Many epidemiological studies of drowning utilise crude or age-standardised drowning rates per 100,000 persons. However, drowning rates per head of population do not consider visitation, proximity to water (i.e. in on, or beside the water), frequency and type of use nor duration of visitation at aquatic locations, and thus impact on drowning risk.

There is a variety of methods for calculating exposure. While surveys are a convenient tool, they have inherent limitations including their retrospective, self-reported nature and the impact of recall bias on accuracy of data [172 339]. Observational studies are a popular alternative, although they are not without their own limitations, such as observer bias, confounding and selection bias and cost [340].

To date, although surveys have been used to quantify drowning risk by exposure [9 94 196 285], with a number of studies in Australia [7 138 196], the only observational studies have been at beaches [279 281 341], despite rivers being the leading location for drowning [132], and a significant contributor to the global estimate of 360,000 fatal drownings each year [22]. There is a dearth of information enabling river drownings to be considered in the context of exposure at river locations.

Computer assisted telephone instrument (CATI) surveys have retrospectively asked participants about their aquatic usage to determine drowning rates by age group and sex [9 196 281]. For overall drowning risk in the Australian state of New South Wales, Mitchell et al. [196] found 25-34 year old males recorded the highest fatal drowning rate per 100,000 persons, however when exposure was taken into account, males 65 years and older recorded the highest rate when exposed via being in or on the water and via swimming. For Australian beaches, Morgan et al. found that males, when compared to females, spent longer in the water, were more likely to use surfing equipment and mainly used a surf zone located farther from the shore and in deeper water [281]. Findings suggest the over-representation of males in surf beach drowning statistics is in part a product of greater total exposure to the water plus more frequent exposure to deeper water and bathing further from shore [281].

For Australian rivers, after adjusting for exposure, Peden et al (2018) [9] found a similar result with males (7.6 times), males 75+ years (8.5 times) and females 55-74 years (8.5 times) more likely to drown. When compared to females, males were 8.5 times more likely to drown with alcohol present and 25.5 times more likely to drown in a watercraft-related incident.

Data on exposure is important to identify those at increased risk of river drowning to guide effective prevention efforts. Given the dearth of information about river exposure, including a lack of real-time data collection in the field [9], this study aimed to test the use of direct, visual observations to calculate river visitation.

5.4.2 Methods

This study utilised direct observation at popular access points to four river drowning locations during summer in Australia. Observers recorded data about patrons' river usage within a pre-defined zone at regular intervals on a pre-prepared data collection sheet. This study forms part of a broader suite of work examining the epidemiology, risk factors and strategies for the prevention of river drowning in Australia [7 9 50 132-134 136 138].

5.4.2.1 Site Selection

Observations were conducted at four river drowning locations namely Alligator Creek (in the Australian state of Queensland) and the Murrumbidgee, Murray and Hawkesbury rivers (in the state of New South Wales). Popular recreational locations with designated entry and exit points were chosen as the locations at the sites where the observational study would be conducted. Locations were chosen based on ease of use (in particular travel between two zones with consecutive days of data collection) and to achieve a mix of locations. Sites chosen spanned two Australian states, represented both council run (local government) and National Park (state and territory owned and operated) locations, were known for a mix of usage, e.g. popular swimming and/or boating locations, were both in town and outside of town and in both tropical and sub-tropical climates.

5.4.2.2 Zone Identification and Study Design

The project team, prior to collecting the data, conducted a site visit to define the zone. Zones were defined by observing the location and identifying common entry and exit points for the river. The zone then extended to a pre-determined point (usually a tree or other geographical feature explained to all observers collecting data at the site) to the left and right, as well as to the riverbank on the opposite side of the river. This was done to ensure consistency of observations and to ensure all observers used the same zone.

The methodology for identification of zones was adapted from the 'Bingeing on the Beach' study, which defined the sand and water between the flags (red and yellow beach flags put out by surf lifesavers to indicate the patrolled location to swim in) as the zones of interest [342]. The zones of interest for this adaptation to beaches used an area that incorporated the water (both underneath and on top of) and the river bank/beach entry area. The riverbank zone extended to the beach entry area at Alligator Creek and the Murrumbidgee River, and to the grassy recreation area at the Murray and Hawkesbury River. When initially defining the zones, it was ensured that no blind spots were within the identified zone. Using direct observation, a minimum of two observers (from a pool of four) collected data on river usage within the pre-defined zone. Within the zone, observers collected data from a consistent location.

5.4.2.3 Data Collection

Data was collected across all sites for Friday, Saturday and Sunday, with the Murray River having four extra data collection days of Monday to Thursday. The Murray River data collection timeframe included Australia Day (Friday 26th January) which is a national public holiday in Australia. A seven day data collection period was used for the Murray due to its popularity and a leading location for fatal drowning. This extended data collection period also allowed for the examination of weekday variation in river usage.

Data collection occurred during the Australian summer (December-February inclusive) and during the daylight savings period (where the sun does not set until 8-9pm at night). Data collection at all sites except the Hawkesbury River occurred during school holidays. For each site data was consistently collected on the half hour, every hour between 10:30am and 4:30pm. These hours were chosen in order to capture what the authors felt would be the majority of river attendees. Data was also collected at various hours outside this in order to allow for greater exploration of people's visitation to rivers and how this changes over time during the day. Although observations were predominately conducted on the half hour, at hourly intervals, this was also varied, if required, based on factors such as needing to leave the site, other activities at the site, and wanting to see greater variation (i.e. 15 minutes intervals). See Table 32 for a description of the sites and an outline of the data collection time periods and number of observations for each site.

Table 32: Sites by time period, time frame of observations, number of observations conducted and number of observers

Site	**Description of site characteristics**	Day	Time period/span *	Number of observations conducted	Number of observers (number of observations)
Alligator Creek, Townsville, Queensland	Located within Bowling Green National Park, no gates or fee to enter. Carpark, BBQ facilities, covered tables for eating, public toilet block, boardwalk area, and beach entry. One camping area with facilities and three camping areas without facilities. There is safety signage warning of previous death and injury at the site & disallowing glass.	Friday 12 January, 2018	10:30-15:30	6	2
		Saturday 13 January, 2018	10:30-17:30	8	2
		Sunday 14 January, 2018	10:30-16:30	10	2
Murrumbidgee River, Wagga Wagga, New South Wales	Carpark, BBQ facilities, covered tables for eating, public toilets and a child's playground. A canoe club is located at the site. There is a grassed area with trees and a sandy beach entry to the river. Walkway past the beach entry and down further along the river. Safety signage was present warning of submerged objects, strong currents and deep water.	Friday 19 January, 2018	10:30-20:30	11	3
		Saturday 20 January, 2018	9:30-20:30	12	3 (8 observations) 2 (4 observation)
		Sunday 21 January, 2018	9:30-17:30	9	3 (2 observations) 2 (7 observations)
Murray River, Albury, New South Wales	Carpark, large public reserve, child's playground, BBQ facilities, picnic tables, public toilets, and public café (licensed – except for Australia Day). The riverbank is covered in grass with concrete stairs and ramps to access the river at certain points. There is safety signage warning about strong currents. The site was a designated 'alcohol free zone' on Australia Day.	Monday 22 January, 2018	9:30-17:00	9	2
		Tuesday 23 January, 2018	10:30-18:00	9	2
		Wednesday 24 January, 2018	7:30-19:00	9	2
		Thursday 25 January, 2018	8:30-17:30	9	2
		Friday 26 January, 2018 (AUSTRALIA DAY)	8:30-17:30	10	2
		Saturday 27 January, 2018	8:30-19:30	12	2
		Sunday 28 January, 2018	8:30-17:30	10	2
Hawkesbury River, Windsor, New South Wales	Carpark, large public reserve, public toilets, a boat ramp and a boardwalk area adjacent to the boat ramp at the river's edge. The boat ramp featured safety signage regarding paddle craft, shallow water, wearing a lifejacket and alcohol.	Friday 2 February, 2018	10:30-17:30	8	2 (7 observations) 1 (1 observation)
		Saturday 3 February, 2018	10:00-17:30	9	2 (3 observations) 1 (6 observations)
		Sunday 4 February, 2018	9:30-16:30	8	2 (7 observations) 1 (1 observation)

* Note: observations were generally conducted on the half hour, every hour within the time period stated.

For each day of observations at each site, each observer had a clipboard with a data collection sheet (developed by the research team) and a pen. The data collection sheet recorded river name and the initials of the data collector. Each observer recorded the date and time of observation, and their interpretation of the total number of people observed, the number of children (under 18 years of age as defined by Australian criminal law [193]) and the number of adults (18 years and over), number of males and females, and the numbers of people who are on the water (i.e. boating or paddling), in the water (i.e. swimming, wading) and beside the water (i.e. on the river bank). Observers stood beside each other to conduct their observations, but did not collude, nor compare results, at the time of data collection.

5.4.2.4 Observer Characteristics

Four observers were used across the data collection period. At any one time, a minimum of two observers were conducting observations. All observers were tertiary educated, three of four have expertise in drowning, two have expertise in CPR and one prior training in observation techniques. All were aged between 22 and 43 years.

5.4.2.5 Data Coding and Cleaning

Data sheets were retained and electronically scanned to the primary researcher's computer as an electronic backup. Data sheets were also photographed at the end of the day in case any sheets were lost. Data was transferred from the paper-based forms to an Excel spreadsheet at the end of each day. Twenty percent (n=7) of the sheets were rechecked by authors AEP and RCF; however no data entry errors were identified. The four spreadsheets for each data collection site; were combined into one file with a new variable added to denote the data collection site. The Excel spreadsheet was then converted into an IBMSPSS V20 dataset for the purposes of analysis. Time of day of observation was coded into the following time bands (Morning, Afternoon and Evening). These time bands correlate to data collection on drowning fatalities and allows for comparison of river exposure data with river drowning fatality data.

5.4.2.6 Statistical Tests

Data was examined using univariate analysis, with mean (SD), and range calculated. ANOVA and T-tests were used to calculate statistical differences in average people observed, males and females observed, adults and children observed and differences in people observed by time of day, day of week, public holidays and weekends. A modified Bonferonni correction, as suggested by Keppel [159], has been applied, deeming statistical significance p=0.007. Interrater reliability for observations was determined using the Intraclass Correlation Coefficient (ICC), with a 95% confidence interval (CI) reported. As per the guidelines outlined for ICC use in Hallgren [177], a one-way random-effects, average measures model examining absolute agreement was the ICC method chosen for this study.

This model was chosen because different raters were used across observations, all observations in the study were performed by multiple raters, and the agreement between values of the raters was of interest to the study [177]. As Australia Day (Friday 26th January) was an outlier, this was removed from the analysis and dealt with separately. As it is a day when most people are not at work or school, data collected on Australia Day was compared to an average weekend day. Only those observations with two or more observers were used for the purposes of calculating ICC, 97.4% of all observations undertaken.

5.4.2.7 Ethics

Ethical approval for this study was provided by Human Research Ethics Committee of James Cook University (HREC - H7249).

5.4.3 Results

There were 309 observations conducted across 149 time points, resulting in 13,326 river interactions observed by multiple observers. Of the 309 observations, 19 (6.1%) were undertaken on Australia Day and 8 (2.6%) were not conducted by a minimum of two observers, and therefore excluded from the calculation of the ICC.

5.4.3.1 Non-Australia Day Observations

Of the 290 observations that did not occur on Australia day, there was an average of 39 people ($M=39.4$, $SD= 29.4$, Range = 0 - 137) per observation. On average, significantly more females than males were observed ($t(287)=-4.07$, $p<0.001$). A significantly higher average number of adults compared to children were also observed ($t(288)=-12.953$, $p<0.001$). (Table 33)

The largest average number of people were observed in the river, in contrast to those beside or on the river. As the day progressed, the average number of people observed significantly increased, with the highest average number of people observed during the evening hours ($F(6, 286)= 50.33$, $p<0.001$). (Table 33).

Table 33: Demographics, proximity to river and day of week and time of day of people observed (n=290 observations)

	People per observation	
	Mean (SD)	Range
Total	39.4 (29.4)	0 - 137
Sex		
Males	18.3 (14.5)	0 - 68
Females	20.6 (16.0) *#	0 - 83
Age group		
Child (0-17 years)	13.3 (11.2)	0 - 50
Adult (18 years and older)	26.0 (20.9) *#	0 - 95
Location		
In the river	20.6 (20.4)* #	0 - 84
On the river	0.7 (1.5)	0 - 12
Beside the river	18.2 (18.9) *# when compared to on the river	0 - 85
Day of week		
Monday	25.3 (17.5)	5 - 58
Tuesday	50.1 (17.6)	27 - 85
Wednesday	31.4 (21.6)	1 - 60
Thursday	32.7 (19.2)	4 – 60
Friday	32.1 (26.8)	1 - 105
Saturday	41.3 (32.5)	0 – 137
Sunday	47.6 (32.9)	3 – 126
Time of day		
Morning (7:30am -11:59am)	20.2 (18.2)	0 – 94
Afternoon (12:00pm to 5:59pm)	44.4 (28.9)	0 – 137
Evening (6:00pm to 8:30pm)	70.8 (22.1) *^	35 - 105

*# Independent samples t-test (p value) ^ One-way ANOVA *=statistical significance p<0.001*

Figure 23 depicts the mean people observed by the number of observations across the day. The number of observations peaked in the morning (10:30) and early afternoon (15:30) (n=30 observations), whereas the average number of people observed peaked in the evening hours (n= 81 people at 19:30). (Figure 23)

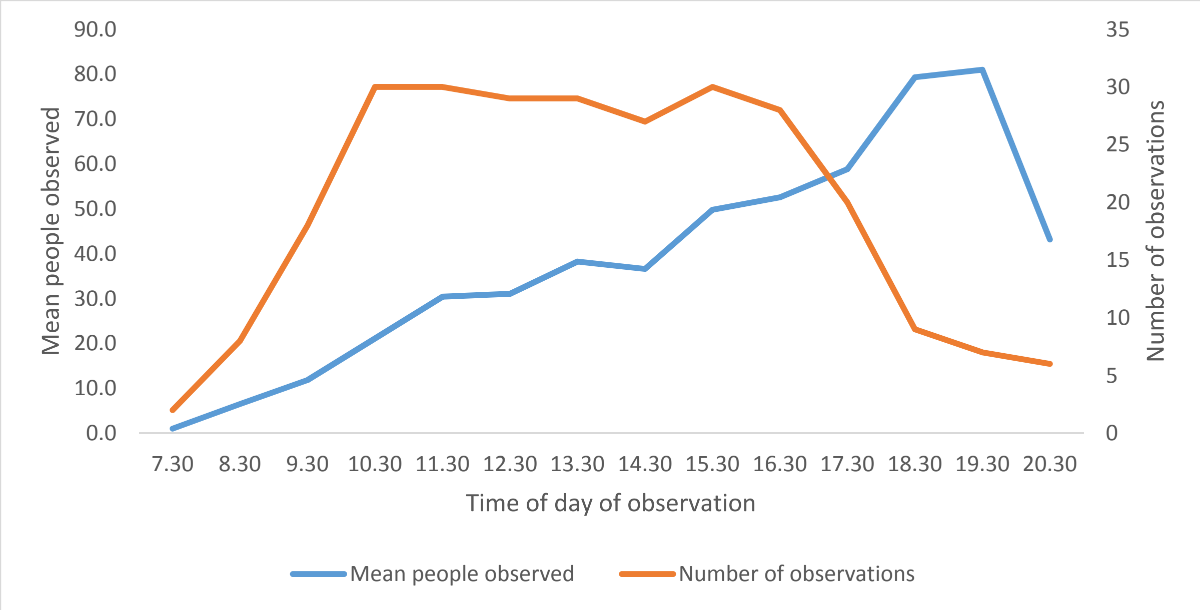

Figure 23: Time of day by average number of people observed by number of observations conducted

Note: This figure depicts the time points where data was consistently collected across all observation sites, being on the half hour.

On average, more females than males were observed on every day of the week. This was significant on Sundays (t(73)=-3.60, p=0.001). Similarly, significantly more females than males were reported during the morning (t(89)=-4.91, p<0.001) and afternoon (t(170)=-2.94, p=0.004) observations. The smallest difference in visitation by sex reported in the evening hours. (Table 34)

Table 34: Differences in river exposure by sex by in, on, or beside river, time of day and day of week

	People per observation			
	Males		Females	
	Mean (SD)	Range	Mean (SD)	Range
Total	18.3 (14.5)	0 – 68	20.6 (16.0) *	0 - 83
Day of week				
Monday	12.3 (10.3)	3 - 37	12.9 (8.6)	2 - 33
Tuesday	22.6 (12.7)	8 – 55	27.3 (10.8)	10 - 55
Wednesday	13.6 (11.0)	1 – 34	20.1 (11.3)	3 – 35
Thursday	14.0 (10.0)	2 – 35	18.7 (11.2)	2 – 35
Friday	15.4 (13.8)	1 – 56	18.1 (14.2)	1 – 65
Saturday	21.0 (15.9)	1 – 60	22.2 (14.9)	1 – 56
Sunday	21.5 (14.9)	2 – 68	26.5 (19.4) *	1 - 83
Time of day				
Morning (7:30am -11:59am)	8.9 (9.0)	1 – 46	12.6 (9.6) *	1 - 48
Afternoon (12:00pm to 5:59pm)	20.9 (13.5)	1 – 68	24.4 (16.1)	1 - 83
Evening (6:00pm to 8:30pm)	34.7 (14.0)	12 – 60	35.3 (12.1)	22 - 65

**=statistical significance p=0.007*

5.4.3.2 Australia Day

Across the 19 observations conducted on Australia Day, an average of 97 people were observed, significantly higher than when compared to the mean number of people observed on an average weekend day (t(176)=3.96, p=0.001) and higher than both an average weekend and an average weekday (excluding Australia Day) at the same location. Similar to non-Australia day findings, more females than males were observed at the river. (Table 35)

A similar average number of children were observed on Australia Day and the average weekend day. Significantly more adults were observed on Australia Day than an average weekend day (F(76, 232)= 3.81, p<0.001). (Table 35)

When examining where people are recreating on the river, a significantly higher number of people on average were recreating beside the river on Australia Day, than on an average weekend day (F(72, 236)= 10.00, p<0.001). More people on average were at the river in the afternoon hours on Australia Day than an average weekend day. There were no observations conducted on Australia Day in the evening hours to allow for comparison. (Table 35)

Table 35: Results of Australia Day observations, compared to average weekend day

	People per observation			
	Australia day average		Average weekend day	
	Mean (SD)	Range	Mean (SD)	Range
Total	96.8 (58.1)*	20 – 190	44.2 (32.7)	0 - 137
Sex				
Males	46.6 (33.1) *	6 – 100	20.6 (15.6)	0 – 68
Females	49.2 (30.5) *	10 – 128	22.9 (17.8)	0 - 83
Age group				
Child (0-17 years)	13.0 (9.4)	2 – 35	13.7 (10.6)	0 – 42
Adult (18 years and older)	81.7 (55.1) *	14 – 185	30.4 (24.0)	0 - 95
Location				
In the river	26.8 (18.1)	1 - 50	25.7 (21.5)	0 – 84
On the river	1.1 (2.4)	0 – 7	0.9 (1.7)	0 – 12
Beside the river	68.9 (39.0) *	13 – 130	17.7 (20.6)	0 - 85
Time of day				
Morning (7:30am -11:59am)	34.9 (16.4)	20 - 60	22.4 (20.9)	0 – 94
Afternoon (12:00pm to 5:59pm)	138.0 (32.0)	96 – 190	51.4 (32.3)	0 – 137
Evening (6:00pm to 8:30pm)	-#	-#	78.3 (20.3)	50 - 103

*# Data was not collected at these times on Australia Day and therefore analysis could not be conducted. *= statistical significance p=0.001*

5.4.3.3 ICC Calculations

Of the 131 calculations with a minimum of two observers, 106 (80.9%) had two observers and 25 (19.1%) had three observers. One observer (AEP) conducted 100.0% of the observations and a second observer (SP) conducted 81.7% of the observations.

There was a high degree of reliability found for all variables. The variable 'on the river' recorded perfect agreement. Average number of people observed had the next highest level of agreement between observers. The only variable with an ICC score below 0.900 was the variable of average number of people observed 'beside the river' which had an ICC(1,k) of 0.892 (CI: 0.769-0.955). (Table 36)

Table 36: Intraclass Coefficient Calculations (ICC 1,k) of accuracy of observations with a minimum of two observers

	Intraclass Correlation ICC (1,k)	Confidence Interval (CI)
Total	0.994	0.988-0.998
Sex		
Males per observation	0.955	0.905-0.981
Females per observation	0.920	0.830-0.967
Age group		
Child (0-17 years)	0.939	0.871-0.975
Adult (18 years and older)	0.961	0.916-0.984
Location		
In the river	0.981	0.959-0.992
On the river	1.000	1.000-1.000
Beside the river	0.892	0.769-0.955

High levels of reliability between observers was also seen on Australia Day, with all variables with an ICC score of above 0.900 with the exception of average number of females observed (ICC(1,k)=0.894 (CI: 0.598-0.973). When comparing the ICC scores for Australia Day to those of an average weekend day, results were mixed. The variables of total people observed, males, females, adults, and beside the river recorded higher ICC scores on the average weekend day, with the variables of children, in the river and on the river recoding higher ICC scores on Australia Day. (Table 37)

Table 37: Intraclass Coefficient Calculations (ICC 1,k) for Australia Day compared to an average day

	Australia Day		Average weekend day	
	Intraclass Correlation ICC (1,k)	Confidence Interval (CI)	Intraclass Correlation ICC (1,k)	Confidence Interval (CI)
Total	0.969	0.884-0.992	0.989	0.982-0.993
Sex				
Males	0.924	0.713-0.981	0.959	0.934-0.975
Females	0.894	0.598-0.973	0.972	0.954-0.983
Age group				
Child (0-17 years)	0.975	0.904-0.994	0.968	0.948-0.980
Adult (18 years and older)	0.930	0.736-0.982	0.984	0.974-0.990
Location				
In the river	0.991	0.965-0.998	0.976	0.962-0.986
On the river	1.000	1.000-1.000	0.998	0.997-0.999
Beside the river	0.957	0.837-0.989	0.968	0.947-0.980

5.4.4 Discussion

Calculating exposure is one of the significant challenges for understanding risk about drowning [9 50 132 281]. Collecting data on river exposure is challenging both at the macro level (i.e. how often do people visit a river in a given time period) and in particular at the micro-level (i.e. what was the person doing at the location and for how long?). This does not take into account challenges around water depth, speed and temperature as well as environmental factors such as air temperature and visibility, which may influence the risk of drowning.

This study used direct observations, which had an excellent level of agreement between observers, at four river drowning locations in Australia. Results show on average more females than males and more adults than children visited rivers. On average, more people were in the river than beside or on the river, although noting this is within the zone of observation only and does not include all people at the river. River usage peaked in the early evening hours with an average of 81 people observed at 7:30pm.

Worldwide, very few studies examining exposure to drowning risk have been conducted [50]. In Australia, much of the published data involves observations conducted at beaches [279 281 341], with one study examining self-reported river visitation (and impact on drowning risk) through the use of a CATI survey [9]. Both the beach observations [281] and survey of river visitation [9], found more males than females visiting the locations, with 70% of beach observations being male [281] and 75% of males visiting a river at least once in the 12 months prior to the survey, compared to 72% of females [9]. By contrast, this study saw a higher average number of females observed than males. Further data collection, or observation studies, at additional river locations are required to further test data on sex differences in river visitation collected through this study.

5.4.4.1 Comparing River Visitation Data to Fatal River Drowning Statistics

When exploring fatal unintentional river drowning males account for 80% of all deaths [132], yet more females than males were observed at the river. This may be due to the fact that women self-report attending the river for non-aquatic activities, and may therefore be at a lower risk of drowning, than males who commonly attend rivers to fish or use watercraft that puts them in closer proximity to the water and therefore increases drowning risk [9]. This study did not examine how river usage differed by sex and is therefore a limitation. Future research should consider means of collecting these data and supplementing such data with qualitative work examining behavioural and attitudinal differences between males and females with respect to river usage and drowning risk.

When examining river visitation by quartile of time of day, the mean number of people observed peaked in the evening hours (M=71) followed by the afternoon (M=44). This slightly differs to findings of the epidemiological analysis of fatal unintentional river drowning by the same time of day. The afternoon hours were found to record the highest proportion of river drowning fatalities (41.7%), compared to 20.8% of deaths in the evening hours [132]. This discrepancy may be explained by the evening time band for deaths running from 6:01pm to 12:00am, as opposed to the observations which ran from 6:00pm to 8:30pm, due to ethical constraints, as well as seasonal variation in drowning risk.

Similarly, due to ethical constraints, no data was captured in the early morning hours (12:01am to 6am), during which time a further 10% of river drowning fatalities occur. Ethical strategies, which do not compromise safety for the data collectors, should be explored to address this gap in river exposure understanding. Options may include remote camera observations or time lapse photography.

5.4.4.2 Errors and Bias

ICC calculations indicated an excellent level of agreement between observers for all data collected. The majority of ICC scores were above 0.900 with the variable of on the river scoring perfect agreement. This may be due to the fact that there were smaller numbers of people on the water boating or kayaking, as opposed to in, or beside the river. Observers were more accurate in calculating the number of males and adults at the river, whereas ICC scores were lower (i.e. <0.900) for the variables of beside the river and females on Australia Day. This may be due to larger numbers, or challenges in determining gender when conducting observations, however overall, variables collected on Australia Day still had reasonably accurate ICC scores.

The locations chosen for observations had a bias towards swimming and activities where the person visiting the river is more likely to be in the water or beside the water, rather than on the water. Rivers often had a beach or step entry encouraging swimming. Only one location (the Hawkesbury River) was more predominately geared toward boating and had a boat ramp. Watercraft-related incidents (including both powered and unpowered boats and craft) account for 14% of all river drowning deaths [132] in Australia. Future data collection must collect data from a diverse range of river drowning locations and explore data collection at different locations along a river (i.e. not only those locations adjacent to popular entry and exit points).

5.4.4.3 Challenges

Rivers are a fluid environment, which poses challenges for the collection of data on exposure. While conducting observations, it was possible for individuals observed to move in and out of the water, to disappear entirely under the water while swimming, and even move in or out of the observation zone entirely. Although there was a high degree of reliability between observers, anecdotally observers reported challenges in determining the sex of a person, especially if only the head of the person was visible above the water and also difficulty in determining if older teenagers were children or adults. Exploring alternative ways to collect such data, such as through participatory public data collection tools including electronic diaries or cell phone 'apps' may be warranted to overcome such data challenges.

Collecting data for the length and breadth of a river is another challenge. This study used observation points at known entry and exit points at rivers. While the rivers chosen were high risk drowning locations, people can drown at any point along a river and this study collected data only from the observation zones at each river. Similarly, the hours chosen to collect data may have affected the number (and activities) of people observed. Observations were conducted during daylight hours (with the last observation conducted at 8:30pm (still light due to daylight savings). However, 21% of unintentional fatal drownings occur in rivers during the evening hours (6:01pm to 12am) and 10% occur during the early morning hours (12:01am to 6am) [132]. Further data are required on behaviour at rivers during the late evening and early morning hours, including the role of alcohol [4 133]. Remote observations cameras and community data collection through diaries or cell phone "apps", might be a possibility to collect data on river visitation and usage during the late evening and early morning hours.

Data were collected on three types of river usage, in the river (i.e. in water), on the river and beside the river. Observations conducted on average people beside the river were not as accurate as in the river or on the river. The observation zones often covered quite a large area immediately from the waters' edge to a discernible area up to several metres beyond the riverbank. Falls (i.e. unintentional entry into water) account for 21% of all fatal unintentional drownings in rivers [132], although it is not known what distance people fall from. Further research is required to examine the specific issue of falls into rivers, including the impact of alcohol on falls among adults.

5.4.4.4 Holidays and the Impact on Exposure

An increase in river visitation was seen on Australia Day with an average of 97 people per observation, compared to an average of 44 on an average weekend day and an average of 39 people per observation. When compared to an average weekend day, significantly more males, females and adults were observed on Australia Day, as well as significantly more people in and beside the river.

Australia Day is a national public holiday where most adults do not attend work and students are on school holidays. Studies have shown an increase in drowning risk on holidays [327 343-345], due to increased leisure time, travel to unfamiliar aquatic environments [199] and alcohol consumption [329]. Studies have also shown increased alcohol consumption at rivers on Australia Day [4]. Such findings must be considered in the development and timing of distribution of public awareness messages about drowning risk at rivers. Further research is also required to determine if more people visiting rivers is protective or increases drowning risk.

It should be noted that there were Australia Day celebration events held at the data collection site (Murray River) which may have attracted more people than usual to the river precinct. The data collected represents this site on one day only and may not be indicative of other river sites on Australia Day. Further research is required to determine if similar increases in visitation are seen at other rivers on Australia Day, and the impact of pre-organised events, on crowd numbers. The importance of conducting a risk assessment and having a risk mitigation plan in place must be communicated to local councils and organisers holding events in and around rivers [16].

5.4.4.5 Implications for Future Research

Observing river usage is a sound methodology for data collection on river visitation and usage, as shown by the high ICC scores, which indicated an excellent level of agreement between observers. The process appears to have good usability in the field, with minimal tools (e.g. two observers and a clipboard and pen with a data collection sheet) yielding consistent and usable data. Direct observations also avoid some of the limitations of surveys [173]. However, the process of conducting observations has its own limitations, as well as being time consuming and labour intensive. While other areas of injury prevention also utilise headcounts [346-348], more realistic methods for gathering data on river exposure and usage should also be explored. Alternative data collection measures may include community observation methods that would see larger amounts of data collected at a larger number of river locations with more diverse geographical dispersion and usage patterns. Alternative data collection methods may support or dispute the accuracy of direct observations to calculate river usage.

5.4.4.6 Practical Applications

Key findings of this study include the increased the higher usage of rivers among females, adults, in the early evening hours and on weekends and public holidays. Findings must be considered when developing advocacy messages and interventions targeted to those more likely to be exposed to the risk of river drowning.

Exposure impacts drowning risk [9 196 281]. Building upon epidemiological studies of drowning by considering exposure, rather than crude drowning rates per 100,000 persons, can provide a more nuanced understanding of those at risk and better inform drowning prevention interventions.

This study detailed a simple approach to the collection of data on exposure that recorded high levels of accuracy between coders. The method was low resource, albeit with some challenges, in particular human resource requirements. Alternative approaches such as remote camera observation or the use of diaries and mobile phone "apps" should be explored to allow for greater data collection, including at a wide range of locations and across more time points [9]. The findings of this study provide justification for observation-based data collection for drowning, in particular at rivers, which have been a neglected yet highly prevalent location for drowning.

5.4.4.7 Strengths and Limitations

This study is the first of its kind to use direct observations at river drowning locations. The study design resulted in observations conducted at different times across the day and during both weekday and weekends. The large number of observations conducted (N=13,326) generated a significant pool of data with which to conduct statistical analysis about river usage. The study design is transferrable to the different sites where data was collected, with a high degree of reliability between observers.

There are limitations associated with this study. The data represents the best efforts of the observers. The fluid nature of river environments, where river users may have moved between zones while being observed (e.g. from beside the water to in the water), may have affected accuracy of data. While observers did not collude or compare findings, they were standing near each other in order to observe the same zone when recording data, which may have impacted the results. Observers may have benefited from practice effects, which saw data recording improve over time.

Data was collected in person (i.e. not using still images or video) and therefore there were site-specific visibility issues (e.g. natural slopes and gullies in the land, trees etc.), which may have impaired an observers ability to accurately record data. Observations zones varied in overall size site by site. As the research attracted media coverage (print, radio, television and online), the results may be subject to social desirability bias. The presence of researchers may have influenced behaviour. While data was collected consistently at all four river locations for Fridays, Saturdays and Sundays, data for Monday – Thursday was collected at one location only. This is a pilot study and represents what was observed at the four sites during data collection times only. The sites chosen aimed to reflect a diverse range of river scenarios, however these sites may not be a representative mix of typical river recreational locations. Further research is required to test these findings more widely at more diverse river locations.

5.4.5 Conclusion

Rivers are a leading location for drowning internationally, and the leading location or drowning in Australia, though little is known about exposure to drowning risk. Through direct observations, this study collected data on river visitation and usage, with a high degree of reliability between multiple observers. Despite males accounting for 80% of unintentional river drowning fatalities, more females were observed at rivers. Increased visitation was recorded on weekends and the Australia Day public holiday. The use of observational headcount provided a greater understanding of river visitation and usage, and therefore drowning risk. Alternative data collection tools and methodologies, such as community observations and the use of cell phone “apps”, should be explored.

5.5 The Flood-Related Behaviour of River Users in Australia (Short Report [SR] 1)

Peden AE, Franklin RC, Leggat P. The Flood-Related Behaviour of River Users in Australia. *PLOS Currents Disasters.* 2018 Jun 14 . Edition 1. doi: 10.1371/currents.dis.89e243413a0625941387c8b9637e291b.

