An Exploration of the Human Health Impacts Associated with Seven Decades of Severe Weather Events in Aotearoa New Zealand: The Need for Better Data

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ABSTRACT

Aim: In this report we aimed to explore the epidemiology and trends, including injuries, hospitalisations, deaths, and other health-related impacts from severe weather events in Aotearoa New Zealand (NZ) for the 70-plus years from 1 January 1950 to 10 February 2022.
Methods: We searched the NZ Historic Weather Events Catalogue compiled by the National Institute of Water and Atmospheric Research (NIWA) to examine severe weather events that caused injuries, deaths, or other health-related impacts. We created an Excel database to record and analyse these events. To assess the sensitivity of the NZ Historic Events Catalogue, we compared a subset of severe weather events that caused drowning deaths, including those associated with boat or ship accidents and vehicle submersions, to media sources ("major newspapers") held by the Factiva database for NZ for the period from 1 January 1990 through 31 December 2019.
Results: There were a total of 498 severe weather events, such as storms, floods, tornadoes, and cyclones in NZ from 1950 to 2022 identified in NIWA's Catalogue. Of these, 185 (37%) reportedly caused at least one non-fatal injury or death. Insurance claims for these 185 weather events totalled more than $1.5 billion (2020 NZ$) and in 92 (50%) of these events it was reported that people were displaced from their homes at least temporarily. However, both NIWA's Catalogue and the Factiva search had suboptimal sensitivity in a specific analysis of severe weather events and drownings (55% and 74%, respectively).
Conclusions: Severe weather events are a notable cause of injuries and deaths, and the occurrence of such events may be rising. However, a complete dataset that spans multiple decades is needed in order to assess the trends. The overall health and wellbeing impact of these events is substantial and includes being displaced from home and major economic damage. In the face of growing climate change impacts, NZ society should do more to mitigate such threats (eg, by relocating houses away from flood plains and coastal areas vulnerable to storm surges).

INTRODUCTION

The impacts of extreme climate events on human health can be severe, including morbidity and mortality from heatwaves, droughts, floods, and storms.[1, 2] Globally, extreme weather events are expected to increase, and sea levels will rise due to climate change.[1, 2] In Aotearoa New Zealand (NZ), increased rainfall intensity has been projected,[3, 4] with fewer cyclones but a greater proportion of severe cyclones.[3] Furthermore, extreme coastal flooding has increased due to sea-level rise superimposed on high tides or storm surges in low-lying coastal locations.[3]

Such events have local and regional impacts through deaths and injuries,[1, 2, 5] but they also indirectly influence human health and wellbeing through economic disruption, infrastructure damage, and population displacement.[1, 5, 6] However, to our knowledge, no analysis of the epidemiology of injury from severe weather events in NZ has been published. Therefore, this report aimed to explore trends in severe weather events causing human injury since 1950 in NZ; identify other human impacts of these events, including displacement from home, power cuts, road blockages, school closures, sewage-related problems, and boil water notices; and estimate costs from severe weather events that are associated with injury.

METHODS

The National Institute of Water and Atmospheric Research (NIWA) is the lead Crown Research Institute responsible for collecting data on climate and weather hazards in NZ. NIWA's Historic Weather Events Catalogue (https://hwe.niwa.co.nz/) was searched for events that contained the terms "injured" or "hospital" or "ambulance" or "deaths" or "killed" or "died" or "fatal" or "drowned" or "hypothermia" from 1 January 1950 to 10 February 2022 in New Zealand. Weather event data was then extracted on associated injuries, hospitalisations, deaths and other health-related impacts. Specifically, we searched for school closures, people displaced from their homes, electrical power cuts, and road blockages during this study's timeframe within the severe weather events associated with non-fatal injury or death (n=185). We also searched for sewage issues and "boil water" notices from 1 January 1995 to 10 February 2022 within the subset of severe weather events associated with non-fatal injury or death (n=112).

