The Impact of a Mine Fire and Smoke Event on Academic Outcomes for Primary and Secondary School Students

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Author Notes:

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Abstract

This study explored how exposure to a mine fire and smoke event influenced students' academic outcomes. National Assessment Program - Literacy and Numeracy scores for 303 students (aged 7.8-16.2 years) were obtained, along with self-reported event-related distress (Children's Revised Impact of Events Scale [CRIES-13]). The longitudinal analysis found that adolescent students from more exposed schools, and not younger children, had delayed academic development after the event (14.9 months delay in year 7 (95% CI: 9.4 to 20.5) and 21.5 months in year 9 (95% CI: 13.6 to 29.5). Increased distress (CRIES-13) was not associated with academic delays. Results have implications for understanding the impact of disasters on adolescent school achievement and how educational institutions might respond to reduce this impact.

Key words: academic outcomes, NAPLAN, mine fire, smoke, posttraumatic stress, students, CRIES-13

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There is a clear relationship between adversity and learning outcomes for children. Children who experience interpersonal trauma, such as maltreatment, neglect, or abuse, have lower standardised test scores, IQ scores, executive functioning, school engagement, and school completion, along with greater rates of school suspension, and year level repetition (Beers & De Bellis, 2002; Boden, Horwood, & Fergusson, 2007; Perfect, Turley, Carlson, Yohanna, & Saint Gilles, 2016; Romano, Babchishin, Marquis, & Fréchette, 2015; Saltzman, Weems, & Carrion, 2006). Exposure to disasters and community violence (e.g. natural disasters, war, terrorism) is also linked to academic challenges in children (Elbert et al., 2009; Husain, Allwood, & Bell, 2008; Perez-Pereira, Tinajero, Rodriguez, Peralbo, & Sabucedo, 2012; Perfect et al., 2016; Siriwardhana, Pannala, Siribaddana, Sumathipala, & Stewart, 2013). However, in general, research in this area has been limited to retrospective measurement of educational outcomes and limited consideration of psychological correlates of childhood trauma and school performance (Boden et al., 2007; Slade & Wissow, 2007).

Research on the relationship between exposure to a community-wide traumatic event and academic outcomes has been somewhat contradictory to date. Strøm, Schultz, Wentzel-Larsen, and Dyb (2016) found student academic performance was lower and absenteeism higher in the year following a terrorist attack in Norway. However, Deprince, Weinzierl, and Combs (2009) reported that academic performance and school satisfaction improved between two assessments one and two years following a traumatic event, suggesting that impacts on children's academic performance may only be short-term. In a study of the Prestige oil spill disaster on the Galician coast of Spain (involving no home destruction or recorded deaths), Perez-Pereira et al. (2012) reported that adolescents aged 15 to16 years living in a more heavily

polluted area had lower academic achievement when assessed one-year after the event. However, no such relationship was observed in pre-school or primary school aged children.

In Australia, Gibbs et al. (2019) found, four years after the 'Black Saturday' bushfires, that higher levels of bushfire impact (i.e. children attending schools and living in communities most impacted by the fires) were associated with delays in academic performance. Counter intuitively, Smilde-van den Doel, Smit, and Wolleswinkel-van den Bosch (2006) found improvements in school performance of Dutch children following a fireworks disaster in the Netherlands. The authors speculated that the affected schools perhaps countered the social and infrastructure disruption by undertaking various additional academic activities (e.g. more time, individual remedial teaching).

One factor that may help to explain these differing findings is whether the trauma exposure is associated with posttraumatic distress. Weems et al. (2013) suggest that there is an indirect pathway between traumatic stress and academic outcomes, with PTSD symptoms playing a mediating role. This is supported by Saigh, Yasik, Oberfield, Halamandaris, and Bremner (2006) who found IQ scores were lower for adolescents with PTSD, compared to other trauma-exposed adolescents without symptoms of PTSD and controls.

This study examines the academic impact of a coal mine fire that burnt for an extended period of time. In February 2014, embers from bushfires spotted into a brown coal mine adjacent to the Hazelwood power station located in the Latrobe Valley, Victoria, Australia. The Hazelwood mine fire burned for about 45 days. Residents of Morwell, a major regional town located immediately adjacent to the mine, were exposed to high levels of smoke and ash over this time, with lower levels of exposure also experienced in surrounding areas of the Latrobe Valley. While the bushfires that ignited the mine fire posed a direct but short-lived threat to life and property, the risk of injury or death posed by the Hazelwood mine fire and associated smoke event was unclear. The prolonged nature of the event raised concerns in the community

about both the immediate and potential long-term health impacts of the smoke, and there was a perceived lack of government assistance and community consultation in response to the event (Teague, Catford, & Petering, 2014; Wood et al., 2015). To address these community concerns, the state government established the Hazelwood Health Study (HHS; https://hazelwoodhealthstudy.org.au/), an independent program comprising several research streams. The Schools Study, a component of the Psychological Impacts Stream of the HHS, investigates the psychological and educational impacts of the mine fire on school-aged children.

The mine fire event caused considerable disruption to the day-to-day functioning of schools located in the affected area, and teachers and school staff faced challenges in maintaining educational continuity for their students (Berger, Carroll, Maybery, & Harrison, 2018). Two Morwell primary schools relocated from Morwell for periods of two to three months during the fire. As a result, dislocation due to the impact of the smoke had the potential to impact on student learning and performance which might be reflected in participant's standardised National Assessment Program - Literacy and Numeracy (NAPLAN) scores obtained in May 2015 (approximately a year post the fire and smoke).

This study aimed to determine the impact of the Hazelwood mine fire and subsequent event-related distress (as measured by the 13 item Children's Revised Impact of Events Scale; CRIES-13) on academic outcomes for years 3, 5, 7 and 9 students from Morwell compared to students from schools located in less exposed areas of the wider Latrobe Valley area. The results will highlight the academic outcomes for children following exposure to the Hazelwood mine fire and inform the response of schools during and following similar critical events. This prospective longitudinal cohort study explores the relationship between exposure to the Hazelwood event and subsequent educational achievement in children, taking into account event-related distress, and controlling for age, gender, and school-sector (government versus nongovernment). Understanding the direct and indirect links between disaster exposure and

academic achievement will improve responses to supporting children in future disasters. While NAPLAN scores are expected to increase between the two-yearly assessment rounds, it is expected that greater exposure to the Hazelwood mine fire event and distress after the event will be related to a reduced rate of increase in NAPLAN scores in the year after, relative to the year before, the event.