5.5.1 Introduction

Flooding is a common natural disaster [240], leading all other natural disasters with respect to the number of people affected and in resultant economic losses [349]. The Centre for Research on the Epidemiology of Disasters (CRED) reported 164 floods claimed the lives of 4,731 people in 2016, with a further 77.8 million people affected [350]. Drowning is a leading cause of death during times of flood [241], with floods estimated to have claimed the lives of over 500,000 people between 1980 and 2009 globally [17].

Rivers have been identified as a leading location for drowning internationally [17] and in Australia [132], and flooding is a known risk factor [134]. Flooding results in the drowning deaths of 13 people, on average, per year in Australia [134].

Geographical remoteness (which includes isolation from major services such as medical assistance) is a risk factor for flood-related drowning in Australia [134]. People in remote and very remote areas experience 80 and 229 times the risk respectively of drowning in a flood-related incident compared to major cities [134]. An exploration of how to prevent drowning incidents during floods in rural and remote Australia is vital to reducing the risk and loss of life.

Driving through floodwaters is the leading activity prior to drowning in floodwaters, both in Australia [134 259] and internationally [70 266]. Recreational interaction with floodwaters, such as for swimming, also claims lives domestically in Australia [134 351], as well as around the world [265 352].

The need for systematic data collection for the prevention of loss of life during disasters has been identified, rather than data collected on an ad-hoc basis at the time of the emergency [70]. To guide prevention efforts, including identifying those most at risk, this study aimed to survey river users on previous participation in two flood-related behaviours; driving through floodwaters and swimming in a flooded river.

5.5.2 Methods

A self-reported survey of adult river users (18 years and older) at four river locations was conducted in January and February 2018 (summer, school holidays, wet season), namely Alligator Creek in

Queensland (classified as Outer Regional) and the Murrumbidgee (Inner Regional), Murray (Inner Regional) and Hawkesbury (Major Cities) rivers in New South Wales. Alligator Creek was located in a national park (no cost to enter), whereas the other three sites were on public land. All locations had BBQ facilities, public toilets and the Hawkesbury site featured a boat ramp. All locations were previously identified as blackspots for fatal drowning.

Potential respondents were randomly approached and asked to participate. Once informed consent was obtained, respondents were asked a range of demographic and river usage questions, as well as questions about knowledge of drowning risk factors and alcohol consumption questions. All river users who completed a survey were also breathalysed, whereby their blood alcohol concentration (BAC) was estimated by recording the alcohol on their expired breath [311]. For analysis, the results of the breathalysing were classified as BAC positive yes/no (i.e. a BAC ≥0.001%) and BAC contributory yes/no (i.e. a BAC ≥0.05%).

The focus of this study is the self-reported flood-related behaviour of river users in Australia. Respondents were asked two questions on flood-related behaviour: 'Have you ever driven through floodwaters?' and 'Have you ever swum in a flooded river?' Respondents could answer yes or no. This study forms part of a wider study on river usage [9] and alcohol consumption [132 133].

The survey was administered as both paper-based forms and online through SurveyGizmo (www.surveygizmo.com) using iPads. Those surveys completed on paper were then transferred into SurveyGizmo on the same day the paper-based survey was undertaken. The final dataset was downloaded from SurveyGizmo into IBM SPSS V20 [157] for analysis. To check accuracy of data entry, every tenth paper-based survey (n=56) was checked (by authors AEP and RCF). This resulted in the checking of 56 x 34 questions, resulting in a 0.7% error rate. These errors were corrected prior to analysis.

In SPSS, remoteness classification of the respondent's postcode was coded using the Australian Standard Geographical Classifications (ASGC) [163]. Residential postcode was coded to its remoteness classification using the Doctor Locator website (www.doctorconnect.gov.au).

Residential postcode of the respondent was also coded to the Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) [316]. The Index is ranked from 1-10, with a low score indicating relatively greater disadvantage (e.g. many people with low incomes and many people in unskilled occupations), compared to a high score which indicates a relative lack of disadvantage. For ease of analysis, IRSAD was categorised as low (rank 1-3), high (rank 8-10) and other/unknown.

Univariate analysis was undertaken as was chi square analysis with a 95% confidence interval ($p<0.05$). Chi square analysis was run using yes or no for each flood-related behaviour. Chi square analysis excluded the unknown variable.

Ethics approval for this study was granted by the James Cook University Human Research Ethics Committee (HREC – H7249).

5.5.3 Results

Of the 688 people surveyed, 98.3% (n=676) answered the question about driving through floodwaters and 98.0% (n=674) answered the swimming in a flooded river question. There were 35.7% of respondents who had driven through floodwaters. Males (43.9%) were more likely to have driven through floodwaters than females (27.8%) ($X^2=19.0$; $p<0.001$) (Figure 24).

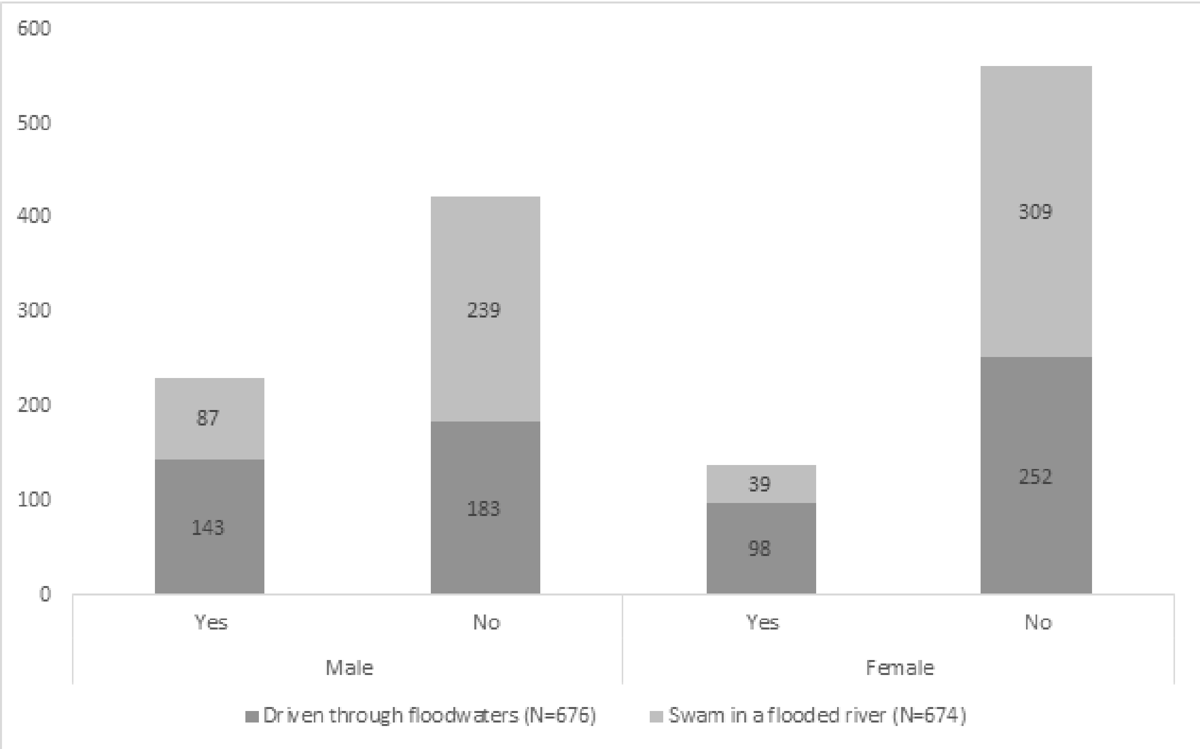

Figure 24: Two flood-related behaviours by sex of river users surveyed

People aged 75+ years (42.9%), 65-74 year olds (40.7%) reported the highest proportion of respondents, who had driven through floodwaters; however, age group did not impact likelihood of having driven through floodwaters. (Table 38)

Table 38: Driven through floodwaters yes/no by demographic variables, chi square analysis (p value) (N=676)

	Total		Driven through floodwaters - yes		Driven through floodwaters - no		X^2 (p value)
	N	%	N	%	N	%	
Total	676	100.0	241	35.7	435	64.3	-
Sex							
Male	326	48.1	143	43.9	183	56.1	18.969 (p<0.001)
Female	350	51.9	98	27.8	254	72.2	
Age group							
18-24 years	190	28.1	67	35.3	123	64.7	0.017 (p=0.895)
25-34 years	144	21.3	55	38.2	89	61.8	0.516 (p=0.473)
35-44 years	124	18.3	44	35.5	80	64.5	0.002 (p=0.966)
45-54 years	120	17.8	38	31.7	82	68.3	1.010 (p=0.315)
55-64 years	64	9.5	23	35.9	41	64.1	0.003 (p=0.960)
65-74 years	27	4.0	11	40.7	16	59.3	0.318 (p=0.573)
75+ years	7	1.0	3	42.9	4	57.1	0.160 (p=0.689)
Country of birth							
Australia	571	84.5	216	37.8	355	62.2	7.598 (p=0.006)
Outside of Australia	105	15.5	25	23.8	80	76.2	
Remoteness classification of residential postcode							
Major Cities	123	18.2	34	27.9	89	73.0	4.906 (p=0.027)
Inner Regional	388	57.4	143	36.9	245	63.1	0.130 (p=0.718)
Outer Regional	136	20.1	58	42.6	78	57.4	2.999 (p=0.083)
Remote & Very Remote	6	0.9	2	33.3	4	66.7	0.023 (p=0.880)
Unknown	23	3.4	4	17.4	19	82.6	-
IRSAD classification of residential postcode							
Low	117	17.3	42	35.9	75	64.1	0.877 (p=0.349)
High	113	16.7	34	30.1	79	69.9	
Other/Unknown	446	66.0	165	37.0	281	63.0	-
Alcohol contributory (BAC ≥0.05%)							
Yes	49	7.2	28	57.1	21	42.9	10.855 (p=0.001)
No	627	92.8	213	34.0	414	66.0	

Please note the unknown variable was excluded from chi square analysis

Respondents born in Australia were significantly more likely to have driven through floodwaters (37.8% yes; X^2=7.6; p=0.006). Respondents residing in outer regional areas had the highest proportion of people driving through floodwaters (42.6%) compared to major cities (27.9%), with residents of major cities significantly less likely to have performed the behaviour (X^2=4.9; p=0.027). Respondents classified as residing in low IRSAD areas reported a slightly higher proportion of respondents having driven through floodwaters (low 35.9%; high 30.1%). (Table 38)

Nineteen percent (19.2%) of those who self-reported having driven through floodwaters recorded a positive BAC reading, with 60.9% of those recording a BAC at contributory levels. Those who had driven through floodwaters were significantly more likely to record a BAC at contributory levels (X^2=10.9; p=0.001). (Table 38)

Of all respondents to the swimming in a flooded river question, 18.7% stated they had swum in a flooded river. Males were significantly more likely to have swum in a flooded river (X^2=26.5; p<0.001). Respondents aged 18-24 years were significantly more likely to self-report having ever swum in a flooded river (X^2=17.9; p<0.001), while 45-54 year olds were significantly less likely to report having done so (X^2=12.0; p=0.001). (Table 39)

Table 39: Swum in a flooded river yes/no by demographic variables, chi square analysis (p value) (N=674)

	Total		Swum in a flooded river - yes		Swum in a flooded river - no		X2 (p value)
	N	%	N	%	N	%	
Total	674	100.0	126	18.7	548	81.3	-
Sex							
Males	326	48.4	87	26.7	239	73.3	26.537 (p<0.001)
Females	348	51.6	39	11.2	309	88.8	
Age group							
18-24 years	191	28.3	55	28.8	136	71.2	17.893 (p<0.001)
25-34 years	143	21.2	33	23.1	110	76.9	2.294 (p=0.130)
35-44 years	124	18.4	18	14.5	106	85.5	1.745 (p=0.186)
45-54 years	120	17.8	9	7.5	111	92.5	12.036 (p=0.001)
55-64 years	63	9.3	6	9.5	57	90.5	3.845 (p=0.050)
65-74 years	26	3.9	2	7.7	24	92.3	2.154 (p=0.142)
75+ years	7	1.0	3	42.9	4	57.1	2.717 (p=0.099)
Country of birth							
Australia	571	84.7	113	19.8	458	80.2	2.950 (p=0.086)
Outside of Australia	103	15.3	13	12.6	90	87.4	
Remoteness classification of residential postcode							
Major Cities	122	18.1	21	17.2	101	82.8	0.084 (p=0.772)
Inner Regional	388	57.6	54	13.9	334	86.1	11.462 (p=0.001)
Outer Regional	136	20.2	43	31.6	93	68.4	21.086 (p<0.001)
Remote & Very Remote	5	0.7	0	0.0	5	100.0	1.116 (p=0.291)
Unknown	23	3.4	8	34.8	15	65.2	-
IRSAD classification of residential postcode							
Low	115	17.1	20	17.4	95	82.6	0.448 (p=0.503)
High	113	16.8	16	14.2	97	85.8	
Other/Unknown	446	66.2	90	20.2	356	79.8	-
Alcohol contributory (BAC ≥0.05%)							
Yes	49	7.3	19	38.8	30	61.2	13.913 (p<0.001)
No	625	92.7	107	17.1	518	82.9	

Please note the unknown variable was excluded from chi square analysis.

Inner regional dwelling respondents were significantly less likely to have swum in a flooded river (X^2=11.5; p=0.001); whereas those residing in outer regional areas were significantly more likely to have done so (X^2=21.1; p<0.001). Country of birth and IRSAD did not significantly impact likelihood of having swum in a flooded river. (Table 39)

Twenty-two percent (22.2%) of those who self-reported ever swimming in a flooded river recorded positive BAC readings when breathalysed. Of these, 67.9% recorded BACs at contributory levels. There was a statistically significant link between those who reported having swum in a flooded river and both positive BACs (X^2=4.4; p=0.037) and BACs at contributory levels (X^2=13.9; p<0.001). (Table 39)

5.5.4 Discussion

Flooding is one of the most deadly, and costly, of all natural disasters [349 350], the frequency of which is likely to increase due to climate change [353]. Minimising the impact of such disasters, including people's interaction with floodwaters, will reduce loss of life. This study found that 36% of river users surveyed had driven through floodwaters and 19% had swum in a flooded river. Both activities were more common among males, with 18-24 year olds and people residing in outer regional areas significantly more likely to report having swum in a flooded river. There was a statistically significant link found between respondents who self-reported having participated in both risky flood-related behaviours and recording BACs at contributory levels when breathalysed at the river.

The movement of people during floods is a challenge for those living in rural Australia. Previous research [121 248 354 355] exploring factors impacting driving through floodwaters and avoiding driving through, has highlighted the issue of fatigue, a particularly important factor as an alternate route can add significant time to a journey and thus tempt drivers to cross flooded roads [121]. Reduced investment in infrastructure such as bridges in regional and remote areas [356] may also contribute to an increased need to drive through floodwaters.

Simply discouraging people from driving through floodwaters is unlikely to be practical in rural Australia, particularly in areas with regular low-level flooding. More effective prevention strategies may include improved education on when it is safe to drive through (low depth, still water, stable road base) and when it is not (e.g. deep water, moving water and unstable road base). However there are challenges in identifying a stable road base and current prevention messages take a didactic approach advising “If it’s flooded, forget it” (http://floodwatersafety.initiatives.qld.gov.au/) and not to drive through.

Outer regional residents were found to have the highest proportion of respondents who self-reported having ever driven through floodwaters, as well as being significantly more likely to have previously swum in a flooded river. This may be due to the lack of infrastructure, lower initial awareness of the risk or over-familiarity with flooding leading to an underestimation of the risk. The link between participation in risky flood-related behaviours and outer regional residents requires further investigation.

Internationally, males are over-represented in drowning statistics [17], accounting for 80% of fatal drownings overall, and fatal river drowning in Australia [132]. Males have been identified as having poorer swimming skills [299] and lower levels of water safety knowledge than their female peers [298], as well as being more prone to risk-taking behaviour [296 323]. However, this proportion is higher than the proportion of 60% male for flood-related fatalities due to driving through floodwaters [134], although it reflects the number of people reporting in this study (i.e. the 59% of male respondents to this survey who reported having driven through floodwaters). Thus highlighting that the risk is about exposure (i.e. driving through floodwaters) rather than related to the sex of the person who drowns. While different messaging for each sex may be appropriate for the effective delivery of prevention messages, there is a need for strategies to mitigate the likelihood of people driving through floodwaters targeted at flood-prone locations, regardless of gender.

Although age was not found to be a statistically significant indicator of likelihood of having driven through floodwaters, respondents in the oldest age groups recorded the highest proportion of respondents who had undertaken the activity, with 43% of 75+ year olds and 41% of 65-74 year olds self-reporting having driven through floodwaters. As the questionnaire did not define a timeframe within which to have performed the activity (i.e. had the respondent ever driven through floodwaters), this may reflect a relatively greater number of flood seasons through which the respondent has lived and therefore, had the opportunity to drive through floodwaters, rather than any riskier behaviour being undertaken by the older age group. Further research may be warranted exploring attitudes towards driving through floodwaters among the older age group.

This study identified one in five respondents had swum in a flooded river. Unlike driving through floodwaters where as people aged, the likelihood of driving through floodwater increased (greater chance of encountering floodwater), young people (18-24 years) were more likely to report swimming in a flooded river. This dichotomy may suggest an element of risk-taking in youth, however this appears to be a recent activity, as older people were less likely to report swimming in floodwaters. Swimming in floodwaters is a poorly understood behaviour with little previous research. The survey tool did not examine the context within which the respondent had swum in a flooded river (e.g. out of necessity, skylarking or performing a rescue). Further research should examine the reasons behind this behaviour. With those residing in outer regional areas found to be more likely to have swum in a flooded river, prevention strategies must take into account the regional and remote context [210].

Alcohol is a known risk factor for drowning and aquatic-related injury [357]. This study identified a statistically significant link between alcohol consumption, in particular respondents recording BACs at contributory levels, and self-reported participation in both risky flood-related behaviours being analysed. While the survey questionnaire did not ask if the respondent was under the influence of alcohol at the time of participating in these risky flood-related behaviours, it may be that alcohol contributes to a person's decision to take risks in and around floodwaters. This is worthy of further research to better understand the motivations underlying a person's decision to interact with floodwaters in such a way. Such information will add a helpful layer to the development of preventative messaging and campaigns [355].

5.5.5 Limitations

As with all self-reported surveys there are limitations. These include recall bias, the survey being administered in English and the survey not defining what was meant by floodwaters (for driving through) or a flooded river (for swimming). Respondent were asked if they had 'ever' undertaken the two flood-related behaviours, and as such caution should be used when interpreting the age group analysis as the age at which the behaviours were performed was not captured. This study did not examine frequency of the behaviours undertaken. This was a cross-sectional study and does not determine cause and effect. The sample was a random convenience sample and therefore results represent the views of those attending the four river locations only. The survey was administered in the summer and wet season months and may impact recall. Refusals were not recorded.

5.5.6 Conclusion

Preventing drowning in floodwaters is an international challenge, made more difficult by people driving through, or swimming in, floodwaters. Practical strategies to reduce loss of life due to driving through floodwaters are required, including skills to assess the risk and make informed decisions on when it is safe to drive through and when it is not. Swimming in floodwaters is a little researched topic. While this study has identified one in five people have undertaken the behaviour, commonly at a young age, there is a need for further research to understand the context of the behaviour and the motivations for engaging in it, including the role of alcohol. Such knowledge would allow for effective, regionally-specific drowning prevention strategies to be developed, targeting those most at-risk, in order to reduce loss of life during times of flood.

Chapter 6: Results Part 3 – Strategies for Prevention

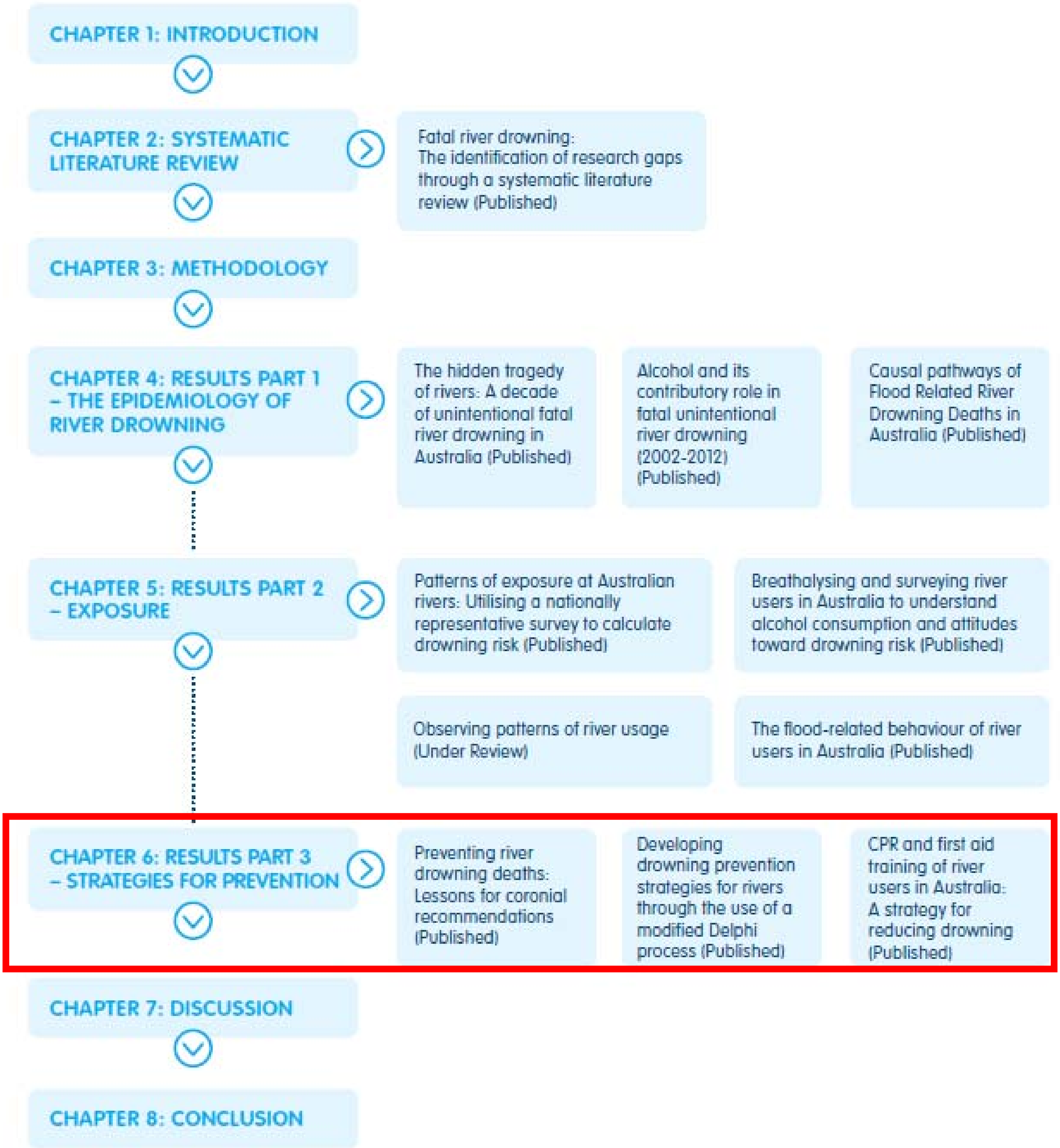

Figure 25: Chapter 6 position within thesis structure

6.0 Overview

Chapter 6 explored river drowning prevention, again addressing a gap in the published literature as identified in the systematic literature review. Very few studies in the systematic literature review proposed river drowning prevention strategies, with only one study publishing the findings of the implementation and evaluation of a proposed strategy. This chapter continues its public health approach to river drowning and attempts to identify evidence to support the recommendation of prevention strategies for river drowning.

The first study in this chapter (Paper 8) uses the 10 year, total population dataset used in the epidemiological studies (Papers 2-4), to explore the frequency and nature of coronial recommendations associated with cases of unintentional fatal river drowning. The study assesses coronial recommendations against a modified SMART principle and against the Hierarchy of Control. This study was published in the *Health Promotion Journal of Australia* in December, 2017. The full reference for this published study is as follows:

> Peden AE, Franklin RC, Leggat PA. Preventing river drowning deaths: Lessons from coronial recommendations. *Health Promotion Journal of Australia*. 2018;29(2):144-152. doi: 10.1002/hpja.24

The second study in this chapter (Paper 9) used a modified Delphi process comprising a panel of drowning prevention researchers and practitioners to identify, assess and refine strategies they felt would be more effective at reducing river drowning. This study was published in Injury Prevention in March 2019. The full reference for this published study is as follows:

> Peden AE, Franklin RC, Leggat PA (2018) Developing drowning prevention strategies for rivers through the use of a modified Delphi process. *Injury Prevention*. Published Online First 30 March 2019. doi: 10.1136/injuryprev-2019-043156

The third study in this chapter (Short Research Article [SRA] 2) uses data collected during the community survey and breathalysing study. This study focused specifically on the CPR training of river users. The study examined lifetime participation in CPR as well as currency of qualification by the demographics of river users aged 18 years and over. This study was published in the *Health Promotion Journal of Australia* in August, 2018. The full reference for this published study is as follows:

> Peden AE, Franklin RC, Leggat PA. Cardiopulmonary resuscitation and first-aid training of river users in Australia: A strategy for reducing drowning. *Health Promotion Journal of Australia*. 2018;00:1–5. https://doi.org/10.1002/hpja.195

6.2 Preventing River Drowning Deaths: Lessons From Coronial Recommendations (Paper 8)

Peden AE, Franklin RC, Leggat PA. Preventing river drowning deaths: Lessons from coronial recommendations. *Health Promotion Journal of Australia*. 2018;29(2):144-152. doi: 10.1002/hpja.24

6.2.1 Introduction

Understanding the causal factors that lead to a drowning are key to developing targeted, effective and evidence-based strategies for prevention. It is rare for such information to be collected, and therefore, only part of the story of a drowning is told. However, a coroner has the power to seek a more complete picture of the circumstances surrounding a death. [358 359]

The coronial process can provide rich information on the causal factors leading to death. [30 156 360] The collation of such information can be vital to the development of prevention strategies supported by evidence. [361] In Australia, this information may be made available to researchers through the NCIS, an Internet-based data storage and retrieval system for Australian and New Zealand coronial cases. [31] Documentation that can be available for each case includes a police report with a narrative of circumstances leading to death, an autopsy report defining cause of death and existence and contribution of any pre-existing medical conditions and a toxicology report detailing the drug and alcohol profile of the victim. [156]

When investigating a death, a coroner may deliver findings with recommendations for the prevention of future deaths. A coroner may take a case, or a series of similar cases, to inquest. [362] A coroner, in handing down inquest findings, can make recommendations aimed at preventing deaths under similar circumstances. [360] A coroner can also note where corrective actions have been undertaken prior to handing down their finding(s).

Drowning, is a global public health issue [17] and unintentional fatal drowning claims an average of 281 lives annually in Australia. [49] Rivers are the leading location for unintentional fatal drowning in Australia, with an annual average of 77 lives lost. [132] Risk factors for unintentional fatal river drowning are increasingly well understood and include being male, alcohol consumption, [133] Aboriginal and Torres Strait Islander people, [132] falls into water by children and activities involving watercraft for adults [132]; however, there is little evidence on the efficacy of proposed prevention strategies. [50] Fatal drownings, like other external cause deaths, are considered sudden and unexpected and must be investigated by a coroner. [31]

Reviewing coronial recommendations can improve understanding of their contribution to injury prevention. [360] Few studies examining coronial recommendations have been conducted [30 360] and none have focused purely on coronial recommendations associated with river drowning. Coronial recommendations developed in accordance with the SMART principle (specific, measurable, achievable, relevant and time bound), [149] and based on sound theory (such as the Hierarchy of Control), may improve the likelihood of preventative impact on future events.

This study of coronial cases of unintentional fatal drowning in Australian rivers from an injury prevention perspective aims to: (i) Examine the demographics and circumstances of cases that resulted in coronial recommendations, (ii) conduct thematic analysis of the unique recommendations made and (iii) apply theory (such as the Hierarchy of Control and a modified SMART principle) to the unique recommendations made.

6.2.2 Methods

6.2.2.1 National Fatal Unintentional River Drowning Data

All cases of unintentional fatal drowning in Australian rivers, creeks and streams (henceforth referred to as rivers) between 1 July 2002 and 30 June 2012 were identified through privileged access to the NCIS. The method for defining and capturing such fatalities has been detailed previously. [132-134]

Cases within the NCIS remain open (i.e. under investigation) until such time as the coroner makes a ruling as to the victim's cause of death and the case is closed. Only those cases that were closed (i.e. no longer under coronial investigation [N = 730]) were included in this study.

The 11 cases with preventative actions and the 26 cases associated with the Queensland Floods Commission of Inquiry were excluded as preventative actions are undertaken upon prior to the coroner making recommendations and the Queensland Floods Commission of Inquiry was a special one off event, established by government and had strict conditions on what could be considered within its scope.

All cases of unintentional fatal river drowning were extracted from the NCIS and entered into an SPSS database (V20). [157] Variables on demographics and circumstances of river drowning cases were collected and included NCIS case number, case status (i.e. open or closed), age, sex, activity prior to drowning, geographical location of drowning, remoteness classification of drowning incident postcode, if the person who drowned was known to identify as Aboriginal and/or Torres Strait Islander and information on Multiple Fatality Events (MFEs) and flooding. [15] A MFE was classified as such if more than one victim drowned in the same incident. Activities prior to drowning were coded as per the RLSSA National Fatal Drowning Database Coding and Definitions Manual. [15]

Ethical approval for this study was gained from the Victorian Department of Justice Human Research Ethics Committee (JHREC -CF/15/13552) and James Cook University (HREC - H6282).

6.2.2.2 Coronial Recommendations

Cases with coronial recommendations were identified through a combination of full-text screening of the available coronial finding reports and reviewing the NCIS "Recommendations Made/Warnings Made" data field. Those cases marked with a "Yes Recommendations Made" were retained and the full text of the coronial report was reviewed.

Unique coronial recommendations were analysed. By unique, the authors mean each recommendation was only analysed once. If, for example a MFE involved four victims and the coronial finding for each of the four victims featured the same three recommendations, these three recommendations were only coded and analysed once. All unique coronial recommendations were extracted into an Excel spreadsheet.

Thematic analysis was conducted using the six phase approach of Braun and Clarke [167] (familiarising yourself with your data; generating initial codes; searching for themes; reviewing themes; defining and naming themes and producing the report). Two authors (AEP and RCF) familiarised themselves with the data and generated initial codes in a deductive manner. The Hierarchy of Control (a 6-level model [elimination, substitution, engineering, administration, behaviour and personal protective equipment (PPE)] used to minimise or eliminate exposure to hazards by utilising a hierarchy to depict hazard controls in order of decreasing effectiveness), [271] was used as the initial coding framework. For administration, (the largest category of recommendations under the Hierarchy), an inductive process was undertaken to further explore the themes of communication, education, regulation, signage and training. Three recommendations that could not otherwise be coded were grouped into an "Other" category. Where there was a discrepancy between authors with respect to coding ($k = 0.8$; $p<0.01$), this was reviewed and discussed by both authors together until consensus was achieved. To provide a further layer of analysis, the remaining administrative recommendations were classified into: actions, procedural, policy and research.

6.2.2.3 Modified SMART Principle

The same two authors (AEP, RCF) then identified where each unique recommendation satisfied any of the aspects of the modified SMART principle as a "yes" or "no." In coding the "specific" component, an inductive process emerged whereby the authors believed two aspects required coding; whether a recommendation mentioned a specific action being recommended and/or the specific organisation or individual who should be responsible for the action. Therefore, each unique recommendation was coded against the six components of the modified SMART principle namely:

(specific actions, specific individuals/organisations responsible, measurable, achievable, relevant and time bound). The definitions used for each component within the modified SMART principle can be found in Table 40. In instances of disagreement in coding, which occurred in 6.8% of cases, the authors discussed coding until consensus was reached.

The "relevant" component was defined as "would the recommendation(s) prevent future similar deaths." This was coded on a 3-point scale, "yes," "no" and "indeterminate" (defined as there being too many factors to make an interpretive decision as to whether it would be effective in preventing future similar deaths).

Table 40: Modified SMART principle [149] criteria definitions

Letter	Term	Definition
S	Specific	Does the recommendation mention a person, organisation or group of organisations that must undertake the recommended action?
		Does the recommendation outline specific actions to be undertaken, rather than being vague?
M	Measurable	Is the success or otherwise of the implementation of the recommendation able to be assessed?
A	Achievable	Is it reasonably foreseeable that the recommendation will be able to be successfully implemented as described?
R	Relevant	Would the recommendation prevent future similar deaths? i.e. is there evidence for its effectiveness?
T	Time bound	Is a timeframe mentioned in the recommendation within which it must be undertaken?