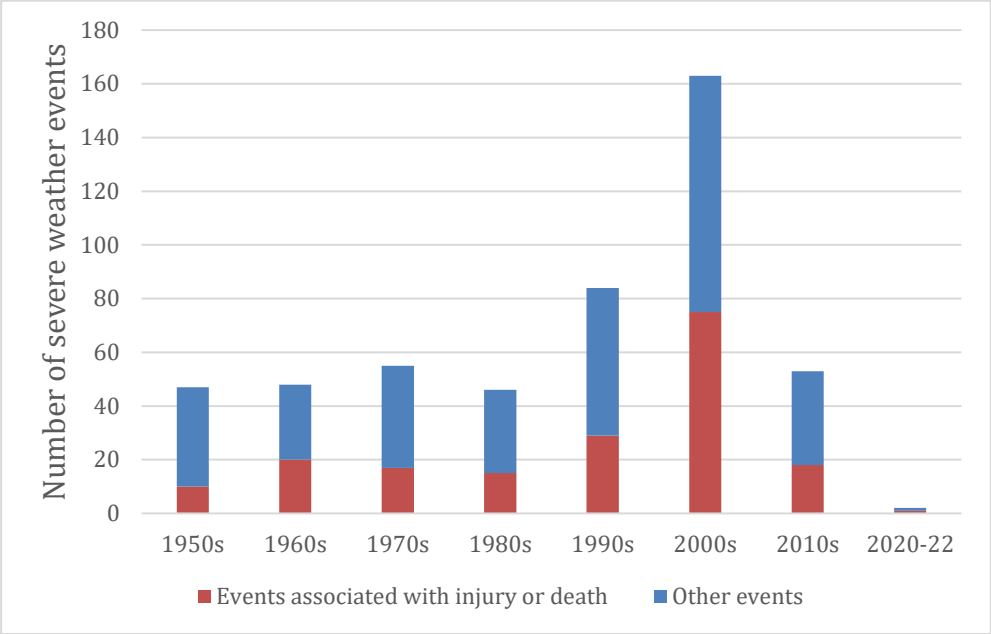
Sensitivity analysis

To assess the sensitivity of the NIWA's Catalogue, we searched the Catalogue for events that reported any casualties, from 1 January 1950 to 10 February 2022 in New Zealand. Weather event data were then extracted on associated drowning deaths. We then searched the Factiva database for the period 1 January 1990 through 31 December 2019 for media items in major NZ newspapers containing the terms "drown" or "drowned", and "flood" or "storm". Media items were identified in several different newspapers, including the *NZ Herald*, the *Dominion Post*, *The Press*, the *Otago Daily Times*, and the *Sunday Star-Times*, as well as items from the NZ Press Association. Articles were excluded if they were not directly related to drowning death(s) that were associated with a severe weather event in NZ. Included media items were compared to weather event data in NIWA's Catalogue.

RESULTS

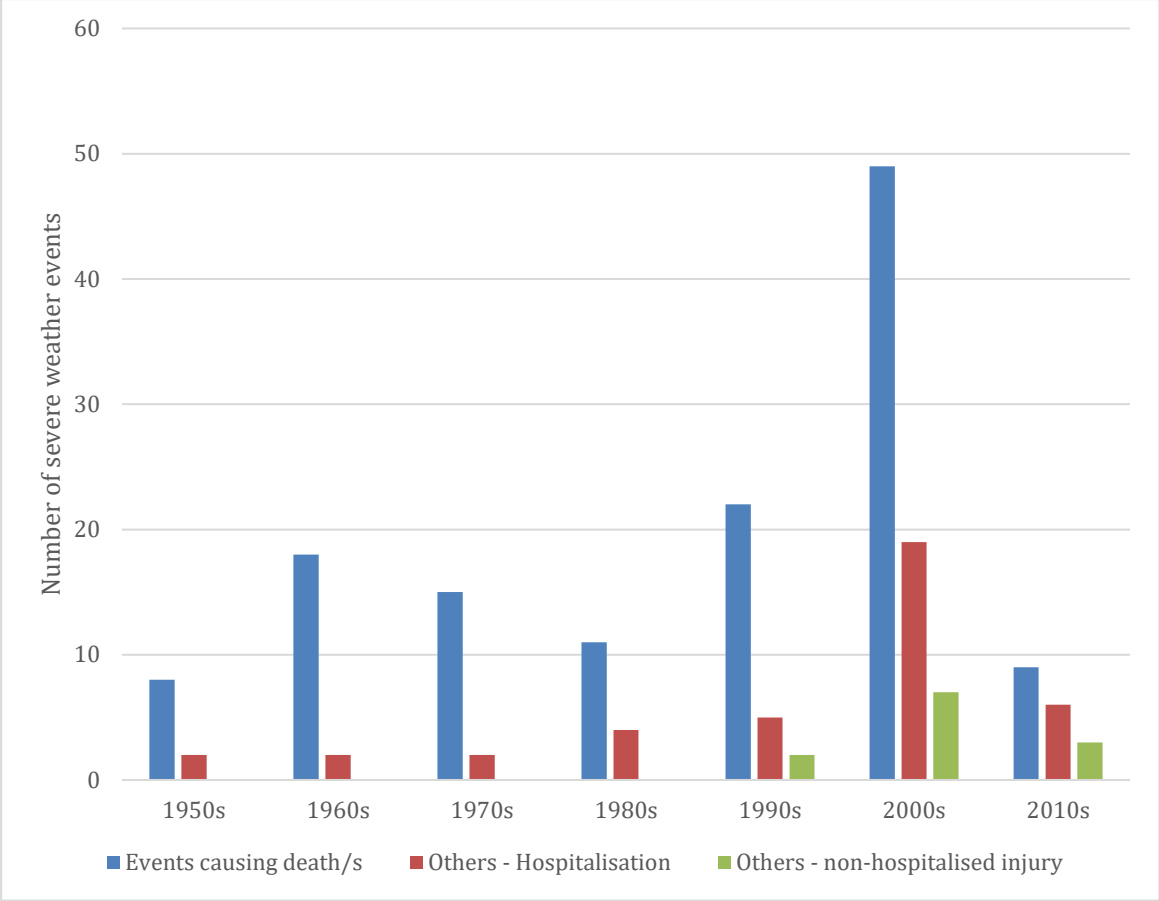
As of 10 February 2022, there were 498 severe weather events in NZ for the period 1950 to 2022 in NIWA's Historic Weather Events Catalogue (Figure 1). From these our search returned 234 events in which potential injury-related terms were used.

