Hazelwood Health Study Technical Report:
2022 Mental Health and Wellbeing Follow-up Survey

A longitudinal study of psychological health and wellbeing among adults who were living in Morwell during the 2014 Hazelwood mine fire

Version 1.0 August 2024

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Acknowledgements

The Hazelwood Health Study is a large program of work that comprises several research streams. Those research streams are run by a multidisciplinary group of academic and administrative staff from several Institutions including Monash University, the University of Tasmania, and Federation University Australia. All staff are thanked for their contribution to this collaborative work.

Caveat

This research was funded by the Victorian Department of Health. However, the report presents the views of the authors and does not represent the views of the Department.

This report presents a preliminary analysis which has not been submitted to independent peer review. Subsequent scientific manuscripts which undergo independent peer review may vary in their findings or interpretation.

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Abbreviations

ANOVA	Analysis of variance
AUDIT-C	Alcohol Use Disorders Identification Test - Consumption
CATI	Computer-assisted telephone interview
CAWI	Computer-assisted web interview
CES-D	Center for Epidemiologic Studies Depression Scale
CIDI-PTSD	Composite International Diagnostic Interview: Posttraumatic Stress Disorder Module
COPD	Chronic obstructive pulmonary disease
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CWI	Community Wellbeing Index
DSSI-11	Duke Social Support Index (11-item form)
EQ-5D-5L	EuroQol Health Status Measure
HHS	Hazelwood Health Study
IES-R	Impact of Event Scale - Revised
IQR	Inter-quartile range
IRSAD	Index of Relative Socioeconomic Advantage and Disadvantage
K10	Kessler Psychological Distress Scale (10-item form)
LTE-Q	List of Traumatic Experiences Questionnaire
M	Mean
Mdn	Median
MUHREC	Monash University Human Research Ethics Committee
OR	Odds ratio
PHQ-15	15-item Patient Health Questionnaire
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of 2.5 micrometres (thousandths of a millimetre) or less
PTGI-SF	Posttraumatic Growth Inventory: Short Form
PTSD	Posttraumatic Stress Disorder
REDCap	Research Electronic Data Capture software application
SD	Standard deviation
95% CI	95% Confidence interval
$\mu g/m^3$	Micrograms (millionths of a gram) per cubic meter of ambient air

1. Executive Summary

The 2014 Hazelwood mine fire was one of the most serious pollution events in the history of the State of Victoria, Australia (Teague et al., 2014). Over a period of 45 days, the mine fire distributed large quantities of smoke and ash containing toxins known to be hazardous to human health into residential areas nearby to the mine. The nearest major town, Morwell, was the most heavily impacted location. In Morwell, peak levels of smoke-related particulate matter 2.5 micrometres or less ($PM_{2.5}$) were estimated to have exceeded levels considered safe by a factor of 600 (Luhar et al., 2020). The event caused major social disruptions and generated widespread concern for the immediate and longer-term health and wellbeing of people in the community exposed to smoke (Jones et al., 2018).

The Hazelwood Health Study (HHS) was commissioned by the Victorian Department of Health to investigate health outcomes in communities exposed to smoke during the Hazelwood mine fire. One of the primary research objectives of the HHS has been to monitor levels of psychological distress within the Morwell community over time. The HHS 2016-2017 *Adult Survey* collected information on the health and wellbeing of Morwell residents (*n* = 3,096), including mental health, some 2.5 years after the mine fire (R1; see Ikin et al., 2020). In order to understand longer-term outcomes, two *Mental Health and Wellbeing Follow-Up Surveys* have taken place. The first follow-up survey was conducted in 2019-2020, approximately six years after the mine fire (R2; see Carroll, Campbell et al., 2022). The second follow-up survey (R3) was conducted in 2022, approximately 8.5 years after the mine fire, and is the focus of this report. In total, 709 participants were recruited into the mental health and wellbeing follow-up cohort, of which 524 participated in this third survey-round.

Mine fire-related posttraumatic stress (Impact of Event Scale – Revised (IES-R); Weiss & Marmar, 1997) and general psychological distress (Kessler Psychological Distress Scale (K10); Kessler & Mroczek, 1994) were each assessed at all three survey-rounds. Mine fire-related posttraumatic growth, (Posttraumatic Growth Inventory – Short Form (PTGI-SF); Cann et al., 2009) was assessed for the first time at R3. Measures of demographic, health, and social factors theorised to associate with longitudinal posttraumatic stress outcomes were variously administered across the schedule of surveys. Three key research questions underpinned the current study:

- What are the levels of mine fire-related posttraumatic stress, general psychological distress, and mine fire-related posttraumatic growth 8.5 years after the mine fire?
- What are the longitudinal trajectories of mine fire-related posttraumatic stress, clinically concerning mine fire-related posttraumatic stress, and general psychological distress across the 8.5 years since the mine fire?
- How are smoke exposure during the event, sociodemographic circumstances, personal health, other adverse experiences, and social connectedness associated with mine fire-related posttraumatic stress, general psychological distress, and mine fire-related posttraumatic growth 8.5 years after the mine fire?

On average, mine fire-related posttraumatic stress levels at R3 in 2022 had dropped significantly from the heightened levels observed at R2 in 2019-2020, with levels at R3 for people exposed to higher levels of smoke during the mine fire akin to those seen for people with little or no exposure to the smoke. This suggests that mine fire-related posttraumatic stress had largely dissipated by R3. The increase in posttraumatic stress levels at R2 is likely attributed to the Black Summer fire and smoke event which coincided with R2 data collection and likely triggered reminders of the earlier mine fire. This is supported by the finding that posttraumatic stress across all three survey-rounds was primarily driven by impacts within the Intrusion symptom domain, characterised by uninvited thoughts about the mine fire and feeling disturbed when reminders of the event were encountered.

The modifying effect of age on the relationship between mine-fire exposure and mine fire-related posttraumatic stress observed in analyses completed after R1 (Broder et al., 2020) and R2 (Carroll, Campbell et al., 2022) was no longer evident at R3 indicating that the greater susceptibility of younger people to posttraumatic stress as a function of smoke exposure had also dissipated over time, likely because of the more general dissipation in mine fire-related posttraumatic stress. Overall, the study revealed that participants' sociodemographic circumstances, such as employment status, education level, household income, physical health conditions, and prior exposures to other

potentially traumatic events, were more integral to shaping longer-term mine fire-related posttraumatic stress outcomes at R3 than their level of exposure to smoke during the mine fire. Prospects for experiencing good mental health after the mine fire have been primarily shaped by personal circumstances. Consistent across time-points in the study, Morwell residents living with social and economic disadvantages have typically experienced poorer mental health as an outcome of the mine fire compared with those in more advantageous circumstances.

In addition to examining levels of mine fire-related posttraumatic stress across the cohort, this study also examined the prevalence of clinically concerning mine fire-related posttraumatic stress (indicated by IES-R scores ≥24; see Asukai et al., 2002), at each time point. This enabled the charting of different trajectories of mine fire-related posttraumatic stress, relative to this threshold, over time. Most participants were below the threshold for clinical concern at all three survey-rounds (resilient trajectory), while lower numbers of participants exhibited clinically concerning posttraumatic stress at each survey-round (chronic), reported clinically concerning levels at R1 then below the threshold at R2 and/or R3 (recovery), or were initially below clinically concerning levels and then above the threshold at R2 and/or R3 (delayed-onset posttraumatic stress). Notably, the second most prevalent trajectory was an intermittent course of posttraumatic stress characterised by a clinically concerning IES-R score at R2 among people who otherwise did not return clinically concerning scores at R1 or R3. This is, again, suggestive of a stress sensitivity having been embedded through experiences of the mine fire and subsequently aroused during the Black Summer bushfire season. The Black Summer bushfire season potentially also triggered some of the cases of delayed-onset posttraumatic stress and extended the timeline to reaching recovery in other cases.

In contrast to the reduction in mine fire-related posttraumatic stress levels observed at R3, the average level of general psychological distress (K10 score) across the cohort has continued to increase over time and, at R3, was at a level indicative of moderate general psychological distress. The longitudinal regression model assessing associations between baseline predictors and K10 score across the three survey-rounds indicated numerous adverse sociodemographic circumstances were associated with greater general psychological distress. While mine fire smoke exposure was a significant predictor of general psychological distress in the wider cohort at R1 (Blackman et al., 2018), this was no longer the case at R2 (Carroll, Campbell et al., 2022) or R3. This incremental rise in general psychological distress likely reflects an accumulation of challenges that have been adversely affecting the local region. Events in the local community that have potentially generated adversity and worry include the subsequent closure of the Hazelwood mine and power station, COVID-19 pandemic and the planned closure of other power stations and mines in coming years as the region, and the nation more generally, transitions away from coal-fired power generation. The cross-sectional analysis provided an opportunity to gain insight to drivers of higher K10 scores at R3. This analysis indicated that alongside personal health circumstances, wider social factors such as COVID-19 pandemic concerns, multiple exposures to recent stressful life-events, low annual household income, and loneliness, each contributed to greater susceptibility to general psychological distress.

Taken together, the analyses of the longitudinal predictors of mine fire-related posttraumatic stress and general psychological distress, along with the cross-sectional analyses of clinically concerning mine fire-related posttraumatic stress and general psychological distress at R3, suggest that the sample-wide trajectories of these two kinds of stress have diverged over time. This indicates that the longitudinal increase in general psychological distress in Morwell is not directly attributable to the mine fire. Accordingly, there is a need to further delve into and address the wider causes of the longer-term deterioration in mental health in Morwell observed here.

The study also examined levels of mine fire-related posttraumatic growth by the time of the final survey. This included positive psychological changes, such as greater appreciation for life and recognising new possibilities, in response to the mine fire. While there were clear indications that experiencing more mine fire-related posttraumatic stress was associated with greater mine fire-related posttraumatic growth, the levels of posttraumatic growth reported were typically small to moderate. Notably, there was no association between smoke exposure during the mine fire and mine fire-related posttraumatic growth some 8.5 years later. The relatively low levels of posttraumatic growth recorded here may be because the 2014 Hazelwood mine fire involved less immediate catastrophic harms to life or damage to personal property and hence had less potential to stimulate posttraumatic growth among those who were exposed.

The findings gleaned from this longitudinal research have applications for improving the provision of emergency, health, and social support services during and after an event such as the mine fire, including the potential for subsequent events to activate stress sensitivities associated with an earlier event. These services need to have familiarity with the recent history of exposure to disaster in the communities they serve and take into consideration the implications that a community's history of exposure to disasters can have on the mental health needs of community members. Mental health care should adopt a longer-term outlook after disasters and be more widely offered to mitigate the risks of delayed-onset or intermittent posttraumatic stress symptoms, particularly in the context of similar events that may trigger or exacerbate sensitivities. Promoting greater awareness of the longer-term timeframes that mental health impacts can present after disaster, as well as the risk factors that underlie vulnerability to longer-term impacts, could also be beneficial. In Morwell, efforts should continue to focus on improving prospects for employment, income, and health, which have underpinned resilient psychological responses to the mine fire.

2. Introduction

2.1. Posttraumatic stress in the context of disaster

Often sudden, unexpected, and broad-reaching in impact, disasters are among the most profound forms of traumatic events. Throughout the world, the frequency and intensity of extreme weather-related disasters, notably landscape fires, have been exacerbated by climate change (Richardson et al., 2022). There is also growing sensitivity within society about the underlying culpability of human activities, particularly industries focused on the extraction and exploitation of natural resources, in bringing about these conditions (Hamilton et al., 2015; Murphy, 2011; Urry, 2015). There is likewise growing urgency for research that contributes to better understanding the immediate and long-term impacts of disasters on the mental health of those who are exposed (Hughes et al., 2016; Leaning & Guha-Sapir, 2013).

In times of disaster most people's psychological responses are resilient (Bryant et al., 2015); nevertheless, over longer-term timeframes, as many as 30% of people develop a stress-related problem of some degree after the event (Galatzer-Levy et al., 2018). Posttraumatic stress symptoms typically emerge soon after such events (Norris et al., 2002) and can become chronic and debilitating problems meeting criteria for a formally diagnosed stress-related condition, such as posttraumatic stress disorder (PTSD), depression, or anxiety (McFarlane, 2010). However, adverse reactions can also be delayed, with posttraumatic stress symptoms only becoming apparent years later (Bryant et al., 2018). Posttraumatic stress symptoms are particularly susceptible to being triggered by situations involving environmental characteristics and sensory cues that stimulate memories and emotions attached to the preceding traumatic experience (McFarlane, 2010).

Outcomes of exposure to potentially traumatic events are not, however, exclusively negative and trauma can also be an impetus for positive change in individuals and communities. The experience of meaningful growth in the longer-term aftermath of trauma is common (Steinberg et al., 2022). Examples of posttraumatic growth include the development of a greater appreciation for one's personal capabilities, health, relationships, and spirituality, as well as realignments of priorities, choices, and behaviours in life (Tedeschi & Calhoun, 2004). Posttraumatic stress and growth are regarded as conceptually distinct (Joseph & Linley, 2008); however, Janoff-Bulman (2004) has suggested that posttraumatic stress may be a catalyst for posttraumatic growth, with the causal pathway being indicative of a personal journey from victimhood to an adaptive integration of that traumatic experience. The two phenomena can be concurrently evident in a person's life, with some cross-sectional disaster research demonstrating a positive correlation between levels of each construct (Holgersen et al., 2010; Liu et al., 2017; Park et al., 2010).

The nature of a disaster, including its origins, the damage and disruption it causes, and its potential and actual implications for health and wellbeing are primary determinants of resultant posttraumatic stress and growth (Newnham et al., 2022). Personal factors, including prior physical and mental health, lived experiences of other traumatic or stressful events, and sociodemographic circumstances, also contribute to the likelihood of posttraumatic stress and growth emerging in a persons' life (McFarlane, 2010). However, the scope of most research on mental health outcomes of disasters has been limited to assessments completed within the first two years following the event, with few studies to date having investigated outcomes over more extensive timeframes (e.g. McFarlane & Van Hoof, 2009; Thoresen et al., 2019). Likewise, the only previous research we are aware of in regards to longer-term community wellbeing outcomes in the context of disaster is our own recent analysis of Morwell residents' perspectives on community wellbeing six years after the Hazelwood mine fire (see Carroll et al., 2023). As such, there is a pressing need for research examining trajectories of mental health and wellbeing over the longer-term post-disaster, which needs to also consider potential cumulative implications that subsequent exposures to other disasters may have.

2.2. The 2014 Hazelwood mine fire

In February 2014, a fire ignited in the open-cut brown coal mine pit adjacent to the Hazelwood Power Station and distributed toxic smoke into the Morwell township and other localities in the Latrobe Valley region of Victoria, Australia (Luhar et al., 2020). The smoke pollution continued for 45 days and was unusual in terms of the intensity, duration, and proximity to population centres. In response to community concerns about the potential health impacts of exposure

to the smoke, the Victorian State Government Department of Health determined that it was important to learn from the event, particularly for:

- the benefit of the local community who were exposed to this smoke, by monitoring any potential long-term health effects; and
- assisting health authorities, environment protection agencies and emergency services to inform and improve future policy and planning in the event of future similar events.

The Department of Health awarded a tender for the longitudinal Hazelwood Health Study (HHS) to a Monash University-led research team with collaborators from Federation University Australia, the University of Tasmania, and others. The HHS program of research has several research streams, each with their own specific aims and objectives. This report represents a cross-stream activity, led by the Psychological Impacts stream in collaboration with the Adult Survey stream, to investigate the longer-term psychological health of Morwell residents.

The 2014 Hazelwood mine fire was a disruptive, stressful, and potentially traumatic event on a community-wide scale. HHS investigations of local health service data found that the mine fire period was associated with subsequent increases in demand for mental health care (Carroll, Gao et al., 2022) and psychiatric medications (Johnson et al., 2019). Analyses of data across two survey-rounds indicated that adults living in Morwell at the time of the mine fire were experiencing, on average, moderate levels of mine fire-related posttraumatic stress some two years after the mine fire (Broder et al., 2020) and again some six years after the event (Carroll, Campbell et al., 2022). At both time-points, mine fire-related posttraumatic stress levels were found to be in a dose-response relationship with levels of smoke exposure during the mine fire and were typically higher among adults who were younger. Smith and Campbell et al. (2023) found that there were different trajectories of mine fire-related posttraumatic stress across the two time-points among participants, including resilient responses as well as cases of posttraumatic stress recovery, delayed-onset, and chronic posttraumatic stress, and that personal sociodemographic circumstances, health status, exposures to recent stressful life-events, and exposures to other traumatic experiences were important determinants of which trajectory participants were on. Notably, mine fire-related posttraumatic stress levels and general psychological distress levels were each significantly higher in 2019-2020 than they had previously been in 2016-2017 (Carroll et al., 2020). The increases, which were broadly evident across the sample, were likely a response to the catastrophic Black Summer bushfire season that impacted south-eastern Australia in 2019-2020 and overlapped with the R2 data collection period. Furthermore, since R2, the region has been subject to the health and social ramifications of the COVID-19 pandemic, potentially adding to existing mental health concerns in the already impacted community.