6.2.2.4 Analysis

Coding was conducted in Excel and then transferred into SPSS for analysis. Descriptive statistics were utilised and chi square analysis was undertaken. A modified Bonferonni test as suggested by Keppel [159] has been applied, deeming statistical significance $p<0.01$. Where variable analysis presents cases less than three, not shown (NS) has been used for both numbers and percentages in Table 41. A score out of six was given to each recommendation based on how many components of the modified SMART principle the recommendation satisfied. These scores were used to calculate a mean and standard deviation by category of recommendation and an ANOVA with F (P value).

6.2.3 Results

There were 730 closed cases of unintentional fatal river drowning, of which 58 cases (7.9%) had 71 unique coronial recommendations. When examining trends over time, the number of cases with coronial recommendations ranged from a low of two in 2009/10 to a high of 10 cases with recommendations in 2007/08. (Figure 26)

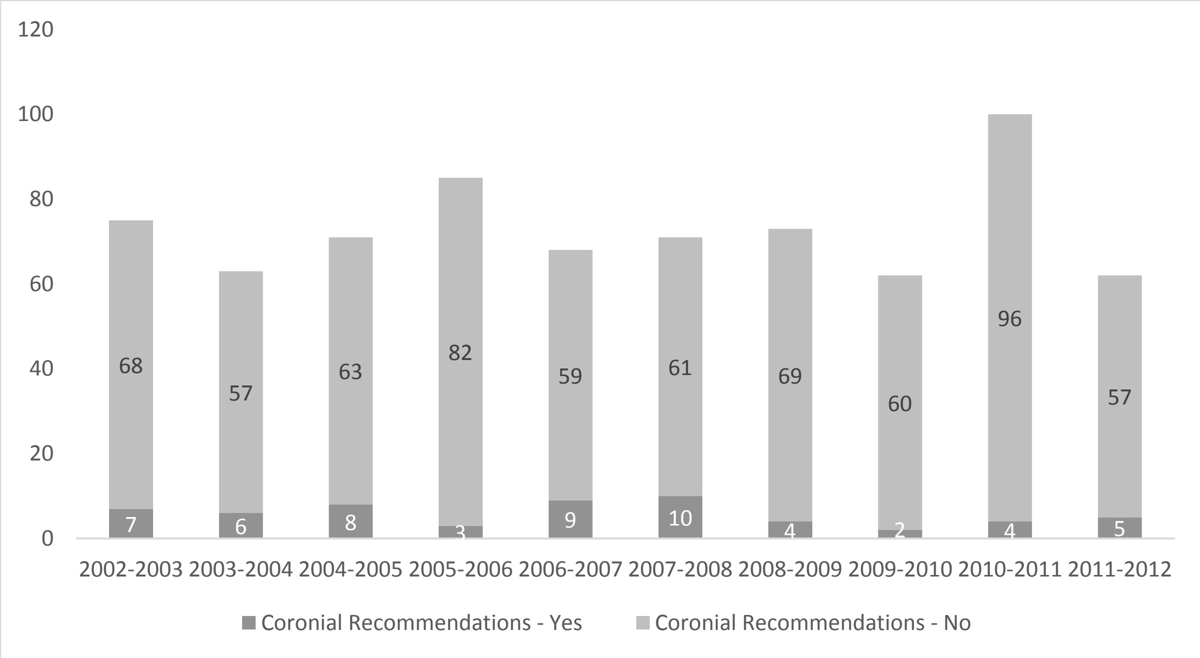

Figure 26: Unintentional fatal river drowning and presence of coronial recommendations, Australia, 2002/03 to 2011/12 (N=730)

6.2.3.1 Cases of Fatal Unintentional River Drowning

Of the 58 cases with coronial recommendations, there were 35 cases from single fatality events and 23 cases from nine MFEs. Over two-thirds (n = 41) of the 58 fatal drowning cases with coronial recommendations involved male victims. Seven percent of all cases of male river drowning generated recommendations, compared to 11.4% of cases involving females. Cases involving people who were known to be Aboriginal or Torres Strait Islander generated a slightly lower proportion of cases with recommendations (5.4%) than those involving people known not to be Aboriginal or Torres Strait Islander (7.5%). Children aged 0-9 years was the age group with the highest proportion of cases with coronial recommendations (16.1%), however, age group was not found to have a statistically significant impact on the likelihood of a case resulting in coronial recommendations. (Table 41)

Table 41: Unintentional fatal river drowning and coronial recommendations by demographic and incident variables, Australia, 2002/03 to 2011/12 (N=730)

	Total		Coronial Recommendations – Yes		Coronial Recommendations – No		X^2 (p value) comparing recommendations - yes to recommendations - no
	N	**%**	**N**	**%**	**N**	**%**	
Total	730	100.0	58	7.9	672	92.1	
Sex							
Male	589	80.7	41	7.0	548	93.0	4.0 (p=0.04)
Female	141	19.3	17	11.4	124	88.6	
People of Aboriginal or Torres Strait Islander descent							
Yes	74	10.1	4	5.4	70	94.6	0.4 (p=0.51)
No	559	76.6	42	7.5	517	92.5	
Unknown	97	13.3	12	12.4	85	87.6	-
Age group							
0-9 years	56	7.7	9	16.1	47	83.9	5.5 (p=0.02)
10-19 years	72	9.9	7	9.7	65	90.3	0.3 (p=0.56)
20-29 years	123	16.8	16	13.0	107	87.0	5.2 (p=0.02)
30-39 years	98	13.4	10	10.2	88	89.8	0.8 (p=0.37)
40-49 years	98	13.4	4	4.1	94	95.9	2.3 (p=0.13)
50-59 years	119	16.3	9	7.6	110	92.4	0.0 (p=0.87)
60-69 years	63	8.6	NS	NS	63	100.0	6.0 (p=0.02)
70-79 years	62	8.5	NS	NS	60	96.8	2.1 (p=0.15)
80+ years	39	5.3	NS	NS	38	97.4	1.6 (p=0.20)
Activity undertaken immediately prior to drowning							
Falls	156	21.4	6	3.8	150	96.2	6.9 (p=0.01)
Jumped In	37	5.1	NS	NS	37	100.0	3.9 (p=0.05)
Non-aquatic Transport	133	18.2	17	12.8	116	87.2	2.8 (p=0.10)
Swept Away	23	3.2	NS	NS	23	100.0	2.4 (p=0.12)
Swimming/Recreating	124	17.0	12	9.7	112	90.3	0.1 (p=0.80)
Watercraft	105	14.4	14	13.3	91	86.7	2.7 (p=0.10)

Other	49	6.7	8	16.3	41	83.7	5.0 (p=0.03)
Unknown	103	14.1	NS	NS	102	99.0	8.0 (p=0.01)
Jurisdiction of drowning case							
Australian Capital Territory (ACT)	5	0.7	NS	NS	5	100.0	0.4 (p=0.51)
New South Wales (NSW)	232	31.8	13	5.6	219	94.4	2.6 (p=0.11)
Northern Territory (NT)	43	5.9	6	14.0	37	86.0	2.3 (p=0.13)
Queensland (QLD)	214	29.3	6	2.8	208	97.2	10.9 (p<0.01)
South Australia (SA)	34	4.7	NS	NS	33	97.1	1.2 (p=0.27)
Tasmania (TAS)	35	4.8	5	14.3	30	85.7	2.0 (p=0.16)
Victoria (VIC)	106	14.5	23	21.7	83	78.3	32.1 (p<0.01)
Western Australia (WA)	61	8.4	4	6.6	57	93.4	0.2 (p=0.68)
Remoteness classification of drowning location							
Major Cities	214	29.3	10	4.7	204	95.3	4.4 (p=0.04)
Inner Regional	217	29.7	19	8.8	198	91.2	0.3 (p=0.60)
Outer Regional	175	24.0	18	10.3	157	89.7	1.7 (p=0.19)
Remote	44	6.0	4	9.1	40	90.9	0.1 (p=0.77)
Very Remote	80	11.0	7	8.8	73	91.3	0.1 (p=0.78)
Flooding							
Yes	124	17.0	14	11.3	110	88.7	2.3 (p=0.13)
No	606	83.0	44	7.3	562	92.7	
Number of cases by Multiple Fatality Event (MFE) [Number of Incidents]							
Yes	92 [30]	12.6	23 [9]	25.0	69 [21]	75.0	41.9 (p<0.01)
No	638	87.4	35	5.5	603	94.5	

Note: Chi squared analysis of the categorical variables was undertaken. A modified Bonferroni has been applied meaning statistical significance is deemed at p<0.01. NS= Not Shown.

6.2.3.2 Circumstances Surrounding Drowning

Drowning deaths associated with the activities of non-aquatic transport (12.8%) and watercraft (13.3%) recorded the highest proportions of coronial recommendations by activity type. Activity being undertaken prior to drowning did not have a significant impact on the likelihood of a case having a coronial recommendation. There was a difference by jurisdiction with cases in the State of Victoria (X^2 = 32.1; p<0.01) more likely to generate coronial recommendations and the State of Queensland less likely (X^2 = 10.9; p<0.01). MFEs (X^2 = 41.9; p<0.01) were significantly more likely to have coronial recommendations when compared to cases of single fatalities. The remoteness classification of the drowning location (e.g. whether the drowning occurred in an area deemed to be a major city or a remote area) (X^2 = 4.8; p= 0.31) and whether the case involved a river in flood (X^2 = 2.3; p= 0.13) did not impact if recommendations were made. (Table 41)

6.2.3.3 Analysis of Recommendations

Of the 58 cases where recommendations were made, the number of recommendations made ranged from one to five, with an average of two recommendations per case (SD = 1.07). These recommendations were coded into the following eight thematic areas (Table 42):

- Administration
- Communication
- Education
- Engineering
- Regulation
- Signage
- Training
- Other

Table 42: Definitions utilised for thematic analysis and corresponding examples of coronial recommendations

Category	Definition	Example of a recommendations
Administration (n=28)	The arrangements and tasks needed to control the operation of a plan or organisation. [363] Administrative recommendations were further classified as action, procedural, policy and research.	**Action:** "I recommend that [the organisation] convene a meeting with the [two other relevant organisations] to identify targeted drowning prevention interventions to prevent or deter alcohol-affected persons from entering the Yarra River, particularly around Federation Square, Crown Casino and the Docklands, where there appears to be a disproportionately high frequency of drownings." **Procedural:** "That all current and future circulars and technical directions (and similar documents) connected with the inspection, maintenance or remediation of culverts and other road assets be provided to local government road authorities on a website accessible to such authorities." **Policy:** "That [the organisation] review the language used to categorise and describe deaths to ensure that the terms used are clear and are likely to be understood by members of the family and/or community of the deceased person." **Research:** "I recommend that the [relevant minister] conduct or commission a review on the safety of the river crossings at [two roads], including consideration of effective strategies to ensure the safety of motorists using that road area during the wet season."
Communication (n=3)	The imparting or exchanging of information by speaking, writing, or using some other medium. [364]	"The [group], in consultation with other agencies, consider the introduction of guidance material relating to undertakings concerned with the interaction of the public with nature activities, such as those offered by the park."
Education (n=3)	The process of teaching or learning…or the knowledge that you get from this. [363]	"….educate staff on emergency responses"
Engineering (n=8)	The branch of science and technology concerned with the design, building, and use of engines, machines, and structures. [364]	"At some future date, I suggest that [the] council consider appropriate remedial work to eliminate all danger if possible in such times of rising water by use of either culvert, rising the causeway level or perhaps bridging the relevant area."
Regulation (n=6)	A rule or directive made and maintained by an authority. [364]	"A Code of Practice be developed for commercial white water rafting operations under the Safety in Recreational Water Activities Act 2011. The Code of Practice be developed in consultation with the operators but as a minimum, it requires the development of safe

		operational procedures specific to each set of rapids by conducting formal risk assessments identifying all hazards, selecting control measures appropriate to the unique attributes of each set of rapids that mitigates the risk to a defined acceptable level, and then periodic review of the control measures for their effectiveness."
Signage (n=13)	A notice on public display that gives information or instructions in a written or symbolic form. [364]	"Further, that appropriate signage be indicated to water depth and the warning of drivers of vehicles that the causeway is to be negotiated with extreme care when water flows over the causeway..."
Training (n=7)	The action of teaching a person or animal a particular skill or type of behaviour. [364]	"…that further training of personnel in identifying water hazards could possibly lead to a person being in a better position to identify the potential hazards they face or may have to face and therefore they would be in a better position to take appropriate steps when facing these circumstances. These highly unusual circumstances could hardly be foreseen, but now that it has happened it would be desirable that the recommendations contained in [the] statement be considered and hopefully adopted by relevant organisations and agencies."
Other (n=3)	Used when a recommendation did not apply to the categories above.	"Finally, having seen the emotional impact the deceased's death is still having on all those involved in the rescue, I am of the view some efforts should be made for contact between participating members, encouraged by their various organizations. Mutual support would seem to be the best option at this stage."

Table 43: Category of unique coronial recommendations associated with closed cases of unintentional fatal river drowning by adherence to components of the SMART principle, Australia, 2002/03 to 2011/12

	Specific n (%)		Measurable n (%)	Achievable n (%)	Relevant (yes) n (%)	Time bound n (%)	Mean components satisfied (SD)	Statistical Significance F (p value)
	Organisation	**Objectives**						
Administration (n=28)	27 (50.0)	24 (38.1)	23 (34.8)	26 (38.2)	4 (30.8)	-	3.7 (0.7)	1.3 (p=0.30)
Communication (n=3)	1 (1.9)	2 (3.2)	3 (4.5)	3 (4.4)	-	-	3.0 (1.0)	1.4 (p=0.23)
Education (n=3)	3 (5.6)	3 (4.8)	3 (4.5)	3 (4.4)	-	-	4.0 (0.0)	0.6 (p=0.71)
Engineering (n=8)	6 (11.1)	8 (12.7)	8 (12.1)	8 (11.8)	5 (38.5)	1 (33.3)	4.5 (0.8)	4.3 (p<0.01)
Regulation (n=6)	4 (7.4)	6 (9.5)	6 (9.1)	6 (8.8)	3 (23.1)	-	4.2 (0.8)	0.5 (p=0.80)
Signage (n=13)	8 (14.8)	10 (15.9)	13 (19.7)	12 (17.6)	-	-	3.3 (0.9)	2.0 (p=0.09)
Training (n=7)	5 (9.3)	7 (11.1)	7 (10.6)	7 (10.3)	1 (7.7)	2 (66.7)	4.1 (1.1)	2.1 (p=0.08)
Other (n=3)	-	3 (4.8)	3 (4.5)	3 (4.4)	-	-	3.0 (0.0)	1.7 (p=0.16)
TOTAL (n=71)	**54 (76.1)**	**63 (88.7)**	**66 (93.0)**	**68 (95.8)**	**13 (18.3)**	**3 (4.2)**	**3.8 (0.9)**	**55.5 (p=0.02)**

Note: An ANOVA was undertaken.

Administration (n = 28) was the most common category of recommendation, followed by signage and engineering. Of the three recommendations coded as "other"; two were bravery award nominations for rescuers and the other involved undertaking a meeting of employees to discuss their grief after an unsuccessful rescue.

Administrative recommendations were most likely to be associated with the activity of swimming/recreating, followed by non-aquatic transport incidents. When further classified, administrative recommendations were most likely to be related to an action to be undertaken, followed by procedural change and policy change (4.2%). In two instances administrative recommendations related to undertaking research.

Recommendations in the signage category commonly mentioned warning signage (warning of hazards or hazardous conditions), followed by depth markers and flood signage (e.g. road closed due to flooding, water over road). Engineering strategies (such as pedestrian cameras or devices on bridges, the fencing of steep embankments and street lighting at creek edges) were significantly more likely to be recommended for river drowning deaths as a result of falls ($X^2 = 7.8$; $p<0.01$). Recommendations coded as training were significantly more likely to be recommended for river drowning deaths as a result of non-aquatic transport ($X^2 = 10.9$; $p<0.01$).

When applying unique recommendations to the Hierarchy of Control, recommendations were commonly low order strategies, namely administrative (n = 46), behaviour (n = 13) and engineering (n = 8). (Figure 27)

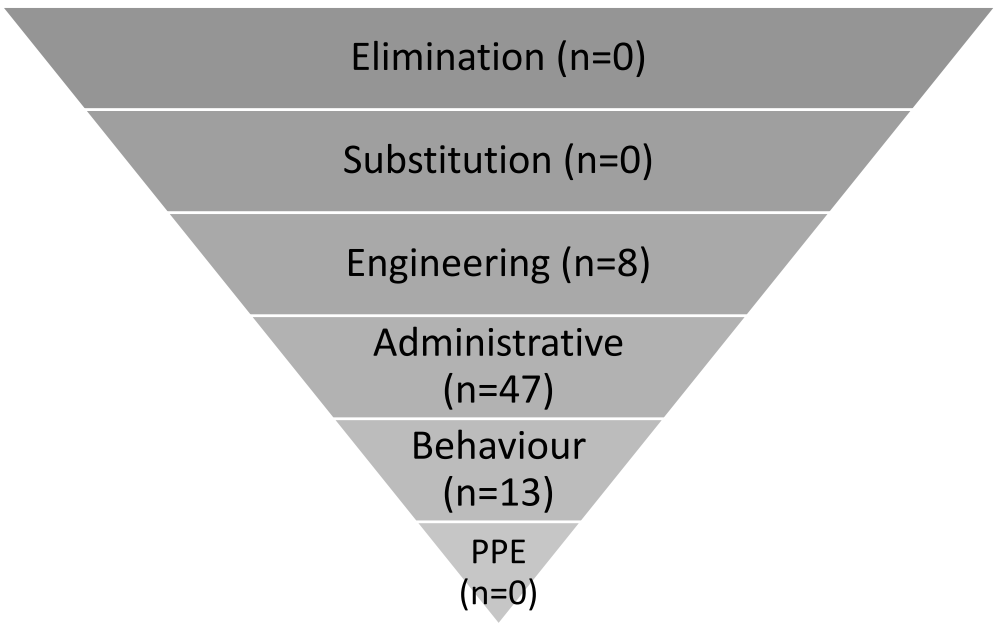

Figure 27: Category of unique recommendations aligned to the Hierarchy of Control (n=71)

When examining recommendations against the modified SMART principle, recommendations ranged from satisfying one component to six. One recommendation satisfied all six components, 10 recommendations satisfied five and 36 satisfied four components. Recommendations most commonly adhered to the achievable component (n = 68), followed by measurable (n = 66) and specific (objectives [n = 63] and organisation [n = 54]). Recommendations were least likely to be time bound (n = 3) and relevant (n = 13). Thirty four recommendations were unable to be classified as being relevant or not (indeterminable). (Table 43)

Out of a possible six modified SMART components, the mean number of components satisfied was four (SD = 0.9). Recommendations related to engineering were significantly more likely to meet a higher number of the six modified SMART principle components (M = 4.5; SD = 0.8; $X^2 = 17.6$; $p<0.01$). (Table 43)

6.2.4 Discussion

Coronial recommendations may prevent future river drowning deaths, however, for recommendations to be as effective as possible they must be SMART, evidence-based and recommend higher order actions. [149] Challenges for coroners in making effective recommendations include the availability of a good knowledge base on prevention, sound evidence, resourcing and timeliness. Coroners work in isolation, however, the advent of the NCIS has allowed coroners to easily review similar previous cases and identify areas where providing recommendations might have greater impact. [365]

This study examined cases of fatal unintentional river drowning with coronial recommendations; whereas only a small number of cases resulted in recommendations (8%) they were from a range of different circumstances including recreational activity, occupational activity and flood-related deaths. Cases with multiple fatalities were more likely to have recommendations. Victoria, as a pioneer in the area of coronial recommendations for injury prevention, [30 366] also had a higher probability of river drowning cases having recommendations.

This study applies an injury prevention lens to coronial recommendations. We posit that the SMART principle could be seen as a model for developing recommendations, provided they are based on the best available evidence. Overall, 36 recommendations met four components and 10 recommendations met five components of the modified SMART principle, however, weaknesses were identified around the issues of timeliness and relevance. Just one recommendation satisfied all six components of the modified SMART principle. While most recommendations satisfied the components of achievable and measurable, very few specified a time frame for action, thus potentially impacting on the likelihood of recommendations being enacted.

The Hierarchy of Control outlines six levels for the minimisation or elimination of hazards. [271] By exploring recommendations using the Hierarchy, there were eight thematic areas identified. The vast majority of these were low-order strategies (primarily administrative and behavioural) rather than elimination, substitution or engineering controls. The authors acknowledge that it is not possible to eliminate the hazard (the river) in this context. Elimination may be possible whereby a particular activity is eliminated, e.g. eliminating the use of jet skis in designated swimming areas or eliminating water skiing or other towing activities in high traffic areas. Substitution as a strategy may also be possible, whereby activities are substituted to different areas of the river, be they deeper or shallower areas depending on the activity being undertaken, as well as closer to shore or an area with fewer currents.

The use of signage for the prevention of river drowning deaths (commonly warning signage, depth markers and flood warning signage) can be a simple and cost effective tool for injury prevention, however, it must be considered as one element of a broader risk management strategy. [16] Limited research on water safety signage and its effectiveness in preventing drowning has been conducted, [272] and such studies have focused on a beach setting. Findings show 1% of students surveyed utilised beach signage in Queensland [367] and 45% of beachgoers surveyed in Victoria reported observing any signage. [368] This suggests signage may not be an effective drowning prevention strategy in isolation, though research is warranted at other aquatic locations including rivers.

Another challenge for the recommendation of higher order strategies is the fact that the majority of drowning deaths within this study were associated with recreation. Recreational activities are something people choose to do and therefore the recommendation of elimination controls is likely to be extremely difficult. Further work should be undertaken to explore other options around substitution for safer activities, such as safer boater options, as well as engineering-based solutions, such as separate river spaces designated for recreational activities and barriers around urban rivers in entertainment precincts.

In some instances, drowning deaths were associated with occupational pursuits, most commonly drowning as a result of non-aquatic transport activities. Engineering solutions, such as bridges and culverts, are likely to have a significant effect on the prevention of drowning in such situations. [121 134 248]

One-third of recommendations coded as regulation dealt with lifejackets. Lifejackets have been recommended as a drowning prevention strategy for rivers; [50] however, they are only effective if people are wearing them. Whilst design improvements have meant modern lifejackets are now more comfortable and user-friendly, achieving long term behaviour change [369] still remains a challenge.

The seven training recommendations identified in this study were largely associated with operational-related training of workforce and investigative staff. One training recommendation dealt with improving the recognition of water hazards and safety responses based on an assessment of drowning risk. The effectiveness of training as an isolated strategy for the prevention of river drowning is unproven. For training to be most effective it is usually implemented as part of a broader approach, such as that used in road safety [370] and manual handling (where training is part of a multi-factorial intervention). [371] The expansion of the evidence base on the role of training as part of a comprehensive river drowning prevention approach is required.

Although outside the scope of this study, it is important to consider the fact that coronial recommendations are only effective if they are actioned. Currently, reviewing the implementation of the recommendations is outside the purview of the coroner's responsibility, [366] except in Victoria, where organisations mentioned in a recommendation are required to respond. In line with good health promotion practice, organisations responsible for the implementation of coronial recommendations need to be at the centre of the decision-making process to ensure effective and sustained efforts. [372 373] Further research should examine the frequency with which coronial recommendations associated with unintentional fatal river drownings are acted upon.

As coroners operate at a State and Territory level in Australia, there are benefits to examining coronial findings nationally. Coroners operate in isolation, therefore identifying commonalities in recommendations may allow those working in the area of prevention to implement and evaluate the effectiveness of regularly proposed prevention strategies.

By considering those at increased risk of river drowning, such as males [132] and Aboriginal and Torres Strait Islanders, [133] as well as the factors that contribute to fatal river drowning, such as alcohol, [133] coroners can better identify cases which may benefit from recommendations through inquest. By understanding more about the contributing factors, the evidence base for recommendations may be strengthened and those most at risk of river drowning will be more effectively targeted by strategies to reduce risk. [141]

6.2.5 Limitations

This study includes cases where the coronial finding document or inquest finding document was made available electronically and attached to the file of the victim within the NCIS. As such, cases where recommendations were made but the finding document was not electronically available on the NCIS (n = 3) have not been included in the analysis. These cases represented 5.2% of all cases with coronial recommendations and came from the jurisdictions of New South Wales, Victoria and Tasmania.

6.2.6 Conclusion

Coroners, and the recommendations they make, have an important role to play in reducing unintentional fatal drowning in rivers. This study found that coroners made recommendations in less than one in 10 fatal unintentional river drowning cases. While rare, coronial recommendations can highlight issues of public safety where modifications can save lives and coroners may be able to compel action better than other lesser resourced organisations.

The recommendations examined in this study covered a diversity of river drowning cases and outlined a range of preventative actions. Coronial recommendations that are evidence-based, SMART and of a higher order on the Hierarchy of Control may be more likely to prevent further loss of life. The findings of this study can be used by other organisations and jurisdictions as a benchmark for what might be considered appropriate safety recommendations.

6.3 Developing Drowning Prevention Strategies for Rivers Through the Use of a Modified Delphi Process (Paper 9)

Peden AE, Franklin RC, Leggat PA (2019) Developing drowning prevention strategies for rivers through the use of a modified Delphi process, *Injury Prevention*. Published Online First: 30 March 2019. doi: 10.1136/injuryprev-2019-043156.

6.3.1 Introduction

Identifying effective strategies for preventing injuries is challenging [53 374]. While effective strategies are available, further work is required to develop the supporting evidence, especially for the issue of drowning and drowning within low- and middle-income countries (LMICs) [375]. Evidence informing the prioritisation of strategies more likely to be effective provides a useful starting point for resource allocation for implementation and subsequent evaluation.

The World Health Organization (WHO) estimates 360,000 deaths from drowning annually [22]. This figure is likely to be substantially higher, with a study from Australia showing the methodologies used by the WHO under-report unintentional fatal drowning by 40% [14]. River drowning is a global problem [59 75 76 90 97] and therefore any prevention strategies implemented must consider the determinants of health [376] and specific country-contexts. In Australia, rivers are the leading location for drowning [132], with risk factors increasingly identified [132-134].

Preventing drowning is challenging as it requires evidence-based changes in policy, behaviour, culture and environment [377-379]. Prevention strategies across the drowning timeline (prepare, prevent, react and mitigate) are required [380]. The Hierarchy of Control is a six domain pyramid that provides a framework for thinking about the effectiveness of a prevention strategy. Strategies range in effectiveness across the six levels from elimination of the hazard (most effective), substitution, engineering, administrative controls, behaviour change and personal protective equipment (PPE) [145]. Strategies that are higher on the Hierarchy of Control [145], although often more difficult to implement, are more likely to be effective [271].

Due to the significant burden of rivers in global drowning statistics and little implementation and evaluation of river drowning prevention strategies [50], this study aimed to use expert opinion to identify strategies more likely to be effective in preventing river drowning.

6.3.2 Methods

This study used a modified Delphi process to develop, refine and rank a range of proposed strategies for the prevention of unintentional drowning in rivers.

6.3.2.1 Study Design

A conventional Delphi process is a long-range, qualitative forecasting technique [381] based on achieving consensus amongst participants through optimal convergence of opinions [382]. A typical Delphi uses a series of phases where information is fed back to panel members using questionnaires.

A Delphi process has previously been used to develop international guidelines to reduce recreational open water drowning deaths [383 384]. The current study invited river drowning prevention researchers and practitioners from around the world to identify strategies more likely to be effective in preventing river drowning, through a series of surveys, using Survey Gizmo [385]. This study modified a Delphi process in that participants assessed the effectiveness as well as the relevance of strategies both through the use of surveys and evidence-based scenarios. The study methodology is outlined below.

6.3.2.2 Participant Selection

Participants (n=39) were identified by being active in drowning prevention research (i.e. published in the last 5 years) and practice (e.g. working national parks, or in disaster consultancy). The initial list of potential participants were identified through a systematic literature review [50] and additional practitioners and researchers were identified using a purposive (i.e. those known by the authors to be active in the field of river drowning prevention via publications, presentations and work practices) and snowballing sampling technique (i.e. if invited participants were unable or unwilling to participate, they suggested another similar person) [386]. All prospective participants were contacted via email and sent the information sheet. Thirty people (76.9%) agreed to participate.

6.3.2.3 Phase 1 – Brainstorming Prevention Strategies

Using free text responses, participants listed all strategies they thought would prevent river drowning. Participants were provided space to list 40 strategies. Two examples were provided, lifejackets and learn to swim (example strategies could be re-used by respondents if deemed suitable). Responses were thematically coded into 11 categories by authors AEP and RCF using an inductive method [167] (Table 44). Duplicates were deleted and strategies similar in wording and intent were merged. The consolidated list was then compared to prevention strategies identified through the previously conducted systematic literature review [50] to ensure that any river drowning prevention strategies with supporting evidence, be it evaluate or proposed via expert opinion, were adequately addressed by the participants' suggestions. All nine proposed prevention strategies, as identified in the literature review, were sufficiently covered by the participants' suggestions.

Table 44: Categories of river drowning prevention strategies proposed by Delphi participants in Phase 1 (n=11)

Category	Number of strategies	Example strategy
Lifejackets	9	*Lifejacket wear for children*
Personal behaviours	17	*Don't engage in water recreation in a river alone*
Knowledge	10	*Strategies to survive cold water immersion*
Public awareness and advocacy	12	*Raise awareness of the dangers of submerged obstacles*
Cardiopulmonary resuscitation (CPR) and rescue	7	*Training for all boat personnel in CPR, calling for rescue and search and rescue*
Personal skills	9	*Teach self-rescue skills to enable unaided movement to water's edge*
Signage	13	*Highly visible signs warning of local hazards at popular swimming destinations*
Engineering	19	*Safe and accessible infrastructure, such as bridges, for crossing rivers*
Flooding	18	*Establish effective early warning systems for notifying at-risk citizens when rivers are flooded*
Alcohol	11	*Restriction of alcohol usage around hire and drive vessels such as houseboats and party boats*
Other	14	*Include river drowning prevention in national and local water safety plans*
TOTAL	139	

6.3.2.4 Phase 2 – Prevention Strategies Ranked for Effectiveness

The consolidated list was presented in categories. Respondents were asked to rank strategy's effectiveness on a 4-point scale ('very effective', 'effective', 'neutral' and 'not effective') with a 'don't know' option. Respondents could add strategies that were not previously included.

6.3.2.5 Phase 3 – Evaluation of Proposed Strategies

Consistent with previous drowning-related Delphi processes [383 384], strategies with 60% agreement or more, and newly proposed strategies (n=3), were carried through to phase 3. New strategies were assessed against the same criteria from phase 2. All strategies (both new and existing) were assessed against their likelihood of effectiveness in countries of different income levels ('highincome countries' (HICs), 'LMICs', 'both HICs and LMICs', 'neither' or 'don't know'). The specific question asked was 'In which of the following country income level categories would the following strategies be effective?' All strategies were also assessed against their known evidence on a scale of: 'no evidence – I would remove', 'no evidence – I would keep', 'I am aware of evidence which supports this', 'I am aware of evidence which does not support this', 'I am unaware of any evidence – I would remove', and 'I am unaware of any evidence – I would keep'). Respondents did not have to provide examples of this evidence.

6.3.2.6 Phase 4 – Alignment and Prioritisation of Effective Strategies Against River Drowning Scenarios

In phase 4, respondents read 10 river drowning scenarios. These scenarios were based on an amalgam of common river drowning incidents in Australia [132]. Scenarios accounted for 63.8% of river drowning deaths in Australia (Table 45). Scenarios can be found in Table 46.

For each scenario, respondents identified the top five strategies they believed would be most effective in preventing a future similar drowning. Strategies were drawn from a consolidated list of strategies merged by authors AEP and RCF. Respondents could also list an 'other' strategy, if they felt the available strategies were not appropriate. Each 'other' strategy suggested for each scenario was evaluated by authors AEP and RCF and re-coded into existing strategies where appropriate. Where 60% or more of the respondents aligned a strategy to a scenario, this strategy was retained. The final list of strategies was coded to the Hierarchy of Control by authors RCF and AEP.

Table 45: Epidemiological profile of unintentional river drowning deaths in Australia on which river drowning scenarios assessed by Delphi participants in Phase 4 were based

River drowning scenario	**N**	**%**
River drowning in remote and very remote areas	131	17.0
Males 55+ and pre-existing medical conditions	118	15.3
Driving into floodwaters	71	9.2
Females and falls into rivers	41	5.3
Males 55-74 boating incidents	26	3.4
Children 0-4 and falls	24	3.1
Males 18-34 and swimming and recreating with alcohol	22	2.9
Fishing from edge	20	2.6
Males 25-54 years boating and alcohol	20	2.6
Males 15-24 who jump in	18	2.3
TOTAL	**491**	**63.8%**

Note: Data was derived from a total population analysis of unintentional fatal river drowning in Australia between 2002 and 2012, drawn primarily from the NCIS. These data have been previously published [132].