Method

Study design

The Schools Study stream of the HHS is a longitudinal cohort study comprising data collected both prior to and following the 2014 Hazelwood mine fire.

Participants

The HHS Schools Study included 20 schools from across the Latrobe Valley, including schools from both the government and nongovernment education sectors, and primary (prep to grade 6) and secondary (grade 7 to 12) education levels, in Morwell and surrounding suburbs. All seven schools located within the highly exposed township of Morwell were included in the study. A sample of 13 schools were selected from amongst 32 Latrobe Valley schools located outside of Morwell to form a lower-exposure comparison group (termed *non-Morwell* for this article). The selected non-Morwell schools were located up to 13 kilometres in distance from Morwell. All students from selected schools in grade 3, 5, 7 and 9 in 2015 were invited to participate and complete the CRIES-13 measure. In total, enrolment records indicated that there were 2,138 eligible students across the 20 included schools. Consistent with research by Gibbs et al. (2019), attendance at school during the mine fire was used as a proxy measure for disaster exposure.

Measures

NAPLAN

NAPLAN is a standardised series of tests undertaken every two years by students in academic years 3, 5, 7 and 9 (National Assessment Program, 2016). NAPLAN covers the four academic domains of reading, writing, language conventions (spelling, grammar and punctuation), and numeracy (Victorian Curriculum and Assessment Authority, 2016). This analysis utilised all available individual-level NAPLAN data spanning from before the mine fire event (2013 and earlier) to three years post-event (2015-2017) to assess changes in educational achievement trajectories after the 2014 Hazelwood mine fire.

Student NAPLAN performance is known to have a non-linear growth trajectory, which is particularly evident when comparing the typical progression of students' NAPLAN performance between years 3 and 5, and between years 7 and 9 (Gross & Chisholm, 2016). However, fitting a non-linear growth curve increases the difficulty of interpreting the results. To address these issues, an analysis approach was developed based on a method used by Dix, Slee, Lawson, and Keeves (2012). Mean NAPLAN scores for all Latrobe Valley schools (obtained from the My School website; https://www.myschool.edu.au/) were used to derive an index of NAPLAN progression for each participant relative to the academic achievement of fellow students in the Latrobe Valley. This index variable indicates relative academic achievement on a yearly time scale (years ahead or behind the reference population), which is hereon referred to as 'equivalent NAPLAN year level'. For example, a year 3 student who achieves an equivalent NAPLAN year level of 2.5 is indicated to be six months behind the average Latrobe Valley year 3 students' performance. The detailed method of calculating the index score is provided in the Appendix.

CRIES-13

The CRIES-13 was adapted for children from the Impact of Events Scale (IES) (Horowitz, Wilner, & Alvarez, 1979), originally designed to screen for symptoms of PTSD in adults exposed to specific traumatic experiences. Each item of the CRIES-13 is designed to assess one symptom-domain of PTSD (avoidance, intrusion or arousal) following trauma exposure and is rated on a four-point scale (0: Not at all; 1: Rarely; 3: Sometimes; 5: Often), with higher scores representing more severe PTSD symptoms. The CRIES-13 has demonstrated reliability as a measure of child symptoms of PTSD, and a cut-off score of 30 or above has been identified as indicating probable diagnosis of PTSD in children admitted to hospital accident and emergency rooms (Perrin, Meiser-Stedman, & Smith, 2005).

Procedure

Approval was obtained from Monash University Human Research Ethics (project number: 5834), Victorian Department of Education and Training, and Catholic Education Office of Sale approval, along with consent from the principal of each school. Participating schools then contacted parents and provided information on behalf of the researchers inviting participation. Participating students were invited to complete the Schools Study Survey that included the CRIES-13 measure in late 2015, between 16-21 months after the mine fire. All available NAPLAN data for students pre and post the mine fire event was accessed. This access to pre-event educational outcomes effectively provided a ‘baseline’ measurement of each student’s academic abilities which enabled a pretest—posttest research methodology to be implemented.

Statistical analysis

Basic model for longitudinal NAPLAN scores

A basic multi-level mixed effect regression model for longitudinal changes in NAPLAN scores of the students was established. We first modelled individual student’s

longitudinal trajectory of NAPLAN results including a random intercept at the school level to control for school-related clustering and random intercept and random slope effects at the individual student level. An unstructured covariance matrix was assumed between the random effects at the individual student level to allow for correlations between random intercept and random slope to be freely estimated. The model also controlled for confounding factors, including student age (coded as months different from the mean age of NAPLAN level test), gender, and school sector (government versus nongovernment). A binary location variable for Morwell students (0) and non-Morwell students (1) was also included. The NAPLAN academic domains of reading, writing, language conventions and numeracy were combined to create a single score, consistent with research by Dix et al. (2012) showing high correlations between the subscales.

Evaluating the impact of school-based exposure to the mine fire

The basic model was first modified to evaluate the impact of higher level of exposure to the mine fire by comparing students attending schools in the most smoke-impacted area (Morwell) with those in less impacted areas (non-Morwell). The model utilised an interrupted time series analysis which introduces a dummy variable for time points after the mine fire event to indicate interruptions of the continuous growth curve. Change in growth slope was not considered due to the limited number of longitudinal observations. An important consideration is that the impact may not be the same for all the students in our cohort due the substantial differences in student ages at the time of the mine fire. Hence, the interruption of the mine fire was estimated separately for each of the four year-level cohorts in the Schools Study. Interactions between exposure level (Morwell and non-Morwell) and the time interruption variable were included to estimate whether the impact of the mine fire was more severe for students who attended schools located closest to the site of the event.