2.3. Study objective and aims

The overall aim of the ongoing Psychological Impacts research stream is to determine whether exposure to smoke from the 2014 Hazelwood mine fire is associated with psychological trauma and distress, and to examine factors associated with recovery and resilience in the affected community, including concerns arising from the 2019-2020 Black Summer fire season and the COVID-19 pandemic. The objective in the current study was to understand the longer-term mental health and wellbeing outcomes and their determinants among people living in communities exposed to smoke during the mine fire. The specific aims in this study were to investigate the following questions:

- What were the levels of mine fire-related posttraumatic stress, general psychological distress, and mine fire-related posttraumatic growth 8.5 years after the mine fire?
- What were the longitudinal trajectories of mine fire-related posttraumatic stress, clinically concerning mine fire-related posttraumatic stress, and general psychological distress across the 8.5 years since the mine fire?
- How were smoke exposure during the event, sociodemographic and health circumstances, personal health, other adverse experiences, and social connectedness associated with mine fire-related posttraumatic stress, general psychological distress, and mine fire-related posttraumatic growth 8.5 years after the mine fire?

3. Method

3.1. Study design

This research adopted a longitudinal design, comprising three rounds of quantitative surveying conducted at time-points approximately 2.5 years (the 2016-2017 Adult Survey), 5.5 years (the 2019-2020 Mental Health and Wellbeing Follow-Up), and 8.5 years (the 2022 Mental Health and Wellbeing Follow-Up) after the mine fire, which are from here onward abbreviated to R1, R2, and R3 respectively. Figure 1 outlines the timeline of the research in the context of the mine fire and other significant events in the community.

3.2. Participants

3.2.1. Sampling

The original population sampling frame for the study were adults living in Morwell at the time of the 2014 Hazelwood mine fire. The R1 survey was open to all people aged ≥18 years and residing in Morwell at 31 of March 2014. The eligible population were identified and invited to participate using information accessed from the Victorian State Electoral Commission roll. A subset of R1 participants were subsequently invited to participate in two further survey-rounds (R2 and R3). Note, the current analysis focuses on the longitudinal follow-up of Morwell adults. The R1 survey also involved a control group comprising participants recruited from sociodemographically comparable areas within the nearby community of Sale who had no exposure, or otherwise very minimal exposure, to smoke during the mine fire. Sale respondents were not invited to participate in R2 or R3. Our earlier reports (see Abramson et al., 2017; Blackman et al., 2018) provide detailed descriptions of the methods used to determine initial eligibility for the Adult Survey cohort and present the wider cross-sectional between-groups analysis undertaken at R1.

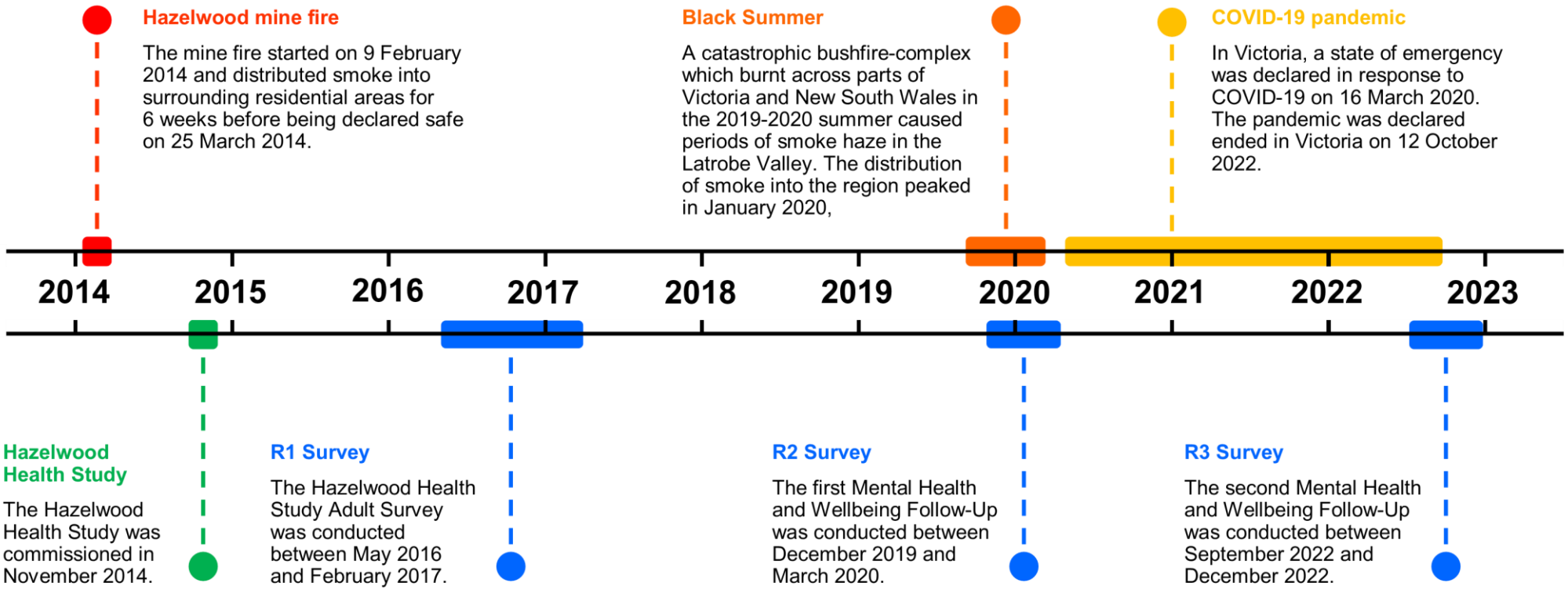
In total, 3,096 Morwell residents participated in R1, which equated to an estimated eligible population response rate of 34%. From the R1 sample, 3,077 were eligible to continue their participation in longitudinal research; reasons for ineligibility were having deceased between R1 and R2 (n = 17) and having withdrawn from ongoing participation in HHS research (n = 2). A weighted random sample of 1,512 adults, stratified by age-group at R1 (<35 years; 35-65 years; >65 years) and by tertile of mine fire-related $PM_{2.5}$ exposure (see "Event exposure" subsection below), was selected for invitation to participate in R2. In total, 709 participants were recruited into R2 (an invitation response rate of 47%), which formed the Mental Health and Wellbeing Follow-Up cohort. All 709 Mental Health and Wellbeing Follow-Up cohort members were invited to participate in R3. From these invitations, 524 participants were recruited into R3, which equated to a response rate of 74%.

3.2.2. Recruitment

Recruitment methods for R1 and R2 have been described in detail elsewhere (see Ikin et al., 2020; Carroll, Campbell et al., 2022). Invitations to R3 included information about the purpose of the survey and instructions for participating or opting out of the study if desired. Invitations and reminders were first sent by email, then by text message to mobile phone number, and finally by letter to postal address. A maximum of three attempts to contact a participant were scheduled via each type of contact method (where available). Contact attempts were scheduled approximately one week apart. Electronically-delivered Invitations included web links providing direct access to the survey. Participants were eligible to receive a $25 gift voucher as reimbursement for their time upon submitting their survey response.

Multiple modes to complete a survey response were made available, with participants able to choose which option they preferred and to undertake their response at their convenience. Computer-assisted web interview (CAWI) was the primary mode of response to the survey. Computer-assisted telephone interviews (CATI) were facilitated by a research team member. Upon participant request, a paper version of the survey was sent out and returned via mail.

Figure 1 Timeline of the Longitudinal Research Within the Context of Significant Events in the Community



3.3. Measures

Table 1 presents an overview of the constructs investigated in the study, how they were measured, and the time-points when measures were administered.

Table 1 Constructs of Interest in the Study: How and When They Were Measured

Construct of interest	Measure	R1	R2	R3
Event exposure				
Smoke exposure during the mine fire	An overlay of $PM_{2.5}$ modelling and personal time-location diaries for the 45-day event (Ikin et al., 2020)	X		
Event-related wellbeing				
Mine fire-related posttraumatic stress	Impact of Event Scale – Revised (Weiss & Marmar, 1997)	X	X	X
General psychological distress	Kessler Psychological Distress Scale (Kessler & Mroczek, 1994)	X	X	X
Mine fire-related posttraumatic growth	Posttraumatic Growth Inventory - Short Form (Cann et al., 2009)			X
Sociodemographic circumstances				
Age	A single-response item	X		
Sex	A single-response item	X		
Highest level of education	A single-response item	X	X	X
Employment status	A single-response item	X	X	X
Household composition	A single-response item		X	X
Annual gross household income	A single-response item			X
Socioeconomic status	Index of Relative Socioeconomic Advantage and Disadvantage (Australian Bureau of Statistics, 2021)			X
Personal health				
Physical health diagnoses	A set of single-response items	X		
Mental health diagnoses	A set of single-response items	X	X	X
Somatic symptoms	15-item Patient Health Questionnaire (Kroenke et al., 2002)		X	X
Health-related quality of life	EuroQol Health Status Measure (Herdman et al., 2011)			X
Other adverse experiences				
Lifetime exposures to other traumatic events	PTSD Module of the Composite International Diagnostic Interview (Kessler & Üstün, 2004)	X		
Recent exposures to stressful life-events	List of Traumatic Experiences Questionnaire (Brugha et al., 1985)		X	X
Black Summer bushfires concerns	A set of scale-response items created specifically for the research			X
COVID-19 pandemic concerns	A set of scale-response items created specifically for the research			X
Social connectedness				
Social support	Duke Social Support Index (Koenig et al., 1993)		X	X
Loneliness	Loneliness Item of the Center for Epidemiologic Studies Depression Scale (Radloff, 1977)		X	X
Satisfaction with community	Community Wellbeing Index (Forjaz et al., 2011)		X	X

3.3.1. Event exposure

Smoke exposure during the mine fire was determined for each participant by estimating their personal exposure to mine fire-related $PM_{2.5}$ from when the mine fire first ignited on 9 February 2014 to when it was officially declared safe on 25 March 2014. Spatiotemporal distribution of mine fire-related $PM_{2.5}$ across the 45-day event was modelled by CSIRO Oceans & Atmosphere (see Luhar et al., 2020). The modelling was superimposed on each participants' self-reported time-location diary for the 45-day event, which was collected at R1, to generate an estimate of their daily mean exposure to mine-fire related $PM_{2.5}$ (see Ikin et al., 2020). Participant mine fire-related $PM_{2.5}$ exposure estimates were categorised based on tertiles of mean daily exposure across 3,091 Morwell R1 participants ("Low exposure": <8.56 µg/m^3; "Medium exposure": 8.56-14.15 µg/m^3; "High exposure": >14.15 µg/m^3).

3.3.2. Event-related wellbeing

Mine fire-related posttraumatic stress was assessed at each survey-round using the Impact of Events Scale – Revised (IES-R; Weiss & Marmar, 1997). Participants rated how much they had experienced each of the IES-R's 22 posttraumatic stress symptoms in response to the mine fire over the preceding seven days (e.g., "I had waves of strong feelings about it") on a 5-point scale (0: "Not at all"; 1: "A little bit"; 2: "Moderately"; 3: "Quite a bit"; 4: "Extremely"). The total IES-R score is the sum of all items and ranges from 0-88, with a higher score indicating greater posttraumatic stress. The IES-R has three subscales aligned with the "Intrusion", "Avoidance", and "Hyperarousal" symptom domains of PTSD. The Intrusion and Avoidance domain scores are each the sum of eight items; the Hyperarousal domain score is the sum of six items and was scaled upward by a factor of 8/6 to facilitate direct comparisons with the other domain scores.

Previous research by Asukai and colleagues (2002) determined that an IES-R score of ≥24 can be used as a threshold for identifying cases of posttraumatic stress at levels of clinical concern. This threshold was applied to categorise participants' IES-R scores (<24: "Sub-clinical level of mine fire-related posttraumatic stress"; ≥24: "Clinically concerning level of mine fire-related posttraumatic stress") at each survey-round. Participants' categorised IES-R scores at each survey-round were then plotted to identify the trajectories of clinically meaningful mine fire-related posttraumatic stress over time and were also analysed to investigate risk factors associated with clinically concerning mine fire-related posttraumatic stress at R3. Table 2 presents the possible trajectories of mine fire-related posttraumatic stress, relative to the threshold for clinical concern, across the three survey-rounds. The mine fire-related posttraumatic stress trajectories were defined with reference to Bonanno's (2004) theoretical trauma-response framework.

Table 2 Long-Term Trajectories of Mine Fire-Related Posttraumatic Stress Investigated in the Study

Trajectory	Operationalisation of the trajectory for the study
Resilient	A consistent set of sub-clinical IES-R scores across survey-rounds
Chronic	A consistent set of clinically concerning IES-R scores across survey-rounds
Recovery	A clinically concerning IES-R score at R1 and/or R2 coupled with a sub-clinical IES-R score at R3
Delayed-onset	A sub-clinical IES-R score at R1 and/or R2 coupled with a clinically concerning IES-R score at R3
Intermittent	IES-R scores that alternated between sub-clinical and clinically concerning across survey-rounds

General psychological distress was assessed at each survey-round with the Kessler Psychological Distress Scale (K10; Kessler & Mroczek, 1994). The K10 comprises ten items assessing the presence and extent of anxiety and depression symptomology over the preceding four weeks (e.g., "About how often did you feel that everything was an effort?"), rated on a 5-point scale (1: "None of the time"; 2: "A little of the time"; 3: "Some of the time"; 4: "Most of the time"; 5: "All of the time"). A K10 score is the sum of all items and ranges from 10-50, with a higher score indicating more severe psychological distress. K10 scores were categorised into four levels of severity ("Low psychological distress": scores ≤15; "Moderate psychological distress": scores 16-21; "High psychological distress": scores 22-29; "Very high psychological distress": scores ≥30) based on an approach routinely implemented in Australian government department health surveys (Australian Bureau of Statistics, 2012).

Mine fire-related posttraumatic growth was assessed at R3 with the Posttraumatic Growth Inventory: Short Form (PTGI-SF; Cann et al., 2009). The PTGI-SF comprises ten items presenting typical examples of positive personal change as a result of exposure to a potentially traumatic event (e.g., "I discovered that I'm stronger than I thought I was"), rated on a 6-point scale (0: "Not at all"; 1: "A very small degree"; 2: "A small degree"; 3: "A moderate degree"; 4: "A great degree"; 5: "A very great degree"). A PTGI-SF score is the sum of all items and ranges from 0-50, with a higher score indicating greater posttraumatic growth. The PTGI-SF has five subscales ("Relating to Others"; "New Possibilities"; "Personal Strength"; "Spiritual Change"; "Appreciation of Life"), each comprising two items. Mean item-scores were calculated for PTGI-SF total score and subscale scores (PTGI-SF total score divided by 10; subscale scores divided by 2) to place and interpret these scores on the same 0-5 scale used in the measure.

To investigate mine fire-related posttraumatic growth outcomes at R3 in relation to various levels of preceding posttraumatic stress, IES-R scores at R1 were further categorised. Following Asukai et al.'s (2002) recommendation that IES-R scores ≥24 are of clinical concern, as well as our previous finding that participants with IES-R scores ≥11 at R1 had significantly greater potential to increase to clinically concerning IES-R scores at R2 (Smith et al., 2023), four posttraumatic stress categories were defined for the analysis (IES-R score at R1 = 0: "No posttraumatic stress"; IES-R score at R1 = 1-10: "Subclinical posttraumatic stress at lesser risk of progressing to clinical concern"; IES-R score at R1 = 11-23: "Subclinical posttraumatic stress at greater risk of progressing to clinical concern"; IES-R score at R1 ≥24: "Posttraumatic stress of clinical concern").

3.3.3. Sociodemographic circumstances

Demographic information collected and/or updated where applicable across the three surveys were age, sex, highest education level, employment status, household composition, and annual household income. In addition, Australian Census data (Australian Bureau of Statistics, 2021) was used to provide an area-level marker of socioeconomic status at R3. The ABS's 2021 Index of Relative Socioeconomic Advantage and Disadvantage (IRSAD), ranked residential areas based on a weighted combination of census indicators. An IRSAD score of 1,000 indicates socioeconomic conditions commensurate to the national average; scores above and below 1,000 indicate comparative socioeconomic advantage and disadvantage respectively. In the study, each participant was assigned the IRSAD score of the Statistical Area Level 1 that their R3 residential address was located within.

3.3.4. Personal health

Physical health diagnoses were assessed at R1 with a set of self-report items identifying whether the participant had ever been diagnosed by a doctor with a health condition within the categories "Asthma", "Chronic obstructive pulmonary disease (COPD)", and "A cardiovascular condition (angina; arrhythmia; heart attack; heart failure; stroke; other heart disease)".

Mental health diagnoses were assessed at each survey-round with a set of self-report items identifying whether the participant had ever been diagnosed by a doctor or psychologist with a mental health condition and, if so, the year the condition was first diagnosed. Participants' responses to this item at each survey-round were aggregated to most comprehensively establish their history of mental health diagnoses. Mental health diagnoses were categorised relative to whether they had been made before or after the mine fire.

Somatic symptoms were assessed at R2 and R3 with the 15-item Patient Health Questionnaire (PHQ-15; Kroenke et al., 2002). The PHQ-15 explores respondents' experiences of typical somatic symptoms over the preceding week (e.g., "How often have you been bothered by stomach pain?") rated on a 3-point scale (0: "Not at all"; 1: "Bothered a little"; 2: "Bothered a lot"). A PHQ-15 score is the sum of all items and ranges from 0-30, with a higher score indicating more severe somatic symptomology.

Health-related quality of life was assessed at R3 with the EuroQol Health Status Measure (EQ-5D-5L; Herdman et al., 2011). The first five EQ-5D-5L items ask the respondent to rate their current health state across five dimensions of health and wellbeing ("Mobility"; "Self-care"; "Usual activities"; "Pain/Discomfort"; "Anxiety/Depression") on 5-point scales (e.g., for "Mobility": 0: "I have no problems in walking about"; 1: "I have slight problems in walking about"; 2: "I have moderate problems in walking about"; 3: "I have severe problems in walking about"; 4: "I am unable to walk

about"). An EQ-5D-5L Health State Index Value was calculated for each participant with reference to an Australian norm EQ-5D-5L Standard Value Set (Norman et al., 2023). An index value of 1 indicates the best possible health state and index values ≤0 indicate the worst possible health states.