Table 46: Full text of river drowning scenarios used in Phase 4 of the Delphi

Scenario number	Scenario description
1	*A 60 year old male is driving a 4wd at night during a storm. He has been consuming alcohol. He has approached a causeway that has been flooded by a nearby swollen river. There were warning signs and depth markers in place but the driver was familiar with the road and had driven through floodwaters on this road previously while driving home. Upon coming to the flooded causeway, which was running higher and faster than usual, the deceased has driven into the water. The force of the water has caused the car to flip, trapping the occupant inside and he has drowned.*
2	*A 24 year old male was at the river with his friends who were all drinking. The male was not a strong swimmer however, under the influence of alcohol, had been encouraged by his friends to try and swim across the river and back. The river current was stronger than the male expected and it appears the male may have been washed further downstream where he has gotten caught on a snag and has panicked. The male disappeared under the water. His body was recovered 3 days later, 2 km downstream from where he initially went missing. His friends tried to rescue him but could not locate his body in the murky water.*
3	*A 72 year old male was alone on his four metre powered boat as he headed out onto the river for a day of fishing. The man was neither wearing a lifejacket, nor was he carrying one on board the vessel. He had not checked the condition of his boat in sometime and had no working radio. The boat capsized when the man leaned over to untangle his fishing line. Witnesses say he struggled to stay afloat and was found drowned some hours later by a passing boat.*
4	*A 3 year old girl was at the river with her family and two other families. The girl was left in the care of older children while her family packed the cars in preparation to leave. After a short while, her parents noticed that she was missing. She was found drowned in the river near where the family left from and marks on the river bank suggested that she fell in.*
5	*A group of males between the ages of 25-54 years were celebrating a function on a party boat on an urban river. Just after midnight, several members of the group were extremely intoxicated and without the captain's knowledge, decided to jump off the roof of the boat. The three males jumped in but one hit the water awkwardly and did not resurface. His friends tried to dive to find him but were unable to find his body among the fast moving current and dark of night. Friends on board notified the captain who threw flotation aids to the two men in the water. The body of the third man was discovered around daybreak the next morning by police divers.*
6	*A recently retired 70 year old male took his dog for a walk through bushland to his local creek. It was a warm day and as part of his usual routine the man and his dog both entered the water for a swim to cool down. The man was throwing sticks onto the creek bed for the dog to retrieve and swim back out to him. It appears the man suffered a massive heart attack and collapsed into the water and drowned. At coronial investigation, the autopsy revealed significant heart disease for which the man had not previously been treated for.*
7	*A woman in her mid-40s was found drowned in a river nearby her house after having been reported missing by her husband some hours earlier. She had decided to walk home from drinks with friends at a restaurant about 1.5 km from her house and appears to have fallen into the river due to a combination of alcohol intoxication, poor visibility due to the cloudy night and slippery and uneven ground on the river bank.*

8	*A group of young people (both males and females aged between 18 and 30 years of age) went to a remote area in a national park for a camping trip over a public holiday long weekend. The group camped close by a river and on their second day, they went into the river for a swim. One member of the group, a young male aged 22 was not a strong swimmer. He tried to stay close to the bank but recent heavy rains upstream had created a stronger than normal current which slowly pulled him further away. He then stepped off a sharp drop off in the river bed and could no longer touch the bottom. He panicked and went under the water. By the time his friends got to him and got him out of the water he was not breathing. Being unfamiliar with their location, a lack of signage and patchy mobile phone coverage resulted in significant delays before emergency assistance arrived. Unfortunately by the time emergency services arrived, the man was deceased.*
9	*A group of young males in their late teens and early twenties were at their local river taking turns to jump into the water from a rope swing they had brought with them and attached to a tree. After jumping off the rope swing and doing tricks into the water for about half an hour, several of the males dared each other to jump off an old railway bridge that went across the river. The drop was about 10 metres from the bridge to the water. The males who were willing to jump went out onto the bridge and took it in turns to jump. One of the males fell awkwardly and did not resurface. His friends tried to find his body but could not do so as the river was extremely deep and visibility under the water was poor. His body was eventually found by divers three days later. Injuries to his body suggest he may have hit debris not visible under the water when he jumped. There was the suggestion of alcohol intoxication but the body was too decomposed for blood alcohol to be determined at autopsy.*
10	*An older male in his 60s was fishing alone from the river bank, at an isolated location. It was a rainy winter’s day and he was wearing multiple layers including a bulky jumper and jacket. He slipped on the wet and muddy river bank and ended up in the water. The man’s skills and fitness had reduced over time. He was found drowned in the river after his wife reported him missing when he didn’t return home.*

6.3.2.7 Ethics Approval

Ethical approval was granted by James Cook University Human Research Ethics Committee (HREC) (H7166).

6.3.3 Results

Thirty participants (70.0% male [n=21]; 23.3% LMICs [n=7]) made up the participant panel. Countries represented included: United States (n=7; 23.3%), Australia (n=6; 20.0%), England (n=3; 10.0%), Canada, Netherlands, Philippines, South Africa (n=2; 6.7% respectively), Uganda, Brazil, Bangladesh, Switzerland and Ireland (n=1; 3.3% respectively). Eleven participants (36.7%) are practitioners, 7 (23.3%) are researchers and 12 (40.0%) are both.

Phase 1 (response rate 100.0%) yielded 424 strategies (Figure 28), with the mean number of responses being 15 strategies (range 6-35). Thirty-two duplicates were removed. The remaining 392 were merged into 139 strategies across 11 categories. This list then proceeded to phase 2.

After being ranked based on their likely effectiveness in phase 2 (response rate 100.0%), the 32 strategies that achieved less than 50% agreement were defined as requiring more evidence and were removed (Table 47). Strategies that showed promise (i.e. scoring between 50-59% effectiveness [n=29]) were also removed (Table 48). Fourteen newly suggested duplicates were also removed or thematically combined with similar strategies.

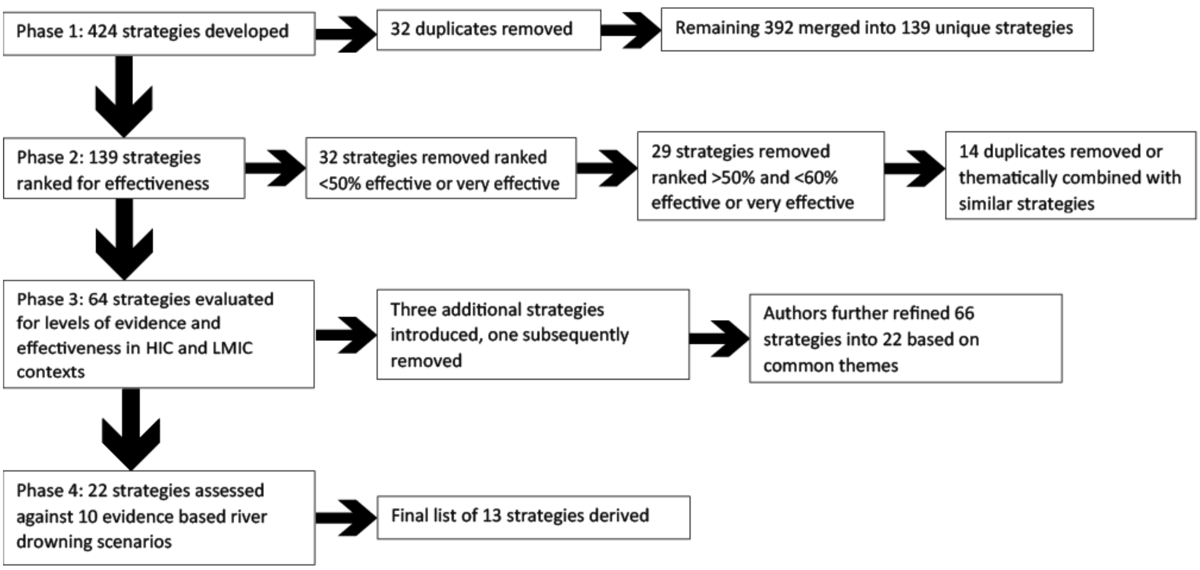

Figure 28: Flow chart of modified Delphi process

Table 47: Strategies that require more evidence (i.e. assessed as <50% effective of very effective in Phase 2 of the Delphi (n=32)

Proposed drowning prevention strategy for rivers	% effective or very effective
Personal behaviours	
Have each person participating carry their cell phone so they can contact emergency response if necessary	31.0
Knowledge	
River tidal conditions	48.3
Environmental hazards - pollutants	13.8
Surrounding terrain	31.0
Public awareness and advocacy	
Campaigns against peer pressure	41.4
Advertising in TV programs at popular times for children	27.6
Fish with a friend campaigns	44.8
Training of communities along rivers in search & rescue	41.4
Train staff in awareness of persons who could become a rescue - Intoxicated, out of shape, young and old	48.3
Signage	
Increase signage and warnings during the snowmelt period	31.0
Warning signs - with lights & sirens	44.8
Warning of unstable river banks	44.8
Warning notices about using rivers as toilets	20.7
Signage showing ice markers / restrictions / depth	34.5
Engineering	
Improved / standardized boat design	41.4
Provision of piped water to riverside communities	48.3
Lighting for common night time areas where walking near the river edge are undertaken	37.9
The highlighting of exit places (ladders & steps) by painting the background white or some fluorescent colour that stands out in the dark	44.8
Make green belt along the river to prevent landslide which can cause drowning	27.6
Explore environmental changes to reduce dangerous currents, whirlpools, etc	41.4
Removal of rope swings from trees beside the river	17.2
Use of CCTV to capture and deter those who engage in risky behaviour	20.7
Flooding	
Use technology to block flooded roads	44.8
Keep the depth of the river optimum by removing sediment sand from the river bed to prevent flood	37.9
Alcohol	
Restriction on alcohol sales	34.5
Other	
Community leadership and empowerment	41.4
Know seizure disorder safety	44.8

If it is going to be an extreme snowmelt period have local media do stories on river safety	44.8
Flow velocities available in an app or at the river site for river users to choose where to paddle / recreate safely	41.4
Risk assessment for rope swings	27.6
Water extraction areas	41.4
Use of a rating system for all signage that is an assessment at specific locations *	28.6

* This strategy was newly introduced at Phase 3 but generated low levels of support for its perceived effectiveness and was removed prior to Phase 4.

Table 48: Strategies that showed promise (i.e. assessed as between 50-60% effective or very effective in Phase 2 of the Delphi) (n=29)

Proposed drowning prevention strategy for rivers	% ranked effective or very effective
Lifejackets	
Wear a lifejacket while swimming/wading	55.2
Personal behaviours	
If going out in a boat, tell someone your put in/take out and route	55.2
Never try to rescue someone if you are not a trained person	51.7
Public awareness and advocacy	
Raise awareness of the dangers of never swimming alone	58.6
Public education re surveillance children and those unable to swim	51.7
Raise awareness of the dangers of submerged obstacles	51.7
Messaging targeting males and risk-taking	58.6
CPR and Rescue	
Junior lifeguard/rescue programs	55.2
Personal skills	
Guided swimming lessons in rivers	55.2
Signage	
Informational safety panels at popular areas	51.7
Warning signage about the danger of driving through floodwaters at areas prone to flooding	51.7
Warning notices telling those boating to put on their lifejacket before climbing into a boat	55.2
Water safety info posted at common entry points	58.6
Signage advising of river conditions (blanket signage and/or advising of current river conditions)	51.7
Engineering	
River flow controls	51.7
The moving of pathways / walkways away from the river edge so that if a walker stumbles they do not immediately fall into the river	58.6
Pool style fencing around homes where children may be at risk e g farms	58.6
Safe access to piped water collection points	58.6
Build safe boat or launch station	55.2
Flooding	
Relocation of persons/communities in flood risk areas	58.6
Incorporation of safety messages in driver training	51.7
Use markers on roads to show flood depth	58.6
Clear demarcations of flood lines and limited building below flood lines	55.2
Avoid water entry in the hours after storms to avoid sudden increases in current and/or water depth	58.6
Alcohol	
Breathalysing skippers of boats on rivers	58.6
No alcohol zones around rivers	51.7
Other	
Attending day care/school	55.2
Monitoring and clearing of debris	51.7
Cold water strategies	51.7

Of the 64 strategies assessed at Phase 3 (response rate 93.3%), 74.6% were assessed as being effective in both LMICs and HICs by 60% or more of the respondents. The strategy assessed as being most likely to be effective in both LMICs and HICs were '*School based river safety education*' assessed by 92.9% of respondents as being effective (100.0% of LMIC respondents and 86.4% of HIC respondents). The strategies deemed least likely to be effective in both contexts were *'Lifejacket loaner programs near popular river access points'* (overall effectiveness in both contexts 32.1%; effectiveness in HICs 50.0%; effectiveness in LMICs 7.1%), and *'Wearing a lifejacket when river flows are fast and water is cold'* (overall effectiveness in both contexts 42.9%; effectiveness in HICs 32.1%; effectiveness in LMICs 3.6%).

When examining results based on the country context of the Delphi participants, 100.0% of participants from LMICs assessed *'Providing safe places away from rivers for pre-school aged children (e.g. day-care/crèche)'* as being effective in reducing river drowning in LMIC contexts, while 68% of HIC participants assessed it as being effective in HIC contexts. By contrast, a strategy such as *'If participating in known hazardous events (e.g. river rafting/white water boating) have a local guide present'* was assessed as being effective in HICs by 82% of participants from HICs, while only 50% of LMIC participants assessed the strategy as being effective in LMICs.

When ranking the levels of evidence, 16.4% of strategies were reported by 60% of respondents or more as having evidence they were aware of which supported the strategy as being effective in reducing river drowning. The strategy with the strongest supportive evidence was '*Provide safe places away from rivers for pre-school aged children (e.g. day-care/crèche)*' (85.7% of respondents being aware of evidence that supported the strategy). '*Risk assessment and management of areas where people jump in*' was the strategy with the lowest level (10.7%).

The effectiveness of three newly introduced strategies were assessed, with one (*Use of a rating system for all signage that is an assessment at specific locations*') removed as it was assessed as being effective or very effective in preventing river drowning by only 28.6% of respondents. (Table 47) The remaining two '*Apply a common risk rating system for rivers where people frequent*' and '*Urban design for runoff retention to reduce high river flow and flooding*', scored highly enough to be carried through, resulting in a total of 66 strategies.

Prior to Phase 4 (response rate 93.3%), authors AEP and RCF consolidated the strategies, refining 66 strategies to 22 (which included an 'other – please specify' option). See Table 49 for the numbered list of original strategies and Table 50 for how these were merged.

Table 49: Merging of similar or duplicate strategies for use in Phase 4 of the Delphi

Revised river drowning prevention strategy	**Original strategies combined (see Table 50)**
Apply a risk rating system	1
Wear a lifejacket	2-7
Avoid open water at night	8
Signage	9-12
Swim/recreate/wash bathe only in designated safe places	13-17
Caregivers maintaining active supervision	18
Don’t engage in water recreation alone	19
Barriers between child play areas and rivers	20-21
Strategies to survive cold water immersion	22
River safety education including recognition and awareness of hazards	23-35
Community wide rescue and resuscitation skills	36-37
Raise awareness of the risks of drowning from alcohol	38-42
Public rescue equipment available	43
Learn to swim with a focus on survival swimming skills	44-45
Build safe and accessible infrastructure such as bridges	46
Designing the urban landscape to improve safety	47-51
Close flooded roads and/or use physical barriers (such as booms)	52-54
Prohibiting/restricting alcohol use	55-58
Establish effective early warning systems	59-61
Community risk mapping and assessment to formulate targeted prevention programs	62-65
Sustainable land use to prevent flooding	66
Other (please specify)	-

Table 50: Original strategies from Delphi participants in Phase 4, with numbers explaining how they were merged in Table 49

Original strategies	Revised river drowning prevention strategy
Apply a common risk rating system for rivers where people frequent	Apply a risk rating system
Choose suitable lifejackets for use on watercraft including stand up paddleboards, motorboats etc	Wear a lifejacket
Wear a lifejacket when river flows are fast and cold	
Use a lifejacket when an occupant of a water vessel and ensure it is properly fitted and maintained; include awareness campaigns and behaviour change strategies	
Lifejacket loaner programs near popular river access points	
Lifejacket wear for children	
Lifejackets campaign	
Avoid open water at night	Avoid open water at night
Enter and exit the water safely, including checking signage at entrance to river	Signage
Signage at key dangerous entry points	
Signage at popular stretches and blackspots (high drowning risk)	
Highly visible signs warning of local hazards at popular swimming destinations	
Swim/recreate/wash bathe only in designated safe places	Swim/recreate/wash bathe only in designated safe places
Check conditions before recreating or getting in the water	
Provide protected river sites for aquatic activity (e.g. swimming/diving)	
Safe watering sites for people and animals	
No swimming or recreating near culverts and weirs at times of heightened risk	
Caregivers maintaining active supervision with children five years and under (constant visual supervision, within reach)	Caregivers maintaining active supervision
Don’t engage in water recreation alone in a river alone	Don’t engage in water recreation alone
Provide safe places away from rivers for pre-school aged children (e.g. day care/crèche)	Barriers between child play areas and rivers
Barriers between child play areas and rivers	
Strategies to survive cold water immersion	Strategies to survive cold water immersion
River safety education including recognition and awareness of river hazards including tidal conditions	River safety education including recognition and awareness of hazards
Educating parents of river drowning risks and prevention strategies	
Knowledge on what to do if caught in river currents	
Educational strategies – specific alerts in high risk areas where there is a large population at risk	

School based river safety education	
Raise public awareness about risk, river safety and drowning prevention in at-risk communities	
Don’t enter unfamiliar waterways	
Do not enter the water is a storm is likely or there is lightening or thunder present	
If you are caught in a current, do not panic or swim against it, just float and call for help immediately	
If participating in known hazardous events (river rafting, white water boating) have a local guide present	
Boater safety knowledge	
Safety training for all boater personnel in CPR, calling for rescue and search and rescue	
Boating skills	
Community wide rescue and resuscitation skills with a particular focus on those living in communities near high risk rivers or people residing in regional and remote locations	Community wide rescue and resuscitation skills
Knowledge and skills to perform basic rescues (in water, out of water)	
Social marketing campaigns for Raise awareness on the risk of drowning from alcohol	Raise awareness of the risks of drowning from alcohol
Alcohol and drowning risk campaigns	
Public education re alcohol in proximity to water	
Utilize social marketing to mount campaign against consuming alcohol near rivers	
Avoid alcohol prior to and during any riverine excursions or water exposure	
Regularly positioned Public rescue equipment available reach and flotation devices assistance devices (rescue ring, throw ropes, reach poles)	Public rescue equipment available
Learn to swim with a focus on survival swimming skills including self-rescue skills to enable unaided movement to water’s edge	Learn to swim with a focus on survival swimming skills
Implementation of free/low-cost swim lessons as part of physical education programs and grants in under-served areas	
Safe and accessible infrastructure such as bridges, for crossing rivers	Build safe and accessible infrastructure such as bridges
Responsible design (barriers, rescue equipment) around urban riverside entertainment precincts	Designing the urban landscape to improve safety
Limiting access to river at locations with high risk of drowning (barriers)	
Fences and barriers to prevent people jumping from bridges	
Risk assessment and management of areas where people jump in	
Urban design for runoff retention to reduce high river flow and flooding	

Close flooded roads and/or use physical barriers (such as booms) at road crossings at high risk of flooding	Close flooded roads and/or use physical barriers (such as booms)
Manage river flooding risk through engineering/environmental modification	
Avoid flooded roads if there is/are alternative road(s)	
Prohibiting/restricting alcohol use in high risk areas	Prohibiting/restricting alcohol use
Avoid use of alcohol while boating	
Consistent per se legislation for alcohol similar to operating a motor vehicle	
Restriction of alcohol usage around hire and drive vessels such as houseboats and party boats	
Establish effective early warning systems for notifying at-risk citizens when rivers are flooded and those catchment and river users likely to be effected by dam releases	Establish effective early warning systems
Consistent flood warning on local/national radio/tv/media	
Flood and weather warnings	
Community risk mapping and assessment to formulate targeted prevention programs by identifying risk factors, risk locations and risk groups by research	Community risk mapping and assessment to formulate targeted prevention programs
Identification of at-risk flooding communities and roll out of mitigation strategies such as swimming lessons, distribution of personal flotation devices (PFDs), flood safety awareness	
Assessment of flood road safety as part of floodplain risk management	
Include river drowning prevention in national and local water safety plans	
Sustainable land use to prevent flooding	Sustainable land use to prevent flooding
	Other (please specify)

Participants were then asked to align the proposed river drowning prevention strategies to the river drowning scenarios they felt the strategy would be most effective at preventing. The strategies of '*Wear a lifejacket*' (110.7% for scenario 3) and '*Caregivers maintaining active supervision*' (107.1% for scenario 4) were the strategies with the highest support from respondents (scoring over 100% when 'other' similarly-worded strategies were recoded). The most commonly recommended strategy was '*River safety education including recognition and awareness of hazards*' (recommended by 60% or more of respondents in 7/10 scenarios). (Table 51)

Table 51: Top five strategies recommended for each river drowning scenario in Phase 4 of the Delphi

Scenario #	Summary of scenario	Strategy 1	%	Strategy 2	%	Strategy 3	%	Strategy 4	%	Strategy 5	%
1	60 yr old male Alcohol consumption Driving into floodwaters at night	Close flooded roads and/or use physical barriers (such as booms)	96.4	Build safe and accessible infrastructure such as bridges	75.0	River safety education including recognition and awareness of hazards	53.6	Prohibiting/restricting alcohol use	42.9	Establish effective early warning systems Raise awareness of the risks of drowning from alcohol	39.3 39.3
2	24 yr old male Alcohol consumption Poor swimmer Strong current	River safety education including recognition and awareness of hazards	89.3	Raise awareness of the risks of drowning from alcohol	82.1	Swim/recreate/wash bathe only in designated safe places	78.6	Prohibiting/restricting alcohol use	57.1	Public rescue equipment available	57.1
3	72 yr old male Small boat No lifejacket Fishing alone	Wear a lifejacket	110.7	Don't engage in water recreation alone	92.9	River safety education including recognition and awareness of hazards	71.4	Learn to swim with a focus on survival swimming skills	50.0	Strategies to survive cold water immersion	25.0
4	3 yr old female No adult supervision Fall into water	Caregivers maintaining active supervision	107.1	Barriers between child play areas and rivers	75.0	River safety education including recognition and awareness of hazards	53.6	Wear a lifejacket	39.3	Learn to swim with a focus on survival swimming skills	32.1
5	Group of males 25-54 yrs Alcohol consumption Boating Jumping in	Prohibiting/restricting alcohol use	96.4	Raise awareness of the risks of drowning from alcohol	85.7	River safety education including recognition and awareness of hazards	64.3	Avoid open water at night	53.6	Wear a lifejacket	39.3
6	70 yr old male Swimming alone Pre-existing medical condition	Don't engage in water recreation alone	92.9	River safety education including recognition and awareness of hazards	50.0	Swim/recreate/wash bathe only in designated safe places	39.3	Community wide rescue and resuscitation skills	32.1	Community risk mapping and assessment to formulate targeted prevention programs	28.6
7	Mid 40s yr old female Alcohol intoxication Slipper river bank Alone Night time	Raise awareness of the risks of drowning from alcohol	85.7	River safety education including recognition and awareness of hazards	71.4	Designing the urban landscape to improve safety	60.7	Community risk mapping and assessment to formulate targeted prevention programs	46.4	Avoid open water at night Build safe and accessible infrastructure such as bridges	39.3 39.3

8	Group of males and females 18-30yrs Remote area Swimming Weak swimmer Strong current Steep drop off Unfamiliar location	Learn to swim with a focus on survival swimming skills	82.1	River safety education including recognition and awareness of hazards	78.6	Community wide rescue and resuscitation skills	78.6	Swim/recreate/wash bathe only in designated safe places	60.7	Signage Public rescue equipment available	39.3 39.3
9	Group of males Late teens and early 20s Rope swing Jumping in from bridge Peer pressure Hidden debris	River safety education including recognition and awareness of hazards	92.9	Swim/recreate/wash bathe only in designated safe places	71.4	Raise awareness of the risks of drowning from alcohol	67.9	Community risk mapping and assessment to formulate targeted prevention programs	46.4	Signage	39.3
10	Male in 60s Fishing alone Fall No lifejacket Bulky clothing Reduced skill and fitness due to age	Don't engage in water recreation alone	85.7	River safety education including recognition and awareness of hazards	75.0	Wear a lifejacket	57.1	Strategies to survive cold water immersion	46.4	Community risk mapping and assessment to formulate targeted prevention programs	42.9

Note: The percentage columns relate to the proportion of respondents who identified the strategy as being effective in reducing the kind of river drowning described in the scenario. Strategies marked with an * amount to more than 100% when strategies listed under the 'other' section were thematically recoded. Strategies which appear more than once are shaded in the darker colour and those that appear only once in the top three are shaded in the lighter colour.

A final list of 13 strategies was derived. Strategies address alcohol (n=2), flood-related measures (n=2) and child drowning prevention (barriers and supervision). Strategies such as *'Prohibiting/restricting alcohol use'* and *'Don't engage in water recreation alone'* are the highest on the Hierarchy of Control, defined as elimination-level strategies (Table 52)

Table 52: Final list of most effective river drowning prevention strategies, country context and levels of evidence

Strategy	**Average Score (%)**	**Effective in both HICs and LMICs (%)**	**% aware of evidence supporting strategy**
Barriers between child play areas and rivers	75.0	71.4	71.4
Build safe and accessible infrastructure such as bridges	40.5	78.6	50.0
Caregivers maintaining active supervision	22.0	82.1	82.1
Close flooded roads and/or use physical barriers (such as booms)	50.0	57.1	57.1
Community-wide rescue and resuscitation skills	24.6	82.1	32.1
Designing the urban landscape to improve safety	19.2	60.7	39.3
Don't engage in water recreation alone	38.8	82.1	32.1
Learn to swim with a focus on survival swimming skills	35.3	85.7	78.6
Prohibiting/restricting alcohol use	53.6	50.0	32.1
Raise awareness of the risks of drowning from alcohol	61.9	67.9	50.0
River safety education including recognition and awareness of hazards	69.7	92.9	32.1
Swim/recreate/wash bathe only in designated safe places	40.6	75.0	39.3
Wear a lifejacket	38.8	57.1	82.1

PPE = Personal Protective Equipment

6.3.4 Discussion

River drowning accounts for a significant proportion of global drowning burden [17 132]. This modified Delphi process addresses a gap in evaluated prevention strategies in the literature [50], using researchers and practitioners to identify river drowning strategies.

An initial list of 424 strategies was refined to 13 which would address 63.8% of Australian fatal river drowning. Strategies target the use of barriers, school-based river safety education, alcohol consumption, flooding, the establishment of safe places, infrastructure, discouraging water recreation alone, use/wear of lifejackets, learning to swim, community-wide rescue and resuscitation skills, improving child supervision and designing the urban landscape. Key issues identified throughout the Delphi process are now discussed.

6.3.4.1 Hierarchy of Control

Although lower order strategies such as signage and administrative strategies were more likely to be recommended by coroners when investigating the prevention of river drowning deaths in Australia [136], strategies which are higher on the Hierarchy of Control are more likely to be effective [145 271]. The final list of 13 river drowning prevention strategies spanned the Hierarchy, ranging from higher order strategies focused on elimination such as 'Prohibiting/restricting alcohol use' to lower order strategies such as personal protective equipment (PPE) 'Wear a lifejacket'. Higher order strategies, based on a sound evidence with adequate resourcing and timeframes, implemented in a supportive environment with policy and behaviour change should be prioritised [377].

6.3.4.2 Lifejackets

The use and wearing of lifejackets was one of the most commonly proposed strategies, also recommended by the WHO [22], with 29 individual strategies mentioning lifejackets at Phase 1. For the 14% of boating and watercraft-related river drowning deaths in Australia, evidence supports wearing lifejackets [238 387] and have also been found to be effective for those recreating in water [106]. However, in order to be effective, a supportive environment must exist whereby policy (and enforcement) [377 388] provide a mechanism for increasing the carriage and wearing of lifejackets.

A barrier to use in LMICs however, is access to low-cost lifejackets [22]. Despite 57% of respondents to the Delphi process stating that the river drowning strategy of '*Wear a lifejacket*' would be effective in both HICs and LMICS, there is a dearth of research from rivers and LMICs on the issue of lifejackets [294]. Lifejackets must be seen as an active prevention strategy (to be worn whenever boating), rather than a re-active one (putting a lifejacket on once the boat has capsized) [148]. Though beyond the scope of this Delphi, the authors note that any river drowning prevention strategy focused on lifejackets must address the personal, social and environmental factors underpinning lifejacket wearing behaviour [294], as well as suitability and availability of lifejackets in the particular country where they are proposed to be used.

6.3.4.3 River Safety Education

Education has long been regarded as a key facet of comprehensive approaches to the prevention of injury [389 390], including drowning [50 148 391 392]. This aligns with the Delphi findings with *'River safety education including recognition and awareness of hazards'* the only drowning prevention strategy that appeared in the top five for every river drowning scenario. Education must be guided by good evidence [148], which may be a challenge given the lack of research on river drowning [50]. Education must also form part of a broader strategy (commonly recognised as being enforcement and engineering) in order to be successful [393].

6.3.4.4 Rescue and Resuscitation Skills

The strategy of '*Community-wide rescue and resuscitation skills'* was recommended, in particular, for the river drowning scenario associated with aquatic recreation in isolated areas without timely access to medical assistance. This is pertinent, given 17% of fatal unintentional river drowning in Australia occur in remote and very remote locations [132], likely to be some distance from timely medical assistance, and only 33% of river users had a current cardiopulmonary resuscitation (CPR) qualification [138]. Training bystanders in safe rescue and resuscitation is also recommended by the WHO as a strategy to mitigate the impact of drowning [22]. While bystanders who undertake aquatic rescues and perform CPR help to save lives, in particular at unpatrolled locations, this is not without risk to the rescuer [394], and self-preservation must be key.

6.3.4.5 Signage

In Australia, signage is commonly recommended as a strategy for improving safety at rivers, often as a form of remote supervision [395]. Signage was also found to be a common theme in coronial recommendations associated with river drowning fatalities in Australia [136]. While signage may be a more feasible alternative to lifeguards, it needs to be part of a comprehensive drowning prevention strategy, noting there is limited evidence supporting its effectiveness when used in isolation [50], and no research specific to a river context [367 368]. The two studies conducted to date examining effectiveness of signage were both conducted in the beach context [367 368] and found that international students rarely utilised beach signage reports and a third would not swim between the flags [367], while a survey of beach users in the Australian state of Victoria, found that just 45% of respondents reported observing any signage at the beach. Further, composition of the sign, nor symbol shape affected recognition [368]. Although 24 strategies that involved signage were mentioned in Phase 1, due to a lack of support, signage did not feature in the final list, indicating a need for further evidence to support its effectiveness, and therefore use.

6.3.4.6 Country Context

This study considered the likely effectiveness of proposed river drowning prevention strategies in both HICs and LMICs. Critical assessment of the appropriateness of river drowning prevention scenarios for LMICs must be conducted. Underlying determinants of health [376], such as socio-economic status, education, and physical environment are factors which impact drowning risk, and need to be considered when developing prevention strategies. Resource implication needs to be considered in light of effectiveness, for example provision of lifejackets is a high cost strategy, low on the Hierarchy of Control (personal protective equipment), whereas signage is a lower cost strategy but higher on the Hierarchy of Control (administrative controls), however effectiveness of signage is unclear. Developing higher order control strategies, such as providing a safe place for pre-school children away from the water (i.e. community crèches) are likely to be more effective in reducing drowning, and are also more cost effective in LMIC countries [396].

Similarly, strategies such as learning to swim rely on identifying a skill base and expertise within the country, as well as safe swimming space being available to be successful and sustainable [396]. Critical reflection is needed to determine the environment to be used for teaching swimming. For example, the transfer of skills learnt in a still water environment to open water environments such as rivers. Engineering solutions are also likely to be costly, both the initial installation, as well as ongoing maintenance. Further research is required to identify the barriers to implementing river drowning prevention strategies in both HICs and LMICS, in order to implement measures to address these barriers.

6.3.4.7 Further Research

Further research includes: the need to implement and evaluate the proposed strategies (including local adjustments); increased understanding of the epidemiology of river drowning in other countries, especially LMICs; evaluation of the best method to provide school-based river safety education; type of messaging, placement and design for safety signage at river locations (including evaluating their impact); and factors impacting lifejacket wear.