Evaluating the impact of distress (CRIES-13) associated with the event

A similar analysis was developed based on the basic mixed-effect regression model to estimate whether event-related distress symptoms in children were related to delays in academic performance. This model included CRIES-13 scores as a predictor of academic performance. Interactions between CRIES-13 scores and the time interruption variable (as described previously) were also included to assess whether event-related distress and event exposure resulted in academic delays for different age groups. The interactions between the time interruption variable and school location cannot be included due to convergence issues that arise with increasing complexity in the model.

Missing data

Missing data were handled longitudinally using multiple imputation (Rubin, 1996) by chained equations with the ICE package under Stata MI procedures (Royston & White, 2011), see imputation details in the Appendix. All analyses were conducted with Stata 15 software (StataCorp. 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC).

Results

Recruitment

From the eligible cohort, 323 students completed a survey including the CRIES-13 measure, which was a participation rate of 15.1% overall. Participation rates were higher for schools located in the most affected area, with 25% of all eligible Morwell students completing the survey compared to 12% of all eligible students from the non-Morwell schools. These response rates are consistent with previous research on disaster and trauma in children and youth (Henderson et al., 2009). A summary of participation by location and year is presented in Table 1. Table 2 details student participant characteristics by location.

[Insert Table 1 here]

[Insert Table 2 here]

Of the 323 students who completed the CRIES-13 in the 2015 Schools Study survey, nine parents did not provide consent to also access their child's NAPLAN records. Additionally, in five cases, parental consent for their child's participation in the study was later withdrawn. This resulted in 309 students where linkage with NAPLAN was attempted. However, a further six students could not be linked due to issues when matching student name and date of birth with those on record with the Australian, Curriculum, Assessment and Reporting Authority (ACARA). In total, 303 consented students (121 from Morwell schools and 182 from non-Morwell schools) were successfully linked to NAPLAN records and included in the final sample for analysis. Records were requested from ACARA for linked student NAPLAN results from both prior to the fire (2013 and earlier) and after the event (2015 and 2017). The number of NAPLAN data points available for each student was dependent on their year level, which determined how many NAPLAN rounds a student had completed in total up to 2017. The weighted mean NAPLAN scores by calendar year, NAPLAN level and location is provided in Table 3.

[Insert Table 3 here]

Sampling Weights

The participant data shows that the response rates were higher in Morwell schools compared with non-Morwell schools, higher in primary schools compared with secondary schools, and higher in nongovernment schools compared with government schools. Hence, multilevel sample weighting was used to account for differences between participants and non-participants by year level, school sector, and school location (Rabe-Hesketh & Skrondal, 2006). The detailed weighting method is included in the Appendix. As shown in Table 2, the student's characteristics are broadly comparable between Morwell and non-Morwell students.

The mean CRIES-13 scores were comparable between Morwell and non-Morwell primary school students, however, the CRIES-13 scores were higher among Morwell secondary school students. As outlined in Table 3, NAPLAN scores were generally lower among Morwell students compared with non-Morwell students.

While all groups, regardless of age or location, showed the expected increase in mean NAPLAN scores across the assessment rounds (see Figure 1), the trend of the crude NAPLAN scores indicates that Morwell students had poorer academic performance on NAPLAN testing in comparison to non-Morwell students before the mine fire. However, Morwell secondary school students' performance progression appeared to drop off after the mine fire. Individual students' trajectories on NAPLAN scores and the equivalent NAPLAN year levels were provided in Figure 1A and Figure 2A in Appendix.

[Insert Figure 1 here]

Results of weighted and unweighted mixed-effect regression analyses for effect of school exposure to the mine fire are presented in Table 4. The equivalent NAPLAN year levels were converted to months for easy interpretation of the effect size. The results from the weighted model suggest that, on average, Morwell students were approximately 6.8 months behind in academic achievement compared with non-Morwell students, although this effect did not reach statistical significance. Importantly, a substantial further delay in academic achievement was evident among secondary Morwell school students after the mine fire, which was not found among non-Morwell students. In Morwell, there was an estimated 14.9 month delay (95% CI: 9.4 to 20.5) in the academic achievement of year 7 students (who were in year 6 during the mine fire period) and a 21.5 month delay (95% CI: 13.6 to 29.5) in the academic achievement of year 9 students (year 8 during the mine fire) after the mine fire using the weighted model. The sensitivity analysis from the unweighted model suggested a very similar effect.

[Insert Table 4 here]

Mixed-effect regression analyses of the impact of CRIES-13 scores are summarised in Table 5. An interaction between fire effect and CRIES-13 was included to evaluate whether the event-related distress related to the mine fire was associated with delays in academic achievement in the broader mine fire impacted areas (Latrobe Valley). The results suggest that although in general students who scored higher on the CRIES-13 had delayed academic achievement, it was not exacerbated post the mine fire.

[Insert Table 5 here]

Discussion

This study has adopted an innovative design to evaluate the impact of a prolonged mine fire on local student's academic performance. The results demonstrate age-specific effects of disaster exposure on academic outcomes for adolescents after the Hazelwood mine fire. The negative impact on adolescents was expected and consistent with Perez-Pereira et al. (2012). In the current analysis, this effect was only present for students more highly exposed to the event (Morwell students), consistent with earlier research (Perfect et al., 2016; Scrimin, Moscardino, Capello, & Axia, 2009) including Gibbs and colleagues' (2019) findings from the Australian Black Saturday bushfires where reading gains were reduced four years after the event.

In terms of the younger children, and contrary to the earlier findings of Strøm et al. (2016), academic outcomes of primary aged children were not found to be affected by event-related distress. The trajectory of academic outcomes for primary aged students did not decline in those highly exposed after the event. One explanation of this counterintuitive finding is that clinically significant thresholds of PTSD were not reached among participants following exposure to the Hazelwood event. In the current situation, clinically significant levels of

posttraumatic distress were not found when the survey was completed 1.5 years after the event, so the level of ongoing distress may not have been large enough to impact on educational outcomes. Perrin et al. (2005) found that a cut-off score of 30 on the CRIES-13 was sensitive enough to classify 75-83% of children with PTSD (Table 2 showed the weighted median CRIES-13 scores for our sample of primary school students was 22 in Morwell and 20 in non-Morwell schools, and 15 in Morwell and 6 in non-Morwell secondary school students).