3.3.5. Other adverse experiences

Lifetime exposure to other potentially traumatic events was assessed at R1 using the PTSD module of the Composite International Diagnostic Interview (CIDI-PTSD; Kessler & Üstün, 2004) which comprises a list of 11 distinct types of traumatic experience (e.g., "Were you ever involved in a life-threatening accident?") to ascertain whether respondents have been exposed to a particular trauma during their lifetime ("Yes"/"No"). Participant responses were categorised into three levels of exposure ("No lifetime exposures"; "One lifetime exposure"; "Multiple lifetime exposures").

Recent exposure to potentially stressful life-events was assessed at R2 and R3 using the List of Traumatic Experiences Questionnaire (LTE-Q; Brugha et al., 1985). The LTE-Q comprises twelve items (e.g., "You were sacked from your job?") to ascertain whether respondents have been exposed to a particular stressful life-event during the preceding twelve months ("Yes"/"No"). Participant responses were categorised into three levels of exposure ("No recent exposures"; "One recent exposure"; "Multiple recent exposures").

Black Summer concerns were assessed at R3 with a set of items developed by the research team specifically for the study. Five items described potential physical or mental health impacts related to the bushfire season (e.g., "Are you or your family currently experiencing any physical health concern as a result of the 2019-2020 bushfire and smoke event?") and respondents indicated to what degree each had concerned them on a 7-point scale (1: "Not at all"; 7: "Extremely"). The Black Summer concerns score is the sum of all items and ranges from 5-35, with a higher score indicating greater concern in relation to the event.

COVID-19 pandemic concerns were assessed at R3 with a set of items developed by the research team specifically for the study. Six items described a potential impact related to the pandemic (e.g., "How lonely are you as a result of the COVID-19 pandemic?") and respondents indicated to what degree each had concerned them on a 7-point scale (1: "Not at all"; 7: "Extremely"). The COVID-19 Pandemic concerns score is the sum of all items and ranges from 6-42, with a higher score indicating greater concern in relation to the event.

3.3.6. Social connectedness

Social support was assessed at R2 and R3 using the Duke Social Support Index (DSSI-11; Koenig et al., 1993). The DSSI-11 comprises eleven items exploring the frequency of various types of social interactions over the preceding week and satisfaction with current social supports (e.g., "Do you know what is going on with your family and friends?"). Following Powers, Goodger, and Byles' (2004) instructions, scores on item 2, item 3, and item 4 of the social interaction subscale were recoded (1: "Hardly ever"; 2: "Some of the time"; 3: "Most of the time") to align with the 3-point scales of the other eight items making up the assessment. The DSSI-11 score is the sum of all items and ranges from 11-33, with a higher score indicating more perceived social support.

Loneliness was assessed at R2 and R3 using the loneliness-focused item of the Center for Epidemiologic Studies Depression Scale (CES-D; Radloff, 1977). The item assesses how frequently a respondent has experienced feelings of loneliness over the preceding week (<1 day: "Rarely"; 1-2 days: "A little of the time"; 3-4 days: "Occasionally"; 5-7 days: "All of the time").

Satisfaction with community was assessed at R2 and R3 with the Community Wellbeing Index (CWI; Forjaz et al., 2011). Each of the ten CWI items (e.g., "How satisfied are you with feeling part of the place where you live?") is scored on a 5-point scale (1: "No satisfaction at all"; 3: "Neutral"; 5: "Completely satisfied"). The CWI comprises three domains. The "Services" domain (four items) measures satisfaction with health and social services, support given to families, and leisure facilities; the "Attachment" domain (three items) measures sense of belonging, safety, and trust in people within the community; and the "Environment" domain (three items) measures satisfaction with the physical environment, social conditions, and economic conditions. A CWI score is the sum of all items and ranges from 10-50, with a higher score indicating greater satisfaction with community.

3.4. Data management

The online survey database used to deliver invitations to participants and to collect data was managed with the web-based application REDCap (Harris et al., 2019; Harris et al., 2009), hosted by Monash University. Data collected via CAWI and CATI were entered directly into the survey database. Paper survey data were manually entered into the survey database by a research team member and their entry cross-checked by another research team member; discrepancies were reviewed and resolved with a third research team member. Data were subject to statistical checks for missing, invalid, inconsistent, or outlying values. Where issues were detected, the research team applied decision rules governing data cleaning. Imputation methods were employed where data was missing after cleaning.

3.5. Statistical analyses

Statistical analyses were performed using Stata version 17 (StataCorp. 2021).

3.5.1. Assessment of response bias

A comparison of characteristics of R2 respondents and R2 non-respondents (see Table A1) indicated that, at R1, responders were on average younger, more educated, more frequently in paid employment, and were less burdened by physical health issues. To address this participation bias into the longitudinal cohort, inverse probability weights were developed using a probit regression model (Chen et al, 2012) predicting survey responses at R2 based on responses at R1. The weights developed for the R1 and R2 data analyses were appropriated in this analysis incorporating R3 data. These weights were applied to all analyses, including descriptive statistics and boxplots. Not all participants who entered into the longitudinal cohort at R2 continued their participation to R3. This loss to follow-up was addressed using linear mixed-effects models with imputation of missing data to maximise the use of information collected at each survey-round.

3.5.2. Descriptive analysis

Categorical variables are presented as counts and weighted percentages; continuous variables are presented as weighted means and weighted standard deviations or, where scoring distributions were skewed, as weighted medians and weighted inter-quartile ranges (IQR). Demographic differences between exposure groups were assessed using weighted Pearson chi-squared tests for categorical variables and weighted analysis of variance (ANOVA) for continuous variables. Data were log-transformed where scoring distributions on continuous variables were heavily skewed. Boxplots were generated to illustrate IES-R scoring distributions within different levels of mine fire-related $PM_{2.5}$ exposure across the survey-rounds. A descriptive summary and boxplots of posttraumatic growth are also presented by levels of IES-R scoring at R1.

3.5.3. Regression modelling

Changes in mine fire-related posttraumatic stress levels over time and associations with mean mine fire-related $PM_{2.5}$ exposure were assessed using linear mixed-effects regression modelling. As mine fire-related posttraumatic stress was assessed over multiple time points, mixed-effects models were used with a participant identifier included as a random intercept in the model to capture individual differences in traumatic experiences, with all other predictors treated as fixed effects in the model. Participants' estimated daily mean level of exposure to mine fire-related $PM_{2.5}$ was included in the models as a continuous variable, scaled by centring at 10 $\mu g/m^3$ and dividing by 10. Time was included in the modelling as a categorical variable defined by survey-round, with R1 as the reference category. The models included "mine fire $PM_{2.5}$ exposure and R2" and "mine fire $PM_{2.5}$ exposure and R3" interaction terms so associations between mean mine fire-related $PM_{2.5}$ exposure and IES-R scores at each survey-round could be derived and change over time assessed. These interaction terms were retained in the modelling regardless of statistical significance. Age at the time of the mine fire was included in regression modelling. Given an interaction between age and exposure had been previously observed at both R1 (Broder et al., 2020) and R2 (Carroll, Campbell et al., 2022), this interaction term was again included and was assumed to be constant across survey-rounds. Age was scaled by centring at the weighted average age and dividing by 10. Models were adjusted for baseline covariates measured at R1, which were sex, education level, employment status, physical health conditions, mental health conditions pre-dating 2014, and number of exposures to other traumatic events.

Regression coefficients represent the mean difference in IES-R score per *x*-unit increase when the covariate was continuous, and the mean difference in IES-R score compared with the nominated reference group when the covariate was categorical. By including the "mine fire $PM_{2.5}$ exposure and age" interaction term, the mine fire $PM_{2.5}$ exposure main effect is interpreted as the estimated exposure effect in R1 at the weighted average age. Interaction effects between mine fire-related $PM_{2.5}$ exposure and R2, and between exposure and R3, estimate the differences in the effect of exposure on IES-R score at each of these time-points compared with the effect at R1. These differences apply for all ages, only the starting point in R1 varies by age. An interaction plot was used to show how IES-R scores predicted by the model varied according to survey-round and mine fire-related $PM_{2.5}$ exposure level. Identical modelling procedures were applied to assess associations between mean mine fire-related $PM_{2.5}$ exposure and each IES-R domain.

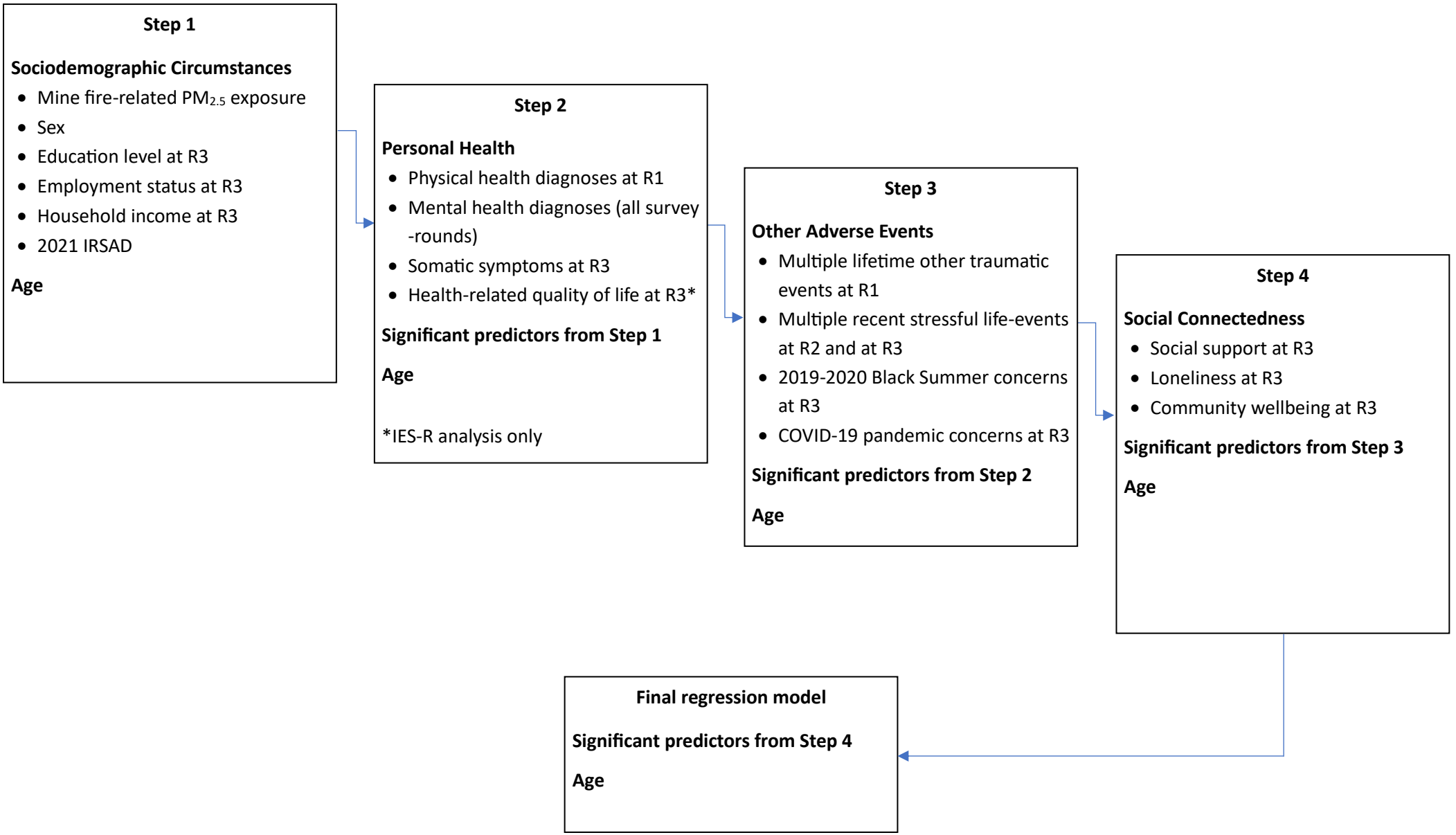
Factors associated with clinically concerning mine fire-related posttraumatic stress at R3 were investigated using a cross-sectional hierarchical logistic regression analysis, which involved grouping risk factors into broad construct groups and introducing them to the model in stepped sequence (see Figure 2). The construct groups were entered into the regression in four steps, with significant risk factors at each step carried into subsequent steps and analysed alongside the next group of risk factors introduced. An exception in this approach was for participant age, which was retained throughout the modelling regardless of statistical significance to account for the age difference between responders and non-responders at R3. The final multivariate model included age and the remaining significant risk factors after completing the four steps. Univariate and multivariate model results are presented as odds ratios (OR) indicating the likelihood of having an IES-R score of clinical concern at R3 for an *x*-unit increase where the risk factor was a continuous variable or, where the risk factor was a categorical variable, in comparison to the nominated reference group.

Changes in general psychological distress over time were assessed using linear mixed-effects regression modelling similar to the models used for analysing change in posttraumatic stress levels. The only difference to the approach in this analysis was that mine fire $PM_{2.5}$ exposure and survey-round were included as main effects only (i.e., a "mine fire $PM_{2.5}$ exposure: within survey-round" interaction term was not included in the model).

Factors associated with general psychological distress at R3 were investigated using the same cross-sectional hierarchical approach used for analysing clinically concerning mine fire-related posttraumatic stress at R3 but with linear regression modelling rather than logistic regression, as K10 at R3 was analysed as a continuous outcome. Model results are presented as mean difference in K10 score per *x*-unit increase for continuous covariates, and mean difference in K10 score compared with the nominated reference group for categorical covariates. The only difference in the construct groups used for this analysis was at Step 2 ("Personal health"), where health-related quality of life (EQ-5D-5L score) was excluded because of its overlap with the general psychological distress construct.

Factors associated with mine fire-related posttraumatic growth at R3 were investigated with a multiple linear regression model limited to participants who completed the PTGI-SF measure at R3. The regression model included baseline covariates measured at R1, which were mine fire-related $PM_{2.5}$ exposure, age during the mine fire, sex, education level, employment status, physical health conditions, mental health conditions pre-dating 2014, and number of exposures to other traumatic events. R2 covariates included in the analysis were social support score, loneliness, and community wellbeing score. Because posttraumatic stress may be a catalyst for posttraumatic growth (Janoff-Bulman, 2004), IES-R score at R1 was included as a predictor in the regression. A descriptive analysis of PTGI-SF measures, categorised by IES-R scoring at R1, was also undertaken.

Figure 2 Hierarchical Approach to Analysis of Clinically Concerning IES-R and K10 Scores at R3



3.5.4. Imputation for missing values

Missing data across the three surveys ranged 0.0-2.0% for demographic variables (except annual gross household income at R3, which was missing for 14.5%) and ranged 2.0-6.3% for the total scores of multi-scaled instruments. To obtain more accurate estimates, multiple-imputation (MI) procedures (Rubin, 1996) using the ICE package (Royston & White, 2011) in conjunction with Stata's inbuilt MI procedures were incorporated in the regression analyses. The imputation was undertaken using chained equations and twenty datasets were imputed. Data were imputed in wide format to account for the longitudinal data structure and transposed back to long format for analysis.

3.5.5. Sensitivity analyses

Sensitivity analyses evaluating the impact of response weighting on estimated effects were conducted using unweighted imputed linear mixed-effects regression modelling for IES-R score and subscale scores, and for K10 score.

3.6. Human Research Ethics Committee approval

The Hazelwood Health Study 2016-2017 Adult Survey protocol was approved by Monash University Human Research Ethics Committee (MUHREC) on 21 May 2015 (project number 6066). The 2019-2020 Mental Health and Wellbeing Follow-up Survey was approved by MUHREC on 16 October 2019 (project number 21151) and the 2022 Mental Health and Wellbeing Follow-up Survey approved by MUHREC on 11 August 2022 (amendment to project number 21151).

4. Results

4.1. Sample description

Table 3 summarises participant characteristics at each survey-round. Sample-wide demographics were relatively stable, with 47% of participants being male and approximately 20% living alone at each survey-round. Across survey-rounds, approximately 50% of participants were in paid employment, while 37% were in unpaid roles or retired and 13% were unemployed or unable to work. The average age of participants was 50.75 years at R1, which progressed to 55.82 years at R3. This five-year progression in age is approximately one year less than the time elapsed between R1 and R3 because those who did not continue their participation beyond R2 (n = 185) were on average three years older than those who did so (t_{707} = 1.96, p = .051). The proportion of the sample with a lifetime mental health diagnosis grew from 35% at R1 to 43% at R3. The proportion of the sample who had experienced a recent stressful life-event was lower at R3 than previously at R2. Average scores on the measures of Black Summer concerns and COVID-19 pandemic concerns were both close to the middle of their respective scoring ranges, indicating participants were typically experiencing moderate levels of concern in response to each event. Levels of social connectedness and satisfaction with community were similar across R2 and R3.