Figure 1. Severe weather events for the period 1950-2022 in NZ as documented in the NIWA Catalogue and including those that were, and were not, associated with injuries (n=498)



Of the 234 events returned by the search, 185 (79%) were identified as being associated with any non-fatal injury or death (Figure 2). The search terms often captured events without associated injuries or deaths because the NIWA Catalogue also typically mentioned any agricultural losses (eg, if a large number of sheep "drowned").

Figure 2. Severe weather events associated with non-fatal injury or death for the period 1950-2022 in NZ (n=185)



Of the 185 events associated with injury or death, 132 (71%) events resulted in one or more deaths, and there was a total of 362 deaths reported (Figure 3, Supplementary Table 1). The mean and median deaths per event were 2 and 1, respectively (range: 0 to 59; Table 1). Common causes of death included ship or boat accidents (39.5%; Table 1) or other drownings (15.5%), motor vehicle crashes (16%) or submersions when driving on flooded roads (5%), and being hit by flying or falling materials during storms (6.6%). Some severe weather events had large numbers of associated deaths. For example, Cyclone Giselle and the sinking of the TEV *Wahine* near Wellington caused 51 deaths on the day of the sinking.[7] There was also evidence that two more people died of their injuries subsequently, and another five deaths were attributed to Cyclone Giselle around NZ.[7]

Table 1. Commonly reported causes of death for severe weather events in NZ for the period 1950-2022

Cause of death	Number of deaths	Percentage
Boat or ship accident	143	39.5%
Motor vehicle crash[1]	58	16.0%
Drowning[2]	56	15.5%
Falling or flying materials	24	6.6%
Vehicle submersion	18	5.0%
Hypothermia	12	3.3%
Landslide or avalanche	9	2.5%
Aircraft crash	8	2.2%
Weather-related fall	6	1.7%
Other[3] **or unknown**[4]	28	7.7%
Total	362	-