An alternate explanation for the lack of academic performance impacts in younger but not older children may be that additional academic support provided by the Victorian Department of Education and schools ameliorated the disaster impacts. Only primary schools and not secondary schools were relocated, making these schools and students the obvious target for additional resources. If this explanation of the findings is correct, there are clear implications for schools regarding academic as well as trauma care following critical events and the potential of targeted programs to prevent academic declines.

The finding that secondary school students were more impacted by the mine fire in relation to their academic outcomes, despite showing lower overall CRIES-13 scores, adds to the complexity of research in this area. It is possible that this relationship between event-related distress and exposure captured factors not related to school proximity to the mine fire, such as the fact that no secondary school relocated at the time of the smoke event. The current analysis also focused on short to mid-term educational outcomes, analysing NAPLAN data collected one and three years after the event. It is possible that there is a delayed academic achievement-psychological distress relationship among disaster-exposed students. For example, higher exposure to the Black Saturday bushfires in Australia was found to impact on academic performance four years after the fires (Gibbs et al., 2019).

Variability may also exist between different types of disasters and community-based traumatic experiences, with the Hazelwood fire and smoke event causing little immediate risk

to life or severe property damage (dissimilar to the Black Saturday bushfires); instead resulting in an extended smoke exposure event with uncertain outcomes. The strength of this study is the focus on the effect of exposure to a disaster event on academic outcomes collected prior to and following the event. It is possible that other disaster-based research could follow a similar methodological approach, accessing naturally occurring cycles of academic assessment to investigate before-and-after effects of disasters in future. A comparable study by Goodman, David Miller, and West-Olatunji (2012) found primary school children with symptoms of PTSD experienced lower standardised test scores in reading, maths, and science achievement compared to students without traumatic stress. However, symptoms of PTSD were measured using clinical child assessments and parent interviews, similar to Saigh et al. (2006), which may have been more sensitive than our measurement of these symptoms via child self-report using the CRIES-13. The finding that, in general, students who scored higher on the CRIES-13 were more likely to experience delayed academic achievement, regardless of their exposure to the mine fire, is supportive of prior research that children who experience psychological distress also experience delays in their academic achievement (Perfect et al., 2016). The CRIES-13 may have captured general distress and not event-related distress in our student sample.

Similar to earlier research, this study highlights the importance of monitoring student performance following disasters. It is particularly important that teachers are made aware of the potential risks to adolescent academic engagement following disasters so that interventions and appropriate school policy can be put into place to protect the learning outcomes of students. At present, school-based trauma-informed approaches do not address student academic concerns following trauma. Instead these approaches focus on emotional, behavioural, and relationship supports in schools to indirectly improve learning outcomes and school engagement of students. Research with teachers found a perceived negative impact of the

Hazelwood fire and smoke event on student behaviour and learning, at both the time of the event and in its aftermath, due to school relocation, reduced routine classes and resources, and poorer school attendance and learning opportunities (Berger et al., 2018). Although event-related distress was not found to impact academic outcomes in the current study, it is possible that other factors, such as interrupted schooling, school absenteeism, staff absenteeism, and changed school routines all had some impact on student learning. Unfortunately the nature of this study, and NAPLAN testing more broadly, means that it was impossible to determine whether this impact corrected itself for year 9 students following disaster exposure because NAPLAN does not continue past year 9.

The findings of this study have an important application in light of the COVID-19 pandemic which has necessitated school closures and alternative schooling arrangements (e.g., online schooling). Our findings suggest that schools will require significant resourcing to support and maintain the academic progress of students at this time, to counter the potential disruption to learning caused by the pandemic.

Limitations

A limitation of this study is that children's exposure to other potentially distressing events were not measured before and after the mine fire event. It was therefore difficult to determine the impact of the Hazelwood event alone on children's academic functioning. Future consideration of other variables, such as home destruction or evacuation, resilience, and social support post critical events that may impact the exposure-academic relationship would be appropriate. The current study also suffers from a small sample size and a low response rate which increases the vulnerability to participation bias and reduces the ability to detect a small effect when there is one. This study does however address some potential limitations by including a broad community sample, pre- and post-evaluation of academic outcomes, and controlling for demographic variables of age, gender, school sector, and event-related distress.

The pre-post methodology separates the current study from the majority of disaster research published to date, which has been limited to utilising post-event measures. Although our measure of mine fire exposure based on school location reflects earlier research (Gibbs et al., 2019), a more objective measure of exposure based on diarised location (home and school) during the event may have improved the capacity to measure exposure-response relationships.

Conclusion

Outcomes of this research provide further clarification on the unique contribution of disaster exposure and disaster-related distress on student academic achievement in schools. While this research points to no negative effects of event-related distress on academic outcomes following a non-life threatening smoke event, results do indicate that adolescents in the year after the mine fire may not have experience expected academic gains compared to less exposed adolescent students. Taken together with earlier research, this study shows that increased school awareness and ongoing monitoring of student academic engagement and achievement after adverse community-wide events is required.