6.3.4.8 Limitations

There are limitations associated with this study. This study represents the opinions of those who agreed to participate in the study only. The strategies recommended were influenced by the scenarios used, which although likely to be similar internationally, only depict drowning scenarios from Australia. Different scenarios may result in different strategies being recommended. Respondents did not have to provide the specific pieces of evidence they based their assessment on. While it would be reasonable to believe that the 65.5% of participants who are researchers or researchers and practitioners would be aware of the evidence on river drowning prevention strategies, the 34.5% of Delphi participants who are practitioners, may be less likely to be aware of such evidence. There may also be limitations associated with having HIC participants comment on the effectiveness of river drowning prevention strategies in LMICs and vice versa.

6.3.5 Conclusion

It is critical that river drowning prevention is prioritised given its burden. In the absence of evidence, a Delphi process can be used to identify strategies that are more likely to be effective. This study represents a vital first step in identifying and prioritising river drowning prevention strategies, especially those targeted at alcohol consumption, learn to swim, flood management and the wear/use of lifejackets. Future research is required to assess the efficacy of the 13 interventions recommended by this study (including implementation and evaluation). Such work is required in both HIC and LMIC contexts to further enhance efforts to save lives from drowning in rivers.

6.4 Cardiopulmonary Resuscitation and First-aid Training of Rivers Users in Australia: A Strategy for Reducing Drowning (Short Report [SR] 2)

Peden AE, Franklin RC, Leggat PA. Cardiopulmonary resuscitation and first-aid training of river users in Australia: A strategy for reducing drowning. *Health Promotion Journal of Australia*. 2018;00:1–5. https://doi.org/10.1002/hpja.195

6.4.1 Introduction

Ensuring people's health and wellbeing involves primary, secondary and tertiary prevention [397] especially for injury prevention. Effective, community-wide cardio-pulmonary resuscitation (CPR) is often promoted as a tertiary drowning prevention strategy [17 22 397 398], as well as being used in the management of cardiac arrest [399].

Unintentional fatal drowning results in an average of 281 deaths in Australia each year [49]. Globally, the World Health Organization (WHO) estimates that 372,000 people drown annually [17], a number shown to under-report drowning by 40% in a high-income country [14].

In Australia, rivers are the leading location for fatal drowning [132] with known risk factors as being male [132], alcohol consumption [133] and flooding [134]. Geographical isolation (defined in Australia as physical remoteness from goods and services including medical care [400]) has also been identified as a river drowning risk factor [132]. The increased risk of drowning in rivers in areas that are geographically isolated from timely medical assistance, is likely to impact survival outcomes [213], highlighting the importance of CPR.

Ensuring effective community-wide CPR as a gold standard in the drowning chain of survival is crucial [148]. Little is known in Australia about this around river locations. This study sought to better understand the CPR and first aid training of river users, including the role of social determinants of health [401] such as economic disadvantage and geographical isolation on participation in CPR training and currency of qualifications.

6.4.2 Methods

Adult river users (18+ years) at four high-risk river drowning locations in two Australian states (Queensland and New South Wales) were surveyed in January and February 2018. One location was in a national park and the other three locations were on public land. All locations had barbeque facilities and toilets and one had a boat ramp.

Respondents were approached and asked to participate. Once informed consent (oral) was obtained, respondents self-reported using a questionnaire that featured questions on demographics, river usage, knowledge, and alcohol consumption. The majority of questions provided set responses for the respondent to choose from. In some places, the respondent was required to write in a number (e.g. how many people are you at the river with today and how far in kilometres did you travel to get to the river today). This study forms part of a wider study on river drowning, river usage and effective strategies for river drowning prevention [9 50 132-134 136].

Respondents were asked "when was the last time you undertook/updated first aid qualifications (including CPR)?" Respondents could answer using one of the following options: 'never', 'completed for the first time in the last 12 months', 'updated in the last 12 months', completed/updated between 13 months and 2 years ago' and 'other'. For 'other' respondents were prompted to record years >2 since they last undertook training. In Australia, CPR can be undertaken as a stand-alone course, or as part of a first aid qualification. Henceforth both types of CPR training, either standalone or in a first aid course, will be referred to as CPR training.

The survey was administered in both paper-based format and online (www.surveygizmo.com) using iPads. Surveys completed on paper were transferred into SurveyGizmo on the same day the paper-based survey was completed. Data were downloaded from SurveyGizmo into IBMSPSS V20 [157] for analysis. To validate accuracy of data entry, every tenth paper-based survey (n=56) was cross-checked (by authors AEP and RCF). This resulted in the checking of 56 x 34 questions, resulting in a 0.7% error rate (due to incorrect data entry), with errors corrected prior to analysis.

The impact of social determinants of health on previous participation in CPR training and currency of qualification were examined using the remoteness classification and the Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) of the respondent's residential postcode. Remoteness classification was coded using the Australian Standard Geographical Classifications (ASGC) [163].

Respondent's residential postcode was coded to IRSAD [316], an index which summarises the economic and social conditions of people and households within an area, including both relative advantage and disadvantage measures. The Index is ranked from 1-10, with a low score indicating relatively greater disadvantage (e.g. many people with low incomes and many people in unskilled occupations), compared to a high score which indicates a relative lack of disadvantage. For analysis IRSAD was categorised as low (rank 1-3), high (rank 8-10) and other/unknown.

Univariate and chi square analysis were undertaken with a 95% confidence interval ($p<0.05$). Chi square analysis was conducted using CPR training undertaken – yes/no and CPR training current as a yes/no option, with yes being training undertaken within the last 12 months in accordance with the recommendations of the Australian Community Services and Health Industry Skills Council [402]. Chi square analysis excluded the unknown variable. Differences in mean time for training and mean time since qualification currency (i.e. time since last trained minus one year) were calculated using ANOVA ($p<0.05$).

Ethics approval was granted by the James Cook University Human Research Ethics Committee (HREC – H7249).

6.4.3 Results

Of river users surveyed (N=688), 677 (98.4%) answered the CPR question. There were 74.9% who had undertaken CPR training previously. The largest proportion of respondents (27.5%; n=186) indicated they had updated their qualification in the last 12 months. A quarter of respondents (25.1%; n=170) had never undertaken CPR training. Of the 144 respondents (21.3%) who stated they had completed/updated their qualification more than two years ago, 43.8% had last undertaken training 3-5 years ago, while 9.0% had undertaken training 21 year ago or longer. Males had an average 4.7 years since last trained, compared to 3.4 years for females ($F=5.6$; $p=0.019$). People aged 65-74 years and 75 years and older had last trained 12.4 years and 13.7 years ago respectively. As a person aged, they were significantly more likely to have a longer mean time since last trained ($F=14.0$; $p<0.001$). (Table 53)

Females ($X^2=7.2$; $p=0.007$) and 35-44 year olds ($X^2=14.7$; $p<0.001$) were significantly more likely to report having undertaken CPR training. Those aged 18-24 years were significantly less likely to have undertaken training ($X^2=9.1$; $p=0.003$). Country of birth, remoteness classification of residential postcode and IRSAD classification of residential postcode were not found to impact likelihood of having undertaken training. (Table 53)

Table 53: CPR training yes/no by river user demographic variables, mean time since last trained (SD±) and F (p value), Chi square (p value) (N=677)

	Total		**Mean time in years since last trained**		**CPR Training**						
					Yes				**No**		**X^2 (p value) comparing CPR training yes to CPR training no**
					Completed/Updated within last 12 months		**Completed/updated more than 12 months ago**				
	N	**%**	**M (SD±)**	**F (p value)**	**N**	**%**	**N**	**%**	**N**	**%**	
Total	677	100.0	4.0 (6.4)	-	223	32.9	284	41.9	170	25.1	-
Sex											
Male	330	48.7	4.7 (7.9)	*5.6 (p=0.019)*	94	28.5	138	41.8	98	29.7	*7.2 (p=0.007)*
Female	347	51.3	3.4 (4.6)		129	37.2	146	42.1	72	20.7	
Age group											
18-24 years	190	28.1	1.8 (1.5)	*14.0 (p<0.001)*	74	38.4	53	27.9	63	33.2	*9.1 (p=0.003)*
25-34 years	142	21.0	2.8 (3.8)		51	35.9	51	35.9	40	28.2	0.9 (p=0.344)
35-44 years	127	18.8	3.9 (5.0)		41	32.3	71	55.9	15	11.8	*14.7 (p<0.001)*
45-54 years	119	17.6	5.9 (7.9)		30	25.2	64	53.8	25	21.0	1.3 (p=0.256)
55-64 years	65	9.6	4.1 (6.5)		23	35.4	24	36.9	18	27.7	0.3 (p=0.614)
65-74 years	27	4.0	12.4 (16.0)		3	11.1	16	59.3	8	29.6	0.3 (p=0.581)
75+ years	7	1.0	13.7 (13.7)		1	14.3	5	71.4	1	14.3	0.4 (p=0.507)
Country of birth											
Australia	572	84.5	4.1 (6.6)	0.3 (p=0.558)	189	33.0	244	42.7	139	24.3	1.3 (p=0.257)
Outside of Australia	105	15.5	3.6 (4.9)		34	32.4	40	38.1	31	29.5	
Remoteness classification of residential postcode											
Major Cities	123	18.2	5.4 (9.1)	2.3 (p=0.077)	45	36.6	46	37.4	32	26.0	0.2 (p=0.901)
Inner Regional	385	56.9	3.9 (5.3)		114	29.6	168	43.6	103	26.8	0.7 (p=0.408)
Outer Regional	139	20.5	3.2 (5.9)		53	38.1	54	38.8	32	23.0	0.6 (p=0.437)
Remote and Very Remote	6	0.9	2.0 (1.5)		3	50.0	3	50.0	0	0.0	2.1 (p=0.149)
Unknown	24	3.5	4.1 (8.4)	-	8	33.3	13	54.2	3	12.5	-
IRSAD classification of residential postcode											
Low	118	17.4	4.8 (7.1)	0.0 (p=0.912)	32	27.1	58	49.2	28	23.7	0.4 (p=0.519)
High	113	16.7	4.9 (7.4)		38	33.6	44	37.3	31	27.4	
Other/Unknown	446	65.9	3.6 (5.9)	-	153	34.3	182	40.8	111	24.9	-

Please note the unknown variable was excluded from chi square analysis. Statistically significant findings have been italicised.

Thirty-three percent (33.1%) of respondents had a current qualification. Females (X^2=5.9; p=0.015) and 18-24 year olds (X^2=4.4; p=0.037) were significantly more likely to report holding a current qualification. People aged 45-54 years (X^2=4.1; p=0.044), 65-74 years (X^2=6.1; p=0.013) and residing in inner regional areas (X^2=4.6; p=0.032) were less likely to report holding a current qualification. Country of birth and IRSAD of residential postcode did not impact currency of qualification. (Table 54)

For those without a current qualification, the mean time since last current was 5.4 years. Age group significantly impacted currency of qualification with 65-74 year olds (M=13.5 years) and 75+ year olds (M=15.2 years) recording the longest time in years since qualifications were last current. (Table 54)

Table 54: Currency of CPR qualification by demographic and river usage variables, mean time since qualification last current (SD±); F (p value), Chi square (p value) (n=674)

	CPR qualification current - Undertaken within the last 12 months		**CPR qualification not current - Undertaken 13 months or more ago**				**CPR qualification not current - Never undertaken**		**X^2 (p value) comparing CPR qualification current to not current**	**Total**	
	N	**%**	**N**	**%**	**M [1] (SD±)**	**F [2] (p value)**	**N**	**%**		**N**	**%**
Total	223	33.1	281	41.7	5.4 (7.8)	-	170	25.2	-	674	100.0
Sex											
Male	94	28.6	137	41.6	6.3 (9.5)	3.7 (p=0.055)	98	29.8	*5.9 (p=0.015)*	329	48.8
Female	129	37.4	144	41.7	4.5 (5.6)		72	20.9		345	51.2
Age group											
18-24 years	74	39.2	52	27.5	2.0 (1.8)	*8.0 (p<0.001)*	63	33.3	*4.4 (p=0.037)*	189	28.0
25-34 years	51	36.2	50	35.5	3.7 (4.7)		40	28.4	0.8 (p=0.381)	141	20.9
35-44 years	41	32.5	70	55.6	4.5 (5.6)		15	11.9	0.0 (p=0.885)	126	18.7
45-54 years	30	25.2	64	53.8	7.2 (8.7)		25	21.0	*4.1 (p=0.044)*	119	17.7
55-64 years	23	35.4	24	36.9	6.1 (8.0)		18	27.7	0.2 (p=0.679)	65	9.6
65-74 years	3	11.1	16	59.3	13.5 (16.6)		8	29.6	*6.1 (p=0.013)*	27	4.0
75+ years	1	14.3	5	71.4	15.2 (13.6)		1	14.3	1.1 (p=0.288)	7	1.0
Country of birth											
Australia	189	33.2	241	42.4	5.5 (8.1)	0.3 (p=0.577)	139	24.4	0.0 (p=0.867)	569	84.4
Outside Australia	34	32.4	40	38.1	4.7 (5.9)		31	29.5		105	15.6
Remoteness classification of residential postcode											
Major Cities	45	36.6	46	37.4	8.6 (11.3)	*3.5 (p=0.016)*	32	26.0	0.8 (p=0.358)	123	18.2
Inner Regional	114	29.8	166	43.3	4.9 (6.2)		103	26.9	*4.6 (p=0.032)*	383	56.8
Outer Regional	53	38.4	53	38.4	4.4 (7.8)		32	23.2	2.3 (p=0.134)	138	20.5
Remote and Very Remote	3	50.0	3	50.0	2.0 (1.7)		0	0.0	0.8 (p=0.376)	6	0.9
Unknown	8	33.3	13	54.2	5.0 (10.3)	-	3	12.5	-	24	3.6
IRSAD classification of residential postcode											
Low	32	27.1	58	49.2	5.8 (8.2)	0.6 (p=0.437)	28	23.7	1.2 (p=0.282)	118	17.5
High	38	33.6	44	38.9	7.2 (8.8)		31	27.4		113	16.8
Other/Unknown	153	34.5	179	40.4	4.8 (7.4)		111	25.1	-	443	65.7

Please note the unknown variable was excluded from chi square analysis. [1] = mean time in years since qualification last current; [2] = ANOVA of the differences by demographic variables. Statistically significant findings have been italicised.

6.4.4 Discussion

Although classified as a tertiary drowning prevention strategy, community-wide CPR is a key component of multi-faceted drowning prevention programmes, as well as vital in improving cardiac arrest outcomes [22 399]. This study has identified 75% of river users had undertaken CPR training at least once, with just 33% holding a current qualification at the time of being surveyed. The cohort surveyed were attending (and recreating at) known high-risk river drowning locations, where CPR skills may need to be used.

Barriers to CPR training are poorly understood [403]; so too for river users. Among the cohort surveyed, social determinants of health such as socio-economic disadvantage and geographical isolation of residential location were not found to be statistically significant barriers to participation in CPR training or possessing a current qualification. Further research is required to understand the barriers faced by 77% of river users surveyed which prevent them from holding a current qualification. In Australia, it is recommended that CPR qualifications be updated every 12 months [402]. Just 33% of those surveyed reporting having a current qualification, with the average being 5.4 years since the average respondent's qualification was last current.

While CPR is often promoted as being better than no CPR [404], good CPR is better than poor CPR. Having undertaken CPR once is not a skill for life. In Australia, several changes in CPR guidelines highlight the importance of regularly refreshing skills [405]. With reduction in skill shown in as little as 6 months post-training [406], there is a need for effective system level, upstream strategies to encourage community members, in particular those visiting high risk river drowning locations, to regularly update skills. Strategies that may enhance community-wide skills and regular updates include provision through secondary schools [407], as a compulsory curriculum component [408] and linking CPR updates to motor vehicle (and boat) license renewals. The latter may prove more effective in rural areas, where distance from healthcare is extensive. This strategy warrants further evaluation given the increased river drowning risk in rural and remote areas [132].

6.4.5 Limitations

This study has limitations. Responses are self-reported and may be subject to recall bias. As the research attracted media coverage (print, radio, television and online) the results may be subject to social desirability bias. The survey was administered in English which may have impacted participation. The sample was a random convenience sample and therefore results represent the views of survey participants attending the four river locations. Caution should be used when extrapolating the results more broadly.

6.4.6 Conclusions

Rivers are the leading location for drowning in Australia. Community-wide CPR and first aid skills are often promoted as a river drowning prevention strategy, however this study found just 33% of river users surveyed hold a current qualification. Upstream strategies must be undertaken to promote the importance of this lifesaving skill to river users, such as development and implementation of system-level strategies to maintain currency of qualifications.

Chapter 7: Discussion

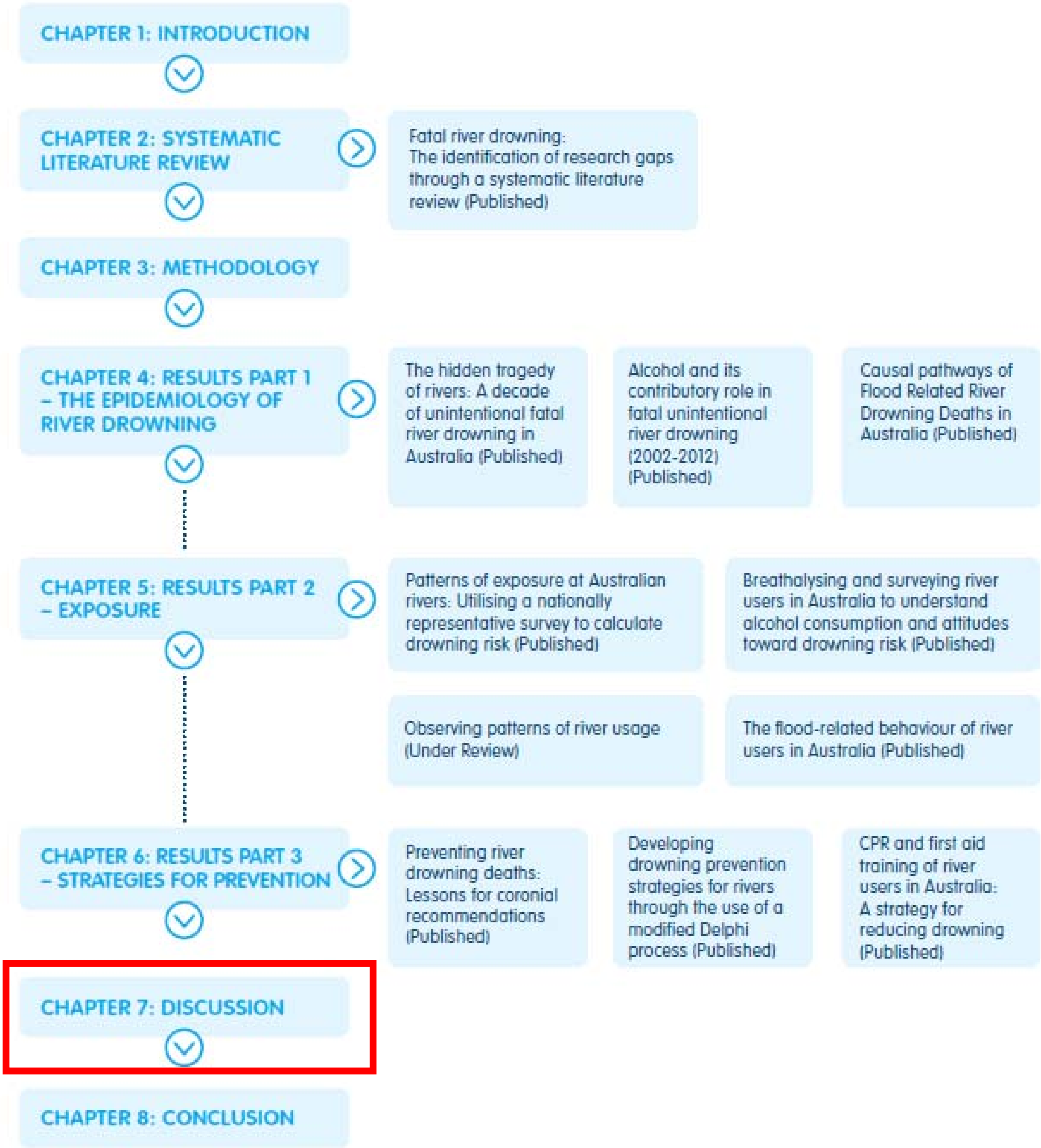

Figure 29: Chapter 7 position within thesis structure

7.0 Overview

This research is the first of its kind to explore river related drowning deaths in a comprehensive and detailed manner. A dearth of prior research is concerning, when rivers account for a significant proportion of the global burden of fatal drowning [17 22 50], which the WHO estimates totals 320,000 lives around the world annually [409]. This figure, however, is thought to be an underestimate due to the coding structures and methodologies utilised [14]. A study conducted in Australia found that ICD-10 coding structures and using the first reported cause of death only, under-reported drowning by 40% [14]. Drowning deaths involving watercraft and non-aquatic transport incidents, as well as flood-related drownings, all of which commonly occur in rivers, were found to be most impacted by the under-report [14]. As such, alternative data collection methodologies are required, when exploring river drowning fatalities, such as the data triangulation method utilised in this study.

In Australia, rivers are the leading location for unintentional fatal drowning [132]. Franklin et al. [35] and the annual *Royal Life Saving National Drowning Report* have highlighted this issue, and the *Australian Water Safety Strategy*, in its three most recent iterations (2008-2011 [48], 2012-15 [46], 2016-2020 [32]) have identified the reduction of river drowning to be a key issue impacting achievement of an overall 50% reduction in unintentional fatal drowning in Australia by the year 2020. Despite this, there has been little focused research on river drowning and its prevention, in contrast to other areas of drowning prevention such as child drowning [37 89 410] and at beaches [279 341 367].

Using a public health approach [131 411] this thesis, and the studies within it, provided a framework to develop a detailed understanding of the epidemiology, risk factors and strategies for the prevention of unintentional fatal drowning in rivers in Australia. Mixed methods were used across the studies within this thesis. The following section details the 21 recommendations resulting from the body of work contained within this thesis.

7.1 Recommendations

This study commenced with a systematic literature review examining literature published on river drowning epidemiology, risk factors and strategies for prevention. The literature review was framed from the perspective of identifying gaps in the published literature [50]. Over the last 28 years (1980-2018), there have been only 45 papers published specifically on river drowning. Gaps identified included: a lack of an agreed definition for rivers; a lack of data on drowning rates for rivers (or wide variation in the rates published); little exploration of risk factors (64.4% of published papers) and a lack of consensus among those identified; few prevention strategies recommended (42.2% of published papers) and even fewer implemented and evaluated (2.2%).

The lack of an agreed definition for rivers, is a significant issue impacting the conduct and comparability of studies. There is a need for consensus on a global definition, with any definition requiring suitability and applicability in all country contexts and be compatible with existing coding frameworks and coronial systems.

Recommendation 1: The creation of an international reference group to develop an agreed definition for rivers.

With limited and sometimes conflicting information on river drowning in the published literature, such as wide diversity in the crude drowning rates reported in both LMICs [91 97] and HICs [90 104] and risk factors, in particular age group [35 97 102], this study set out to describe the burden and identify risk factors associated with unintentional fatal drowning in rivers in Australia within a public health approach. A 10-year epidemiological analysis was undertaken which utilised a data triangulation method of case capture (coronial data through the NCIS, media reports and information from lifesaving organisations). This method offsets the under-reporting and a lack of fidelity associated with ICD coding structures [374], for example in the 2017/18 financial year 75.9% of Australian drowning deaths would be classified to the natural waterways code [36]. Longitudinal analysis was also undertaken to ensure more accurate analysis of long-term trends, rather than yearly fluctuations influencing decision-making for prevention. Such epidemiological analysis of river drowning must be maintained to ensure ongoing monitoring, analysis and evaluation of interventions to identify impact on drowning figures [35 271 273].

Recommendation 2: Ongoing monitoring of unintentional fatal river drowning on an annual basis in Australia be conducted.

Similar to drowning in other high-income countries [75 219 220 302], the epidemiological analysis of river drowning fatalities identified alcohol as a major risk factor. Among river drowning victims, analysis found alcohol was known to be involved in 41% of cases, with 36% recording a positive BAC and 26% recording a BAC ≥0.05%. Although there were no studies specific to alcohol burden in rivers, these findings are similar to, yet slightly lower than, those from Sweden (44% with alcohol in their blood among the unintentional drowning group) [302], Finland (alcohol contributory in 64% of boating-related drownings and 52% of other drownings) [75] and New Zealand (43% of unintentional drownings) [219].

The reporting of alcohol levels is not without it challenges. These include a lack of data on alcohol involvement where a case is still under coronial investigation, no autopsy is performed, a body is not recovered, or a body is too decomposed to attain an accurate BAC reading [187]. Another challenge is understanding what constitutes a BAC level that has an impact on the drowning. A BAC of ≥0.05% was chosen to be a level of alcohol consumption that was contributory to the drowning death [133]. This level was also chosen in part to offset the body's natural post-mortem production of alcohol during decomposition, known effects on the body [233] and a BAC of 0.049% being the upper legal BAC limit for an operator of a motor vehicle or powered vessel in most Australian states or territories [233]. However, other studies have used a range of estimates, from 0.080% to ≥0.100% [218]. There is a lack of consensus among researchers as to what a "risky" level of alcohol is and how to determine its contributory role in drowning [237]. It could be argued that any amount of alcohol causes impairment and increases drowning risk due to adversely impacting decision-making, balance, coordination and motor skills [233].

With respect to the role of decomposition on blood alcohol concentrations post mortem, which can be exacerbated due to bodies being in water, a recent study from Finland examining endogenous ethanol production in drowning victims, published several years after our study, appears to find minimal impact on BAC readings [412], although further research is required in warmer climates such as Australia, where the impact of decomposition on a body's BAC at time of autopsy may be higher.

Recommendation 3: Conduct further research using a range of climates to explore the impact of decomposition on natural alcohol production and BACs among river drowning victims. Research should also explore time until found and impact on BACs at time of autopsy.

To further explore the role of alcohol in river drowning, a community survey and breathalysing of river users was also undertaken to explore alcohol consumption and river usage at four highly patronised river locations [4]. This novel approach garnered information from 684 river users of which, 16% had a positive BAC ranging from 0.001% to 0.334%), with 7.2% having a BAC ≥0.050%.

River users who were more likely to have BACs ≥0.050% were aged 18–34 years and resided in inner regional and low socio-economic areas, were more likely in the afternoon and on hotter days. The inner regional finding was surprising considering alcohol usage has been found to increase as remoteness increases [413]. In contrast, increased alcohol consumption among those residing in areas classified as low socio-economic was less surprising and links to the body of literature that has identified people from low socio-economic backgrounds as being at higher risk of injury-related mortality and morbidity [414], including drowning [415]. The finding of increased likelihood of alcohol consumption at rivers in the afternoon hours and on hotter days links to a body of research indicating afternoons as the most common time for drowning both at rivers [132], for children with ASD [120], for children in Bangladesh [416], drowning rescuers [182] and children who drown in the bathtub [306], as well as the link between drowning and warm weather [331 417].

River users on Australia Day (a national public holiday) were significantly more likely to drink heavily (Mean BAC ≥0.05% was 0.175%; SD = 0.09) [4], which links to other research findings indicating increased drowning risk on public holidays [327] and increased alcohol intoxication in the context of major public holidays, sporting and social events [329]. When designing awareness campaigns around alcohol and the risk of river drowning these findings should be considered to ensure the identification of targets of messaging as well as the opportune time for triggering any such campaigns.

Recommendation 4: Awareness campaigns on the topic of alcohol and river drowning risk must be designed with consideration for those groups at highest risk and triggered at opportune times, such as in the warmer months and in the lead up to public holidays.

Although both males and females were found to record similarly high BAC levels when breathalysed [4], males continued to be overrepresented in alcohol-related river drowning fatalities [132]. However, recent studies have shown a convergence in the rates of alcohol use among males and females [321], with an increase in the number of females in younger cohorts recording higher levels of alcohol use and abuse [322]. Similarly, despite decreases in the number of males exceeding lifetime alcohol risk guidelines, this exceedance among females has remained similar [308]. Further data are required on the sex differences in alcohol consumption and, importantly, behaviours and attitudes towards consuming alcohol and undertaking aquatic activity at the river to guide prevention efforts, particularly among males and both males and females in high-risk age groups.

A challenge in collecting these data, is exploring alcohol usage among those under the legal drinking age of 18 years. Ethically, this study was only allowed to survey and breathalyse adult (i.e. 18 years and over) river users who gave informed consent [4]. However, epidemiological analysis of river drowning deaths identified 3% of cases of river drowning involving alcohol among children (i.e. those aged 17 years or younger) of which 35% recorded a BAC ≥0.05% at the time of death [133]. Further research on alcohol consumption at rivers among this age group is recommended.

Anecdotally, those conducting research in the field noted that when breathalysing those who had been drinking, the individual was always surprised at their BAC and was never able to accurately assess their BAC. Similar research has been conducted within the context of drink driving [418 419] and among college students [420]. Studies across both contexts found that people generally underestimated their BACs, and those who were more likely to underestimate their BAC attained higher BACs [418-420]. Within a drowning prevention context, this is an area worthy of further research and may also provide an opportunity for awareness raising and education on alcohol-related drowning risk among participants.

Recommendation 5: Conduct further field-based research into the consumption of alcohol at rivers across all age groups, including behavioural and attitudinal factors related to alcohol consumption.

A challenge associated with the community fieldwork on river usage and alcohol consumption was the collection of data on alcohol consumption and aquatic activity at rivers in the late evening and early morning hours, due to limited people attending the locations. Data was collected between 8am and 6pm[4], however one-fifth (20%) of all fatal drownings in Australian rivers known to involve a BAC ≥0.05% occurred in the early morning hours (12:01 am to 6 am) [133]. Although challenging, strategies for collecting data at this time of night, need to be considered in further research.

Recommendation 6: Explore strategies for collecting alcohol consumption and river usage data during the late evening and early morning hours.

Flooding, another risk factor for river drowning identified in the epidemiological study of river drowning, was implicated in 17% of unintentional river drowning deaths [134]. The study found flood-related river drowning deaths occurred more commonly due to slow onset flooding (55.8%). River flood-related drowning risk was 80 times higher for those residing in remote areas, and 230 times higher for those residing in very remote areas, when compared to those residing in areas classified as major cities [134]. Non-aquatic transport incidents (i.e. vehicles driven or being swept into floodwaters) were the leading cause of death during times of flood, accounting for 55% of all deaths. Non-aquatic transport flood-related incidents commonly affected those driving 4WDs [134].

Despite work to understand the behavioural aspects of reasons for driving into [121 270] and avoiding driving into [421] floodwaters and the impact of performing flood-related rescues on rescuers [422], translating research findings into effective drowning prevention strategies can be challenging. In Australia, evaluation of a video infographic aimed at discouraging people from driving into floodwater, found immediate positive impact on self-reported likelihood of participating in the behaviour among both males and females, but this was only retained by females at the six month follow-up [355]. Further research is required to identify the messages likely to reduce the likelihood of males driving into floodwater. Research must include a focus on those residing in rural and remote communities where regular, low level flooding may be impacting attitudes towards risk and therefore willingness to drive into floodwaters [7 134]. Research must consider the experiences of those residing in rural and remote locations, where regular, low-level flooding may be impacting likelihood of undertaking this potentially risky activity.

Similarly, further research is needed to explore the timing of messages, with flooding often difficult to predict. Working closely with organisations such as the BOM to identify periods of predicted rainfall, as well as mapping known flooding blackspots, may assist in targeting locally appropriate messaging at a time more likely to be effective in preventing such risky behaviour around rivers in flood. Timing of messaging also extends to optimal delivery to impact decision-making. For example, information delivered during times of flood, along the flooded route and/or at culverts and flood-crossings, are likely to be too late to impact behaviour if a decision to cross the floodwaters has already been made.

Recommendation 7: Conduct further research to identify effective interventions to discourage driving into floodwater.

Similar to codes of practice for alcohol advertising [423] and food advertising to children [424], river flood-related drowning prevention advocates should give consideration to developing an advertising code of practice around the advertising of 4WDs. A code of practice would discourage the overt marketing of a vehicles' capacity to drive into floodwaters, including visual advertising that may glamourise or normalise the behaviour. Such a recommendation is warranted given motor vehicle advertising is self-regulated in Australia, as it is in many developed countries [425].

Recommendation 8: Development of an advertising code of practice or add to the existing code to define rules around advertising of vehicles driving through floodwaters.

Trucks and motorcycles were found to record drowning rates per 100,000 registration 4.33 and 3.67 times respectively that of cars [134]. Although registration data are used as a proxy for exposure in these calculations, research shows occupants of bigger vehicles are often more likely to attempt to drive into floodwaters [268]. This indicates a need for further focus among this high risk cohort, with education and prevention efforts targeted at this group.