Table 3 Participant Characteristics at Each Survey-Round

	R1 (*n* = 709)	R2 (*n* = 709)	R3 (*n* = 524)
Event exposure			
Mine fire-related $PM_{2.5}$ exposure (μg/m^3)[1]	11.01 (7.79-18.92)	11.01 (7.79-18.92)	11.01 (7.74-18.97)
Sociodemographic circumstances			
Age at survey-round (years)[1]	50.75 (17.80)	54.06 (17.82)	55.82 (17.24)
Male[2]	319 (47%)	319 (47%)	235 (47%)
First Nations heritage[2]	8 (1%)	8 (1%)	4 (1%)
Living alone[2]		121 (19%)	104 (22%)
Education level[2]			
Secondary Year 10 or below	154 (27%)	144 (25%)	119 (27%)
Secondary Year 11 or Year 12	164 (24%)	156 (24%)	121 (24%)
Postsecondary qualification	376 (49%)	393 (52%)	279 (49%)
Employment status[2]			
Paid employment (full-time; part-time; self-employed)	391 (51%)	381 (50%)	279 (50%)
Other (student; volunteer; home-duties; retired)	221 (36%)	229 (37%)	185 (39%)
Unemployed or unable to work	89 (13%)	89 (13%)	57 (11%)
Annual household income[2]			
Below $50,000			200 (45%)
$50,000AU to $99,999			132 (29%)
$100,000 or greater			116 (26%)
Personal health			
Asthma[2]	210 (30%)		
Chronic obstructive pulmonary disease (COPD)[2]	30 (5%)		
A cardiovascular condition[2]	123 (20%)		
Mental health diagnosis[2]	248 (35%)	308 (43%)	248 (47%)
Somatic symptoms (PHQ-15; range: 0-30)[1]		8.32 (6.27)	7.93 (5.85)
Health-related quality of life (EQ-5D-5L; range: -0.301-1.000)[1]			0.84 (0.21)
Other adverse experiences			
Lifetime exposures to other traumatic events[2]			
None	229 (32%)		
One	146 (20%)		
Multiple	330 (48%)		
Recent exposures to stressful life-events[2]			
None		213 (30%)	193 (36%)
One		195 (28%)	147 (29%)
Multiple		284 (42%)	177 (35%)
Black Summer concerns (range: 5-35)[1]			16.37 (8.60)
COVID-19 pandemic concerns (range: 6-42)[1]			22.80 (10.59)
Social connectedness			
Loneliness experienced ≥1 day in the last week[2]		279 (42%)	194 (38%)
Social support (DSSI-11; range: 11-33)[1]		26.10 (4.52)	25.93 (4.49)
Satisfaction with community (CWI; range: 10-50)[1]		29.00 (8.20)	30.05 (8.27)
Mental health and wellbeing outcomes			
Posttraumatic stress (IES-R; range: 0-88)[1]	9.65 (15.03)	12.74 (16.57)	7.79 (13.44)
General psychological distress (K10; range: 0-50)[1]	16.78 (8.13)	18.57 (8.29)	19.49 (9.08)
Posttraumatic growth (PTGI-SF; range: 10-50)[1]			10.83 (11.85)

Notes. Missing data (%): First Nations heritage (0.7); living alone (0.9); education level (1.9); employment status (1.1); annual household income (14.5); asthma (0.3); COPD (0.0); a cardiovascular condition (1.1); mental health diagnosis (0.1); PHQ-15 (2.0); K10 (2.4); EQ-5D-5L (2.5); lifetime traumatic events (0.6); recent stressful life-events (2.0); Black Summer concerns (2.3); COVID-19 pandemic concerns (2.7); PTGI-SF (3.4); loneliness (3.1); DSSI-11 (6.3); CWI (4.9).

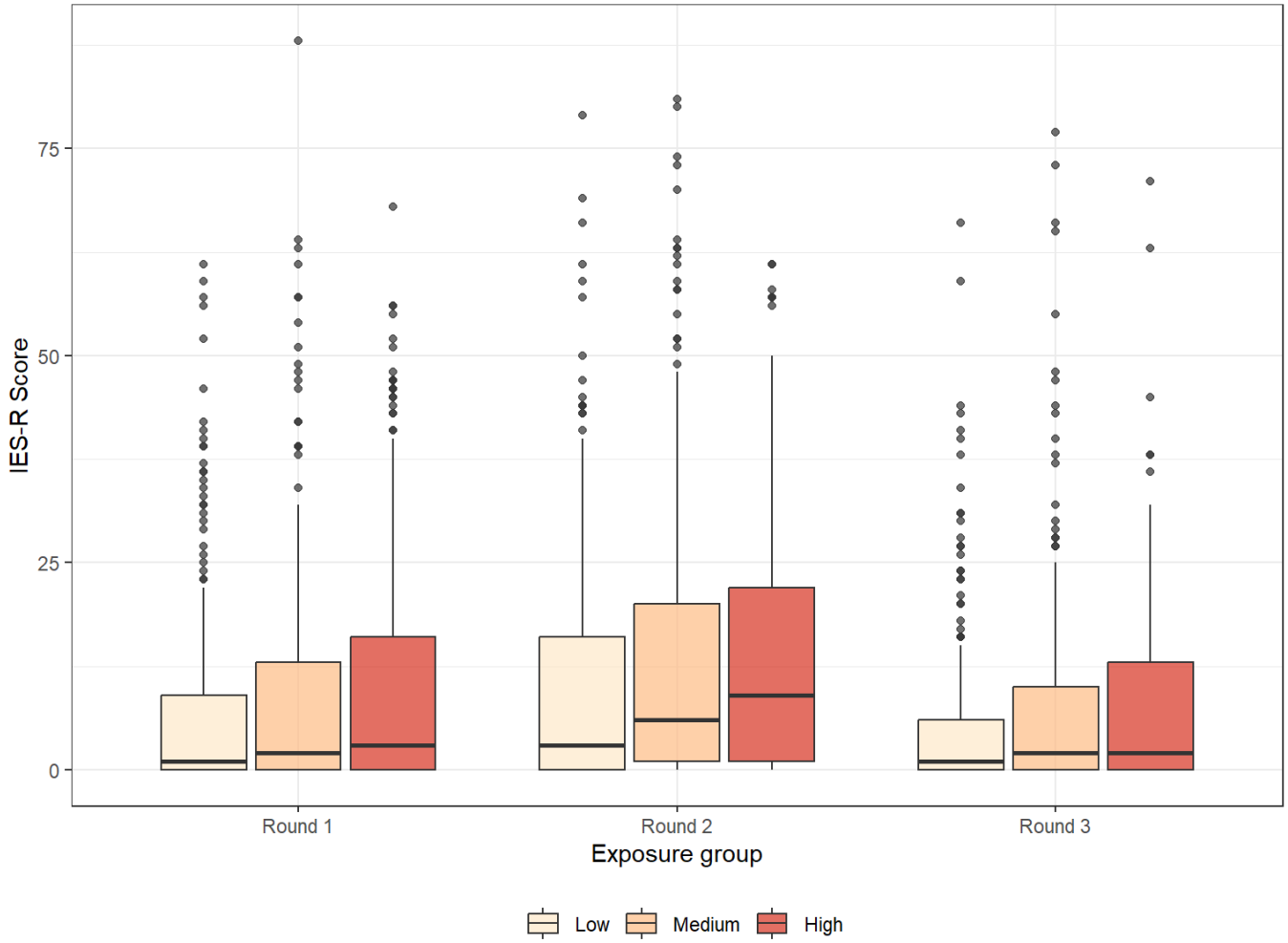
[1] Statistics reported: weighted mean (*SD*).

[2] Statistics reported: *n* (weighted %).

4.2. Changes in posttraumatic stress levels over time

Figure 3 presents the distributions of IES-R scores within mine fire-related $PM_{2.5}$ exposure groups at each survey-round and Table A2 provides accompanying descriptive statistics. Median IES-R scores increased from R1 to R2 and then decreased from R2 to R3 within each mine fire-related $PM_{2.5}$ exposure group and across the sample as a whole. Significant between-group differences in mean or median IES-R scores and Intrusion domain scores were found at both R1 and R2; a between-group difference was also found for the Avoidance domain at R2. However, at R3, there were no longer any between-group differences evident.

Figure 3 Posttraumatic Stress: IES-R Score Distributions at Each Survey-Round by Exposure Group



4.3. Effect of $PM_{2.5}$ exposure on posttraumatic stress levels over time

Table 4 presents the linear mixed-effects regression model results for IES-R score. At R1, for those at the weighted mean age during the mine fire (48.7 years), the main effect of a 10 µg/m^3 increase in mine fire-related $PM_{2.5}$ exposure was a 1.15-point (95% CI: 0.03, 2.27) mean increase in IES-R score. The effect of $PM_{2.5}$ exposure on mine fire-related posttraumatic stress levels was more acute for younger aged participants relative to those who were older; for every 10-year increase in age, the main $PM_{2.5}$ exposure effect reduced by 0.41 points (95% CI: -0.95, 0.13). Although the exposure effect at R1 was age-dependent, the changes over time in the exposure effect, both from R1 to R2 and from R1 to R3, were independent of age. The associations between mine fire-related $PM_{2.5}$ exposure and IES-R score were 0.41 points lower (95% CI: -1.45, 0.62) at R2 and 0.86 points lower (95% CI: -1.82, 0.10) at R3.

Figure 4 presents effects of the interaction between survey-round and mine fire-related $PM_{2.5}$ exposure on predicted IES-R scores, at the weighted mean age during the mine fire. Although the predicted IES-R scores across all $PM_{2.5}$ exposure levels increased at R2 and then decreased at R3, the attenuating strength of association between $PM_{2.5}$ exposure and IES-R score is also evident across the survey-rounds. For a mine fire-related $PM_{2.5}$ exposure level of 10 $\mu g/m^3$, there was a mean increase in IES-R score of 2.83 points (95% CI: 1.37, 4.29) from R1 to R2, and a mean decrease in IES-R score of 1.15 points (95% CI: -2.41, 0.10) from R1 to R3; the IESR-score predicted at R3 was comparable to that predicted at R1 for zero-level exposure to $PM_{2.5}$ during the mine fire.

Table 4 also presents the effects of other sociodemographic and personal health-related factors on mine fire-related posttraumatic stress levels. The baseline covariates associated with higher IES-R scoring over time were: having experienced multiple traumatic events, self-reported diagnosis of COPD, not having a postsecondary education, and being unemployed or unable to work. The interaction effect of mine fire-related $PM_{2.5}$ exposure and age on IES-R score was not significant at R3, in contrast to our previous reporting for R1 (Broder et al., 2020) and R2 (Carroll, Campbell et al., 2022). This reduction in the $PM_{2.5}$ exposure-age effect is predominantly a function of the more general reduction in the exposure effect at R3 at all mine fire-related $PM_{2.5}$ exposure levels.

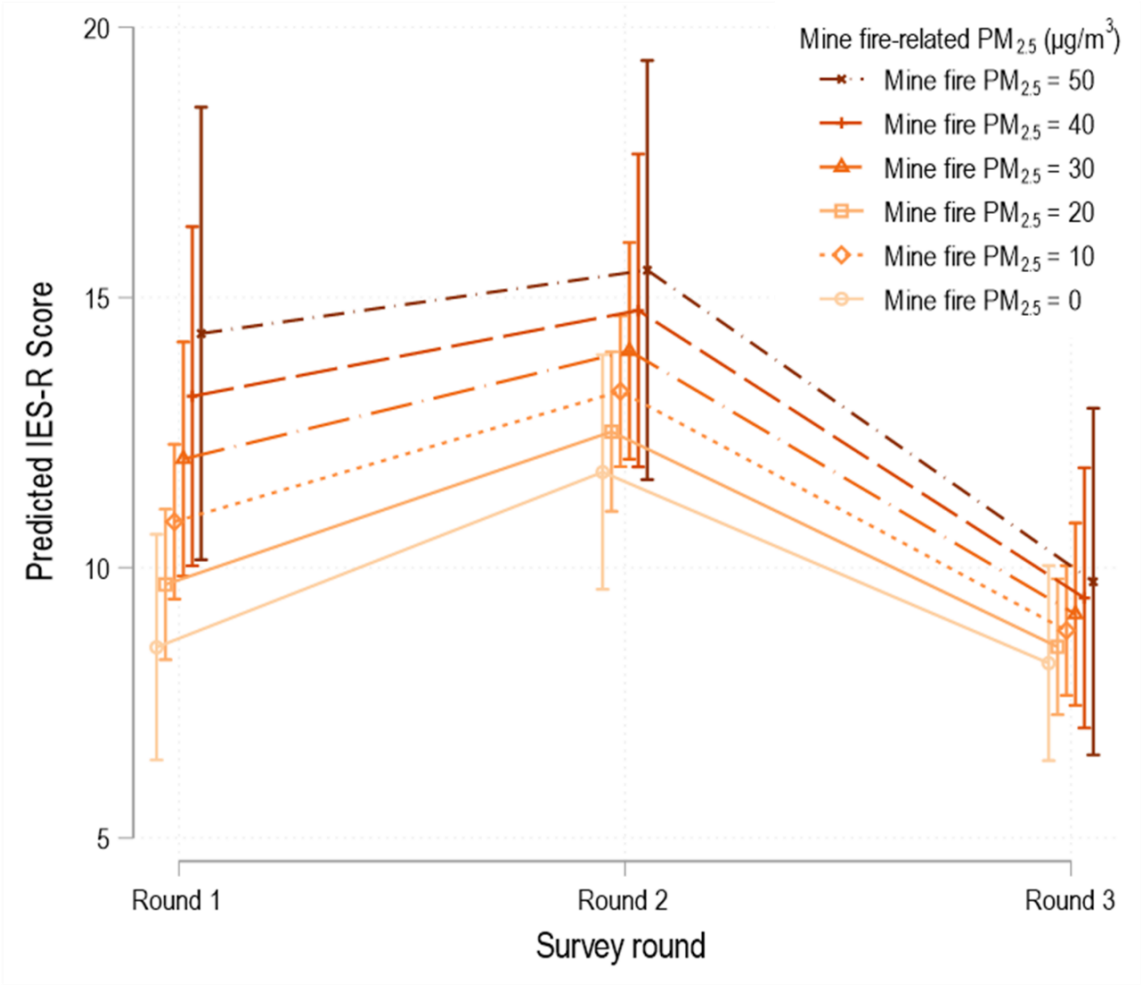
Table 4 Posttraumatic Stress: Linear Mixed-Effects Regression Model for IES-R Score

	Mean difference in IES-R score [95% CI]	***p*-value**
Mean mine fire-related $PM_{2.5}$ (per 10 $\mu g/m^3$ increment)[1]	1.15 [0.03, 2.27]	.045
Survey-round		
R1	*Reference time-point*	
R2	2.83 [1.37, 4.29]	<.001
R3	-1.15 [-2.41, 0.10]	.072
Age (per 10-year increment)[2]	0.29 [-0.60, 1.18]	.522
Interaction: mine fire-related $PM_{2.5}$ and R2	-0.41 [-1.45, 0.62]	.433
Interaction: mine fire-related $PM_{2.5}$ and R3	-0.86 [-1.82, 0.10]	.078
Interaction: mine fire-related $PM_{2.5}$ and age	-0.41 [-0.95, 0.13]	.136
Male	0.31 [-1.65, 2.28]	.755
Education level at R1		
Secondary Year 10 or below	*Reference group*	
Secondary Year 11 or Year 12	-2.45 [-6.00, 1.09]	.175
Postsecondary qualification	-4.66 [-7.55, -1.78]	.002
Employment status at R1		
Paid employment (full-time; part-time; self-employed)	*Reference group*	
Other (student; volunteer; home-duties; retired)	1.22 [-1.61, 4.06]	.396
Unemployed or unable to work	4.75 [1.05, 8.45]	.012
Asthma at R1	1.59 [-0.60, 3.79]	.155
Chronic obstructive pulmonary disease (COPD) at R1	8.01 [1.40, 14.62]	.018
A cardiovascular condition at R1	1.69 [-1.57, 4.94]	.309
Mental health diagnosis prior to the mine fire	1.51 [-0.76, 3.79]	.193
Lifetime exposures to other traumatic events at R1		
None	*Reference group*	
One	1.65 [-0.92, 4.23]	.209
Multiple	4.21 [1.91, 6.52]	<.001

[1] Centred at 10 $\mu g/m^3$.

[2] Centred at weighted mean age

Figure 4 $PM_{2.5}$ Exposure Effect: Predicted IES-R Score at 10 µg/m³ Increments Across Survey-Rounds



4.4. Effect of $PM_{2.5}$ exposure on posttraumatic stress symptom domains over time

Table 5 presents the results of the mixed-effects regression models for the three IES-R posttraumatic stress symptom domains. The effect of mine fire-related $PM_{2.5}$ exposure on IES-R score was largely attributable to an impact within the Intrusion domain. At the weighted average age, a 10 µg/m³ increase in mine fire-related $PM_{2.5}$ exposure was associated with a 0.64-point (95% CI: 0.18, 1.11) increase in mean Intrusion domain score at R1. Compared with the exposure effect at R1, the mine fire-related $PM_{2.5}$ exposure coefficient reduced by 0.30 points (95%CI: -0.72, 0.13) at R2 and by 0.53 points (95%CI: -0.94, -0.12) at R3 respectively. In comparison, mine fire-related $PM_{2.5}$ exposure had a weaker effect on Avoidance and Hyperarousal domain scores at R1. For the Avoidance domain, the $PM_{2.5}$ exposure effect held constant at R2 before attenuating at R3. For the Hyperarousal domain, the $PM_{2.5}$ exposure effect reduced at R2 and remained at that level at R3.

Patterns of change over the three survey-rounds in each of the IES-R domains were generally consistent with that observed for the total IES-R score. For a mine fire-related $PM_{2.5}$ exposure level of 10 µg/m³, there were increases in the mean scores for each IES-R domain at R2. At R3, the mean Intrusion and Hyperarousal domain scores were significantly lower than they each were at R1, while the mean Avoidance domain score was similar to what it was at R1.