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Tables and figures

Table 1. Participation Rates for the Student Survey by School Location and Year

Year	7 Morwell schools		13 non-Morwell schools		All 20 schools	
	Eligible N	Participants N (%)	Eligible N	Participants N (%)	Eligible N	Participants N (%)
3	174	58 (33.3)	300	55 (18.3)	474	113 (23.8)
5	162	47 (29.0)	278	43 (15.1)	440	90 (20.5)
7	77	16 (20.8)	550	68 (12.4)	627	84 (13.4)
9	90	5 (5.6)	507	31 (6.1)	597	36 (6.0)
Total	503	126 (25.0)	1635	197 (12.0)	2,138	323 (15.1)

Table 2. Student characteristics by location

	Morwell (N=121)	Non-Morwell (N=182)	p-value
Gender, n (weighted %)			0.47
Male	66 (52%)	81 (47%)	
Female	55 (48%)	101 (53%)	
School Sector, n (weighted %)			0.53
Government	73 (75%)	100 (60%)	
Nongovernment	48 (25%)	82 (40%)	
Year level in 2015 survey, n (weighted %)			0.57
Year 3	57 (36%)	49 (25%)	
Year 5	45 (31%)	41 (23%)	
Year 7	14 (14%)	64 (23%)	
Year 9	5 (19%)	28 (29%)	
Age difference (month), weighted mean (SD) *	-1.6 (6.8)	-1.0 (4.2)	0.37
Primary school students, weighted median (IQR)			
Intrusion (scores 0-20)	6 (1-13)	5 (1-10)	0.10
Avoidance (scores 0-20)	9 (3-15)	7 (2-14)	0.46
Arousal (scores 0-25)	8 (2-13)	5 (1-10)	0.09
CRIES (scores 0-65)	22 (10-38)	20 (7-32)	0.18
Secondary school students, weighted median (IQR)			
Intrusion (scores 0-20)	2 (0-5)	0 (0-5)	0.13
Avoidance (scores 0-20)	1 (0-3)	0 (0-3)	0.11
Arousal (scores 0-25)	6 (1-15)	3 (0-6)	<0.001
CRIES (scores 0-65)	15 (4-21)	6 (0-12)	0.021

* A relative measurement students' age compared with their wider peers. It was calculated as age differences (months) at the time of NAPLAN testing between the study participant compared with the whole Victorian student cohort at each grade level. Across the time-range of the study, in Victoria, the average age of students at the time of NAPLAN testing was: grade 3 = 8 years and 9 months; grade 5 = 10 years and 9 months; grade 7 = 12 years and 9 months; grade 9 = 15 years and 9 months.

Table 3. NAPLAN results by year, NAPLAN level and location

	Morwell	Non-Morwell		Latrobe Valley
	Weighted mean (SD)	Weighted mean (SD)	p-value	Mean^
	N=57	**N=49**		
Year 3 in 2015 survey				
Average score at year 3 NAPLAN test (2015)*	369 (149)	413 (56)	0.010	396
Average score at year 5 NAPLAN test (2017)*	451 (116)	495 (47)	0.003	478
	N=45	**N=41**		
Year 5 in 2015 survey				
Average score at year 3 NAPLAN test (2013)	372 (161)	411 (50)	0.09	399
Average score at year 5 NAPLAN test (2015)*	467 (136)	500 (46)	0.06	476
Average score at year 7 NAPLAN test (2017)*	508 (148)	552 (46)	0.017	518
	N=14	**N=64**		
Year 7 in 2015 survey				
Average score at year 3 NAPLAN test (2011)	400 (105)	412 (64)	0.22	402
Average score at year 5 NAPLAN test (2013)	478 (84)	483 (56)	0.40	482
Average score at year 7 NAPLAN test (2015)*	499 (106)	532 (55)	<0.001	518
Average score at year 9 NAPLAN test (2017)*	540 (113)	562 (62)	0.005	546
	N=5	**N=28**		
Year 9 in 2015 survey				
Average score at year 3 NAPLAN test (2009)	435 (40)	443 (42)	0.47	409
Average score at year 5 NAPLAN test (2011)	482 (44)	517 (32)	0.010	473
Average score at year 7 NAPLAN test (2013)	539 (61)	557 (32)	0.23	517
Average score at year 9 NAPLAN test (2015)*	538 (56)	601 (30)	<0.001	549

* NAPLAN results post mine fire

^ Estimated Latrobe Valley mean score using My School data and student enrolment data in 2015

Table 4. Mixed effect regression results of the mine fire effect on NAPLAN scores for weighted and unweighted models

	Un-weighted			Weighted		
	Coef	**95% CI**	**p-value**	**Coef**	**95% CI**	**p-value**
Male	-9.1	-14.9, -3.3	0.002	-7.2	-15.2, 0.9	0.08
Nongovernment	5.4	-2.6, 13.3	0.18	9.7	0.2, 19.3	0.046
Age*	0.7	0.1, 1.4	0.034	0.7	-0.0, 1.5	0.05
NAPLAN year level^	13.7	12.9, 14.5	<0.001	14.3	12.9, 15.7	<0.001
Morwell	-11.6	-21.3, -2.0	0.018	-6.8	-22.9, 9.3	0.41
Fire effect for Non-Morwell students						
Year 3 in 2015 survey	-2.6	-12.0, 6.8	0.59	-0.1	-12.7, 12.5	0.99
Year 5 in 2015 survey	10.5	4.8, 16.2	<0.001	8.4	2.8, 14.0	0.003
Year 7 in 2015 survey	-2.6	-7.2, 2.1	0.28	-4.6	-10.4, 1.1	0.12
Year 9 in 2015 survey	-2.3	-9.3, 4.6	0.51	-3.2	-9.7, 3.2	0.32
Fire effect for Morwell students						
Year 3 in 2015 survey	-0.4	-13.7, 12.9	0.95	-1.6	-18.6, 15.4	0.85
Year 5 in 2015 survey	-2.0	-9.1, 5.1	0.58	-2.7	-9.1, 3.7	0.41
Year 7 in 2015 survey	-15.6	-25.7, -5.5	0.003	-14.9	-20.5, -9.4	<0.001
Year 9 in 2015 survey	-22.0	-38.3, -5.6	0.009	-21.5	-29.5, -13.6	<0.001

* A time invariant variable representing relative age of the student. The coefficient is per 1 month difference from the average age of Victorian students taking the same year level NAPLAN test.

^ Coefficient is per 1-year increase in student's year level.

Note: All models include random intercepts at school-level and random intercepts and random slopes with unstructured correlation at student-level. Missing data were imputed with MICE using 20 imputed datasets.