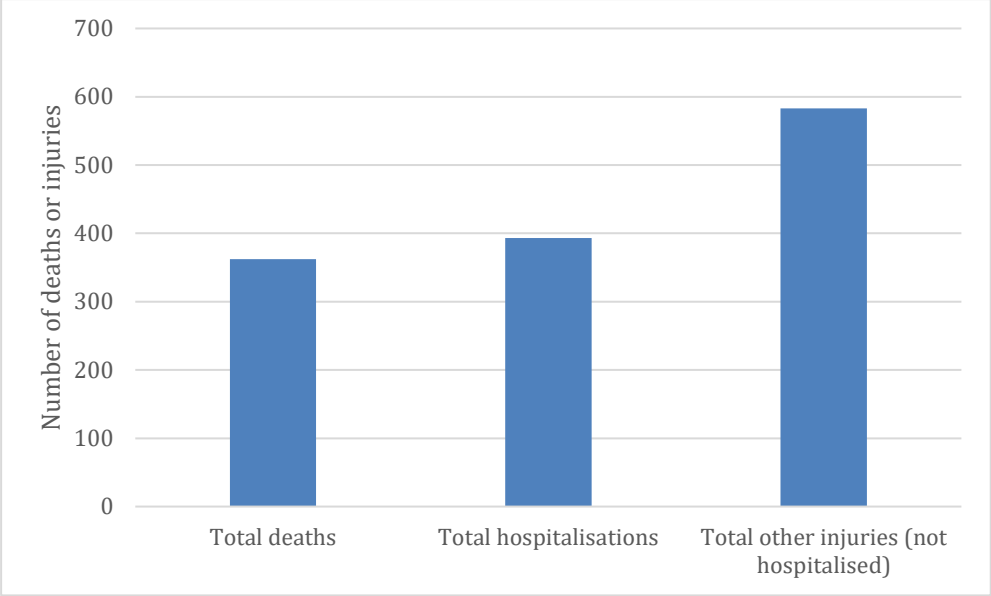
[1] Excluding submersion
[2] Excluding boat or ship accidents
[3] Other causes of death included, but were not limited to: lightning strike, weather-related fire, electrocution from downed power lines, train derailment, weather-related lack of health care access, collapsing bridge
[4] In some cases, details about the cause of death were unavailable

An estimated 85 events resulted in one or more non-fatal injuries requiring hospitalisation, while 102 events resulted in one or more non-fatal injuries that did not require hospitalisation (Table 2).

Table 2. Injuries and deaths associated with the severe weather events (n=185 events)

Variables	Mean	Median	Range
Deaths per severe weather event	2	1	0 to 59
Hospitalisations per severe weather event	2	0	0 to 87
Non-hospitalised injuries per severe weather event	3	1	0 to 91

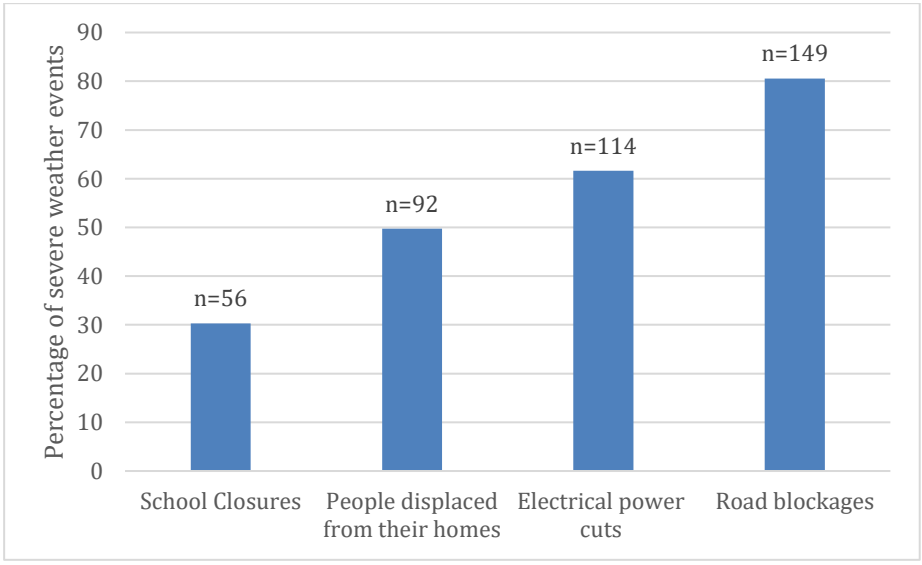
Figure 3. Health burden from severe weather events (n=185) associated with injury or death for the period 1950-2022 in NZ



Severe weather events can also cause considerable economic and social disruption. Insurance claims for the 185 events associated with non-fatal injury or death totalled more than $1.5 billion (2020 NZ$), and total damage estimates were often substantially higher than the insurance claims alone. Events also frequently caused road blockages (80.5%), electrical power cuts (61.6%), school closures (30.3%), and displaced people from their homes (49.7%), (Figure 4; Supplementary Table 2).

Of the subset of 112 events with associated non-fatal injury or death from 1 January 1995 to 10 February 2022, 31 (28%) mentioned sewage issues (eg, sewage overflows) and 9 (8%) mentioned that boil water notices were issued (Supplementary Table 3). At least four events caused sewage spills that led to public warnings to avoid swimming or collecting shellfish.