Table 5 Posttraumatic Stress: Linear Mixed-Effects Regression Model for IES-R Domain Scores

	IES-R Intrusion domain score		IES-R Avoidance domain score		IES-R Hyperarousal domain score	
	Mean difference [95% CI]	***p*-value**	**Mean difference [95% CI]**	***p*-value**	**Mean difference [95% CI]**	***p*-value**
Mean mine fire-related $PM_{2.5}$ (per 10 µg/m^3 increment)[1]	0.64 [0.18, 1.11]	.006	0.35 [-0.08, 0.78]	.110	0.21 [-0.21, 0.63]	.327
Survey-round						
R1	*Reference time-point*		*Reference time-point*		*Reference time-point*	
R2	1.45 [0.86, 2.04]	<.001	0.82 [0.27, 1.37]	.003	0.74 [0.17, 1.31]	.011
R3	-0.55 [-1.05, -0.05]	.032	-0.04 [-0.53, 0.46]	.888	-0.78 [-1.32, -0.24]	.005
Age (per 10-year increment)[2]	0.13 [-0.22, 0.49]	.465	0.16 [-0.14, 0.47]	.296	-0.01 [-0.36, 0.34]	.946
Interaction: mine fire-related $PM_{2.5}$ and R2	-0.30 [-0.72, 0.13]	.176	0.02 [-0.41, 0.45]	.932	-0.18 [-0.62, 0.26]	.420
Interaction: mine fire-related $PM_{2.5}$ and R3	-0.53 [-0.94, -0.12]	.012	-0.20 [-0.61, 0.21]	.345	-0.19 [-0.59, 0.21]	.359
Interaction: mine fire-related $PM_{2.5}$ and age	-0.19 [-0.41, 0.04]	.101	-0.16 [-0.34, 0.02]	.085	-0.08 [-0.30, 0.13]	.451
Male	0.35 [-0.44, 1.13]	.385	-0.23 [-0.92, 0.46]	.517	0.25 [-0.51, 1.01]	.525
Education level at R1						
Secondary Year 10 or below	*Reference group*		*Reference group*		*Reference group*	
Secondary Year 11 or Year 12	-0.90 [-2.27, 0.47]	.199	-0.81 [-2.04, 0.42]	.197	-0.99 [-2.38, 0.41]	.168
Postsecondary qualification	-1.63 [-2.77, -0.50]	.005	-1.45 [-2.46, -0.45]	.005	-2.11 [-3.24, -0.98]	<.001
Employment status at R1						
Paid employment (full-time; part-time; self-employed)	*Reference group*		*Reference group*		*Reference group*	
Other (student; volunteer; home-duties; retired)	0.58 [-0.55, 1.71]	.315	0.21 [-0.77, 1.18]	.679	0.60 [-0.48, 1.68]	.279
Unemployed or unable to work	1.73 [0.30, 3.16]	.018	1.52 [0.26, 2.78]	.018	2.01 [0.50, 3.53]	.009
Asthma at R1	0.62 [-0.23, 1.47]	.150	0.43 [-0.36, 1.22]	.284	0.70 [-0.16, 1.56]	.110
Chronic obstructive pulmonary disease (COPD) at R1	2.35 [-0.16, 4.86]	.066	2.75 [0.47, 5.02]	.018	3.94 [1.26, 6.61]	.004
A cardiovascular condition at R1	0.82 [-0.46, 2.09]	.211	0.29 [-0.85, 1.43]	.621	0.80 [-0.45, 2.05]	.212
Mental health diagnosis prior to the mine fire	0.66 [-0.22, 1.55]	.142	0.44 [-0.38, 1.27]	.292	0.54 [-0.33, 1.41]	.222
Lifetime exposures to other traumatic events at R1						
None	*Reference group*		*Reference group*		*Reference group*	
One	0.42 [-0.57, 1.42]	.407	0.63 [-0.31, 1.57]	.186	0.79 [-0.19, 1.77]	.113
Multiple	1.61 [0.70, 2.52]	<.001	1.39 [0.57, 2.21]	<.001	1.61 [0.74, 2.49]	<.001

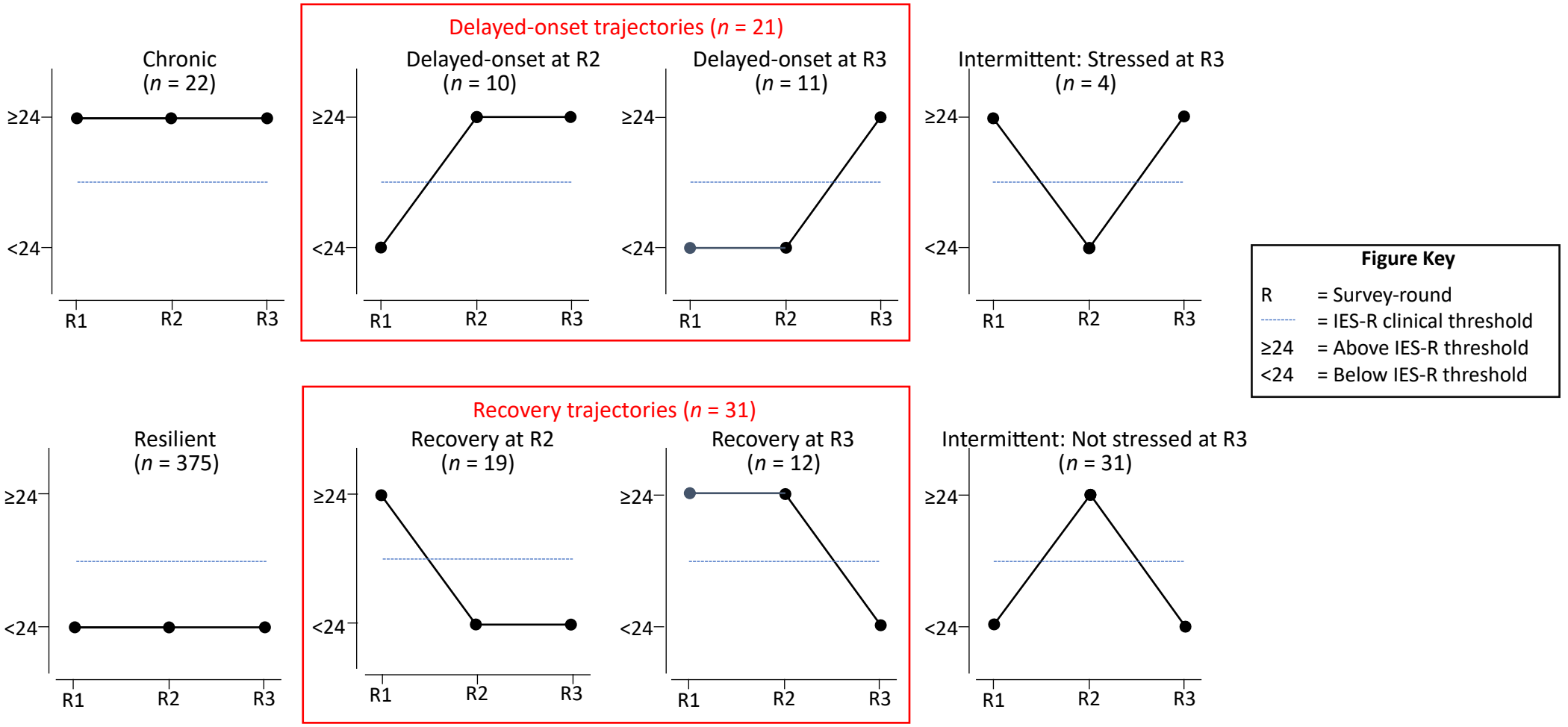
[1] Centred at 10 µg/m^3.

[2] Centred at weighted mean age.

4.5. Trajectories of posttraumatic stress, relative to clinical concern, over time

Figure 5 presents the numbers of participants in each of the eight possible trajectories of mine fire-related posttraumatic stress response, relative to the IES-R threshold ≥24 for clinical concern, spanning the three survey-rounds. Across the 484 participants who provided complete IES-R data for each survey-round, 77% recorded subclinical IES-R scores at all three time-points (resilient trajectory) and 5% recorded clinically concerning IES-R scores at all three time-points (chronic trajectory). Recovery trajectories were apparent in 6% of participants and delayed-onset trajectories were apparent in 4% of participants. The remaining 7% of participants displayed intermittent trajectories, of which the large majority recorded a single clinically concerning IES-R score at R2 bookended by subclinical IES-R scores at R1 and R3. Overall, 23% of participants who completed the longitudinal study recorded an IES-R score exceeding the threshold for clinical concern at some point.

Figure 5 Posttraumatic Stress: Long-Term Trajectories Relative to the IES-R Threshold for Clinical Concern



4.6. Factors associated with clinically concerning posttraumatic stress at R3

Table 6 presents univariate and multivariate logistic regression results where clinically concerning mine fire-related posttraumatic stress at R3 was the outcome of interest; Table A3 presents the results at each hierarchical step preceding the final multivariate analysis. In the univariate analysis, clinically concerning IES-R scores at R3 were associated with the majority of risk factors investigated, with mine fire-related $PM_{2.5}$ exposure, sex, and asthma diagnosis being the exceptions. In the multivariate analysis, three dominant risk factors for clinically concerning IES-R scores at R3 were identified. Annual incomes below $50,000 increased the odds of a clinically concerning IES-R score at R3 by 238% (95% CI: 62%, 604%), an *SD* increase in Black Summer concerns score increased the odds of a clinically concerning IES-R score at R3 by 222% (95% CI: 82%, 470%), and an *SD* increase in somatic symptoms (PHQ-15) score increased the odds of a clinically concerning IES-R score at R3 by 85% (95% CI: 27%, 169%).

Table 6 Posttraumatic Stress: Associations Between Risk Factors and Clinically Concerning IES-R Score at R3

	Univariate regression analysis		**Multivariate regression analysis**	
	OR for IES-R score ≥24 at R3 [95% CI]	***p*-value**	**Adjusted OR for IES-R score ≥24 at R3 [95% CI]**	***p*-value**
Mean mine fire-related $PM_{2.5}$ (per 10 µg/m^3 increment)[1]	0.97 [0.75, 1.26]	.822		
Age (per 10-year increment)[2]	1.19 [1.01, 1.41]	.035	1.10 [0.89, 1.36]	.382
Male	1.13 [0.65, 1.97]	.670		
Postsecondary education at R3	0.52 [0.28, 0.95]	.034		
Unemployed or unable to work at R3	2.07 [0.97, 4.42]	.060		
2021 IRSAD score (per 100-point increment)	0.71 [0.53, 0.94]	.016		
Annual household income below $50,000 at R3	4.38 (2.27, 8.45)	<.001	3.38 [1.62, 7.04]	.001
Asthma at R1	0.99 [0.54, 1.81]	.975		
Chronic obstructive pulmonary disease (COPD) at R1	3.55 [1.16, 10.92]	.027		
A cardiovascular condition at R1	3.07 [1.59, 5.95]	<.001		
Mental health diagnosis (any survey-round)	1.90 [1.02, 3.52]	.043		
Somatic symptoms score at R3 (per *SD* increment)	3.17 [2.36, 4.26]	<.001	1.85 [1.27, 2.69]	.001
Health-related quality of life score at R3 (per 0.2-point increment)	0.61 [0.49, 0.75]	<.001		
Multiple exposures to other traumatic events at R1	2.70 [1.44, 5.09]	.002		
Multiple exposures to recent stressful life-events at R2	3.05 [1.69, 5.52]	<.001		
Multiple exposures to recent stressful life-events at R3	2.30 [1.26, 4.22]	.007		
Black Summer concerns score at R3 (per *SD* increment)	4.42 [2.67, 7.32]	<.001	3.22 [1.82, 5.70]	<.001
COVID-19 pandemic concerns score at R3 (per *SD* increment)	3.64 [2.36, 5.61]	<.001		
Loneliness experienced ≥1 day in last week at R3	3.49 [1.83, 6.63]	<.001		
Social support score at R3 (per *SD* increment)	0.73 [0.54, 0.98]	.034		
Community wellbeing score at R3 (per *SD* increment)	0.63 [0.45, 0.89]	.009		

[1] Centred at 10 µg/m^3.

[2] Centred at weighted mean age

4.7. Changes in general psychological distress levels over time

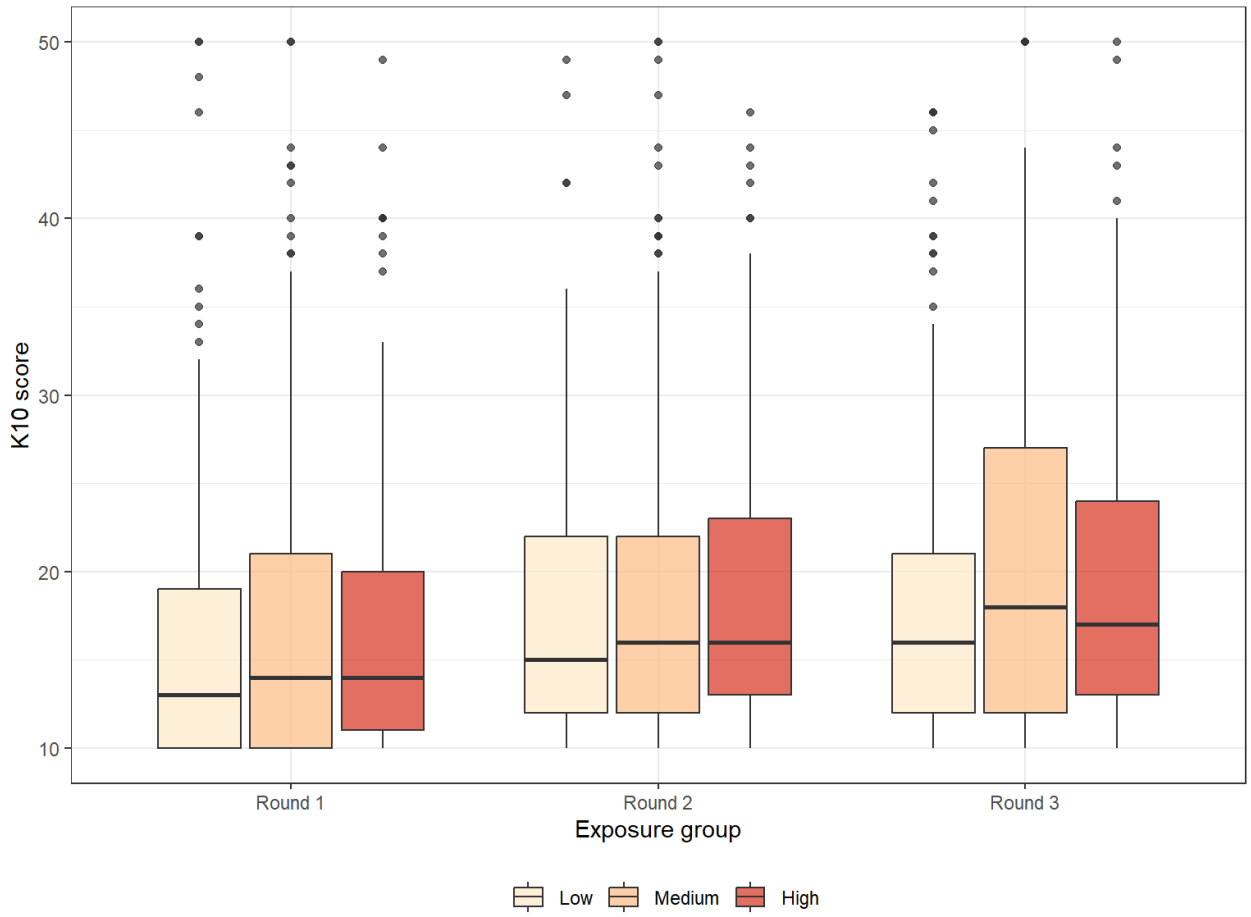
Table 7 presents mean and median K10 scores across mine fire-related $PM_{2.5}$ exposure groups at each survey-round; Figure 6 presents boxplots where K10 score distributions by mine fire-related $PM_{2.5}$ exposure group at each survey-round are compared. There were no statistically significant differences between mine fire-related $PM_{2.5}$ exposure groups in relation to K10 score across survey-rounds. However, a cohort-wide trend of progressively increasing K10 scores across time was evident. All mean K10 scores placed within the moderate psychological distress band.

Table 7 General Psychological Distress: K10 Scores at Each Survey-Round Categorised by Exposure Group

	Cohort	Low exposure	Medium exposure	High exposure	*p*-value
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	
R1	16.78 (8.13)	16.04 (8.02)	17.42 (8.75)	16.90 (7.54)	.254
R2	18.57 (8.29)	17.83 (7.95)	18.88 (8.70)	19.01 (8.18)	.274
R3	19.49 (9.08)	18.30 (8.50)	20.54 (9.75)	19.59 (8.50)	.098
	Mdn [IQR]	**Mdn [IQR]**	**Mdn [IQR]**	**Mdn [IQR]**	
R1	14 [11, 20]	13 [10, 19]	14 [10, 21]	14 [11, 20]	.196
R2	16 [12, 23]	15 [12, 22]	16 [12, 22]	16 [13, 23]	.251
R3	17 [12, 24]	16 [12, 21]	18 [12, 27]	17 [13, 24]	.105

Notes. Missing data: K10 item missingness ranged 0.7-1.1% at R1, 1.8-2.7% at R2, and 1.9-2.5% at R3; K10 score missing for 2.0% at R1, 2.7% at R2, and 2.5% at R3.