To build upon the increased understanding of river flood-related drowning risk from the epidemiological analysis, river users were surveyed about their flood-related behaviour [7]. Findings showed 36% of river users stated they had driven into floodwaters, with males, those born in Australia and those residing in major cities being significantly more likely to self-report having driven into floodwaters [7]. This is in contrast to findings from the epidemiological study of river flood-related fatalities which found risk of drowning during times of flood increases as remoteness increases [134].

A limitation of the study [7], and other studies [242 259 260], is the lack of a consistent definition of what is meant by the term flood. Jonkman and Kelman, in their 2005 study [70], discuss the challenges in defining and classifying floods to due to complex and interrelated factors which can cause and influence floods. Rather, a working definition is proposed namely that a flood is defined as "...the presence of water in areas that are usually dry" (p 75) [70]. Although a broad and simple definition, this is not necessarily suitable for differentiating between rivers which generally have water in them and the same river during a time of flood.

In the study reported within this thesis [7], rather than provide a definition of flood, participants in the survey were asked to consider whether they had ever driven through floodwaters and/or swum in a flooded river, leaving the participants to determine if they felt the river was in flood at the time. This may have resulted in different perceptions of what was classified as 'floodwaters' or a 'flooded river' when answering these questions. There may be value in conducting research to explore what people consider to be 'floodwaters' or a 'river in flood' and how this differs by factors such as age, sex and the remoteness classification of the respondent's residential location.

Recommendation 9: Conduct research to determine what people consider to be 'floodwaters' and a 'flooded river', factors impacting this definition, and impacts upon behaviour to interact with floodwaters.

Almost one fifth (19%) of those surveyed self-reported having swum in a flooded river [7]. Males, those aged 18-24 years and residing in outer regional areas were significantly more likely to report having swum in a flooded river. This is consistent with other research that indicates that those in adolescence and their early 20s are the age groups most likely to undertake risky behaviour [324 325], likely linked to the gap between puberty and the slow maturation of the cognitive control system [426]. A meta-analysis of the psychological literature also shows differences in male and female risk-taking narrows over successive age levels [427]. Such factors should be taken into account by drowning prevention advocates when communicating flood risk to an age group prone to risk-taking.

The survey did not ask any further questions on the circumstances surrounding the respondent undertaking such risky activity. Therefore, further research is recommended to understand the factors behind this and the context within which the activity was undertaken be it recreational, escape to safety, conducting a rescue for example.

Recommendation 10: Undertake further research into why people swim in flooded rivers.

Exposure is a challenge when exploring drowning risk. Most studies use population-based rates to express drowning risk, however this clearly does not take into account people who never see or visit a river and those who are regularly exposed to rivers. It also does not take into account geographical differences, i.e. those areas with many rivers, high rainfall, or areas which are drought prone, in exposure to rivers and therefore river drowning risk. To explore exposure, the next phase of the research built upon the epidemiological study of river drowning to explore exposure to rivers and its impact on drowning risk using several methods. The first study within this thesis to consider exposure used data on a nationally representative sample's self-reported responses to a CATI survey on river visitation and usage to calculate fatal unintentional river drowning rates based on exposure, rather than population rates [9]. The study acknowledged the limitations associated with self-reported data including recall bias [172 173].

While 80% of river drowning deaths are males, the CATI survey identified similar numbers of males and females visit rivers, often for different activities. Females were more likely to visit the river for activities that did not involve entering the water (e.g. walking beside the river and having a picnic) and males were more likely to visit the river for fishing and to use watercraft (i.e. activities which put them in direct contact with the water). Males were also more likely to report consuming alcohol at the river, with river drowning rates based on exposure finding males to be nine times more likely than females to drown with alcohol present [9]. This may go some way towards explaining why males account for 80% of river drowning statistics, despite similar visitation figures among males and females. Similarly, other studies within the drowning prevention literature have hypothesized as to why males are at a higher risk of drowning. These include differences in beach bathing in males compared to females (i.e. spending longer in the water and in deeper water) [281], increased exposure, risk-taking behaviours and alcohol use on or near water [202]and interacting factors such as alcohol use combined with non-use of lifejackets, even when available [295]. In the broader injury literature, sex differences are also seen including increased risk-taking behaviour among males [428] and differing responses to engaging in injury-risk behaviours [429] and supervision behaviours [430] among mothers of toddlers. There is however, a dearth of research on this topic, specific to sex differences in river visitation and usage and therefore further research in this space is recommended.

Recommendation 11: Conduct further research examining sex differences in river visitation and usage and examine any differences between urban and rural settings.

It is not clear why or how people pick which aquatic location to visit. Seasonal facilities (i.e. public pools that are only open for a part of the year, usually summer) and the increasing cost to enter such facilities [431], may be influencing decisions to swim in a river. So too may the lack of a facility, or suitability of facility. Further research on this aspect of river drowning risk is required, to build on the increased knowledge this study has generated regarding where river drownings occur and who is most at risk.

Recommendation 12: Examine the environmental and psychological factors impacting a person's decision to swim in a river.

To add to the findings of the CATI survey, a study was conducted at the same four locations where the community survey and breathalysing study took place, to collect data on usage via direct observation [135]. Using a minimum of two coders, within a designated zone, the total number of people were captured, including estimated breakdowns of males and females, adults and children, and those who were in, on, or beside the water. The interrater reliability between coders was also examined to evaluate the data collection method [135]. Interrater reliability was excellent, consistently above 0.900 for all variables collected (apart from the variable of beside the river) [135].

More females (M=20.6) and adults (M=26.0) than males (M=18.3) and children (M=13.3) were observed. Average numbers of river users increased on weekends and the Australia Day national public holiday.

This is the first study in the world to use direct observation to explore exposure to rivers and builds upon direct observation exposure studies at Australian beaches [281 314]. In contrast to beach findings which reported a significantly higher numbers of males visiting and bathing at beaches under observation [281], more females than males were reported within the zones of interest at the river locations observed. However, the study reported within this thesis [135], reflects only the findings from the four river locations where observations were conducted and did find local variations, which were particularly influenced by the environment of the site (e.g. boat ramp, beach entry for swimming). Data collection in this method was found to be accurate between coders and reasonably low resource, aside from the human resource requirements. Further population level, real time data on river visitation and usage is required. Data collection techniques may include direct measurement, such as utilising sites with known entrance points where visitation is monitored (e.g. National Parks) and exploring alternative methods for data capture such as remote sensing equipment as has been used in construction site occupational injury [432], mobile phone 'apps' [433], diaries (such as those used to record data among older people [434]) and remote camera observations [435].

Recommendation 13: Explore population level, real time data on river visitation and usage.

The next step in the public health approach is to develop interventions. Building upon the epidemiological and exposure studies, this thesis sought to establish an evidence-base for river drowning prevention strategies. Several methods were used including an analysis of coronial recommendations [136], the use of an expert panel to identify river drowning prevention strategies more likely to be effective [137] and explored factors impacting participation in CPR training and the currency of CPR qualifications of river users [138].

Under the medico-legal process of death investigation in Australia, a coroner can make recommendations in the interests of public safety, to prevent similar future deaths [30]. For the cases of river drowning, the presence and content of coronial recommendations were examined [136]. Recommendations were assessed against a modified SMART [149] principle and assessed against the Hierarchy of Control as a means of exploring their likely effectiveness.

Eight percent of closed cases had recommendations, resulting in 71 unique recommendations [136]. Though there have been few other studies exploring the frequency of coronial recommendations in Australia, this study's findings compare favourably to coronial recommendations made in association with cases of injury-related deaths of nursing home residents in Australia (1.6%) [436] and four coronial court cases examining pressure ulcers in cases of elder abuse in Australia, despite a national prevalence of 34% among residents of Australia residential aged care facilities [437]. Just six percent of coronial investigations into fatal heavy vehicle crashes in Victoria, Australia resulted in recommendations [438].

Within river drowning cases, commonly recommended categories of strategies included administrative (39.4% of the unique recommendations) and signage-related (18.3%). Recommendations were often low on the Hierarchy of Control [150], namely administrative recommendations and behaviour-related. Half of the unique recommendations made satisfied 4 of 6 modified SMART principle components, often lacking the time-bound (n=3 unique recommendations) and relevant (n=13 recommendations) [136] components [136].

This study addressed an important research gap around the response of the coronial system to river drowning deaths and their prevention. However, a limitation of the study is that it did not explore how often and what kind of coronial recommendations are enacted, rather than just recommended. A study of coronial recommendations in Victoria, an Australian state with a mandatory response regime, identified coronial recommendations were implemented in a third of instances [366] and highlighted important findings around the quality of recommendations rejected by those charged with implementing them, and the adequacy of consultation between coroners and affected organisations for those coronial recommendations which had already been actioned [366]. There are likely to be similar lessons for river drowning prevention by undertaking a similar process.

Recommendation 14: Conduct research examining the outcomes from coronial recommendations on river drowning.

The modified Delphi process was conducted using a global panel of researchers and practitioners representing both HICs and LMICs [137]. The expert panel listed, refined and prioritised drowning prevention strategies more likely to be effective, including identifying levels of evidence, their likely effectiveness in both HICs and LMICs and against 10 river drowning scenarios from Australia.

Through multiple rounds, the 29-person panel refined an initial list 424 prevention strategies a final list of 13. Prevention strategies assessed as being more likely to be effective include: avoiding alcohol, engineering and early warning systems to reduce the risks of flooding, child supervision, learning to swim, lifejackets, and community-wide resuscitation skills [137].

Table 55 compares river drowning prevention strategies identified in the published literature, with those recommended in the final stage of the Delphi process. Additional strategies identified within the Delphi that were not identified with the review of published literature include: raise awareness of the risks of drowning from alcohol ingestion; prohibiting/restricting alcohol use; close flooded roads and/or use physical barriers (such as booms); build safe and accessible infrastructure such as bridges; do not engage in water recreation alone; community-wide rescue and resuscitation skills; and designing the urban landscape to improve safety [137].

Table 55: Comparison of strategies identified in published literature and those recommended within the Delphi process

Strategies identified in published literature	Strategies identified through Delphi process
Lifejackets	√
Education	√
Signage	
Supervision	√
Barriers to restrict access	√
Grills and covers	
Basic swimming and water safety instruction	√
Supervised safe places to swim	√
Risk communications	
Search and rescue presence	
Targeting messages about driving into floodwaters	
Exclusion of those under the influence of alcohol from canoeing and kayaking	
Health requirements for kayaking and canoeing	
Setting of an upper limit of difficulty of rapids based on individual's previous kayaking or canoeing experience	
Issuing of general flood evacuation warnings	
Automated systems for maritime safety	

Although signage was not identified in the Delphi process as being an effective strategy for preventing river drowning, signage continues to be used at rivers, often as a form of remote supervision [395]. While signage may be seen by land managers and local councils as a cost-effective and simpler means of making river users aware of the hazards and safe behaviours to follow, there is limited evidence supporting its effectiveness, with previous studies of signage at beaches finding negligible benefit [367 368]. Further research in a river-specific context is required, in particular identifying the impact, or not, of signage on behaviour at rivers.

Recommendation 15: Conduct research exploring the impact of signage on river users.

While the modified Delphi process addresses a research gap around strategies more likely to be effective in preventing river drowning, expert opinion represents a low level of evidence [73]. The next step in this process, though beyond the scope of this thesis, is to secure funds to implement and evaluate prevention strategies in pilot locations before expanding those successful strategies to the population level.

Recommendation 16: Secure funding to implement and evaluate prevention strategies more likely to be effective in preventing river drowning deaths.

Although the Delphi panel featured participants from LMIC backgrounds, and the entire panel was tasked with considering the effectiveness of river drowning prevention strategies in both HIC and LMIC contexts [137], there remains a death of information on the epidemiological profile of river drowning deaths in LMICs [50]. This poses a challenge for assessing if recommended prevention strategies are truly suitable in an LMIC context.

Recommendation 17: Increase the number of population level epidemiological studies on rivers from LMIC contexts including drowning prevention strategies.

When considering strategies for reducing drowning-related loss of life at rivers, CPR may be an effective tertiary drowning prevention strategy [148 398], particularly considering the increase in drowning risk in geographically isolated locations [132 134] that are often large distances from timely and sophisticated medical care. To further explore CPR as a river drowning prevention strategy, river users were surveyed about their CPR training and currency of CPR qualification [138]. Seventy five percent of respondents self-reported having undertaken CPR training previously. This compares favourably to the estimated five percent of the population in Australia who have been trained in CPR [439] and to findings from Greece which report low prevalence of basic CPR knowledge in the general population [440] and Sweden, which reports between 30-45% of the adult population having ever participated in CPR training [441].

The study also found females and 35-44 year olds were significantly more likely to have undertaken training. Males and older people (65+ years of age) were less likely to hold a current qualification. Major city residents reported a longer mean time (5.4 years) since last trained than remote and very remote locations (2.0 years). People residing in low socio–economic areas had a shorter time since qualification last current (5.8 years) than those residing in areas deemed as high (7.2 years).

There is however, debate surrounding the strength of evidence behind CPR as a component of a strategy for drowning prevention. It is a reactive, tertiary strategy [148], designed to improve the outcome of a drowning victim, as opposed to preventing the initial immersion or submersion incident. The WHO implementation guide for preventing drowning [22] recommends 'training bystanders in safe rescue and resuscitation' while acknowledging that rescue and resuscitation have limited impact on preventing drowning incidents, such skills can reduce drowning mortality and morbidity [22]. Allocation of resources to strategies other than learning CPR or rescue sills may be more cost-effective when applied to drowning prevention. Further research is required to assess the cost-effectiveness of different drowning prevention strategies.

Further qualitative and quantitative research is recommended to improve understanding of the most effective way to train bystanders in safe rescue and resuscitation. Much of the available evidence is from HICs which may not be suitable for implementation in LMICs and contexts with specific cultural considerations. Additionally, as many children are rescued by other children, consideration (of positives and negatives) is required to determine at what age children can be successfully trained in safe rescue and resuscitation skills [22].

Despite little evidence in support of the effectiveness of CPR as a drowning prevention strategies, the authors maintain that community-wide CPR skills are a component of a cohesive strategy to prevent river drowning deaths. CPR skills are of greater importance for river users in geographically isolated locations where timely medical assistance may not be available. With social determinants of health, namely geographical remoteness and socio-economic status not found to impact likelihood of undertaking CPR training and currency of CPR qualification, there is a need for further research to understand which strategies are more likely to be effective in improving the number of people with a current CPR qualification. Strategies to be considered include linking CPR qualification and renewal to car or vessel licensing renewal.

Recommendation 18: Increase the number of people in the community with CPR skills who hold a current qualification.

7.2 River Drowning Prevention Advocacy and Awareness Programs Influenced By This Thesis

As a result of the research presented in this thesis, industry partner RLSSA has developed and implemented two drowning prevention education and awareness programs aimed at rivers. These are the 'Respect The River' [442] and 'Don't Let Your Mates Drink and Drown' [320] programs.

The national Respect the River program is supported by the Federal Government and aims to educate Australians about the tragic statistic that rivers have claimed more lives due to drowning than any other location. The program highlights key facts about the river environment that can make them dangerous, and highlights safety tips including four key steps to reduce drowning risk. These are 'Never Swim Alone', Avoid Alcohol Around Water', 'Wear a Lifejacket' and 'Learn How to Save a Life' meaning CPR, first aid and safe rescue skills [442]. The program also uses epidemiological data to highlight the top ten river drowning blackspots around the country (the leading location being the Murray River) as a tool for engaging media and local communities around rivers of high drowning risk [176]. Aside from education and awareness raising among the community, the program involves state and territory Royal Life Saving offices, developing locally led river drowning prevention action plans [442].

The 'Don't Your Mates Drink and Drown' program [320] is aimed at males and urges men to look out for their mates and stand up to the sorts of risk-taking behaviours that can lead to accidents and drowning. Also supported by the Federal government, this program aims to combat a culture of risk-taking behaviour among men, and when combined with alcohol and/or drugs it can often be fatal. The program uses a character called Dave who always looks after his mates when they've had a few too many drinks around the water. Through the campaign Dave offers the following safety tips: 1. Avoid entering the water after drinking alcohol; 2. Know your limits; 3. Never swim alone; and 4. Learn how to resuscitate [320].

Getting messages out about river safety, in particular the dangers of combining alcohol and aquatic activity at the river, can be challenging. Timing is key, as in a health belief model [443], the recipient of the message needs to recognise the message is aimed at someone like them and be ready and willing to change their behaviour in response. Providing the recipient with a message about the dangers of combining alcohol and aquatic activity is useless if they are already on the river in their boat with their mates drinking alcohol.

Since the implementation of the Respect the River program in 2015, fatal unintentional drowning in rivers has reduced by 18% [444]. With no other national campaigns targeting river safety, it would seem this may be in part, a campaign effect, recognising river water levels may have been impacted by drought during the same period. An interim pre and post-launch qualitative evaluation of Respect the River was conducted through a third party [445]. A CATI survey was used among communities living within 50 km of the Murray River (the number one river drowning blackspot in the country). The evaluation identified improvements in awareness of rivers as the leading location for drowning in Australia (32% aware pre-intervention and 45% aware post-intervention). Within the post wave, recognition was higher among those aware of the Respect the River campaign (51% if aware and 42% if not aware) confirming the increase between the pre and post waves was a campaign effect [445].

Although an interim evaluation of the Respect the River campaign was undertaken, there is an overall lack of evaluation of drowning prevention interventions for rivers, including recall of messaging and impact on behaviour for public education campaigns. A review of the published literature identified just 2.2% of proposed river drowning prevention strategies had been evaluated between 1980 and 2018 [50]. Further evaluation of river drowning prevention interventions is required to inform investment and targeting of effort for the best effect.

Recommendation 19: Awareness raising interventions targeted at reducing drowning in rivers need to be evaluated.

7.3 Economic Burden of Fatal River Drowning

Related to the issue of fatal unintentional drowning in rivers, is the associated economic burden. A 2018 study by Barnsley et al. [114] examined the economic burden of fatal unintentional drowning in different aquatic locations in Australia. The study estimated the economic burden of drowning in Australia by combining the Value of a Statistical Life Year (VSLY), hospitalisation, productivity and emergency services costs. The study included foregone life years from each drowning, estimated based on Australian life expectancies for the year of death [114].

The cost of fatal unintentional drowning annually in Australia was estimated at $1.24 billion, with rivers, creeks and streams attracting the largest economic burden of any drowning location, at a cost of $318.70 million per annum, 1.6 times higher than the next highest location being beaches at $199.68 million per annum [114].

There is no silver bullet for river drowning prevention, with a range of evidence-based strategies required, that aim to address the challenges identified in this thesis. Given the long-term significant investment in drowning prevention at beaches at the national, state and territory, and local government level [446], and the economic burden posed by river drowning [114], further investment in the development, implementation and evaluation of evidence-based drowning prevention interventions is warranted.

7.4 Non-Fatal Drowning in Rivers

This study adopted the following definition of drowning, as endorsed by the WHO, namely that drowning is a process with outcomes being classified as fatal or non-fatal with or without morbidity [12]. The epidemiology of this study focused on fatal drowning only, although risk factors and preventative strategies are likely to be relevant to preventing both fatal and non-fatal river drowning.

Recent studies of non-fatal drowning [21 45], defined in Australia as a drowning incident resulting in hospital separation (i.e. admission and subsequent release from hospital alive) have identified a fatal to non-fatal drowning ratio in Australia of 1:2.78, meaning for every fatal drowning in Australia, almost three people are admitted, treated and released from hospital alive. Similarly, studies of ambulance call outs for drowning in the state of Victoria [447], and ambulance data, emergency department (ED) presentations and hospital admissions in children in the state of Queensland [43] have drawn attention to the burden of non-fatal drowning in Australia.

Nationally, rivers have been identified as a location with a negative fatal to non-fatal drowning ratio (1:0.48) [21 45], meaning drowning is more likely to be fatal at river locations. While preventing the initial submersion or immersion incident must be the goal, the findings of such studies highlight the importance of tertiary drowning prevention strategies in a drowning chain of survival [148], such as community-wide rescue and resuscitation skills [138 398]. It must be noted however, that the teaching of rescue skills must be accompanied with the knowledge of when and how to use these skills, as rescues performed by laypersons [394 448 449] and even among skilled volunteer personnel [450] are not without risks including loss of life to the rescuer.

Recommendation 20: Explore strategies for enhancing number of laypersons with rescue and resuscitation skills.

There is a lack of understanding in Australia on the relative severity of individuals hospitalised with non-fatal drowning, including those at rivers. Further research is needed in this area to determine impact on the health system and families as a result of non-fatal river drowning, including time in hospital, economic burden and status of individual upon hospital separation.

Similarly, there is a need to complete the injury pyramid [451] for river drowning nationally, to build a full understanding of the drowning burden at such locations. This includes data collection for ED presentations, ambulance call outs and bystander rescues at river locations, in addition to fatal drowning cases and non-fatal drowning resulting in hospital admission and subsequent separation alive.

Recommendation 21: Explore non-fatal drowning cases at rivers.

7.5 International Impact of This Research

There is a need for a greater understanding on river drowning globally, with the review of literature indicating a paucity of epidemiological studies focusing on rivers from LMICs [50], likely due to challenges around a lack of death registry and a lack of fidelity around ICD-10 codes for drowning location. It is hoped changes in the coding of location in the forthcoming ICD-11 will assist countries struggling with this challenge, recognising there remain challenges in adoption of ICD in LMICs. Although, alternative methods, such as surveys [452] and verbal autopsy [453], have been used to attempt to quantify the fatal drowning burden in countries without death registry, these are not without their own limitations.

While challenging to address the difficulties facing LMICs in conducting epidemiological research into river drowning, the body of work represented in this thesis did provide guidance to LMICs on measuring exposure and prevention strategies. The direct observation study of exposure, provides a low resource method for capturing river drowning exposure that was found to result in accurate recording of data between coders [135]. Although reflecting a low level of evidence (i.e. expert opinion) and with little epidemiological studies of river drowning from LMICs on which to base the judgements, the Delphi study [137] provides a set of recommendations deemed effective in reducing river drowning deaths in LMICs. This set of recommendations can be used as a basis for pilot implementation and evaluation to test effectiveness of proposed strategies in reducing river drowning deaths in LMICs.

7.6 Strengths and Limitations

This research is a cohesive body of work, which has advanced understanding of river drowning and its prevention. A public health approach was utilised to gather evidence to directly influence river drowning prevention interventions. The epidemiological studies and examination of coronial recommendations use total population coronial data, with rich data on the circumstances and causal factors. A nationally representative CATI survey was used to consider exposure, the first time this has been undertaken. Breathalysing and community survey work captured both subjective and objective measures of alcohol consumption. The Delphi process captured river drowning prevention strategies more likely to be effective in both HICs and LMICs through the views of both drowning prevention researchers and practitioners.

However this study is not without its limitations, not all cases of river drowning were closed within the NCIS when analysis was undertaken. Cases that remain open are still under coronial investigation and therefore subject to change. The CATI survey was administered in winter and may have suffered from recall bias among participations with respect to river visitation and usage. The community survey and breathalysing attracted media attention, which may have introduced social desirability which may have impacted the survey responses [338]. Delphi participants were asked about levels of evidence supporting river drowning prevention strategies, but were not asked to cite or provide examples of this evidence. River drowning scenarios used in the Delphi were from Australian coronial data and different scenarios may produce different results. Delphi participants from HICs may not be able to comment on river drowning prevention strategies more likely to be effective in LMICs and vice versa.

7.7 Recommendations in brief

Rivers are constantly changing and dynamic environments, used by a diverse range of people for a wide variety of activities. The prevention of drowning in rivers presents a challenge, sometimes referred to as a 'wicked problem' [454], where usage of such locations is encouraged, often accompanied with alcohol consumption, a lack of on-site rescue services (lifeguards) and difficulties around enforcement of legislation regulations due to geographical dispersal and isolation.

This thesis, and the body of work within it, makes the following recommendations:

- Recommendation 1: The creation of an international reference group to develop an agreed definition for rivers.
- Recommendation 2: Ongoing monitoring of unintentional fatal river drowning on an annual basis in Australia be conducted.
- Recommendation 3: Conduct further research using a range of climates to explore the impact of decomposition on natural alcohol production and BACs among river drowning victims. Research should also explore time until found and impact on BACs at time of autopsy.
- Recommendation 4: Awareness campaigns on the topic of alcohol and river drowning risk must be designed with consideration for those groups at highest risk and triggered at opportune times, such as in the warmer months and in the lead up to public holidays.
- Recommendation 5: Conduct further field-based research into the consumption of alcohol at rivers across all age groups, including behavioural and attitudinal factors related to alcohol consumption.
- Recommendation 6: Explore strategies for collecting alcohol consumption and river usage data during the late evening and early morning hours.
- Recommendation 7: Conduct further research to identify effective interventions to discourage driving into floodwater.
- Recommendation 8: Development of an advertising code of practice or add to the existing code to define rules around advertising of vehicles driving through floodwaters.
- Recommendation 9: Conduct research to determine what people consider to be 'floodwaters' and a 'flooded river', factors impacting this definition, and impacts upon behaviour to interact with floodwaters.
- Recommendation 10: Undertake further research into why people swim in flooded rivers.
- Recommendation 11: Conduct further research examining sex differences in river visitation and usage and examine any differences between urban and rural settings.

- Recommendation 12: Examine the environmental and psychological factors impacting a person’s decision to swim in a river.
- Recommendation 13: Explore population level, real time data on river visitation and usage.
- Recommendation 14: Conduct research examining the outcomes from coronial recommendations on river drowning.
- Recommendation 15: Conduct research exploring the impact of signage on river users.
- Recommendation 16: Secure funding to implement and evaluate prevention strategies more likely to be effective in preventing river drowning deaths.
- Recommendation 17: Increase the number of population level epidemiological studies on rivers from LMIC contexts including drowning prevention strategies.
- Recommendation 18: Increase the number of people in the community with CPR skills who hold a current qualification.
- Recommendation 19: Awareness raising interventions targeted at reducing drowning in rivers need to be evaluated.
- Recommendation 20: Explore strategies for enhancing number of laypersons with rescue and resuscitation skills.
- Recommendation 21: Explore non-fatal drowning cases at rivers.

Chapter 8: Conclusion

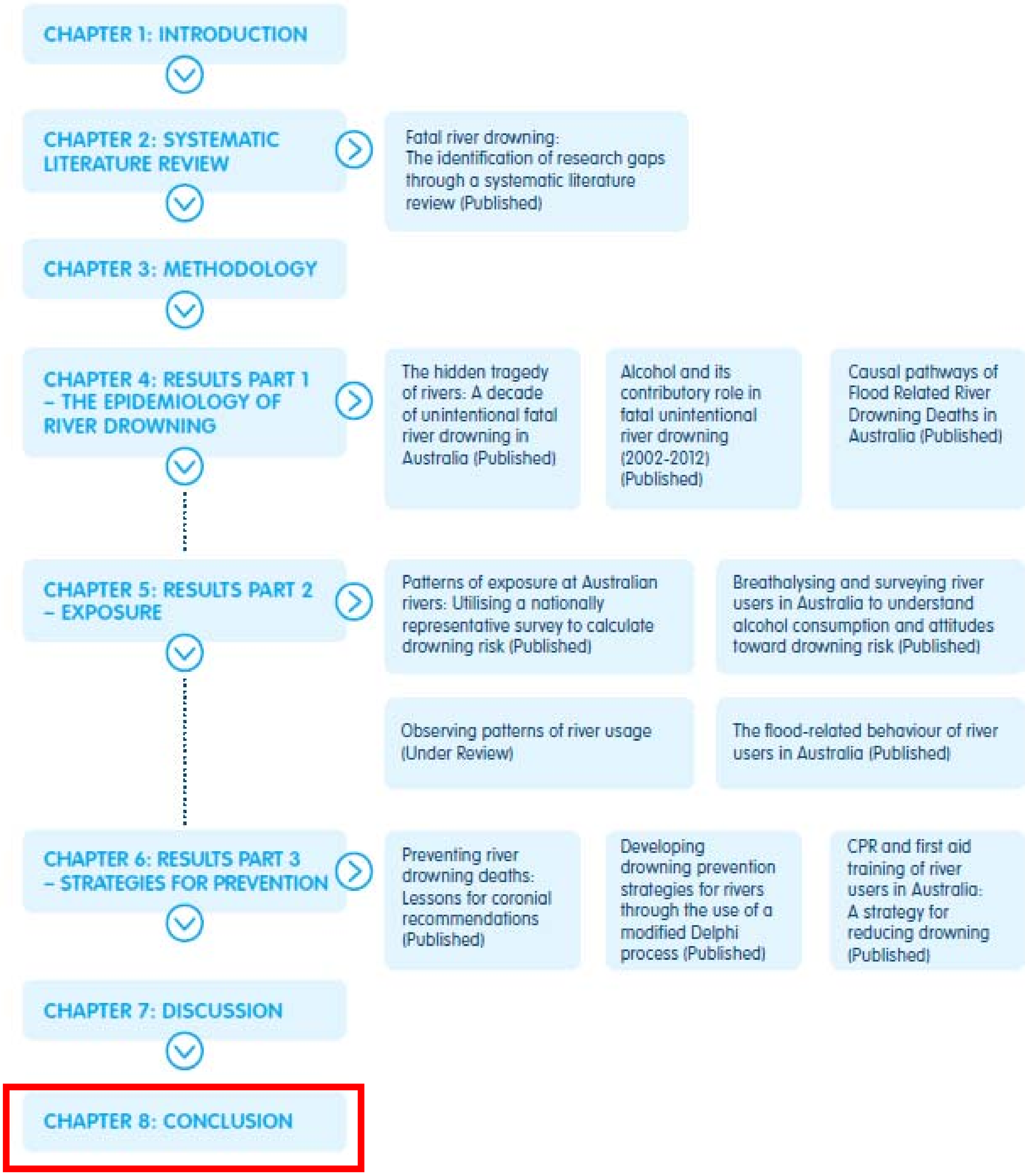

Figure 30: Chapter 8 position within thesis structure

Rivers remain the leading location for drowning in Australia and likely contributing to a significant proportion of the global drowning burden. This first of its kind in the world body of work, used a mixed methods public health approach resulting in 11 publications and has substantially enhanced the previously limited evidence base for river drowning and its prevention.

Although ICD coding structures and a lack of death registry is hampering population level research into river drowning in other countries (in particular LMICs), the recent update to the literature review appears to indicate an improvement in the number of studies with information on river drowning.

Risk factors for river drowning in Australia include being male, alcohol consumption, entering flood waters and geographical remoteness. Community surveys examined river exposure, as well as factors impacting river visitation and the consumption of alcohol. Breathalysing of river users identified high blood alcohol readings among both males and females, with alcohol consumption more prevalent in the afternoon and early evening hours, on days with higher average temperatures and on weekends and public holidays; important considerations for the delivery of public awareness campaigns especially around the risk of alcohol and river drowning. Direct observation of river visitation saw the number of river users vary by time of day, weather and day of week, with river visitation higher on afternoons, hot days, weekends and public holidays. The headcount method utilised resulted in excellent interrater reliability, providing support for the method as a data collection tool for exposure to drowning risk.

River drowning prevention strategies were also considered. Coronial recommendations, though a powerful tool for change, were rare and often recommended lower order strategies. A modified Delphi process recommended strategies including: avoiding alcohol; flood-related early warning systems; child supervision; learning to swim; lifejackets; and community-wide resuscitation skills.

Through industry partner, RLSSA, this research, has provided the evidence for the development of the river drowning prevention programs 'Respect the River' and 'Don't Let Your Mates Drink and Drown', which to date, have resulted in an 18% reduction in fatal unintentional river drowning in Australia.

Rivers continue to attract a large fatal drowning burden, estimated to cost the Australian economy $318.70 million dollars per annum. Therefore further investment in the development, implementation and evaluation of evidence-based drowning prevention interventions is warranted to reduce the number of families, friends and communities impacted by river drowning and to ensure people can enjoy our rivers, creeks and streams safely into the future.

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Appendix 1: Papers As They Appeared in The Journal in Which They Were Published

Please note due to copyright restrictions the content contained in Appendix 1 has been removed from the online version of this thesis. Content can be made available on request via email to amy.peden@my.jcu.edu.au or apeden@rlssa.org.au.

Appendix 1: Papers As They Appeared in The Journal in Which They Were Published

Paper 1: Fatal River Drowning: The Identification of Research Gaps Through a Systematic Literature Review as it Appears in *Injury Prevention*

Peden AE, Franklin RC, Leggat PA (2016) Fatal river drowning: the identification of research gaps through a systematic literature review. *Injury Prevention* 22: 202-209: doi:10.1136/injuryprev-2015-041750

Abstract

Introduction: Drowning is a leading cause of unintentional death. Rivers are a common location for drowning. Unlike other location-specific prevention efforts (home swimming pools and beaches), little is known about prevention targeting river drowning deaths.

Methods: A systematic literature review was undertaken using English language papers published between 1980 and 2014, exploring gaps in the literature, with a focus on epidemiology, risk factors and prevention strategies for river drowning.