Figure 4. Social impacts[1] from severe weather events associated with injury or death (n=185) for the period 1950-2022 in NZ



[1] The totals given for each impact represent the number of events for which the impact was reported (ie, people were displaced from their homes during 92 severe weather events)

Sensitivity Analysis

From the 498 severe weather events in NZ for the period 1950 to 2022 in NIWA's Catalogue, we identified 82 events in which at least one drowning death was reported (Figures 5-6), including boat or ship accidents and vehicle submersions.

Figure 5. Severe weather events for the period 1950-2022 in NZ as documented in the NIWA Catalogue and including those that were associated with drowning deaths (n=498)

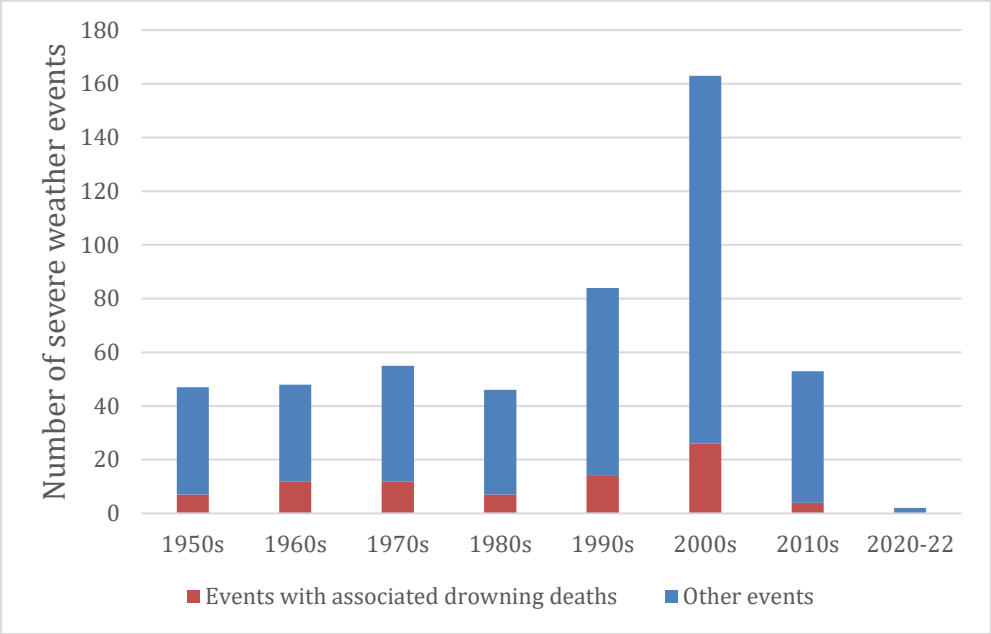
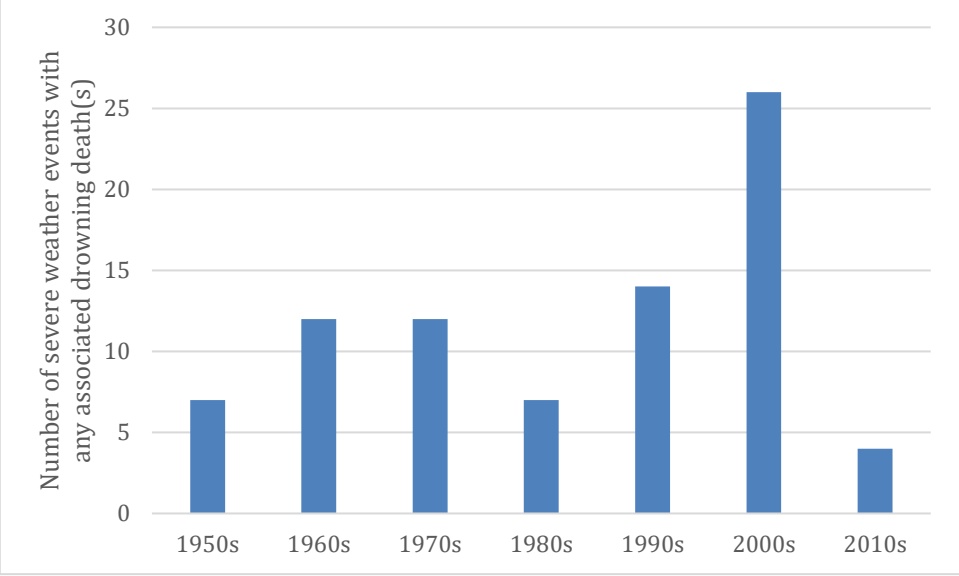
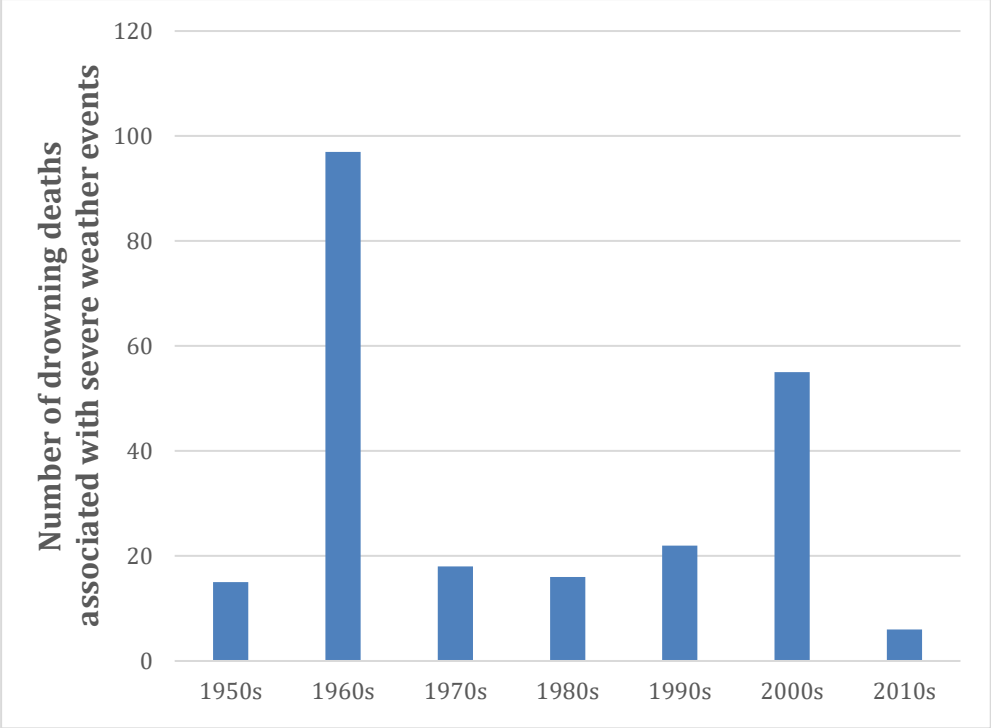