Figure 6 General Psychological Distress: K10 Score Distributions at Each Survey-Round by Exposure Group



4.8. Factors associated with general psychological distress at R3

Table 8 presents results of the linear mixed-effects regression model assessing longitudinal changes in K10 scores. In comparison with the mean score at R1, there was a mean increase of 1.80 points in K10 score at R2 (95% CI: 1.18, 2.42) which further grew to a mean increase of 2.85 points at R3 (95% CI: 2.16, 3.53). K10 score was not associated with mine fire-related $PM_{2.5}$ exposure, but was associated with most other baseline covariates included in the model. Being unemployed or unable to work, having a physical diagnosis (asthma, COPD, or a cardiovascular condition), having a prior mental health diagnosis, or having a lifetime exposure to other traumatic events were all associated with higher K10 scoring. Greater age and postsecondary educational qualifications were each protective in relation to K10 scoring.

Table 8 General Psychological Distress: Linear Mixed-Effects Regression Model for K10 Score

	Mean difference in K10 score [95% CI]	***p*-value**
Mean mine fire-related $PM_{2.5}$ (per 10 µg/m^3 increment)[1]	0.09 [-0.35, 0.54]	.676
Survey-round		
R1	*Reference time-point*	
R2	1.80 [1.18, 2.42]	<.001
R3	2.85 [2.16, 3.53]	<.001
Age (per 10-year increment)[2]	-0.96 [-1.37, -0.54]	<.001
Male	-0.62 [-1.58, 0.34]	.205
Education level at R1		
Secondary Year 10 or below	*Reference group*	
Secondary Year 11 or Year 12	-1.34 [-2.95, 0.28]	.104
Postsecondary qualification	-2.20 [-3.56, -0.83]	.002
Employment status at R1		
Paid employment (full-time; part-time; self-employed)	*Reference group*	
Other (student; volunteer; home-duties; retired)	0.56 [-0.70, 1.82]	.381
Unemployed or unable to work	4.45 [2.42, 6.47]	<.001
Asthma at R1	1.21 [0.09, 2.33]	.035
Chronic obstructive pulmonary disease (COPD) at R1	3.73 [1.02, 6.45]	.007
A cardiovascular condition at R1	1.47 [0.01, 2.93]	.049
Mental health diagnosis prior to the mine fire	4.19 [3.02, 5.36]	<.001
Lifetime exposures to other traumatic events at R1		
None	*Reference group*	
One	2.51 [1.16, 3.86]	<.001
Multiple	3.37 [2.25, 4.48]	<.001

[1] Centred at 10 µg/m^3.
[2] Centred at weighted mean age.

Table 9 presents univariate and multivariate linear regression results where general psychological distress at R3 was the outcome of interest; Table A4 presents the results at each hierarchical step preceding the final multivariate analysis. In the univariate analysis, the majority of risk factors investigated were associated with higher K10 scores at R3, with mine fire-related $PM_{2.5}$ exposure, postsecondary education, IRSAD, and diagnosis of a cardiac condition being the exceptions. Having a COPD diagnosis was estimated to increase K10 score at R3 by 6.25 points, however, a limitation to this particular result is that the small number of participants with COPD is likely to have influenced the significance test. In the multivariate analysis, six risk factors were associated with higher K10 scores at R3 and two factors were identified as protective. Risk factors for higher K10 scores at R3 were having an annual household income below $50,000, having a mental health diagnosis, a greater presence of somatic symptoms, exposure to multiple recent stressful life-events at R3, greater concern in relation to the COVID-19 pandemic, and experiencing loneliness. Age and social support were protective factors in relation to K10 score at R3.

Table 9 General Psychological Distress: Associations Between Risk Factors and K10 Score at R3

	Univariate regression analysis		Multivariate regression analysis	
	Mean difference in K10 score at R3 [95% CI]	***p*-value**	**Adjusted mean difference in K10 score at R3 [95% CI]**	***p*-value**
Mean mine fire-related $PM_{2.5}$ (per 10 µg/m^3 increment)[1]	-0.16 [-0.96, 0.63]	.688		
Age (per 10-year increment)[2]	-0.98 [-1.45, -0.50]	<.001	-0.80 [-1.14, -0.46]	<.001
Male	-1.88 [-3.50, -0.27]	.022		
Postsecondary education at R3	-0.73 [-2.37, 0.91]	.380		
Unemployed or unable to work at R3	8.50 [5.47, 11.54]	<.001		
2021 IRSAD score (per 100-point increment)	-0.76 [-1.63, 0.11]	.087		
Annual household income below $50,000 at R3	2.68 [0.98, 4.39]	.002	1.33 [0.22, 2.43]	.019
Asthma at R1	1.93 [0.00, 3.87]	.050		
Chronic obstructive pulmonary disease (COPD) at R1	6.25 [-0.70, 13.21]	.078		
A cardiovascular condition at R1	0.80 [-1.46, 3.06]	.488		
Mental health diagnosis (any survey-round)	7.41 [5.84, 8.98]	<.001	2.15 [1.09, 3.22]	<.001
Somatic symptoms score at R3 (per *SD* increment)	6.30 [5.61, 6.99]	<.001	3.75 [2.95, 4.56]	<.001
Multiple exposures to other traumatic events at R1	3.67 [2.02, 5.31]	<.001		
Multiple exposures to recent stressful life-events at R2	3.66 [2.09, 5.24]	<.001		
Multiple exposures to recent stressful life-events at R3	6.52 [4.71, 8.32]	<.001	1.68 [0.48, 2.88]	.006
Black Summer concerns score at R3 (per *SD* increment)	4.19 [3.36, 5.02]	<.001		
COVID-19 pandemic concerns score at R3 (per *SD* increment)	5.00 [4.29, 5.72]	<.001	1.20 [0.53, 1.88]	<.001
Loneliness experienced ≥1 day in last week at R3	9.92 [8.31, 11.54]	<.001	3.42 [1.99, 4.85]	<.001
Social support score at R3 (per *SD* increment)	-4.27 [-5.12, -3.42]	<.001	-1.43 [-2.11, -0.76]	<.001
Community wellbeing score at R3 (per *SD* increment)	-2.30 [-3.23, -1.37]	<.001		

[1] Centred at 10 µg/m^3.

[2] Centred at weighted mean age

4.9. Posttraumatic growth at R3

Table 10 presents summary statistics for PTGI-SF score and domain scores at R3 grouped by IES-R scoring at R1; Figure 7 presents boxplots where PTGI-SF mean item-scores by IES-R scoring group at R1 are compared. Across all PTGI domains, the mean item-score increased in correspondence with IES-R score at R1; however, even in the highest IES-R scoring group (those with a mine fire-related posttraumatic stress level of clinical concern at R1), the median PTGI-SF mean item-score was 2.2 (IQR: 1.0, 3.0) indicating that, overall across the sample, the degree of posttraumatic growth in response to the mine fire was small to moderate. PTGI-SF domains with the highest mean item-scores were Appreciation of Life and Personal Strength. Over 25% of participants in the IES-R ≥24 group had a mean item-score of at least 4.0 for the Appreciation of Life and Relating to Others domains.

Table 11 presents results of the regression analysis where mine fire-related posttraumatic growth was the outcome of interest. Covariates associated with PTGI-SF scores were IES-R score at R1 and loneliness at R2. An *SD* increment in IES-R score at R1 was associated with a mean increase in PTGI-SF score of 3.99 points (95% CI: 2.88, 5.10). The PTGI-SF scores of participants experiencing loneliness at R2 was, on average, 4.30 points (95% CI: 1.87, 6.73) higher. The estimated mean increase in PTGI-SF score for participants with a COPD diagnosis was 3.36 points; however, due to the small number of participants in the sample with the condition, the confidence interval for this particular result was wide (95% CI: -1.63, 8.35).

Table 10 Posttraumatic Growth: PTGI-SF Mean Item-Scores at R3 Grouped by IES-R Score at R1

	IES-R = 0 *n* = 192	IES-R = 1-10 *n* = 189	IES-R = 11-23 *n* = 63	IES-R ≥24 *n* = 60	*p*-value
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	
PTGI-SF total score	0.68 (1.03)	0.98 (1.06)	1.40 (1.17)	2.20 (1.28)	<.001
Relating to Others domain score	0.89 (1.32)	1.14 (1.33)	1.71 (1.50)	2.24 (1.61)	<.001
New Possibilities domain score	0.66 (1.18)	0.86 (1.21)	1.31 (1.35)	2.12 (1.53)	<.001
Personal Strength domain score	0.79 (1.31)	1.20 (1.45)	1.53 (1.46)	2.53 (1.41)	<.001
Spiritual Change domain score	0.32 (0.81)	0.52 (1.00)	0.64 (1.07)	1.39 (1.46)	<.001
Appreciation of Life domain score	0.81 (1.23)	1.14 (1.25)	1.84 (1.44)	2.78 (1.46)	<.001
	Mdn [IQR]	**Mdn [IQR]**	**Mdn [IQR]**	**Mdn [IQR]**	
PTGI-SF total score	0.1 [0.0, 1.0]	0.6 [0.1, 1.6]	1.2 [0.4, 1.9]	2.2 [1.0, 3.0]	<.001
Relating to Others domain score	0.0 [0.0, 1.5]	0.5 [0.0, 2.0]	1.0 [0.5, 3.0]	2.0 [1.0, 4.0]	<.001
New Possibilities domain score	0.0 [0.0, 1.0]	0.0 [0.0, 1.5]	1.0 [0.0, 2.0]	2.0 [1.0, 3.0]	<.001
Personal Strength domain score	0.0 [0.0, 1.5]	0.5 [0.0, 2.0]	1.0 [0.0, 2.5]	3.0 [1.0, 3.5]	<.001
Spiritual Change domain score	0.0 [0.0, 0.0]	0.0 [0.0, 0.5]	0.0 [0.0, 1.0]	1.0 [0.0, 2.5]	<.001
Appreciation of Life domain score	0.0 [0.0, 1.5]	1.0 [0.0, 2.0]	1.5 [0.5, 3.0]	3.0 [1.5, 4.0]	<.001

Notes. Missing data: Missingness ranged 0.8-2.3% across the individual items comprising the PTGI-SF; the resultant missing values for the five PTGI-SF domain scores ranged 1.2-2.3% and was 3.4% for PTGI-SF total score. IES-R score at R1 was missing for 3.8% of R3 participants.

Figure 7 Posttraumatic Growth: Box-Plots of PTGI-SF Mean Item-Score Distributions at R3 by IES-R Scoring at R1

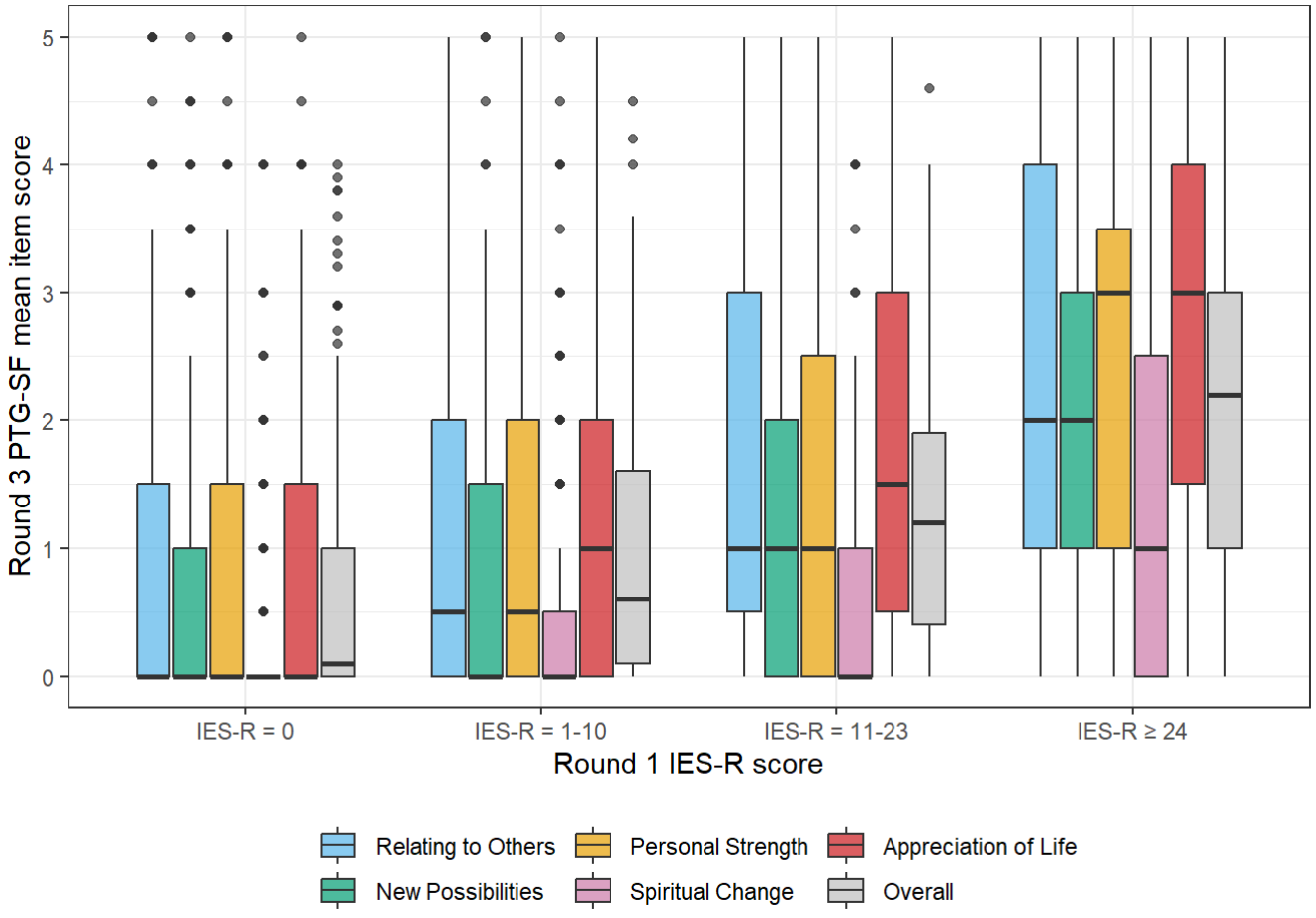


Table 11 Posttraumatic Growth: Linear Regression Model for PTGI-SF Score

	Mean difference in PTGI-SF score [95% CI]	***p*-value**
IES-R score at R1 (per *SD* increment)	3.99 [2.88, 5.10]	<.001
Mean mine fire-related $PM_{2.5}$ (per 10 µg/m^3 increment)[1]	-0.24 [-1.02, 0.55]	.556
Age (per 10-year increment)[2]	0.33 [-0.38, 1.04]	.357
Male	-1.65 [-3.62, 0.33]	.101
Education level at R1		
Secondary Year 10 or below	*Reference group*	
Secondary Year 11 or Year 12	-0.56 [-3.58, 2.45]	.713
Postsecondary qualification	-1.23 [-3.94, 1.49]	.375
Employment status at R1		
Paid employment (full-time; part-time; self-employed)	*Reference group*	
Other (student; volunteer; home-duties; retired)	-0.38 [-2.81, 2.05]	.757
Unemployed or unable to work	-1.19 [-4.74, 2.37]	.512
Asthma at R1	-0.78 [-2.89, 1.33]	.467
Chronic obstructive pulmonary disease (COPD) at R1	3.36 [-1.63, 8.35]	.186
A cardiovascular condition at R1	0.17 [-2.49, 2.83]	.900
Mental health diagnosis prior to the mine fire	-0.51 [-2.76, 1.74]	.655
Lifetime exposures to other traumatic events at R1		
None	*Reference group*	
One	-0.54 [-3.01, 1.93]	.667
Multiple	1.63 [-0.62, 3.87]	.155
Social support score at R1 (per *SD* increment)	1.08 [-0.06, 2.22]	.063
Loneliness experienced ≥1 day in last week at R2	4.30 [1.87, 6.73]	<.001
Community wellbeing score at R2 (per *SD* increment)	0.08 [-1.05, 1.20]	.894

[1] Centred at 10 µg/m^3.
[2] Centred at weighted mean age.

4.10. Sensitivity analyses

Table A5 presents the sensitivity analysis comparing unweighted regression results with the weighted regression results of the primary IES-R score analysis. All regression coefficients in the unweighted analysis were in the same direction as those in the weighted analysis. The magnitude of effect in the unweighted analysis was marginally higher for both the mine fire-related $PM_{2.5}$ exposure and survey-round coefficients, and was marginally lower for the cardiovascular condition coefficient. Coefficients for all other factors were similar across the two analyses. Table A6 presents the sensitivity analysis comparing unweighted regression results with the weighted regression results of the primary K10 score analysis. The regression coefficients in the unweighted analysis were all similar to the corresponding coefficients in the weighted analysis, suggesting the main results for K10 score were not impacted by weighting. Overall, the sensitivity analyses aligned with the main analyses and further support the findings arrived at in the study.