Results: Twenty-nine papers were deemed relevant to the study design including 21 (72.4%) on epidemiology, 18 (62.1%) on risk factors and 10 (34.5%) that proposed strategies for prevention. Risk factors identified included age, falls into water, swimming, using watercraft, sex and alcohol.

Discussion: Gaps were identified in the published literature. These included a lack of an agreed definition for rivers, rates for fatal river drowning (however, crude rates were calculated for 12 papers, ranging from 0.20 to 1.89 per 100 000 people per annum), and consensus around risk factors, especially age. There was only one paper that explored a prevention programme; the remaining nine outlined proposed prevention activities. There is a need for studies into exposure patterns for rivers and an agreed definition (with consistent coding).

Conclusion: This systematic review has identified that river drowning deaths are an issue in many regions and countries around the world. Further work to address gaps in the published research to date would benefit prevention efforts.

Paper 2: The Hidden Tragedy of Rivers: A Decade of Unintentional Fatal Drowning in Australia as it Appears in *PLOSONE*

Peden AE, Franklin RC, Leggat PA (2016) The Hidden Tragedy of Rivers: A decade of unintentional fatal drowning in Australia, *PLOSONE* 11(8): e0160709 doi: 10.1371/journal.pone.0160709

Abstract

Objective(s) – Describe unintentional drowning deaths in rivers, creeks and streams (rivers) in Australia and identify risk factors to inform prevention.

Design & Setting – This study is a cross-sectional, total population audit of all unintentional fatal drownings in Australian rivers between 1-July-2002 and 30-June-2012 using Australian coronial data. A modified Bonferroni test has been applied, deeming statistical significance p<0.04.

Results –Rivers (n=770; 26.6%) were the leading location among the 2,892 people who died from unintentional fatal drowning. This is a rate of 0.37/100,000 people / annum. Within river drowning deaths common groups include; males (80.4%), adults (85.3%), adults who have consumed alcohol (28.8%), people who fell in (21.3%), people involved in non-aquatic transport incidents (18.2%) and locals (74.0%). Children were 1.75 times more likely than adults (p<0.04) to drown in rivers as a result of a fall and adults 1.50 times more likely to drown in rivers as a result of watercraft incidents when compared to children (p<0.04). When compared to males, females were 2.14 and 4.47 times respectively more likely to drown in rivers as a result of incidents involving non-aquatic transport (p<0.04) and being swept away by floodwaters (p<0.04). Males were 2.66 and 4.27 times respectively more likely to drown in rivers as a result of watercraft incidents (p<0.04) and as a result of jumping in (p<0.04) when compared to females.

Conclusion(s) – While rivers are the leading location for drowning in Australia, little is understood about the risks. This study has identified key groups (males, adults, locals) and activities. While males were more likely to drown, the risk profile for females differed.

Paper 3: Alcohol and Its Contributory Role in Fatal Drowning in Australian Rivers, 2002-2012 as it Appears in *Accident Analysis and Prevention*

Peden AE, Franklin RC, Leggat PA (2016) Alcohol and its contributory role in fatal drowning in Australian rivers, 2002-2012, *Accident Analysis and Prevention*, 2017, 98: 259-265. doi: 10.1016/j.aap.2016.10.009

Abstract

Objective: Examine the prevalence of alcohol and its contributory role in unintentional fatal river drowning in Australia to inform strategies for prevention.

Methods: Cases of unintentional fatal river drowning in Australia, 1-July-2002 to 30-June-2012, were extracted from the National Coronial Information System. Cases with positive alcohol readings found through autopsy or toxicology reports were retained for analysis. Discrete analysis was conducted on cases with a Blood Alcohol Concentration (BAC) of ≥0.05% (0.05 grams of alcohol in every 100 millilitres of blood).

Results: Alcohol was known to be involved in 314 cases (40.8%), 279 recorded a positive BAC, 196 (70.3%) recorded a BAC of ≥0.05%. 40.3% of adult victims had a BAC of ≥0.20%. Known alcohol involvement was found to be more likely for victims who drowned as a result of jumping in (X^2= 7.8; $p < 0.01$), identify as Aboriginal and Torres Strait Islander (X^2= 8.9; $p < 0.01$) and drowned in the evening (X^2= 7.8; $p < 0.01$) and early morning (X^2= 16.1; $p < 0.01$) hours.

Discussion: The number of people who drown with alcohol in their bloodstream is concerning and challenging for prevention. To assist with the prevention of alcohol related-river drowning improved data quality, as well as a greater understanding of alcohol's contribution and consumption patterns at rivers(especially those <18 years of age) is required.

Conclusion: Alcohol contributes to fatal unintentional drowning in Australian rivers. Although prevention is challenging, better data and exposure studies are the next step to enhance prevention efforts.

Paper 4: Causal Pathways of Flood Related River Drowning Deaths in Australia as it Appears in *PLOS Currents Disasters*

Peden AE, Franklin RC, Leggat PA, Aitken P. Causal Pathways of Flood Related River Drowning Deaths in Australia. *PLOS Currents Disasters*. 2017 May 18. Edition 1. doi: 10.1371/currents.dis.001072490b201118f0f689c0fbe7d437

Abstract

Introduction: Globally, flooding is the most common of all natural disasters and drowning is the leading cause of death during floods. In Australia, rivers are the most common location of drowning and experience flooding on a regular basis.

Methods: A cross-sectional, total population audit of all known unintentional river flood-related fatal drownings in Australia between 1-July-2002 and 30-June-2012 was conducted to identify trends and causal factors.

Results: There were 129 (16.8%) deaths involving river flooding, representing a crude drowning rate of 0.06 per 100,000 people per annum. Half (55.8%) were due to slow onset flooding, 27.1% flash flooding and the type of flooding was unknown in 17.1% of cases. Those at an increased risk were males, children, driving (non-aquatic transport) and victims who were swept away ($p<0.01$). When compared to drownings in major cities, people in remote and very remote locations were 79.6 and 229.1 times respectively more likely to drown in river floods. Common causal factors for falls into flooded rivers included being alone and a blood alcohol concentration ≥0.05% (for adults). Non-aquatic transport incident victims were commonly the drivers of four wheel drive vehicles and were alone in the car, whilst attempting to reach their own home or a friend's.

Discussion: Flood-related river drownings are preventable. Strategies for prevention must target causal factors such as being alone, influence of alcohol, type/size of vehicle, and intended destination. Strategies to be explored and evaluated include effective signage, early warning systems, alternate routes and public awareness for drivers.

Paper 5: Exploring Visitation at Rivers to Understand Drowning Risk as it Appears in *Injury Prevention*

Peden AE, Franklin RC, Leggat PA (2018) Exploring visitation at rivers to understand drowning risk, *Injury Prevention*, doi: http://dx.doi.org/10.1136/injuryprev-2018-042819

Abstract

Introduction: Globally, rivers are a common drowning location. In Australia, rivers are the leading location for fatal drowning. Limited information exists on exposure and impact on river drowning risk.

Methods: Australian unintentional fatal river drowning data (sourced from coronial records) and nationally representative survey data on river visitation were used to estimate river drowning risk based on exposure for adults (18 years and older). Differences in river drowning rates per 100,000 (population and exposed population) were examined by sex, age group, activity prior to drowning, alcohol presence and watercraft usage.

Results: Between 1-January-2014 and 31-December-2016, 151 people drowned in Australian rivers; 86% male and 40% aged 18-34 years. Of survey respondents, 73% had visited a river within the last 12 months. After adjusting for exposure: males were 7.6 times more likely to drown at rivers; female drowning rate increased by 50% (0.06 to 0.09 per 100,000); males aged 75+ and females aged 55-74 years were at highest risk of river drowning; and swimming and recreating pose a high risk to both males and females. After adjusting for exposure, males were more likely to drown with alcohol present (RR=8.5; CI: 2.6-27.4) and in a watercraft-related incident (RR=25.5; CI: 3.5-186.9).

Conclusions: Calculating exposure for river drowning is challenging due to diverse usage, time spent and number of visits. While males were more likely to drown, the differences between males and females narrow after adjusting for exposure. This is an important factor to consider when designing and implementing drowning prevention strategies to effectively target those at risk.

Paper 6: Breathalysing and Surveying River Users in Australia to Understand Alcohol Consumption and Attitudes Toward Drowning Risk as it Appears in *BMC Public Health*

Peden, AE., Franklin, RC and Leggat, PA. (2018). Breathalysing and surveying river users in Australia to understand alcohol consumption and attitudes toward drowning risk. *BMC Public Health* 18(1): 1393.

Abstract

Background: Little is known about people's river usage, a leading drowning location. This study examines alcohol consumption patterns of river users and their attitudes to drowning risk.

Methods: A convenience sample of adult (18+ years) river users were surveyed at four river locations. The survey covered eight domains: demographics; river attendance frequency; frequency of engaging in water activities; drinking patterns; alcohol and water safety knowledge; alcohol and water safety attitudes; alcohol consumption; and Blood Alcohol Concentration (BAC). For BAC, participants were asked to record time since their last alcoholic drink and were then breathalysed to record an estimate of their BAC. BAC was examined by BAC reading (negative, positive, ≥0.050%). Hazardous lifetime drinking levels were calculated and their impact on drowning risk evaluated. Univariate and chi square analysis (95% confidence interval) was conducted.

Results: Six hundred eighty four people participated (51.6% female; 49.0% aged 18–34 years). Sixteen percent (15.9%) had a positive BAC (Mean + BAC = 0.068%; SD ± 0.08; Range = 0.001–0.334%), with 7.2% ≥0.050% (Mean BAC ≥0.050% =0.132%; SD ± 0.06). Those significantly more likely to record a BAC ≥0.050% at the river were: aged 18–34 years, resided in inner regional and low socio-economic areas, visited the river in the afternoon, with friends, on days with higher maximum air temperatures, frequent river users (11+ times in the last 30 days) and those who spend longer in the water (301+ minutes). River users who recorded a BAC ≥0.050% were more likely to self-report engaging in risky activities (i.e. diving into water of unknown depth and jumping into the river from height). River users on Australia day (a national public holiday) were significantly more likely to drink heavily (Mean BAC ≥0.05% = 0.175%; SD ± 0.09).

Conclusions: Despite males accounting for 85% of alcohol-related river drowning deaths, similar numbers of males and females were consuming alcohol at the river. This study has addressed a gap in knowledge by identifying river usage and alcohol consumption patterns among those at increased drowning risk. Implications for prevention include delivering alcohol-related river drowning prevention strategies to both males and females; at peak times including during hot weather, afternoons, public holidays and to river users who swim.

Paper 7: Observing Patterns of River Usage (Under Review)

Peden AE, Franklin RC, Leggat PA, Lindsay D (Under Review) Observing patterns of river usage

Abstract

Objective: Rivers are a leading location for drowning, yet little is known about people's usage of these waterways. This study aimed to test the use of direct observations to calculate river usage.

Methods: Direct observations were conducted at regular intervals within defined zones at four river drowning locations in Australia (including weekends and the Australia Day national public holiday). Data recorded were date and time of observation, total people (including males, females, children and adults), and number of people on, in and beside the water. Univariate analysis with mean (SD) and range was conducted. Interrater reliability for observations was determined using the intraclass correlation coefficient (ICC) (one-way random-effects, average measures model), with a 95% confidence interval (CI).

Results: Across 149 time points, 309 observations resulted in 13,326 river interactions observed by multiple observers. There was an average of 39 people (M=39.4, SD = 29.4, Range=0 - 137) per observation, 44 people (M=44.2, SD = 32.7, Range =0-137) on an average weekend and 97 people (M=96.8, SD= 58.1, Range =20-190) on Australia Day. More females (M=20.6, SD=16.0, Range=0-83) than males (M=18.3, SD=14.5, Range =0-68) were observed. More people were observed in water (M=20.6, SD=20.4, Range=0-84) than beside or on the water. Interrater reliability was excellent, consistently above 0.900 for all variables collected (apart from beside the river).

Conclusion: Despite males accounting for 80% of river drowning fatalities, more females were observed than males. Increased visitation on the Australia Day public holiday may link to increased drowning risk.

Practical Applications: This study detailed a simple approach to data collection exploring exposure within a defined zone at river locations. River usage is dynamic with people's movement in and out of the water changing their risk exposure. Observational-based data collection for drowning, particularly for rivers, is an important yet highly neglected area of research.

Short Report 1 (SR1): The Flood-Related Behaviour of River Users in Australia as it Appears in *PLOS Currents Disasters*

Peden AE, Franklin RC, Leggat P. The Flood-Related Behaviour of River Users in Australia. *PLOS Currents Disasters.* 2018 Jun 14 . Edition 1. doi: 10.1371/currents.dis.89e243413a0625941387c8b9637e291b.

Abstract

Introduction: Flooding is a common natural disaster affecting 77.8 million people and claiming the lives of 4,731 people globally in 2016. During times of flood, drowning is a leading cause of death. Flooding is a known risk factor for river drowning in Australia. With little known about river usage in Australia, this study aimed to examine the links between person demographics and self-reported participation in two flood-related behaviours, driving through floodwaters and swimming in a flooded river.

Methods: A self-reported questionnaire was administered to adult river users at four high-risk river drowning locations; Alligator Creek, Townsville, Queensland; Murrumbidgee River, Wagga Wagga, New South Wales; Murray River, Albury, New South Wales; and Hawkesbury River, Windsor, New South Wales. Univariate and chi square analysis was undertaken with a 95% confidence interval ($p<0.05$). All river users surveyed, were also breathalysed to record an estimate of their blood alcohol concentration (BAC) on their expired breath.

Results: 688 river users responded to the questionnaire; 676 (98.3%) answered the driving question and 674 (98.0%) answered the swimming in floodwaters questions. Of the respondents, 35.7% stated they had driven through floodwater and 18.7% had swum in a flooded river. Males were more likely ($p<0.001$) to reported having undertaken both activities. Australian-born respondents were more likely to report having driven through floodwaters ($p=0.006$). Those aged 18-24 years old and those residing in outer regional areas were more likely ($p<0.001$) to have swum in a flooded river. Those who self-reported participating in both driving through floodwaters ($p=0.001$) and swimming in a flooded river ($p<0.001$) were significantly more likely to record contributory levels of alcohol (i.e. a BAC ≥0.05%) when breathalysed at the river.

Discussion: Ensuring the safe movement of people during floods is difficult, particularly for those living in regional Australia, due in part to long distances travelled and reduced investment in infrastructure such as bridges. With males and females equally exposed, more effective prevention strategies must target both sexes and may include improved education on when it is safe to drive through (low depth, still water, stable road base) and when it is not (e.g. deep water, moving water and unstable road base). This study identified one in five respondents had swum in a flooded river,

most commonly young people aged 18-24 years, with participants significantly more likely to have recorded contributory levels of alcohol when breathalysed. Further research should examine the reasons behind participation in this behaviour, including the role of alcohol.

Conclusion: Preventing drowning in floodwaters is an international challenge, made more difficult by people driving through or swimming in floodwaters. Strategies for driving through floodwaters should educate both males and females on when it is safe to drive through floodwaters and when it is not. Further research is required to improve knowledge of the poorly understood behaviour of swimming in flooded rivers.

Paper 8: Preventing River Drowning Deaths: Lessons From Coronial Recommendations as it Appears in *Health Promotion Journal of Australia*

Peden AE, Franklin RC, Leggat PA. Preventing river drowning deaths: Lessons from coronial recommendations. *Health Promotion Journal of Australia*. 2018;29:144-152. doi: 10.1002/hpja.24

Abstract

Issue addressed: Coronial data provide rich information on drowning causal factors. Coroners may make recommendations to prevent future drowning events. Rivers are the leading drowning location in Australia. This study examines coronial recommendations associated with unintentional fatal drowning in Australian rivers from an injury prevention perspective.

Methods: All river drowning cases in Australia between 1-July-2002 and 30-June-2012 were extracted from the National Coronial Information System (NCIS). Recommendations were thematically analysed. Using a deductive process, each unique recommendation was coded to a category aligned to the Hierarchy of Control's six levels. An inductive process was used for those not categorised. Recommendations were also coded against a modified SMART principle.

Results: Of the 730 river drownings, 58 cases (7.9%) resulted in 71 unique recommendations. Victorian cases (X2 = 32.1; p<0.01) and multiple fatality events (X2 = 41.9; p <0.01) were more likely to have recommendations. Common categories of recommendations were administrative (39.4%) and signage-related (18.3%). Recommendations were often low on the Hierarchy; namely administrative (67.6%) and behaviour (19.1%). Half (50.7%) satisfied 4 of 6 modified SMART principle components.

Conclusion: Coronial recommendations associated with river drowning in Australia are reasonably rare. Recommendations provide opportunities for organisations to enact change, however, they could be strengthened with a specified time period and higher order control strategies recommended.

So what? SMART coronial recommendations may be more successful in achieving the behavioural, social and societal change required to prevent future river drownings. The recommendations examined in this study can be used as a benchmark for what could be considered appropriate safety actions.

Paper 9: Developing Drowning Prevention Strategies For Rivers Through the Use of a Modified Delphi Process as it Appears in *Injury Prevention*

Peden AE, Franklin RC, Leggat, PA (2019) Developing Drowning Prevention Strategies for Rivers Through The Use of a Modified Delphi Process, *Injury Prevention.* Published Online First: 30 March 2019. doi: 10.1136/injuryprev-2019-043156

Abstract

Introduction: Internationally, rivers are a leading drowning location, yet little evidence exists evaluating river drowning prevention strategies. This study aims to use expert opinion to identify strategies more likely to be effective.

Methods: Using a modified Delphi process, a virtual panel of 30 experts from 12 countries considered, grouped and prioritised strategies for river drowning prevention. Proposed strategies were assessed against known evidence and suitability in high-income countries (HICs), as well as low-and middle-income countries (LMICs) using expert opinion. The final phase, consolidated a list of strategies whose effectiveness was assessed against 10 evidence-based river drowning scenarios.

Results: An initial list of 424 prevention strategies was refined to 22. After being assessed against the 10 scenarios, a final list of 13 strategies was derived. Strategies addressed alcohol consumption around rivers, flood mitigation, improving child supervision, learning to swim, increased lifejacket wear, and achieving community-wide resuscitation skills.

Discussion: While all 13 strategies were assessed as being effective in both LMICs and HICs by at least 60% of respondents, further work is required to define river drowning at a country level, and therefore allow for effective solutions to be developed, particularly in LMICs. No strategy will be effective in isolation and must be implemented alongside policy and behaviour change, public awareness and education. Evaluation should be incorporated as part of any future implementation of strategies.

Conclusion: This Delphi process identified 13 drowning prevention strategies for rivers. Further research is required to validate the efficacy of these findings through implementation and evaluation.

Short Report 2 (SR2): Cardiopulmonary Resuscitation and First-aid Training of River Users in Australia: A Strategy for Reducing Drowning as it appears in *Health Promotion Journal of Australia*

Peden AE, Franklin RC, Leggat PA. Cardiopulmonary resuscitation and first-aid training of river users in Australia: A strategy for reducing drowning. *Health Promotion Journal of Australia*. 2018;00:1–5. https://doi.org/10.1002/hpja.195

Abstract

Issue addressed: Rivers are a leading location for fatal drowning worldwide; often geographically isolated from timely medical assistance. Cardio-pulmonary resuscitation (CPR) benefits drowning victims and those who suffer cardiac arrests. This study explored CPR and first aid training of river users in Australia.

Methods: Adult river users (18+ years) were surveyed at four high-risk river drowning sites. Respondents were asked the last time they undertook CPR (responses converted into: 'CPR ever undertaken' -yes/no; and 'CPR training current' -yes/no (training undertaken ≤12 months ago). Responses were explored by demographics and social determinants of health.

Results: Of those surveyed (N=688), 98.4% responded regarding CPR. Seventy-five percent (74.9%) had undertaken CPR training previously. Females and 35-44 year olds were more likely to have undertaken training ($p<0.05$). Males and older people (65+ years) were less likely to hold a current qualification ($p<0.05$). Major city residents reported a longer mean time (5.4 years) since last trained than remote and very remote locations (2.0 years). People in low socio-economic areas had a shorter time since qualification current (5.8 years) than those in areas deemed high (7.2 years).

Conclusion: Current CPR qualifications are important, particularly among those visiting high-risk river drowning locations. System-level, upstream strategies that should be explored include compulsory CPR training in secondary schools and linking CPR updates to motor vehicle licence renewals.

So what? CPR is a vital component of multi-faceted river drowning prevention. Social determinants of health, such as socio-economic disadvantage and geographical isolation, were not barriers to participation or currency of qualification.

Appendix 2: Ethics Approvals

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Appendix 3: List of Papers Completed During Enrolment Related to River Drowning But Not Included in Thesis

Peden AE, Franklin RC, Leggat PA (2016). "International travelers and unintentional fatal drowning in Australia - a 10 year review 2002-12." *Journal of Travel Medicine* 23(2): 1-7.

Introduction. Drowning deaths of travelers are commonly reported in the media, creating a perception that they are at a higher risk of drowning than residents. This may be true, due in part to unfamiliarity with the risks posed by the hazard, however there is limited information about drowning deaths of travelers in Australia. This study aims to identify the incidence of drowning among international travelers in Australia and examine the risk factors to inform prevention strategies.

Methods. Data on unintentional fatal drowning in Australian waterways of victims with a residential postcode from outside Australia were extracted from the Royal Life Saving Society—Australia National Fatal Drowning Database.

Results. Between 1 July 2002 and 30 June 2012 drowning deaths among people known to be international travelers accounted for 4.3% (N¼123) of the 2870 drowning deaths reported in Australian waterways. Key locations for drowning deaths included beaches (39.0%), ocean/harbour (22.0%) and swimming pools (12.2%). Leading activities prior to drowning included swimming (52.0%), diving (17.9%) and watercraft incidents (13.0%).

Discussion. International travelers pose a unique challenge from a drowning prevention perspective. The ability to exchange information on water safety is complicated due to potential language barriers, possible differences in swimming ability, different attitudes to safety in the traveler's home country and culture, a lack of opportunities to discuss safety, a relaxed attitude to safety which may result in an increase in risk taking behaviour and alcohol consumption.

Conclusion. Prevention is vital both to reduce loss of life in the aquatic environment and promote Australia as a safe and enjoyable holiday destination for international travelers.

Hamilton, K., **Peden, A.E**., Pearson, M., & Hagger, M.S. (2016). Stop there's water on the road! Identifying key beliefs guiding people's willingness to drive through flooded waterways. *Safety Science*, 86, 308-314. doi:10.1016/j.ssci.2016.07.004

Floods are among the most widespread of natural disasters and exposure to floodwaters increases drowning risk. A leading cause of flood-related drowning deaths is driving through flooded waterways. Drawing on the Theory of Planned Behaviour, a two-phased research program was conducted. Phase 1 (N = 25; Mage = 32.38, SD = 11.46) identified common beliefs about driving through a flooded waterway. Phase 2 (N = 174; Mage = 27.43, SD = 10.76) adopted a cross-sectional design to examine the belief predictors of drivers' willingness to drive through a flooded waterway. Given differences in consequences due to the depth of water, scenarios of low (road covered in 20 cm of water) and high (road covered in 60 cm of water) risk situations were investigated. A range of beliefs emerged as predicting drivers' willingness to engage in this unsafe driving behaviour. These included attitudinal beliefs (e.g., sustain vehicle damage, become stuck/stranded), beliefs of social expectations (e.g., pressure from friends, family members, police), and efficacy beliefs (e.g., small distance of water to drive through, presence of signage). The results of the current study support using a Theory of Planned Behaviour belief-based approach to the understanding of risky transport-related aquatic activities. The findings highlight the role that specific key beliefs play in guiding people's willingness to drive through flooded waterways and, in turn, provide possible targets for future interventions to curb this risky and potentially fatal driving behaviour.

Mahony AJ, **Peden AE**, Franklin RC, Pearn JH, Scarr J (2017) Fatal, unintentional drowning in older people: Pre-existing medical conditions, *Healthy Aging Research*, 6: 1-8

Background: The number of older people (aged 65 y and over) is increasing in Australia and chronic medical conditions are common. Aquatic activities provide physical and social benefits; however, understanding the risks related to aquatic activity is important for ongoing health and wellbeing. We explore the impact of preexisting medical conditions on unintentional fatal drowning among older people in Australia.

Methods: Using coronial, forensic, and medical histories from the Australian National Coronial Information System, all cases of unintentional death by drowning (or where drowning was a factor) among older people in Australia between July 1, 2002 and June 30, 2012 were investigated. Preexisting medical conditions were reviewed to determine whether they were contributory to drowning.

Results: Of the 506 older people who drowned, 69.0% had a preexisting medical condition. The leading contributory medical condition was cardiovascular disease, followed by dementia, depression, epilepsy, and Parkinson disease. All conditions except cardiovascular disease and depression were overrepresented compared with the proportion of the disease in the population. Falling into water was the most common activity immediately before drowning, especially among those with dementia, whereas those with cardiovascular disease were most likely to drown while swimming.

Conclusions: Preexisting medical conditions contribute to drowning in older people but with unequal contributions. With the prevalence of medical conditions expected to increase as the population ages, targeted education for older people will be important. Risk management will enable older people to safely participate in aquatic activities.

Franklin RC, Pearn JH, **Peden AE**. Drowning fatalities in childhood: the role of pre-existing medical conditions. *Archives of Disease in Childhood* 2017;102(10):888-893.doi: 10.1136/archdischild-2017-312684

Objectives This study is an analysis of the contribution of pre-existing medical conditions to unintentional fatal child (0–14 years) drowning and a of critique prevention strategies, with an exploration of issues of equity in recreation.

Design This study is a total population, cross-sectional audit of all demographic, forensic and on-site situational details surrounding unintentional fatal drowning of children 0–14 years in Australia for the period of 1 July 2002 to 30 June 2012. Data were sourced from the National (Australia) Coronial Information System. Age-specific disease patterns in the general population were obtained from the Australian Institute of Health and Welfare.

Results Four hundred and sixty-eight children drowned during the study period. Fifty-three (11.3%) had a pre-existing medical condition, of whom 19 suffered from epilepsy, 13 from autism and 5 with non-specific intellectual disabilities. Epilepsy is a risk factor in childhood drowning deaths, with a prevalence of 4.1% of drowning fatalities, compared with 0.7%–1.7% among the general 0–14 years population (relative risk: 2.4–5.8). Epilepsy was deemed to be contributory in 16 of 19 cases (84.2% of epilepsy cases) with a median age of 8 years. Asthma and intellectual disabilities were under-represented in the drowning cohort.

Conclusion Except for epilepsy, this research has indicated that the risks of drowning while undertaking aquatic activities are not increased in children with pre-existing medical conditions. Children with pre-existing medical conditions can enjoy aquatic activities when appropriately supervised.

Peden, Amy E.; Franklin, Richard Charles; and Scarr, Justin (2017) "Measuring Australian Children's Water Safety Knowledge: The National Water Safety Quiz," *International Journal of Aquatic Research and Education*: Vol. 10: No. 2, Article 4. Available at: https://scholarworks.bgsu.edu/ijare/vol10/iss2/4

Water safety knowledge levels of Australian children are poorly understood. Royal Life Saving developed an online National Water Safety Quiz (NWSQ) as an interactive means of determining water safety knowledge amongst Australian primary school children (ages 5 to 12 years). Over a period of 8 months, a total of 4,215 children participated in the NWSQ. The NWSQ identified areas of water safety where knowledge was poor including the topics of cardio pulmonary resuscitation (CPR), swimming, and river safety. Children achieved a better result as they aged. Females out-performed males overall and specifically from ages 10-12 years. Children from independent schools performed better. This research is the first of its kind to measure water safety knowledge at a population level for primary school children, using an online web-based tool. Understanding children's water safety knowledge is important as it enables the tailoring, delivery and evaluation of programs which help to reduce the burden of drowning.

Peden AE, Franklin RC, Mahony AJ, et al Using a retrospective cross-sectional study to analyse unintentional fatal drowning in Australia: ICD-10 coding-based methodologies verses actual deaths *BMJ Open* 2017;7:e019407. doi: 10.1136/bmjopen-2017-019407

Objectives: Fatal drowning estimates using a single underlying cause of death (UCoD) may under-represent the number of drowning deaths. This study explores how data vary by International Classification of Diseases (ICD)-10 coding combinations and the use of multiple underlying causes of death using a national register of drowning deaths.

Design: An analysis of ICD-10 external cause codes of unintentional drowning deaths for the period 2007–2011 as extracted from an Australian total population unintentional drowning database developed by Royal Life Saving Society—Australia (the Database). The study analysed results against three reporting methodologies: primary drowning codes (W65-74), drowning-related codes, plus cases where drowning was identified but not the UCoD.

Setting: Australia, 2007–2011.

Participants: Unintentional fatal drowning cases.

Results: The Database recorded 1428 drowning deaths. 866 (60.6%) had an UCoD of W65-74 (accidental drowning), 249 (17.2%) cases had an UCoD of either T75.1 (0.2%), V90 (5.5%), V92 (3.5%), X38 (2.4%) or Y21 (5.9%) and 53 (3.7%) lacked ICD coding. Children (aged 0–17 years) were closely aligned (73.9%); however, watercraft (29.2%) and non-aquatic transport (13.0%) were not.

When the UCoD and all subsequent causes are used, 67.2% of cases include W65-74 codes. 91.6% of all cases had a drowning code (T75.1, V90, V92, W65-74, X38 and Y21) at any level.

Conclusion: Defining drowning with the codes W65-74 and using only the UCoD captures 61% of all drowning deaths in Australia. This is unevenly distributed with adults, watercraft and non-aquatic transport-related drowning deaths under-represented. Using a wider inclusion of ICD codes, which are drowning-related and multiple causes of death minimises this under-representation. A narrow approach to counting drowning deaths will negatively impact the design of policy, advocacy and programme planning for prevention.

Peden AE, Franklin RC, Queiroga AC Epidemiology, risk factors and strategies for the prevention of global unintentional fatal drowning in people aged 50 years and older: a systematic review. *Injury Prevention* 2018;24:240-247. doi: 10.1136/injuryprev-2017-042351

Purpose: Drowning is a global public health issue and prevention poses an ongoing challenge for all countries. Many nations are experiencing ageing populations, and little is known about the epidemiology, risk factors and prevention of drowning deaths among older people. This paper reports on a systematic review of literature published on drowning among older people.

Methods: A systematic literature review was undertaken using English-language, Portuguese-language and Spanish-language papers published between 1980 and 2015. The review explores gaps in the literature with a focus on the epidemiology, risk factors and strategies for the prevention of unintentional fatal drowning among people 50 years and over.

Results: Thirty-eight papers were deemed relevant to the study design, including 18 (47%) on epidemiology, 19 (50%) on risk factors and 9 (24%) on strategies for prevention. Risk factors identified included male gender, ethnicity, rurality and increasing age. Prevention strategies commonly proposed were education and wearing life jackets. Gaps identified in the published literature include a lack of consistency around age groupings used for epidemiological studies; a lack of consensus on risk factors; a lack of total population, country-level analysis; and the need for older age-specific prevention strategies that have been implemented and their effectiveness evaluated.

Conclusion: This review identified drowning deaths among older people as a global issue. Further work is required to reduce drowning in this cohort. High quality epidemiological studies identifying risk factors using standardised age groupings to allow for international comparisons are required, as are implementation and evaluation of older age-specific prevention strategies.

Hamilton, K., S. Price, J. J. Keech, **A. E. Peden** and M. S. Hagger (2018). Drivers' experiences during floods: Investigating the psychological influences underpinning decisions to avoid driving through floodwater. *International Journal of Disaster Risk Reduction* 28: 507-518. doi.org/10.1016/j.ijdrr.2017.12.013.

A major risk factor for many flood-related drownings is driving through floodwater. We aimed to understand Australian drivers' experiences and beliefs with respect to avoid driving through floodwater using the theory of planned behaviour as a framework. Study 1 (N = 23) used a qualitative design to gain an in-depth understanding of individuals' experiences with driving through floodwater. Study 2 (N = 157) used a survey-based design to identify the factors related to this behaviour including knowledge, beliefs, and social-cognitive factors. In Study 1, drivers identified a range of advantages (e.g., didn't damage car), disadvantages (e.g., inconvenient, but not so terrible), barriers (e.g., urgency to reach destination), and facilitators (e.g., making plans and using existing plans) to avoiding driving through floodwater. Normative factors were also important influences on drivers' decisions including normative expectancy, approval of significant others, and a moral obligation for the safety of others. In Study 2, participants were able to recall information about driving through floodwater (e.g., dangerous/risky) and its meaning (e.g., body of water over road). A range of experiences were described for avoiding driving through floodwater (e.g., took an alternative route). Across the studies, a range of behavioural, normative, and control beliefs were elicited. Finally, sex (women more likely), attitude, subjective norm, and perceived behavioural control significantly predicted intentions to avoid driving through floodwater, with the model explaining 55% of the variance. These findings can inform intervention targets and development of prevention strategies for effective behaviour change, saving lives otherwise lost to Australian waterways in flood.