Table 5. Mixed effect regression results of the CRIES score effect on NAPLAN scores for unweighted and weighted models

	Un-weighted			Weighted		
	Coef	**95% CI**	**p-value**	**Coef**	**95% CI**	**p-value**
Male	-9.1	-14.9, -3.3	0.002	-7.2	-15.0, 0.7	0.07
Nongovernment	3.9	-3.5, 11.3	0.30	8.6	-0.4, 17.7	0.06
Age[*]	0.8	0.1, 1.4	0.027	0.7	-0.1, 1.5	0.07
NAPLAN year level[^]	13.7	12.8, 14.5	<0.001	14.3	12.9, 15.7	<0.001
Morwell	-9.5	-17.3, -1.8	0.016	-6.7	-18.9, 5.5	0.28
CRIES score[#]	-3.6	-6.2, -0.9	0.008	-1.8	-3.7, 0.1	0.06
Fire effect for all students						
Year 3 in 2015 survey	-5.0	-13.4, 3.4	0.24	-0.8	-11.3, 9.6	0.87
Year 5 in 2015 survey	9.7	4.9, 14.4	<0.001	8.2	2.6, 13.9	0.004
Year 7 in 2015 survey	-5.2	-9.6, -0.9	0.019	-5.8	-11.8, 0.3	0.06
Year 9 in 2015 survey	-5.8	-12.2, 0.5	0.07	-5.5	-12.0, 1.0	0.10
Interaction between CRIES and mine fire effect[$]						
Year 3 in 2015 survey	3.4	-0.6, 7.4	0.09	1.3	-2.2, 4.9	0.46
Year 5 in 2015 survey	-0.1	-2.5, 2.3	0.93	-0.4	-3.0, 2.1	0.73
Year 7 in 2015 survey	-0.2	-3.7, 3.3	0.91	-0.6	-3.9, 2.8	0.74
Year 9 in 2015 survey	-2.6	-7.7, 2.5	0.32	-1.7	-9.7, 6.3	0.68

[*]A time invariant variable representing relative age of the student. The coefficient is per 1 month difference from the average age of Victorian students taking the same year level NAPLAN test.

[^]Coefficient is per 1 year increase in student's year level.

[#]Coefficient is per 10 unit change in CRIES-13 score (centred at a mean score of 10).

[$]Coefficient is the effect of the mine fire for students at the mean CRIES-13 score.

Note: All models include random intercepts at school-level and random intercepts and random slopes with unstructured correlation at student-level. Missing data were imputed with MICE using 20 imputed datasets.

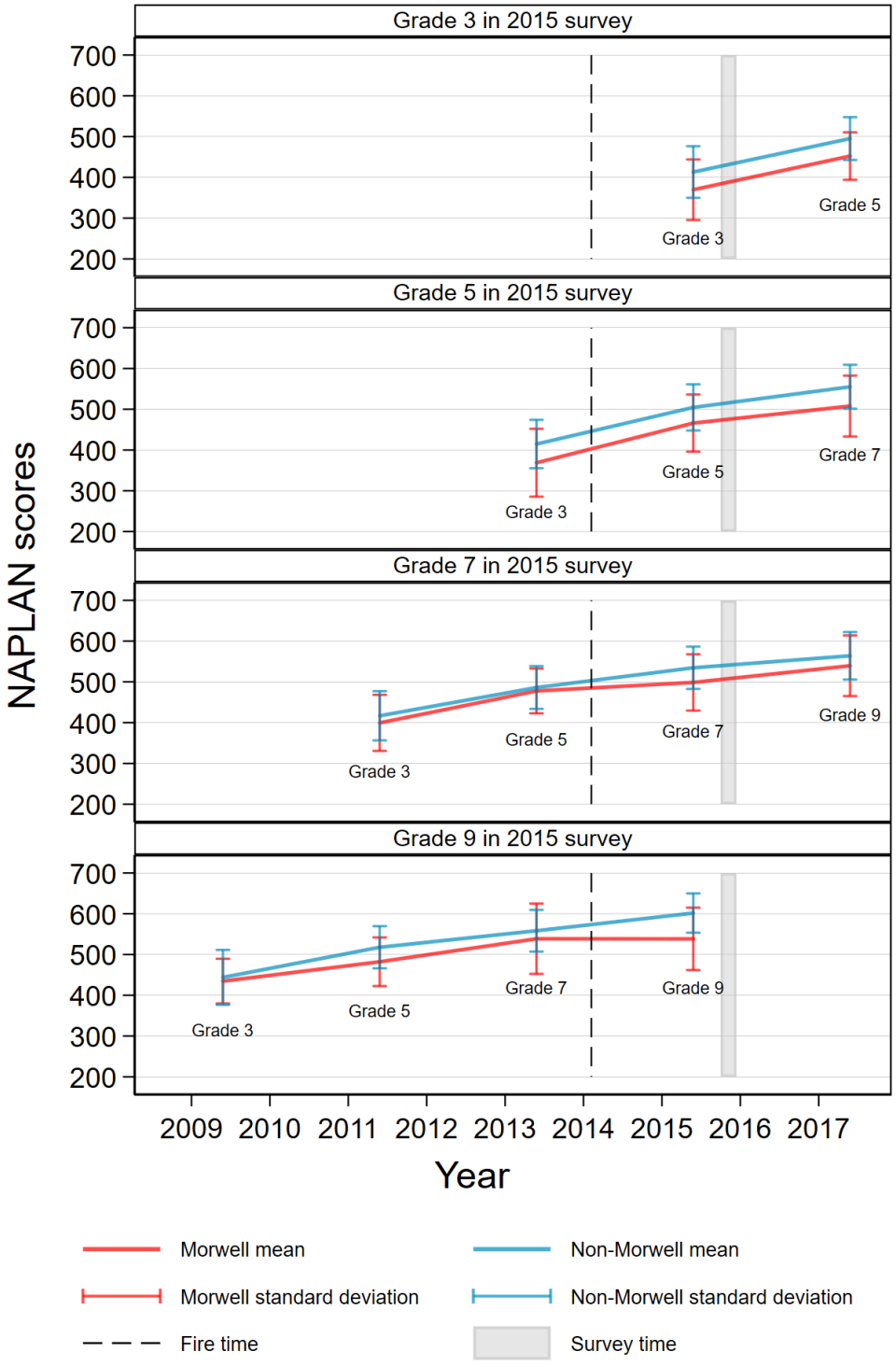

Figure 1. The trajectory of student mean NAPLAN scores and associated standard deviation by location and time