5.Discussion

5.1. Posttraumatic stress in Morwell after the mine fire

In 2022, some 8.5 years after the mine fire, the average level of posttraumatic stress in specific response to the event had markedly dissipated from levels previously observed in 2016-2017 and 2019-2020. However, a notable feature in the longitudinal data is the non-linear progression of the average mine fire-related posttraumatic stress level across that span of time. There was an increase in average posttraumatic stress levels, consistent across all levels of smoke exposure, between R1 and R2, which was followed by a considerable drop between R2 and R3. The spike in posttraumatic stress at R2 was likely triggered by the Black Summer bushfire season, which overlapped with the R2 data collection period (Carroll, Campbell et al., 2022). There is theoretical support for this explanation. For instance, McFarlane (2010) has posited that a potential consequence of trauma is subsequent stress sensitivity that may be stimulated during events that reprise elements of that experience. This would typically be most apparent in the context of environmental stimuli that resemble or echo some central or salient elements of the original traumatic experience. In this regard, the extreme hot weather, heavy smoke cover, emergency services activity, and associated media content that engulfed Morwell and the wider region during the 2019-2020 Black Summer bushfire season was reminiscent of environmental and social conditions during the 2014 Hazelwood mine fire. Furthermore, the mine fire-related posttraumatic stress observed in the cohort was primarily driven by impacts within the Intrusion symptom domain. The Black Summer event likely served as a reminder of the Hazelwood mine fire, potentially prompting flashbacks to it. This assertion is further supported by the finding that a greater level of concern in relation to Black Summer was one of the strongest predictors of posttraumatic stress at R3. Accordingly, the results of the study infer that stress sensitivity in relation to fire and smoke events may be a longer-term psychological outcome of the mine fire for some people who lived through the Hazelwood mine fire.

Analyses previously undertaken after R1 (Broder et al., 2020) and after R2 (Carroll, Campbell et al., 2022) indicated the effect of smoke exposure on posttraumatic stress levels was most acute among those adults who were youngest in the cohort and that the exposure effect tapered with increasing age. However, in the present study, with R3 data now added to the modelling, the interaction between age and exposure was no longer statistically significant. This suggests that, 8.5 years after the mine fire, the moderating effect of age on the association between smoke exposure and mine fire-related posttraumatic stress had become negligible. This is likely because of the general decrease in posttraumatic stress across all age groups by R3. Across all survey-rounds, the main socioeconomic risk factor for greater levels of mine fire-related posttraumatic stress was being unemployed or unable to work. Conversely, having a postsecondary educational qualification was a significant protective factor against posttraumatic stress. The main health and wellbeing risk factors for greater levels of posttraumatic stress were COPD diagnosis, and having been exposed to two or more previous potentially traumatic experiences.

A focus of the study was to investigate clinically concerning mine fire-related posttraumatic stress over the longer term. The proportions of the cohort on resilient (77%), recovery (6%), delayed-onset (4%), and chronic (5%) trajectories were largely consistent with a recent review, which calculated the average proportions across 54 studies of posttraumatic stress trajectories (Galatzer-Levy et al., 2018). However, the proportion of the current cohort in the resilient group was higher than that observed in the Galatzer-Levy and colleagues' review (77% vs 66%), suggesting the mine fire may have been less impactful relative to most other disasters and traumatic events that have been studied. Furthermore, the longitudinal design of the study enabled us to identify intermittent trajectories of mine fire-related posttraumatic stress (7% of the cohort), which have been given limited research attention to date but are important for understanding the nature of how people respond to potentially traumatic events over long timeframes. The analysis of longitudinal posttraumatic stress responses indicated that, although a considerable majority of participants were on a consistent resilient trajectory, one in four had experienced clinically concerning mine fire-related posttraumatic stress at some stage over the 8.5-year study period. Notably, within the cohort the next most prevalent trajectory was an intermittent course characterised by a clinically concerning IES-R score at R2 during the Black Summer bushfire season in between recording subclinical IES-R scores at R1 and R3. This is, again, suggestive of a stress sensitivity resulting from the mine

fire, which was subsequently activated by the Black Summer bushfire season. It is also possible that the Black Summer bushfire season may be implicated in the prevalence of other posttraumatic stress trajectories. For instance, it can be reasonably argued that the Black Summer bushfire season potentially triggered some of the cases of delayed-onset posttraumatic stress and may have extended the timeline to reaching recovery in other cases.

The dominant risk factors for clinically concerning mine fire-related posttraumatic stress at R3 were having an annual income below $50,000, having a relatively greater level of concern in relation to the 2019-2020 Black Summer bushfire season, and the presence of somatic symptomology. Accordingly, these findings demonstrate that after a potentially traumatic event, sociodemographic factors and subsequent exposure to a similar event can be critical determinants of concerning levels of posttraumatic stress in the longer-term; in the case of the Hazelwood mine fire, these factors were more relevant to long-term posttraumatic stress outcomes than levels of smoke exposure during the event itself.

5.2. General psychological distress in Morwell after the mine fire

General psychological distress levels steadily increased over the 8.5 years after the mine fire with the mean K10 score increasing 2.71 points (2.85 adjusted) from R1 to R3. The average K10 score at R3 (19.49) places the study participants in the moderate psychological distress band according to Australian Bureau of Statistics (ABS, 2012) cut-offs. This study also identified numerous risk factors associated with longitudinal changes in general psychological distress, which included being younger aged, unemployed or being unable to work, lower-level education, having a physical or mental health diagnosis, and having experienced multiple traumatic events. These associations are not surprising as they are consistent with observations in other Australian-based research (see Enticott et al., 2015; Isaacs et al., 2018) and overlap with the risk factors identified for mine fire-related posttraumatic stress in the present study. Furthermore, it is well recognised that the Latrobe Valley has some of the highest rates of unemployment and poor health relative to neighbouring regions of Victoria (Duffy & Whyte, 2017; Weller, 2017).

While there was a clear association between level of smoke exposure during the event and levels of general psychological distress across the wider cohort at R1 (Blackman et al., 2018), the R3 analysis is consistent with the earlier R2 analysis (Carroll, Campbell et al., 2022) in finding that that there was no longer any association between smoke exposure and general psychological distress. It is also evident that the longitudinal courses of general psychological distress and mine fire-related posttraumatic stress diverged at R3, with mine fire-related posttraumatic stress decreasing while general psychological distress continued to increase. This suggests that other stressors besides the 2014 Hazelwood mine fire have been impacting on the mental health of Morwell residents over the longitudinal course of the study. There have been several significant events in the Latrobe Valley region during the study's timeframe that are likely contributors to this outcome. These include the expedited decommissioning of the Hazelwood power station, one of the largest employers in the community, in 2017, along with the subsequent closures of other industries that had operated in the region, the Black Summer bushfire season that had catastrophic impacts in nearby parts of Victoria in 2019-2020, and, from 2020 onwards, the profound health, social, and economic repercussions of the COVID-19 pandemic. It may be that these events in combination with pre-existing socioeconomic disadvantage in Morwell have, over time, had a compounding negative impact on the mental health of people living in Morwell in particular. The cross-sectional analysis of general psychological distress at R3 provided the opportunity to assess a number of these potential risk factors, with COVID-19 pandemic concerns, prior mental health conditions, loneliness and lack of social support, exposures to multiple recent stressful life-events such as job loss, and low annual household incomes found to be significant drivers of higher K10 scores at this latest time-point. Comparisons between K10 levels reported for this cohort and those in National Health Survey data (ABS, 2022) also collected in 2022 suggest that Morwell might be facing particular challenges, with the cohort mean K10 score (19.49) being higher than scores observed for both the wider Latrobe Valley (16.7) and the adjacent, but less exposed, Wellington Shire (14.4).

5.3. Posttraumatic growth in Morwell after the mine fire

Participant responses at R3 suggested that there had been a small to moderate degree of posttraumatic growth across the cohort in the aftermath of the mine fire. Higher levels of mine fire-related posttraumatic growth were typically reported by those who also reported the highest levels of mine fire-related posttraumatic stress, though the between-group differences were small. However, whilst mine fire-related posttraumatic growth was associated with posttraumatic stress, posttraumatic growth was not associated with levels of smoke exposure during the event. Furthermore, in contrast to the numerous sociodemographic predictors identified for posttraumatic stress and general psychological distress, the only predictor found for posttraumatic growth at R3 was the experience of loneliness one or more days of the week at R2, with higher levels of loneliness at R2 associated with greater posttraumatic growth at R3, 2.5 years later.

A low amount of mine fire-related posttraumatic growth across the cohort does not suggest inhibited progress and should not necessarily be interpreted as an undesirable outcome or cause for concern. For instance, as previously discussed, a large majority of participants in the study were on a psychologically resilient trajectory in response to their exposure to the mine fire. Furthermore, it has been theorised (see Janoff-Bulman, 2004; Westphal & Bonanno, 2007) and observed in other research (see Dekel et al., 2012) that people who consistently reported being largely psychologically unaffected by an event have low impetus for posttraumatic growth. Accordingly, the small to moderate amount of mine fire-related posttraumatic growth observed may reflect that the 2014 Hazelwood mine fire, which did not involve immediate catastrophic harms to life or damage to personal property, was a relatively moderate-intensity trauma exposure within the broad spectrum of potentially traumatic events that people may encounter.

5.4. Implications of the research

As time has passed since the mine fire, the amount of smoke each individual was exposed to has become less central to the psychological impact the event had on them. The results of this study also clearly signal that sociodemographic circumstances have become the integral determinants of who in the community has been more acutely susceptible to poorer mental health outcomes in the longer-term aftermath of the event. Together these findings give direction to where emergency, health, and social support services are particularly needed during and after an event such as the mine fire. In Morwell, those efforts should continue to focus on improving prospects for employment, income, and health. Looking forwards, similar supports and initiatives could be targeted at communities likely to be exposed to future disaster events to foster pre-disaster resilience. This could afford community members better levels of personal security and mobility to cope during and after an event like the mine fire.

While it might be reasonable to anticipate that trajectories of mental health in response to disaster will generally track towards improvement over the longer-term, that trend will, in reality, be shaped and potentially interrupted by subsequent events, circumstances, and experiences, including other disasters. A somewhat unique aspect to this particular longitudinal study is that it captured data on posttraumatic stress responses in the context of a disaster somewhat reminiscent of the original disaster under investigation. The 2019-2020 Black Summer bushfire season appeared to have a marked effect on posttraumatic stress associated specifically with the preceding mine fire, exacerbating some people's symptoms and potentially triggering symptoms for the first time in others. Emergency, health, and social support services should recognise the potential for compounded mental health impacts and sensitivities in communities subject to repeated disaster events – in this study, large-scale fire and smoke events – and prepare accordingly. It is imperative that emergency planning take into consideration a community's recent history of exposure to disaster and the implications that particular history has for mental health needs in such events. This recommendation has similar application within the context of mental health care practice, where screening for other previous disaster exposures could contribute to enhancing post-disaster counselling and therapy. It should also be recognised that in some cases, posttraumatic stress symptoms take years to become apparent and posttraumatic stress symptoms might only become outwardly apparent within the context of a comparable event. This suggests that mental health care responses to disaster should adopt a longer-term outlook and services be more widely offered to better meet the needs of people who may be at risk of delayed-onset or intermittent posttraumatic stress symptoms.

Promoting greater awareness of the longer-term timeframes that mental health impacts can present after disaster, as well as the risk factors that underlie vulnerability to longer-term impacts, could also be beneficial.

When results of the respective longitudinal and cross-sectional analyses of mine fire-related posttraumatic stress and of general psychological distress are brought together, contrasting factors appear to underlie the distinct directions of these two kinds of stress in Morwell after the mine fire. Mine fire-related posttraumatic stress was longitudinally associated with smoke exposure during the mine fire and clinically concerning mine fire-related posttraumatic stress at R3 was exclusively associated with Black Summer concerns (which likely acted as a reminder of the earlier Hazelwood smoke event). In contrast, general psychological distress was not longitudinally associated with smoke exposure during the mine fire and, in the cross-sectional analysis examining general distress at R3, was exclusively associated with COVID-19 pandemic concerns. This suggests that the sample-wide courses of these two kinds of stress have diverged over time. This indicates that the longitudinal increase in general psychological distress in Morwell is not directly attributable to the mine fire. Further investigation is needed to shed better light on the reasons underlying this longer-term deterioration in general psychological distress in Morwell, which in turn could provide a foundation for developing an action-plan to reverse this trend in the community.

5.5. Strengths and weaknesses of the research

This study has a number of methodological strengths, as well as recognised limitations. The longitudinal study design is of particular value as it facilitates the exploration of causal pathways within associations detected between variables that have been measured at different time-points. The present study is among only a few that have implemented a longitudinal design reaching beyond eight years to investigate posttraumatic stress and posttraumatic growth outcomes after disaster (e.g., Bryant et al., 2021; Grace et al., 1993; McFarlane & Van Hoolf, 2009; Holgersen et al., 2011).

The high response rates demonstrate the ongoing interest and commitment to understanding the long-term health outcomes of the event that exist in the community. Furthermore, the high response rates at each survey-round contributed to maintaining the representativeness of the sample and capturing the diversity of experiences and mental health and wellbeing outcomes in the community. However, as identified within the analysis, participants in the eldest age-group of the cohort were less likely to progress their participation to R3 compared with younger participants. The age difference between responders and non-responders at R3 may reflect natural age-related attrition due to later life-stage health issues and mortality reducing ability or availability to participate; this phenomenon is common in research spanning large timeframes (Chatfield et al., 2005). Alternatively, it could also reflect a response bias. For instance, previous survey-round analyses indicated younger participants were more acutely impacted, which therefore may have meant younger-age participants had greater personal motivations to participate compared with those who were older.

Another key strength is that, in contrast to utilising population-level exposure data which is common in air pollution research, the study generated individual-level exposure data, which enabled a much more precise exploration of the relationship between smoke exposure and health and wellbeing outcomes. Whilst the psychometric properties of most instruments administered in the study are well-established, the psychometric properties of the instruments used to measure participant's Black Summer concerns and COVID-19 pandemic concerns, which were developed specifically for the purposes of this study, were not previously established. Accordingly, results and conclusions in specific relation to Black Summer concerns and COVID-19 pandemic concerns should be considered with appropriate care. More generally, self-reported health data are recognised to have a variety of practical limitations that introduce potential for response biases (Baker et al., 2004). Finally, weighted sampling in R2 and response weighting within the statistical analyses contribute to mitigating the influence of selection and participation biases. Nevertheless, there is still some potential for biases to be present even with these safeguards applied.

5.6. Conclusions

Overall, the improvement in mine fire-related posttraumatic stress levels at R3 is encouraging and suggests that, in general, people across all levels of exposure to smoke during the 2014 Hazelwood mine fire have been able to adaptively process their experiences and move forward. This is complimented by indications that those who were most psychologically affected by the event also typically reported the most posttraumatic growth in relation to it. However, across 8.5 years of periodic inquiry, around one in four Morwell residents experienced clinical-level symptoms of posttraumatic stress in response to the mine fire at some point. Importantly, the significant spike in mine fire-related posttraumatic stress measured during the 2019-2020 Black Summer bushfire season, and association between clinically concerning mine fire-related posttraumatic stress levels and self-reported concerns regarding Black Summer, is a strong indication that a stress sensitivity in relation to fire events has developed in this community. It is clear that prospects for good mental health after the mine fire have been primarily shaped by personal circumstances. In this regard, the study shows that, consistent across time, Morwell residents living with socioeconomic disadvantages have typically experienced poorer mental health as an outcome of the mine fire compared with those in more stable circumstances. The implications of socioeconomic disadvantage for mental health in Morwell also holds true more generally. Whilst overall levels of posttraumatic stress in response to the mine fire have reduced substantially in 2022 compared with previous years, general psychological distress in Morwell has steadily increased over time and is approaching a level considered high. This incremental rise in general psychological distress likely reflects an accumulation of challenges, the mine fire among them, that have been adversely affecting the local region. Further research is needed to better understand this concerning increase in general psychological distress in Morwell and to develop evidence-based responses to address it.

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7. Appendices

Table A1 Participant Characteristics: R2 Responders Compared with R2 Non-Responders

	Unweighted comparison			Weighted comparison (derived response weights)		
	R2 responders	**R2 non-responders**		**R2 responders**	**R2 non-responders**	
Factors measured at R1	***n* = 709**	***n* = 803**	***p*-value**	***n* = 709**	***n* = 803**	***p*-value**
Age during the mine fire (years)[1]	46.94 (17.05)	50.89 (19.03)	<.001	48.73 (17.87)	50.89 (19.03)	.035
Male[2]	319 (45%)	387 (48%)	.199	319 (47%)	387 (48%)	.741
Mean mine fire-related $PM_{2.5}$[1]	14.78 (10.94)	15.03 (11.02)	.693	14.93 (11.02)	15.03 (11.02)	.875
Married or de facto relationship[2]	429 (61%)	463 (58%)	.277	429 (59%)	463 (58%)	.677
Employment[2]						
Paid employment (full-time; part-time; self-employed)	391 (56%)	373 (47%)	.005	391 (51%)	373 (47%)	.453
Other (student; volunteer; home-duties; retired)	221 (32%)	305 (39%)		221 (36%)	305 (39%)	
Unemployed or unable to work	89 (13%)	110 (14%)		89 (13%)	110 (14%)	
Education level[2]						
Secondary Year 10 or below	154 (22%)	245 (31%)	<.001	154 (27%)	245 (31%)	.097
Secondary Year 11 or Year 12	164 (24%)	207 (26%)		164 (24%)	207 (26%)	
Postsecondary qualification	376 (54%)	339 (43%)		376 (49%)	339 (43%)	
Self-reported general health status[2]						
Excellent or very good	303 (43%)	298 (37%)	.053	303 (40%)	298 (37%)	.596
Good	239 (34%)	276 (35%)		239 (34%)	276 (35%)	
Fair or poor	166 (23%)	224 (28%)		166 (26%)	224 (28%)	
Smoking status[2]						
Current smoker	107 (15%)	161 (20%)	.011	107 (18%)	161 (20%)	.52
Former smoker	183 (26%)	226 (29%)		183 (27%)	226 (29%)	
Occasional smoker	17 (2%)	18 (2%)		17 (2%)	18 (2%)	
Never smokes	399 (57%)	381 (48%)		399 (52%)	381 (48%)	
Alcohol consumption (AUDIT-C score)[2]						
Non-drinker	158 (23%)	204 (27%)	.010	158 (25%)	204 (27%)	.383
Low-risk drinker	286 (41%)	254 (33%)		286 (37%)	254 (33%)	
High-risk drinker	249 (36%)	301 (40%)		249 (38%)	301 (40%)	
2021 IRSAD score[1]	867.17 (97.16)	860.39 (91.83)	.185	862.88 (98.29)	860.39 (91.83)	.634

[1] Statistics reported: weighted mean (*SD*).
[2] Statistics reported: *n* (weighted %).