Hamilton K, **Peden AE**, Keech JJ, Hagger, MS (2018) Changing people's attitudes and beliefs toward driving through floodwaters: evaluation of a video infographic, *Transportation Research Part F: Psychology and Behaviour,* 53(2018): 50-60

Despite awareness of campaigns such as 'Turn Around, Don't Drown' and the Australian state of Queensland's 'If It's Flooded, Forget It', people continue to drive through floodwaters, causing loss of life, risk to rescuers, and damage to vehicles. The aim of this study was to develop a video infographic that highlights the dangers of driving through floodwaters and provide safety tips to reduce the risk, and to evaluate its effectiveness in changing the beliefs and intentions of Australian adults toward this risky driving behaviour. This study adopted an online three-wave non-controlled pretest–posttest design. Australian licensed drivers (N = 201, male = 41, female = 160; Mage = 34.10) self-reported their demographic and psychological variables (intention, attitude, subjective norm, barrier self-efficacy, risk perception, anticipated regret, perceived susceptibility, and perceived severity) at baseline (T1), immediately post-intervention (T2), and at a one-month follow-up (T3). Messages in the video infographic were developed based on psychological theory and empirical evidence, using data on causal factors derived from coronial records and the findings of behavioural research. Results indicated that men had significantly higher intentions and attitudes and significantly lower barrier self-efficacy, risk perception, anticipated regret, perceived susceptibility, and perceived severity with respect to driving through floodwater than women. Statistically significant time x gender interaction effects were also found; attitude and subjective norm were significantly lower between T1 and T2 for both men and women but scores between T2 and T3 remained significantly lower for women only. In addition, perceived susceptibility and perceived severity scores were significantly higher in women across T1 and T2, with the difference maintained at T3. In contrast, there were no differences in scores across the three-time points for men. The implications of these findings for road safety and drowning prevention messages targeting drivers during floods are discussed.

Peden, A. E., Demant, D., Hagger, M. S., & Hamilton, K. (2018). Personal, social, and environmental factors associated with lifejacket wear in adults and children: A systematic literature review. *PLOSONE*. 13(5): e0196421. https://doi.org/10.1371/journal.pone.0196421

Objective: Drowning claims 7% of the global burden of injury-related deaths. Lifejackets are routinely recommended as a drowning prevention strategy; however, a review of related factors regarding lifejacket wear has not previously been investigated.

Methods: This systematic review examined literature published from inception to December 2016 in English and German languages. The personal, social, and environmental factors associated with lifejacket wear among adults and children were investigated, a quantitative evaluation of the results undertaken, and gaps in the literature identified.

Results: Twenty studies, with sample sizes of studies ranging between 20 and 482,331, were identified. Fifty-five percent were cross-sectional studies. All studies were scored IV or V on the Australian National Health and Medical Research Council (NHMRC) grading system indicating mostly descriptive and cross-sectional levels of evidence. Factors associated with increased wear included age (mostly children), gender (mostly female), boat type (nonmotorised), boat size (small boats), role modelling (children influenced by adult lifejacket wear), and activity (water-skiing, fishing). Factors not associated or inconsistent with lifejacket wear included education, household income, ethnicity, boating ability, confidence in lifejackets, waterway type, and weather and water conditions. Factors associated with reduced lifejacket wear included adults, males, discomfort, cost and accessibility, consumption of alcohol, and swimming ability. Three studies evaluated the impact of interventions.

Conclusion: This review identified factors associated with both increased and decreased lifejacket wear. Future research should address the motivational factors associated with individuals' decisions to wear or not wear lifejackets. This, combined with further research on the evaluation of interventions designed to increase lifejacket wear, will enhance the evidence base to support future drowning prevention interventions.

Hamilton, K., Keech, J. J., **Peden, A. E**. and Hagger, M. S. (2018), Alcohol use, aquatic injury, and unintentional drowning: A systematic literature review. *Drug and Alcohol Review*., 37: 752-773. doi:10.1111/dar.12817

Issues: Drowning is a global public health issue, and there is a strong association between alcohol and risk of drowning. No previous systematic review known to date has identified factors associated with alcohol use and engagement in aquatic activities resulting in injury or drowning (fatal and non-fatal).

Approach: Literature published from inception until 31 January 2017 was reviewed. Included articles were divided into three categories: (i) prevalence and/or risk factors for alcohol-related fatal and non-fatal drowning and aquatic injury, (ii) understanding alcohol use and aquatic activities, and (iii) prevention strategies. Methodological quality of studies was assessed using National Health and Medical Research Council (NHMRC). Level of Evidence and risk of bias was assessed using the Newcastle-Ottawa Quality Assessment Scales.

Key Findings: In total, 74 studies were included (57 on prevalence and/or risk factors, 15 on understanding alcohol use, and two on prevention strategies). Prevalence rates for alcohol involvement in fatal and non-fatal drowning varied greatly. Males, boating, not wearing lifejackets, and swimming alone (at night, and at locations without lifeguards) were risk factors for alcohol-related drowning. No specific age groups were consistently identified as being at risk. Study quality was consistently low, and risk of bias was consistently high across studies. Only two studies evaluated prevention strategies.

Implications: There is a need for higher quality studies and behavioural basic and applied research to better understand and change this risky behaviour.

Conclusion: On average, 49.46% and 34.87% of fatal and non-fatal drownings, respectively, involved alcohol, with large variations among studies observed.

Keech JJ, Smith SR, **Peden AE**, Hagger MS, Hamilton K. The lived experience of rescuing people who have driven into floodwater: Understanding challenges and identifying areas for providing support. *Health Promotion Journal of Australia*. 2018;00:1–6. https://doi.org/10.1002/hpja.181

Background: Drowning is a major public health issue, with risk increasing during times of flood. Driving into floodwater is a major risk factor for flood-related drowning and injury, and despite widespread public health campaigns, many people continue to undertake this risky behaviour and require rescue.

Purpose: We aimed to identify key challenges faced by emergency services personnel when rescuing those who have driven into floodwater, and to identify strategies for supporting rescuers in this important role.

Methods: Australian flood rescue operators (N = 8) who had previously rescued a driver who had driven into floodwater participated in semi‐structured interviews. Data were analysed using thematic analysis.

Results: Four challenges emerged from their experiences: involvement of untrained personnel; varying information provided by emergency telephone operators; behaviour of drivers complicating the rescue; people sightseeing floods or flood rescues or ignoring closed roads providing rescuers with sources of distraction and frustration.

Conclusions: We propose five strategies for translating these results into practice, including: training and protocol development for (i) emergency personnel and (ii) telephone operators; (iii) training for rescuers regarding non‐compliant rescuees; (iv) educating the public and (v) increasing compliance with closed roads. Current findings provide valuable insights into how rescuers can be supported in performing their roles, and implementation of these strategies has the potential to reduce

fatalities occurring due to attempting to drive through floodwater.

So what? The strategies presented have the potential to reduce the frequency and improve the outcomes of floodwater rescues, aiding in the prevention of injury and death.

Barnsley, PD., **AE. Peden** and J. Scarr (2018). Calculating the economic burden of fatal drowning in Australia. *Journal of Safety Research* 67: 57-63. doi: 10.1016/j.jsr.2018.09.002

Background: Aquatic activities provide physical and social benefits, while the risk of drowning generates countervailing social costs. Drawing on estimates of fatal drowning gathered by Royal Life Saving Society – Australia, this paper outlines a method for estimating the economic burden attributable to fatal drowning.

Methods: This study estimated the burden of fatal drowning by combining Value of a Statistical Life Year (VSLY), hospitalization, productivity and emergency services costs. All unintentional fatal drowning cases in Australia between 1-July-2002 and 30-June-2017 were included. Foregone life years from each drowning were estimated based on Australian life expectancies for the year of death. The societal value of these Years of Life Lost was calculated using the VSLY for Australia, adjusted to reflect income elasticity. Corrections to discounting of VSLY were applied. Estimates of productivity losses not captured in VSLY were produced using net national capital growth. Time spent in hospital was found using coronial data and existing estimates of search, ambulance and coronial costs were adapted and incorporated.

Results: The study covers 4285 cases of unintentional fatal drowning over 15 years. Based on this sample and estimates for the VSLY ($203,000), the economic burden of fatal drowning for Australia over this 14 year period was $18.63 billion in 2017 Australian dollars, averaging $1.24 billion annually.

Conclusions: Fatal drowning represents a significant source of health burden in Australia, underlining the need for further preventative measures.

Practical applications: We provide an easily-understood estimate of the scale of Australia's fatal drowning problem, permitting comparison with other social problems. They can also be used in determining net benefits of proposed drowning prevention policies and to identify situations where burden of fatal drowning is disproportionate. Suggestions for improving the calculation of societal burden of illness can be incorporated in cost-benefit analyses in related fields of study.

Peden, AE., Barnsley, PD., and Queiroga, AC. (2019) The association between school holidays and unintentional fatal drowning among children and adolescents aged 5–17 years. *Journal of Paediatrics and Child Health*, 55(5):pp 533-538. doi:10.1111/jpc.14235

Aim: Children aged 5–17 years in Australia have one of the lowest unintentional fatal drowning rates. One possible explanation is the protective effect of formal schooling, reducing leisure time for exposure to water hazards. We examine differences in frequency and circumstances of drowning deaths in this age group between school holidays and school days in Australia.

Methods: A total population survey (2005–2014) of unintentional fatal drownings was extracted from the (Australian) Royal Life Saving National Fatal Drowning Database. Date of drowning incident and state of residence were used to determine if the drowning occurred during school days or school holidays (including public holidays).

Results: A total of 188 5–17 year-olds drowned during the study period. We found a statistically significant difference between drowning incidence during school holidays and school days, with relative risk (RR) of drowning on a holiday 2.40 times higher (confidence interval (CI):1.82–3.18) than on a school day. This risk was similar for males (RR = 2.41; CI: 1.75–3.33) and females (RR = 2.38; CI: 1.33–4.27) but differs between children 5–9 years (RR = 3.05; CI: 1.98–4.72) and adolescents 10–17 years of age (RR = 2.02; CI: 1.38–2.93).

Conclusions: Drowning rates among 5–17 year-olds are more than twice as high during holidays than on school days. Impact of school holidays was the strongest among younger children, visitors to the drowning location and in pools and inland waterways. Results were robust to alternative specifications excluding weekends and treating them as holidays. Prevention strategies may include counselling parents and care providers of the increased risk ahead of school holidays, education on drowning risk in the school curriculum and extra holidays for parents and caregivers.

Barnsley PD, **Peden AE**. A Retrospective, Cross-Sectional Cohort Study Examining the Risk of Unintentional Fatal Drowning during Public Holidays in Australia. *Safety*. 2018; 4(4):42. doi.org/10.3390/safety4040042

Australia's celebration of its public holidays often involves aquatic recreation, frequently mixed with consumption of alcohol, both of which are risk factors for drowning. This study examines how the demographics and circumstances of public holiday drownings compare to the average day drownings. A total population survey (1 July 2002 to 30 June 2017) of unintentional fatal drownings in Australia were extracted from the Royal Life Saving National Fatal Drowning Database. Date of drowning and state/territory of residence were used to determine if the drowning occurred on a public holiday in the person's place of residence. 4175 persons drowned during the study period. There was a statistically significant difference between the incidence of fatal drowning on public holidays and the other days, with fatal drowning 1.73 times more likely to occur on public holidays (CI: 1.57–1.89). The increased risk of drowning on public holidays should inform the timing and the content of drowning prevention campaigns and strategies.

Peden AE, Mahony AJ, Barnsley PD, et al. Understanding the full burden of drowning: a retrospective, cross-sectional analysis of fatal and non-fatal drowning in Australia. *BMJ Open* 2018;8:e024868. doi: 10.1136/bmjopen-2018-024868

Objectives: The epidemiology of fatal drowning is increasingly understood. By contrast, there is relatively little population-level research on non-fatal drowning. This study compares data on fatal and non-fatal drowning in Australia, identifying differences in outcomes to guide identification of the best practice in minimising the lethality of exposure to drowning.

Design: A subset of data on fatal unintentional drowning from the Royal Life Saving National Fatal Drowning Database was compared on a like-for-like basis to data on hospital separations sourced from the Australian Institute of Health and Welfare's National Hospital Morbidity Database for the 13-year period 1 July 2002 to 30 June 2015. A restrictive definition was applied to the fatal drowning data to estimate the effect of the more narrow inclusion criteria for the non-fatal data (International Classification of Diseases (ICD) codes W65-74 and first reported cause only). Incidence and ratios of fatal to non-fatal drowning with univariate and X^2 analysis are reported and used to calculate case-fatality rates.

Setting: Australia, 1 July 2002 to 30 June 2015.

Participants: Unintentional fatal drowning cases and cases of non-fatal drowning resulting in hospital separation.

Results: 2272 fatalities and 6158 hospital separations occurred during the study period, a ratio of 1:2.71. Children 0–4 years (1:7.63) and swimming pools (1:4.35) recorded high fatal to non-fatal ratios, whereas drownings among people aged 65–74 years (1:0.92), 75+ years (1:0.87) and incidents in natural waterways (1:0.94) were more likely to be fatal.

Conclusions: This study highlights the extent of the drowning burden when non-fatal incidents are considered, although coding limitations remain. Documenting the full burden of drowning is vital to ensuring that the issue is fully understood and its prevention adequately resourced. Further research examining the severity of non-fatal drowning cases requiring hospitalisation and tracking outcomes of those discharged will provide a more complete picture.

Hamilton K, **Peden AE**, Keech JJ, Hagger MS (2018) Driving through floodwater: exploring driver decisions through the lived experience, *International Journal of Disaster Risk Reduction*. Available online 26 December 2018

More than half of unintentional flood-related drowning deaths in Australia are due to driving through floodwater, despite on-going public campaigns. Currently, there is a knowledge gap in understanding why individuals choose to drive through floodwater and the decisions that may lead to such actions. We propose that a more complete understanding of individuals' decisions to drive through floodwater needs to be considered in the context of the lived experience. Australian drivers (N=20) who had intentionally driven through floodwater participated in semi-structured interviews. Data were analysed using a thematic analysis based in an interpretivist approach. Past experience, individual perceptions (e.g., situation perceived as different to warnings), and the social and environmental context (e.g., pressure and encouragement from others, seeing other motorists driving through) emerged as major themes. Most salient was that although there was a common awareness of the risk posed by driving through flooded waterways, the decision to take this risk emerged as being heavily reliant on one's ability to construct a sense of self-efficacy in the lead-up to the incident. This study is the first to explore the lived experience of drivers who intentionally decided to drive through floodwater. Future research and public campaigns can draw on these findings to develop evidence-based interventions aimed at combating this risky driving behaviour.

Cenderadewi, M., Franklin RC., **Peden, AE**,. Devine, S. (2019) Pattern of intentional drowning mortality: A total population retrospective cohort study in Australia, 2006-2014, *BMC Public Health*, 19:207. doi: 10.1186/s12889-019-6476-z

Background: While a downward trend in unintentional drowning deaths in Australia has been observed, little is known about intentional drowning mortality. Limited information on intentional drowning death impedes the planning, implementation, and evaluation of prevention strategies. This study aims to describe rates of intentional fatal drowning in Australia and compare these to other categories of drowning.

Methods: Data were sourced from the Australian Bureau of Statistics (ABS) over a 9-year period (2006–2014). Rates and trends of intentional drowning were compared with unintentional, water-transport related and undetermined intent drowning. Rates of intentional drowning deaths across gender, age groups, states/territories, remoteness of residence and First Peoples of Australia were calculated. Relative risk (RR) (95% confidence interval [CI]) was calculated, and chi-square tests of independence were performed ($p < 0.05$).

Results: The crude mortality rate for intentional drowning deaths in Australia over the study period was 0.23/100000, lower than unintentional drowning (0.89/100000). Males were 1.6 (CI: 1.4–2.0) times more likely than females to intentionally drown, however females made up a significantly larger proportion of intentional drowning deaths (38.2%) compared to unintentional deaths (22.4%) ($\chi2 = 47.3$; df = 1; $p < 0.05$). A significant linear association between age group and intentional drowning was observed ($\chi2 = 131.3$; $p < 0.05$), with individuals aged 75 years and over 32.6 times more likely to intentionally drown. Non-Indigenous peoples were 4.1 times more likely to intentionally drown in comparison to First Peoples of Australia. Residents of Inner Regional, Outer Regional, and Major Cities were 4.2 times (CI: 0.6–30.0), 4.1 times (CI: 0.6–29.9), and 4.0 times (CI: 0.6–28.6) more likely to intentionally drown, respectively, compared with residents of Very Remote areas.

Conclusions: This study adds to the limited evidence currently available about intentional drowning rates and trends in Australia. Being male, of older age groups, non-Indigenous, residing in Inner and Outer Regional areas, and Major Cities were risk factors for intentional drowning deaths. Improving data collection systems and furthering understanding of the risk factors of intentional drowning, as well as the development, implementation, and evaluation of prevention programmes, are required to reduce the risk of intentional drowning death in Australia.

Hamilton, K., Keech, JJ., **Peden AE**., Hagger, MS. (2019) Testing a novel implementation imagery e-health intervention to change driver behaviour during floods: A randomised controlled trial protocol, *BMJ Open*,9(2):e025565. doi: 10.1136/bmjopen-2018-025565

Introduction: Drowning due to driving into floodwater accounts for a significant proportion of all deaths by drowning. Despite awareness campaigns such as 'If it's flooded, forget it', people continue to drive into floodwater. This causes loss of life, risk to rescuers and damage to vehicles. The aim of this study was to develop and evaluate an online e-health intervention to promote safe driving behaviour during flood events.

Methods and analysis: The study will use a 2×3 randomised controlled trial in which participants are randomised into one of two conditions: (1) education about the risks of driving into floodwater or (2) education about the risks of driving into floodwater plus a theory-based behaviour change intervention using planning and imagery exercises. The effect of the intervention on the primary outcome, intention to drive through floodwater and the secondary outcomes will be assessed using a series of mixed-model analysis of covariances.

Ethics and dissemination: The study has been approved by the Griffith University Human Research Ethics Committee. Participants will review a study information sheet and provide informed consent prior to commencing participation. Results will be disseminated through peer-reviewed publications, industry reports, media releases and at academic conferences. Deidentified data will be made publicly available following publication of the results.

Trial registration number: ACTRN12618001212246.

Pearn JH, **Peden AE**, Franklin RC (2019) The influence of alcohol and drugs on drowning among victims of senior years, *Safety*, 5(1), 8. doi: 10.3390/safety5010008

Unintentional fatal drowning among older people is an issue as lifespans lengthen and older people embrace active retirement. While pre-existing medical conditions are a known risk factor for drowning among this age group, less is known about the role of alcohol and drugs. This 15-year (1 July 2002 to 30 June 2017) Australian study used coronial data to investigate the impact on older people (aged 65 years and older) of the obtundent effects of prescribed drugs which had been ingested by those with a positive blood alcohol concentration (BAC). Of the closed coronial cases with toxicological information (N = 471), one quarter (24.6%; N = 116) had consumed alcohol prior to drowning (one in seven BAC ≥ 0.05%), of which a third also had obtundent drugs present (33.6%; N = 39). Rivers/creeks/streams and swimming pools were the locations with the highest number of drowning deaths. Bathtubs (36.8%) and rivers/creeks/streams (17.9%) recorded the highest proportion of cases with victims having a BAC ≥ 0.05%. Bathtubs (13.2%), lakes (7.0%), and rivers/creeks/streams (6.8%) recorded the highest proportion of drowning cases with obtundent drug involvement. Obtundent drug involvement was significantly more likely for activities where the person who drowned was alone (i.e., unknown activity) ($X^2 = 6.8$; $p = 0.009$). Common obtundent drugs included Diazepam, Tempazepam, and Codeine. Advocacy to prevent drowning in older people is a complex challenge, due to the myriad of locations where drowning occurs, the consumption of alcohol, and polypharmacy required for treating illness and maintaining good health.

Franklin RC, **Peden AE**, Leggat PA, Brander R (In Press) Who rescues who? Understanding aquatic rescues in Australia using coronial data and a survey, *Australian and New Zealand Journal of Public Health,* Published Online First 11 June, 2019. doi:10.1111/1753-6405.12900

Objective: To examine fatal drowning associated with aquatic rescues and prior self-reported experience of undertaking an aquatic rescue in Australia.

Methods: Previous aquatic rescue experience was sourced through the 2013 Queensland Computer Assisted Telephone Instrument Survey and compared to data on rescue-related fatal unintentional drowning between 1 January 2006 and 31 December 2015.

Results: Twenty-three per cent (n=294/1291) of survey respondents had previously performed an aquatic rescue. Males (X^2=35.2; p<0.001) were more likely to have performed a rescue; commonly at a beach/ocean/harbour location (X^2=13.5; p<0.001). Females were more likely to have rescued a child (0-4 years of age) (X^2=29.2; p<0.001) from a swimming pool (X^2=34.3; p<0.001). Fifty-one people drowned while performing an aquatic rescue (Males=82.4%; 25-44 years of age=53.0%; beaches=54.9%).

Conclusions: Drownings are prevented by bystanders; this is not without risk to the rescuer. Most people perform only one rescue in their life, often at a younger age, on an altruistic basis, of family members or young children. Community-wide rescue skills, taught at a young age, with consideration for coastal, inland and swimming pool environments, may prevent drowning.

Implications for public health: There is a need to train people early in their life on how to undertake a safe rescue and provide resuscitation, including promoting regular updates, in particular if supervising children.

Appendix 4: Examples of Media Coverage Generated By Research Within This Thesis

Appendix 4: Examples of Media Coverage Generated by Research Within This Thesis

Please note due to copyright restrictions the content contained in Appendix 4 has been removed from the online version of this thesis. Content can be made available on request via email to amy.peden@my.jcu.edu.au or apeden@rlssa.org.au.

Appendix 5 – Conference Presentations On Work Within This Thesis

Below is a list of peer reviewed oral and poster presentations on work contained within this thesis. AEP the doctoral candidate is denoted in bold text and the presenting author is indicated with an asterix.

Oral Presentations

Peden AE, Franklin RC*, Leggat PA (2019) Breathalysing and surveying river users in Australia, World Conference on Drowning Prevention 2019, 8-10 October, Durban, South Africa.

Peden AE*, Franklin RC, Leggat PA (2017) Unintentional fatal drowning in rivers and the role of alcohol, 13th Australasian Injury Prevention and Safety Promotion Conference, 13-15 November 2017, Ballarat

Roberts C, **Peden AE***, Scarr J (2017) Increasing awareness of drowning risk through the National Inland Waterways Drowning Prevention program, 13th Australasian Injury Prevention and Safety Promotion Conference, 13-15 November 2017, Ballarat

Peden AE*, Franklin RC, Leggat PA (2017) Challenges around the prevention of river drowning and the role of alcohol, World Conference on Drowning Prevention 2017, Vancouver Canada.

Peden AE*, Franklin RC, Leggat PA (2017) Causal pathways of flood-related deaths in Australia, World Conference on Drowning Prevention 2017, Vancouver Canada.

Peden AE*, Franklin RC, Leggatt P (2017) The Challenges of Preventing River Drowning, 15th World Congress on Public Health 2017, Melbourne Convention and Exhibition Centre, Victoria

Peden AE*, Franklin RC, Leggat P (2015) Reducing river drowning deaths: A systematic review of the literature and analysis of unintentional fatal drowning data from Australia, 12th Australasian Injury Prevention and Safety Promotion Conference, November 25-27, University of Sydney

Peden AE*, Franklin RC, Scarr J (2015) River drowning deaths: A systematic literature review of the epidemiology, risk factors and strategies for prevention, World Conference on Drowning Prevention 2015, November 4-6, Penang Malaysia

Poster Presentations

Peden AE, Franklin RC*, Leggat PA (2019) Using a Delphi Process to Identify River Drowning Prevention Strategies, World Conference on Drowning Prevention 2019, 8-10 October, Durban, South Africa.

Peden AE*, Franklin RC, Leggat PA, Pearn JH (2019) Social Determinants Impacting on CPR Training: Research Experience from River Drowning 'Blackspots', Spark of Life Conference, ICC Sydney, May 9-11.

Peden AE*, Franklin RC, Leggat PA (2018) Building the evidence base for river drowning prevention: The Australian Experience, Safety 2018 - 13th World Conference on Injury Prevention and Safety Promotion, 5-7 November 2017, Bangkok, Thailand

Non-peer Reviewed and Invited Presentations

Peden AE*, Franklin RC, Leggat PA (2018) An evidence base for river drowning prevention in regional Australia, Farmsafe Conference 2018, October 3-5, The Ville, Townsville (**Key Note Presentation**)

Peden AE* (2018) Alcohol and river drowning: What can we do to reduce the risk? Statewide Mutual Risk Management Conference, ICC Sydney, 20-21 August 2018 **(Invited Key Note Speaker)**

Peden AE* (2018) NSW river drowning blackspots: Epidemiology & strategies for prevention, NSW Water Safety Forum, NSW Parliament House, May 2nd, 2018 **(Invited Guest Speaker)**

Peden AE* (2018) Building the evidence base for river drowning and its prevention, George Institute for Global Health Seminar Series, February 28th, 2018 **(Invited Guest Speaker)**

Peden AE* (2017) Alcohol and its role in boating and watercraft related drowning deaths on Australian rivers, Boating Safety Forum, Marine17, 31 July-2 August 2017, Sydney **(Invited Guest Speaker**)

Appendix 6 – Examples of Poster Presentations

BUILDING THE EVIDENCE BASE FOR RIVER DROWNING PREVENTION: THE AUSTRALIAN EXPERIENCE

Amy E Peden [1,2], Richard C Franklin [1,2], Peter A Leggat [2]

1 Royal Life Saving Society – Australia, Sydney, NSW, Australia
2 College of Public Health, Medical and Veterinary Sciences, James Cook University, Townsville, QLD, Australia

ROYAL LIFE SAVING AUSTRALIA | JAMES COOK UNIVERSITY AUSTRALIA

EVIDENCE BASE

DROWNING FATALITIES AND RISK FACTORS

770 **RIVER DROWNING DEATHS** 2002/03 TO 2011/12[1]

80%[1]

40% ADULT RIVER DROWNING VICTIMS WHO HAD BEEN DRINKING HAD A BLOOD ALCOHOL CONCENTRATION (BAC) ≥0.20%[2]

ALCOHOL RELATED DROWNING MORE LIKELY AS A RESULT OF JUMPING INTO THE RIVER[2]

ABORIGINAL AND TORRES STRAIT ISLANDERS WERE 4 TIMES MORE LIKELY TO DROWN IN RIVERS THAN NON-INDIGENOUS PEOPLE[1]

ALCOHOL-RELATED RIVER DROWNING SIGNIFICANTLY MORE COMMON IN BETWEEN 6PM AND 6AM[2]

17% OF DEATHS **INVOLVE FLOODING**[3]

55% OF FLOOD-RELATED RIVER DROWNINGS WERE AS A RESULT OF PEOPLE **DRIVING THROUGH FLOODWATER**[3]

80 TIMES THE RISK OF DROWNING IN A RIVER FLOOD **IN A REMOTE AREA**[3]

229 TIMES THE RISK OF DROWNING IN A FLOOD **IN A VERY REMOTE AREA**[3]

EXPOSURE

73% **OF AUSTRALIAN POPULATION SURVEYED HAD VISITED A RIVER AT LEAST ONCE IN LAST 12 MONTHS**[4]

MALES WERE MORE LIKELY TO VISIT THE RIVER FOR FISHING AND WATERCRAFT[4]

FEMALES MORE LIKELY TO VISIT THE RIVER FOR NON-AQUATIC ACTIVITIES (WALKING OR PICNICKING)[4]

MALES 8 TIMES MORE LIKELY TO DROWN AT RIVERS ADJUSTING FOR EXPOSURE[4]

COMMUNITY SURVEILLANCE

7% OF RIVER USERS **BREATHALYSED HAD A BAC ≥0.05%**[5]

75% OF RIVER USERS SURVEYED **HAD PREVIOUSLY HAD CPR TRAINING**[6]

36% OF RIVER USERS SURVEYED HAD DRIVEN THROUGH FLOODWATERS[7]

19% OF RIVER USERS SURVEYED HAD SWUM IN A FLOODED RIVER[7]

PREVENTION

References available on request

RESPECT THE RIVER

Royal Life Saving's Respect The River program aims to encourage safe usage of Australia's beautiful rivers, creeks and streams by making the community aware of the key risk factors leading to drowning and aquatic injury. Drawn from the research, the program is targeting communities around the nation's top 10 river drowning blackspots with easy to follow drowning prevention tips:

- **WEAR A LIFEJACKET**
- **AVOID ALCOHOL AROUND WATER**
- **NEVER SWIM ALONE**
- **LEARN HOW TO SAVE A LIFE**

DON'T LET YOUR MATES DRINK AND DROWN

Royal Life Saving's Don't Let Your Mates Drink and Drown program aims to address the overrepresentation of males in drowning statistics, in particular those involving alcohol.

The program encourages people to be like 'Dave' the hero of the program, who looks after his mates around the water if they have been drinking. Be Like Dave and remember: Alcohol and Water Don't Mix!

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SOCIAL DETERMINANTS IMPACTING CPR TRAINING: RESEARCH EXPERIENCE FROM RIVER DROWNING 'BLACKSPOTS'

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INTRODUCTION

In Australia, an average of 279 people die from unintentional drowning annually [1]. Rivers, creeks and streams are the leading location for drowning, accounting for 26% of all deaths [2]. Drowning risk in rivers is impacted by a range of factors including geographical isolation [2-5].

Cardiopulmonary resuscitation (CPR) is recognised as a tertiary drowning prevention strategy [6]. CPR skills among river users and those residing in regional and remote areas are especially important. Given the burden of river drowning, this study aimed to explore the CPR and first aid training of river users in Australia.

METHODS

Surveys at four river drowning 'blackspots' in Queensland and New South Wales were undertaken (Figure 1). Respondents (river users aged 18 + years) were asked "when was the last time you undertook/updated first-aid qualifications (including CPR)?"

Chi square analysis was conducted using CPR training undertaken as a yes/no and CPR training current as a yes/no option, with yes being training undertaken within the last 12 months in accordance with the recommendations of the Australian Community Services and Health Industry Skills Council. Ethics approval was granted by the James Cook University Human Research Ethics Committee (HREC—7249).

Figure 1: Map of research sites

RESULTS

74.9% of participants had undertaken CPR training previously. Females ($X^2 = 7.2$; $P = 0.007$) and 35- to 44-year-olds ($X^2 = 14.7$; $P < 0.001$) were significantly more likely to report having undertaken CPR training. Those aged 18-24 years were significantly less likely to have undertaken training ($X^2 = 9.1$; $P = 0.003$). Country of birth, remoteness classification of residential postcode and IRSAD classification of residential postcode were not found to impact likelihood of having undertaken training (Table 1).

33.1% of respondents had a current qualification (Figure 2). Females ($X^2 = 5.9$; $P = 0.015$) and 18 to 24 year olds ($X^2 = 4.4$; $P = 0.037$) were significantly more likely to report holding a current qualification. For those without a current qualification, the mean time since last current was 5.4 years. Residents of major city areas (5.4 years), compared to those living more remotely (2.0 years), reported a longer mean time since last trained in CPR. People residing in areas classified as low socio-economic had a shorter time since qualification current (5.8 years) than those residing in more affluent areas (7.2 years).

Figure 2: Infographic of key results

677 PEOPLE SURVEYED REGARDING CPR

51% FEMALE

28% 18-24 YEARS

75% HAD EVER DONE CPR TRAINING

33% HELD A CURRENT QUALIFICATION

DISCUSSION & CONCLUSIONS

Although classified as a tertiary drowning prevention strategy, community-wide CPR is a key component of multifaceted drowning prevention programs, as well as vital in improving cardiac arrest outcomes [7-9]. Among the cohort surveyed, social determinants of health such as socio-economic disadvantage and geographical isolation of residential location were not found to be statistically significant barriers to participation in CPR training or possessing a current qualification. This study indicates that advocacy for currency of CPR training and increased vigour for those in major metropolitan areas and among those in more affluent areas is required.

Acknowledgements

This research is supported by Royal Life Saving Society - Australia. Research at Royal Life Saving Society - Australia is supported by the Australian Government. The authors would like to thank the river users who kindly gave up their time to participate in our survey. The authors wish to thank Stacey Pidgeon and Matthew Riggs for their assistance in gathering the survey data. Lead author AEP's doctoral studies are supported through an Australian Government Research Training Program Scholarship.

Table 1: Participation and currency of CPR qualification by age group

AGE	EVER PARTICIPATED	CURRENT QUALIFICATION
18-24 years	67%	58%
25-34 years	72%	50%
35-44 years	88%	37%
45-54 years	79%	32%
55-64 years	72%	49%
65-74 years	70%	16%
75+ years	86%	17%

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