Appendix

Sampling weight

The study was sampled at two levels, the first level was the school and the second level was the students. All schools in Morwell were selected, hence were given a school level weight of one. The non-Morwell schools in each stratum (a primary/secondary and government/ nongovernment combination) were sampled according to the representing geographical location. Hence we assume the probability of each school being sampled in stratum were the same, which is proportional to all students being sampled in the stratum.

$$w_j^* = \frac{1}{p_j^*} = \frac{\sum_{all\ schools} S_j}{\sum_{sampled\ schools} S_j}$$

All schools that were approached agreed to participated the study there is no school level non-response adjustment. All student in the eligible year level of the selected schools were sampled hence were given a sampling weight of 1. Student non-response adjustment was calculated within each stratum (a Morwell/ non-Morwell, primary/ secondary and government/ nongovernment combination) (Rabe-Hesketh & Skrondal, 2006). The non-response adjustment of student i in stratum k is calculated as follow:

$$f_{i_k} = \frac{\sum_{j\ in\ k} \sum_{X(i)} w_j}{\sum_{j\ in\ k} \sum_{\Delta(i)} w_j}$$

where j is a school in stratum k, $X(i)$ is all eligible student in the school j, and $\Delta(i)$ is all assessed students in school j. Therefor the student weight given a school is:

$$W_{i|j} = f_{i_k}$$

Both weighted and unweighted results are presented for sensitivity purpose.

NAPLAN score conversion

Due to the nonlinearity of NAPLAN score increase across students year levels, a new method is adopted to convert individual scores to a relative academic performance index which represent relative Mean NAPLAN scores for all Latrobe Valley schools (obtained from https://www.myschool.edu.au/) were used to derive an index for each participants' NAPLAN progression in a time scale relative to the academic achievement of fellow students in the Latrobe Valley. This index is referred to as 'equivalent NAPLAN year level'.

This process involved: firstly, fitting a prediction model between NAPLAN year level (used as the outcome) and the reference NAPLAN scores (mean scores of Latrobe Valley students) in each domain (used as the predictor). Here we fitted two linear regression modes, one between NAPLAN year 3 and year 5, and other between year 5 and year 9. These two models were then used to estimate an equivalent NAPLAN year level, relative to the Latrobe Valley reference population. This equivalent NAPLAN year level can then be interoperated as the student's academic achievement, in terms of how many year/months ahead or behind they are, in comparison with the Latrobe Valley reference population. For example, if the equivalent year level of a year 3 student is 2.5, the student is 6 months behind the reference population.

The reference scores used were derived from school level NAPLAN data obtained from the Australian Myschool website. Numbers of students for each school and each year were approximated by the enrolment data in 2015.

Imputation for missing data

Multiple imputation using chained equations (MICE) was implemented to deal with missing data. The imputation procedure operated by first fitting a set of imputation models, one regression model for each variable with any missing values (linear, logistic or multinomial logistic regression depending on the measurement scale of the variable being continuous, binary or multi-category respectively). MICE was carried out using the Stata user-written

package ‘ice’, which allowed us to define individual chained equations to deal with multiple sub-scales for psychological variables and to use conditional imputation for longitudinal variables. Due to the longitudinal nature of the data, the imputation was performed with the data in “wide” format (one record per individual including NAPLAN results at each year level as separate variables). For each item with multiple sub-scales of CRIES-13 (avoidance, intrusion and arousal), the imputation model was reduced from including all other items to only including items within the sub-scale, the sum scores for other sub-scales, and other characteristic variables and the outcome variables. NAPLAN scores in each domain were imputed separately, with imputation including the scores of other domains in the same NAPLAN test and the previous year’s mean results for all domains, as well as other characteristic variables included in the regression model. Both imputed and unimputed results were presented for sensitivity purpose.