Figure 6. Severe weather events with associated drowning death(s) for the period 1950-2019 in NZ as documented in the NIWA Catalogue (n=82)



A total of 229 drowning deaths were reported (Figure 7, Supplementary Table 4). For the 82 events with associated drowning deaths, the mean and median drowning deaths per event were 2.8 and 1.0, respectively (range: 1 to 51).

Figure 7. Total number of drowning deaths associated with severe weather events for the period 1950-2019 in NZ as documented in the NIWA Catalogue (n=229)



Assuming that there were no false positives in either the NIWA Catalogue or the Factiva search, the sensitivity of NIWA's Catalogue was estimated at 55%, while the sensitivity of the Factiva search was estimated at 74% (Table 3).

Table 3. Comparison of NIWA's Catalogue and Factiva search results for severe weather events involving a drowning in the 1990 to 2019 period

Time period	All severe weather events in NIWA's Catalogue	Events in NIWA's Catalogue with drowning death(s) associated	Events in Factiva search with drowning death(s) associated	Number of matching events in Factiva search and NIWA's Catalogue	Events in Factiva search that were not included by NIWA's Catalogue	Events in NIWA's Catalogue that were not captured by Factiva search
1990-1999	84	14	13	5	8	9
2000-2009	163	26	31	16	15	10
2010-2019	53	4	15	2	13	2
Total	300	44*	59*	23	36	21*

* Assuming no false positives in either dataset, the sensitivity of the Factiva dataset can be estimated at 74% (ie, 59 / (59 + 21)). Similarly, the sensitivity of NIWA's catalogue was 55% (ie, 44 / (59 + 21)). False positives could occur if a drowning was misreported (it was not actually a drowning) or if there was a drowning that was not actually associated with a severe weather event. Also, it is possible that both sensitivity estimates are over-estimates if both datasets missed the same drownings from severe weather events.