Table A2 Posttraumatic Stress: IES-R Scores and Domain Scores at Each Survey-Round by Exposure Group

		Cohort	Low exposure	Medium exposure	High exposure	
		***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***p*-value**
R1	IES-R score	9.65 (15.03)	7.66 (13.31)	10.12 (15.83)	11.25 (15.67)	.052
	Intrusion domain score	3.91 (5.90)	3.00 (5.07)	4.05 (6.13)	4.73 (6.34)	.009
	Avoidance domain score	3.41 (5.58)	2.69 (4.81)	3.62 (5.98)	3.94 (5.82)	.069
	Hyperarousal domain score	3.50 (6.21)	3.11 (6.11)	3.57 (6.18)	3.85 (6.39)	.552
		Mdn [IQR]	**Mdn [IQR]**	**Mdn [IQR]**	**Mdn [IQR]**	***p*-value**
	IES-R score	2 [0, 13]	1 [0, 9]	2 [0, 13]	3 [0, 16]	.024
	Intrusion domain score	1 [0, 6]	1 [0, 4]	1 [0, 7]	2 [0, 7]	.007
	Avoidance domain score	0 [0, 5]	0 [0, 4]	0 [0, 5]	1 [0, 6]	.060
	Hyperarousal domain score	0.0 [0.0, 4.0]	0.0 [0.0, 2.7]	0.0 [0.0, 4.0]	0.0 [0.0, 5.3]	.295
		***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***p*-value**
R2	IES-R score	12.74 (16.57)	10.64 (15.83)	13.98 (18.55)	13.63 (14.79)	.083
	Intrusion domain score	5.35 (6.70)	4.41 (6.32)	5.87 (7.45)	5.79 (6.14)	.040
	Avoidance domain score	4.36 (5.82)	3.56 (5.50)	4.68 (6.45)	4.86 (5.32)	.043
	Hyperarousal domain score	4.16 (6.62)	3.67 (6.30)	4.70 (7.39)	4.11 (6.03)	.340
		Mdn [IQR]	**Mdn [IQR]**	**Mdn [IQR]**	**Mdn [IQR]**	***p*-value**
	IES-R score	6 [0, 19]	3 [0, 16]	6 [1, 20]	9 [1, 22]	.007
	Intrusion domain score	3 [0, 8]	1 [0, 6]	3 [0, 8]	4 [0, 10]	.008
	Avoidance domain score	2 [0, 7]	1 [0, 5]	1 [0, 7]	3 [0, 8]	.008
	Hyperarousal domain score	0.0 [0.0, 7.0]	0.0 [0.0, 5.3]	1.3 [0.0, 6.7]	1.3 [0.0, 6.7]	.227
		***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***p*-value**
R3	IES-R score	7.79 (13.44)	6.33 (11.94)	9.08 (15.46)	7.93 (12.29)	.205
	Intrusion domain score	3.02 (5.27)	2.48 (4.68)	3.44 (6.04)	3.14 (4.88)	.263
	Avoidance domain score	3.11 (5.12)	2.49 (4.67)	3.49 (5.58)	3.35 (4.98)	.165
	Hyperarousal domain score	2.31 (4.92)	1.84 (4.38)	2.83 (5.86)	2.24 (4.24)	.246
		Mdn [IQR]	**Mdn [IQR]**	**Mdn [IQR]**	**Mdn [IQR]**	***p*-value**
	IES-R score	1 [0, 10]	1 [0, 6]	2 [0, 10]	2 [0, 13]	.121
	Intrusion domain score	0 [0, 4]	0 [0, 2]	0 [0, 4]	1 [0, 5]	.216
	Avoidance domain score	0 [0, 5]	0 [0, 3]	0 [0, 5]	0 [0, 6]	.083
	Hyperarousal domain score	0.0 [0.0, 2.7]	0.0 [0.0, 1.3]	0.0 [0.0, 2.7]	0.0 [0.0, 2.7]	.221

Notes. Missing data: IES-R item missingness ranged 0.6-1.7% at R1, 0.0-1.1% at R2, 0.2-0.8% at R3; IES-R score missing for 4.5% at R1, 3.1% at R2, 1.7% at R3; Intrusion domain score missing for 3.0% at R1, 1.4% at R2, 1.0% at R3; Avoidance domain score missing for 3.7% at R1, 2.5% at R2, 1.0% at R3; Hyperarousal domain score missing for 1.8% at R1, 1.3% at R2, 0.4% at R3. Statistics presented are weighted mean (*SD*) and weighted median [IQR]. Statistical tests performed: weighted ANOVA when mean (*SD*) is reported and weighted ANOVA with log-transformed outcome when median [IQR] is reported. Hyperarousal domain scores were scaled to facilitate direct comparisons with the Intrusion and Avoidance domain scores; hence, median Hyperarousal domain scores are presented to one decimal place.

Table A3 Posttraumatic Stress: Hierarchical Logistic Regression Model for Clinically Concerning IES-R Score at R3

	Set 1 Sociodemographic circumstances		Set 2 Personal health		Set 3 Other adverse events		Set 4 Social connectedness	
	OR for IES-R score ≥24 at R3 [95% CI]	***p*-value**	**OR for IES-R score ≥24 at R3 [95% CI]**	***p*-value**	**OR for IES-R score ≥24 at R3 [95% CI]**	***p*-value**	**OR for IES-R score ≥24 at R3 [95% CI]**	***p*-value**
Mean mine fire-related $PM_{2.5}$ (per 10 µg/m^3 increment)[1]	0.91 [0.70, 1.17]	.462						
Age (per 10-year increment)[2]	1.02 [0.84, 1.24]	.849	1.10 [0.89, 1.36]	.387	1.11 [0.89, 1.38]	.372	1.11 [0.89, 1.39]	.334
Male	1.18 [0.66, 2.14]	.573						
Postsecondary education at R3	0.77 [0.40, 1.47]	.430						
Unemployed or unable to work at R3	1.50 [0.61, 3.68]	.372						
2021 IRSAD score (per 100-point increment)	0.92 [0.67, 1.27]	.623						
Annual household income below $50,000 at R3	3.65 [1.72, 7.76]	<.001	2.91 [1.35, 6.29]	.007	3.24 [1.55, 6.79]	.002	3.41 [1.57, 7.41]	.002
Asthma at R1			0.74 [0.36, 1.53]	.418				
Chronic obstructive pulmonary disease (COPD) at R1			1.06 [0.30, 3.76]	.931				
A cardiovascular condition at R1			1.51 [0.77, 2.98]	.233				
Mental health diagnosis (any survey-round)			1.21 [0.59, 2.46]	.603				
Somatic symptoms score at R3 (per *SD* increment; at R3)[3]			3.25 [2.10, 5.02]	<.001	1.63 [1.11, 2.40]	.013	1.74 [1.16, 2.62]	.008
Health-related quality of life score at R3 (per 0.2-point increment)			1.13 [0.81, 1.58]	.479				
Multiple exposures to other traumatic events at R1					1.40 [0.66, 2.99]	.377		
Multiple exposures to recent stressful life-events at R2					1.34 [0.64, 2.77]	.435		
Multiple exposures to recent stressful life-events at R3					0.81 [0.39, 1.68]	.572		
Black Summer concerns score at R3 (per *SD* increment)[3]					2.47 [1.27, 4.81]	.008	3.08 [1.72, 5.51]	<.001
COVID-19 pandemic concerns score at R3 (per *SD* increment)[3]					1.71 [0.84, 3.50]	.142		
Loneliness experienced ≥1 day of last week at R3							1.47 [0.65, 3.36]	.355
Social support score at R3 (per *SD* increment)[3]							1.14 [0.80, 1.63]	.455
Community wellbeing score at R3 (per *SD* increment)[3]							0.79 [0.54, 1.16]	.229

[1] Centred at 10 µg/m^3.
[2] Centred at mean age.
[3] Standardised scores.

Table A4 General Psychological Distress: Hierarchical Linear Regression Model for K10 Score at R3

	Set 1 Sociodemographic circumstances		Set 2 Personal health		Set 3 Other adverse events		Set 4 Social connectedness	
	Mean difference in K10 score at R3 [95% CI]	*p*-value	Mean difference in K10 score at R3 [95% CI]	*p*-value	Mean difference in K10 score at R3 [95% CI]	*p*-value	Mean difference in K10 score at R3 [95% CI]	*p*-value
Mean mine fire-related $PM_{2.5}$ (per 10 µg/m^3 increment)[1]	-0.22 [-0.93, 0.48]	.539						
Age (per 10-year increment)[2]	-1.30 [-1.87, -0.72]	<.001	-1.06 [-1.46, -0.65]	<.001	-1.09 [-1.46, -0.73]	<.001	-0.81 [-1.15, -0.47]	<.001
Male	-1.12 [-2.60, 0.36]	.137						
Postsecondary education at R3	-0.58 [-2.18, 1.01]	.472						
Unemployed or unable to work at R3	6.14 [3.01, 9.28]	<.001	1.43 [-0.99, 3.86]	.246				
2021 IRSAD score (per 100-point increment)	-0.12 [-1.00, 0.76]	.786						
Annual household income below $50,000 at R3	3.71 [1.74, 5.68]	<.001	1.87 [0.61, 3.13]	.004	2.08 [0.88, 3.29]	<.001	1.30 [0.19, 2.41]	.021
Asthma at R1			-0.20 [-1.39, 1.00]	.744				
Chronic obstructive pulmonary disease (COPD) at R1			2.90 [-1.06, 6.86]	.151				
A cardiovascular condition at R1			-1.09 [-2.68, 0.51]	.181				
Mental health diagnosis (any survey-round)			3.20 [2.06, 4.35]	<.001	3.04 [1.92, 4.16]	<.001	2.16 [1.09, 3.22]	<.001
Somatic symptoms score at R3 (per *SD* increment)[3]			5.53 [4.89, 6.18]	<.001	4.20 [3.36, 5.05]	<.001	3.78 [2.98, 4.59]	<.001
Multiple exposures to other traumatic events at R1					0.46 [-0.66, 1.57]	.424		
Multiple exposures to recent stressful life-events at R2					-0.05 [-1.17, 1.07]	.936		
Multiple exposures to recent stressful life-events at R3					1.68 [0.36, 3.00]	.013	1.70 [0.50, 2.90]	.006
Black Summer concerns score at R3 (per *SD* increment)[3]					0.19 [-0.57, 0.94]	.627		
COVID-19 pandemic concerns score at R3 (per *SD* increment)[3]					1.68 [0.90, 2.47]	<.001	1.20 [0.53, 1.87]	<.001
Loneliness experienced ≥1 day of last week at R3							3.44 [2.00, 4.87]	<.001
Social support score at R3 (per *SD* increment)[3]							-1.47 [-2.15, -0.79]	<.001
Community wellbeing score at R3 (per *SD* increment)[3]							0.17 [-0.37, 0.71]	.530

[1] Centred at 10 µg/m^3.
[2] Centred at mean age.
[3] Standardised scores.

Table A5 Sensitivity Analysis: Weighted and Unweighted Linear Mixed-Effects Regression Models for IES-R Score

	Weighted results		Unweighted results	
	Mean difference in IES-R score [95% CI]	***p*-value**	**Mean difference in IES-R score [95% CI]**	***p*-value**
Mean mine fire-related $PM_{2.5}$ (per 10 µg/m^3 increment)[1]	1.15 [0.03, 2.27]	.045	1.33 [0.24, 2.41]	.017
Survey-round				
R1	*Reference time-point*		*Reference time-point*	
R2	2.83 [1.37, 4.29]	<.001	2.94 [1.68, 4.20]	<.001
R3	-1.15 [-2.41, 0.10]	.072	-0.91 [-2.05, 0.23]	.118
Age (per 10-year increment)[2]	0.29 [-0.60, 1.18]	.522	0.43 [-0.40, 1.27]	.307
Interaction: Mine fire-related $PM_{2.5}$ and R2	-0.41 [-1.45, 0.62]	.433	-0.54 [-1.51, 0.43]	.273
Interaction: Mine fire-related $PM_{2.5}$ and R3	-0.86 [-1.82, 0.10]	.078	-1.06 [-1.97, -0.16]	.022
Interaction: mine fire-related $PM_{2.5}$ and age	-0.41 [-0.95, 0.13]	.136	-0.39 [-0.89, 0.12]	.131
Male	0.31 [-1.65, 2.28]	.755	0.14 [-1.67, 1.94]	.880
Education level at R1				
Secondary Year 10 or below	*Reference group*		*Reference group*	
Secondary Year 11 or Year 12	-2.45 [-6.00, 1.09]	.175	-2.37 [-5.78, 1.03]	.172
Postsecondary qualification	-4.66 [-7.55, -1.78]	.002	-4.51 [-7.34, -1.69]	.002
Employment status at R1				
Paid employment (full-time; part-time; self-employed)	*Reference group*		*Reference group*	
Other (student; volunteer; home-duties; retired)	1.22 [-1.61, 4.06]	.396	0.92 [-1.73, 3.57]	.495
Unemployed or unable to work	4.75 [1.05, 8.45]	.012	4.80 [1.26, 8.33]	.008
Asthma at R1	1.59 [-0.60, 3.79]	.155	1.13 [-0.89, 3.14]	.273
Chronic obstructive pulmonary disease (COPD) at R1	8.01 [1.40, 14.62]	.018	8.52 [1.91, 15.12]	.011
A cardiovascular condition at R1	1.69 [-1.57, 4.94]	.309	0.97 [-1.90, 3.84]	.508
Mental health diagnosis prior to the mine fire	1.51 [-0.76, 3.79]	.193	1.76 [-0.29, 3.81]	.093
Lifetime exposures to other traumatic events at R1				
None	*Reference group*		*Reference group*	
One	1.65 [-0.92, 4.23]	.209	1.33 [-1.00, 3.67]	.263
Multiple	4.21 [1.91, 6.52]	<.001	3.78 [1.63, 5.93]	<.001

[1] Centred at 10 µg/m^3.

[2] Centred at mean age.

Table A6 Sensitivity Analysis: Weighted and Unweighted Linear Mixed-Effects Regression Models for K10 Score

	Weighted results		Unweighted results	
	Mean difference in K10 score [95% CI]	***p*-value**	**Mean difference in K10 score [95% CI]**	***p*-value**
Mean mine fire-related $PM_{2.5}$ (per 10 µg/m^3 increment)[1]	0.09 [-0.35, 0.54]	.676	0.16 [-0.27, 0.58]	0.471
Survey-round				
R1	*Reference time-point*		*Reference time-point*	
R2	1.80 [1.18, 2.42]	<.001	1.80 [1.25, 2.35]	<0.001
R3	2.85 [2.16, 3.53]	<.001	2.89 [2.28, 3.49]	<0.001
Age (per 10-year increment)[2]	-0.96 [-1.37, -0.54]	<.001	-0.97 [-1.37, -0.58]	<0.001
Male	-0.62 [-1.58, 0.34]	.205	-0.49 [-1.41, 0.43]	0.300
Education level at R1				
Secondary Year 10 or below	*Reference group*		*Reference group*	
Secondary Year 11 or Year 12	-1.34 [-2.95, 0.28]	.104	-1.46 [-3.06, 0.13]	0.072
Postsecondary qualification	-2.20 [-3.56, -0.83]	.002	-2.21 [-3.58, -0.85]	0.001
Employment status at R1				
Paid employment (full-time; part-time; self-employed)	*Reference group*		*Reference group*	
Other (student; volunteer; home-duties; retired)	0.56 [-0.70, 1.82]	.381	0.53 [-0.68, 1.75]	0.389
Unemployed or unable to work	4.45 [2.42, 6.47]	<.001	4.33 [2.42, 6.23]	<0.001
Asthma at R1	1.21 [0.09, 2.33]	.035	0.98 [-0.10,2.06]	0.074
Chronic obstructive pulmonary disease (COPD) at R1	3.73 [1.02, 6.45]	.007	3.89 [1.05,6.73]	0.007
A cardiovascular condition at R1	1.47 [0.01, 2.93]	.049	1.08 [-0.32,2.48]	0.129
Mental health diagnosis prior to the mine fire	4.19 [3.02, 5.36]	<.001	4.43 [3.32, 5.54]	<0.001
Lifetime exposures to other traumatic events at R1				
None	*Reference group*		*Reference group*	
One	2.51 [1.16, 3.86]	<.001	2.52 [1.22, 3.82]	<0.001
Multiple	3.37 [2.25, 4.48]	<.001	3.28 [2.21, 4.35]	<0.001

[1] Centred at 10 µg/m^3.

[2] Centred at mean age.

8. Document History

Version number	Date approved	Approved by	Brief description
1.0	13 August 2024	Senior Project Manager	Submitted to Department of Health