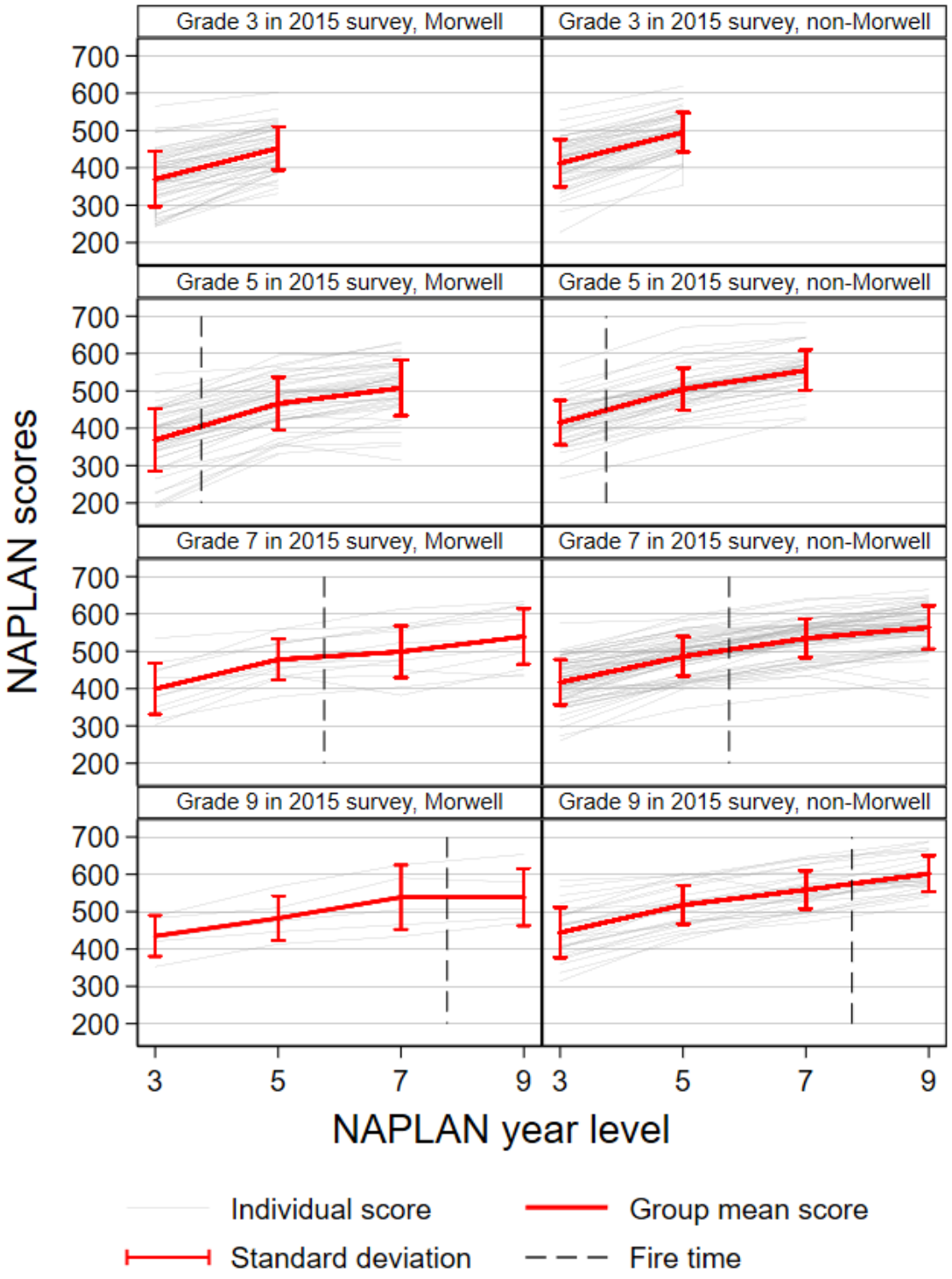

Figure A1. The trajectory of student NAPLAN scores by location and the survey year level.

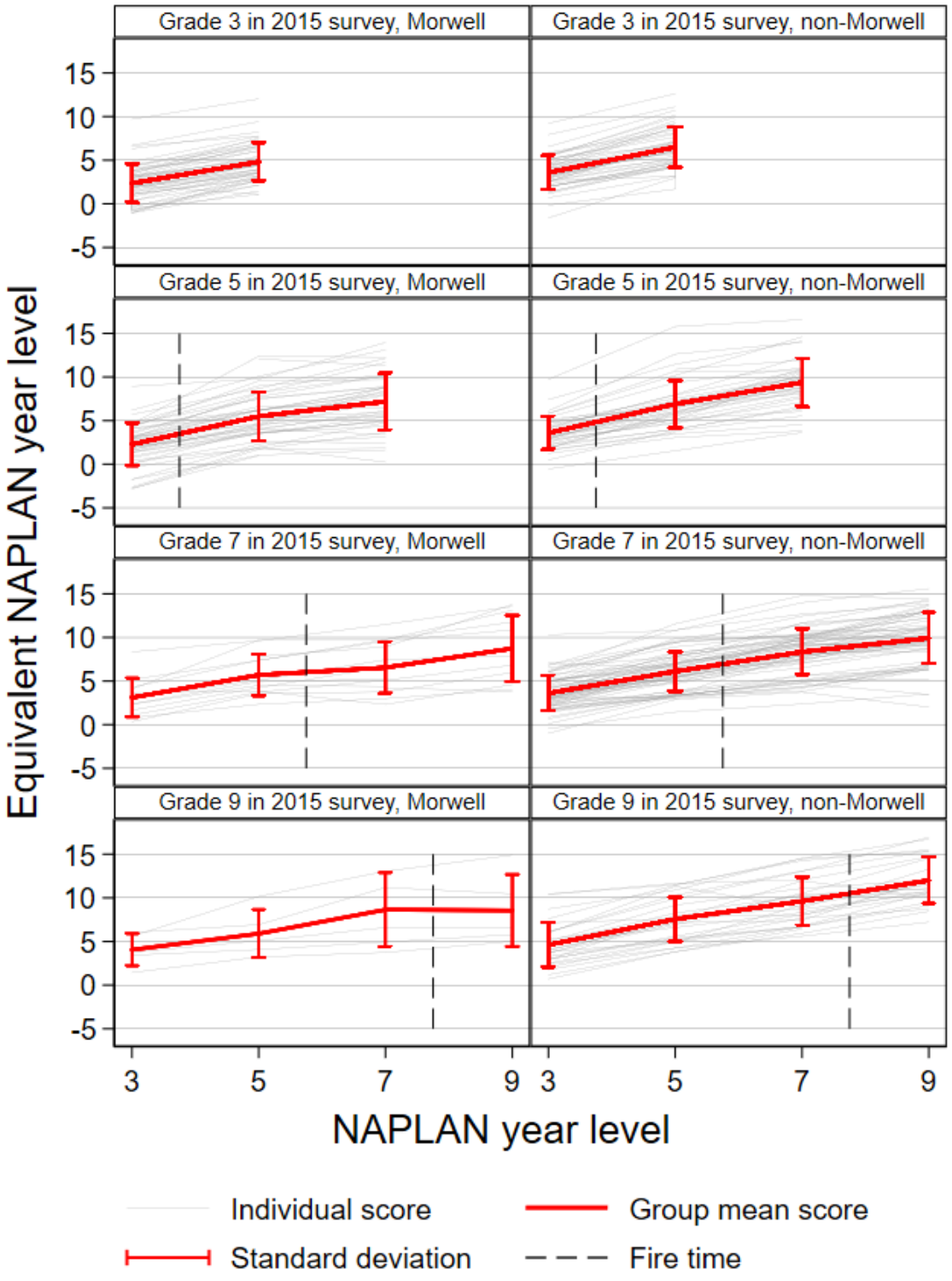

Figure A2. Trajectory of equivalent NAPLAN year level by location and survey year level.