DISCUSSION

Main findings

The health impact of severe weather events in NZ is notable. The most commonly reported causes of death associated with severe weather events from 1950 to 2022 were boat or ship accidents, vehicle accidents, other drownings (ie, not associated with boat or ship accidents), falling or flying materials, and vehicle submersion. While boat or ship accidents were the most frequently reported cause of death (39.5%), accidents involving large ships (eg, the sinking of the TEV *Wahine* during Cyclone Giselle) may be becoming more rare due to improvements in technology (eg, more sophisticated navigation systems and weather forecasting). Additionally, more people may now be travelling by aircraft relative to passenger ships. Indeed, a reduction in transport-related fatal mass-casualty events in NZ was noted in a previous analysis.[8]

There appeared to be a decrease in events associated with drowning deaths in the 2010s, relative to the 2000s (see Figure 1). However, NIWA's inclusion criteria for storm events were tightened in the 2010s and involved subjective aspects, potentially also influenced by personnel changes at NIWA in this decade [Personal communication Gregor Macara, NIWA]. The trends observed may also be influenced by changes in media reporting over time.

Despite the notable number of reported deaths and injuries, much of the overall burden of severe weather events might be the psychosocial disruption from road closures, school closures, electrical power cuts, people displaced from their homes, and economic damage. While we estimated insurance payments in this study, insurance payments likely represent only a modest fraction of the total damage from each event.

Strengths

To our knowledge, this is one of the first analyses of drowning deaths associated with severe weather events in NZ, and a strength of this study is that it examined events for an extended time period (70+ years). Another strength of this study is that several economic and social impacts were assessed in addition to the direct morbidity and mortality impacts of severe weather events. Including such impacts can assist in future planning and resource allocation (eg, planning for temporary or even permanent home displacements in low-lying areas). However, there is also a need to assess the potential cultural and ecological impacts for a more accurate measure of the full health and wellbeing impacts.

Limitations

There are a number of potential limitations with this study, with the major one being the suboptimal sensitivity for detecting injury inducing weather events as shown in the sensitivity analysis for both NIWA's Catalogue and for the additional Factiva search of major NZ newspapers. The Factiva search strategy used the search terms "drown" or "drowned", along with "flood" or "storm". These terms may have missed detecting drownings where other terms were used (eg, "swept away", "washed away", "missing at sea", or "lost at sea", etc). Furthermore, newspaper articles or other media articles may not consistently link individual drowning deaths to severe weather events.

Another key limitation identified was an apparent change in the inclusion criteria for NIWA's Catalogue in the 2010s decade, which likely led to the exclusion of a number of weather events that previously would have been included in the Catalogue. Furthermore, the Catalogue generally excludes high rainfall events that are not defined as storms or floods, but which may still have substantial health impacts. For example, a heavy rainfall

event led to the 2016 Havelock North campylobacteriosis outbreak. This outbreak had a very large health impact with between 6260 and 8320 people infected, 42 hospitalisations and four deaths.[9] Yet this precipitating weather event was not recorded in NIWA's Catalogue.

Additionally, the estimates for deaths, injuries and other health-related impacts expressed in this study are likely to be underestimates due to under-reporting. Importantly, the NIWA Catalogue typically relies on newspaper articles or other media articles, which may only highlight limited examples of health-related impacts. Moreover, serious injuries that may have caused delayed hospitalisations or deaths could have gone undocumented. For example, the authors are aware that two delayed deaths associated with Cyclone Giselle and the TEV *Wahine* sinking were not captured by the NIWA Catalogue.[7]

The Catalogue may also be affected by media reporting biases. For example, in the past the media may have been less likely to report minor injuries, school closures, insurance claims, or other impacts. Furthermore, we only estimated insurance payments and other social impacts for severe weather events associated with injury (n=185), as opposed to estimates for all severe weather events (n=498). However, the impacts from events associated with injury may not necessarily be as expensive or disruptive as events in which injuries did not occur.

Research and policy implications

This suboptimal sensitivity for NIWA's Catalogue and the Factiva search in this study reveals the need for a more complete dataset that covers events over the span of multiple decades in order to assess the trends in severe weather events that caused injuries and deaths. This may be possible in the future when the Papers Past database [paperspast.natlib.govt.nz/], which provides digitised full-text NZ newspapers and other media formats, is expanded from mid-20th century up to the current time. Alternatively a shorter time series could be studied for trends (eg, using Factiva) but after far more work on elucidating the appropriately wide range of search terms. Furthermore, the overall impact of these events extends beyond morbidity and mortality and future research should assess economic, social, cultural, and environmental impacts associated with severe weather events in order to provide a more accurate measure of the health and wellbeing burden.

Several policy implications also arise from this study. According to the NZ Ministry for the Environment, flooding is the country's most frequent natural hazard.[10] Furthermore, it has been estimated that around two-thirds of NZ's population lives in areas prone to flooding.[11] Given that climate change is expected to result in increased rainfall intensity and sea-level rise in NZ,[3, 4] additional efforts are required to prevent or mitigate flood risk. In particular, homes located in flood plains or in coastal areas that are susceptible to storm surges may need to be relocated. There may also be benefit in additional educational efforts that highlight the risks of driving or boating during severe weather events. For example, the NZ public should be regularly encouraged to check weather forecasts and make appropriate adjustments to their plans before boating.

Generally, the effects of severe weather events can be compounded by infrastructure failures. For example, secondary or tertiary consequences from storms can include injuries due to transport system damage (eg, collapsing bridges that lead to motor vehicle crashes) or electrical grid damage (eg, downed power lines resulting in electrocutions, or power outages leading to house fires from candles). Therefore, consistent monitoring of

infrastructure and investment in improvements and repairs will likely benefit human health and wellbeing.

CONCLUSIONS

Severe weather events are a notable cause of injury and death in NZ, and the occurrence of those events causing injury may be rising. The overall health impact of such events is considerable and includes people being displaced from their homes and extensive social disruption and economic damage. In the face of growing climate change impacts including projections of more frequent extreme weather, NZ needs to do more to mitigate threats to human health and wellbeing.

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Supplementary Materials

Supplementary Table 1. Decadal trends in severe weather events in NZ for the period 1950-2022

Decade	All severe weather events	Severe weather events with associated injury or death	Events associated with any deaths	Total deaths	Events associated with any hospitalisations	Events associated with any non-hospitalised injuries
1950s	47	10	8	16	3	3
1960s	48	20	18	116	5	5
1970s	55	17	15	27	5	8
1980s	46	15	11	23	7	7
1990s	84	29	22	53	8	12
2000s	163	75	49	114	47	54
2010s	53	18	9	13	10	12
2020-22	2	1	0	0	0	1
Total	498	185	132	362	85	102

Supplementary Table 2. Decadal trends in economic and social impacts from severe weather events with associated injury or death in NZ for the period 1950-2022

Decade	Reported insurance claims for severe weather events with associated injury or death (million; NZ$ 2020)	Severe weather events with associated injury or death with any people displaced from their homes	Severe weather events with associated injury or death with any road blockages	Severe weather events with associated injury or death with any school closures	Severe weather events with associated injury or death with any power cuts
1950s	$0	7	9	2	9
1960s	$240.8	11	15	7	11
1970s	$162.8	10	12	6	8
1980s	$295.0	10	9	4	8
1990s	$52.1	15	21	6	17
2000s	$469.7	26	66	23	47
2010s	$333.5	12	16	8	13
2020-22	$19.7	1	1	0	1
Total	$1,573.6	92	149	56	114

Supplementary Table 3. Trends in water and wastewater infrastructure impacts from severe events with associated injury or death in NZ for the period 1995-2022

Time Period	Severe weather events with associated injury or death with any reported sewage issues	Severe weather events with associated injury or death with any reported "boil water" notices
1995-1999	7	2
2000-2004	8	2
2005-2009	14	5
2010-2014	2	0
2015-2019	0	0
2020-2022	0	0
Total	31	9

Supplementary Table 4. Decadal trends in severe weather events associated with drowning deaths in NZ for the period 1950-2022

Decade	All severe weather events in NIWA's Catalogue	Number of severe weather events with associated drowning deaths	Proportion of all severe weather events associated with drowning deaths (%)	Total drowning deaths	Total drowning deaths per million person-years[1]
1950s	47	7	14.89	15	0.71
1960s	48	12	25.00	97	3.73
1970s	55	12	21.82	18	0.60
1980s	46	7	15.22	16	0.49
1990s	84	14	16.67	22	0.60
2000s	163	26	15.95	55	1.34
2010s	53	4	7.55	6	0.13
2020-22	2	0	-	0	-
Total	498	82	16.53	229	0.92

[1] Adjusted in terms of person-years of exposure, annual population data obtained from Stats NZ[(12)]

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