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SELF-PERCEIVED WILDFIRE SMOKE EXPOSURE AND MENTAL HEALTH OUTCOMES AMONG CANADIAN ADOLESCENTS

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Abstract

Climate change contributes to increasingly severe wildfires and wildfire smoke (WFS) in Canada. WFS exposure may impact adolescent mental health; however, there is little empirical research on this. In this thesis, survey data of self-perceived WFS exposure, mental health problems, and climate worry among adolescents were utilized. Through multiple linear regression, the relationships between WFS exposure and depression, anxiety, stress, and climate worry were explored. Findings indicated that depression, anxiety, stress, and climate worry scores among participants who experienced only WFS in the last 12 months were not significantly different compared to non-exposed participants. Individuals who experienced WFS and four or more other climate change related acute events had higher anxiety, stress, and climate worry than non-exposed participants. These findings are relevant to the mental health counselling field. Counsellors may benefit from specialized training, and adolescents exposed to multiple climate change related acute events may benefit from counselling support.

Keywords: climate change, wildfire, wildfire smoke, adolescence, depression, anxiety, stress, climate worry, counselling, cross-sectional, survey

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List of Abbreviations

BCa	Bias-Corrected and Accelerated
CI	Confidence Interval
DASS	Depression Anxiety Stress Scales
DASS-Y	Depression Anxiety Stress Scales – Youth Version
MHP	Mental Health Professional
PM	Particulate Matter
$PM_{2.5}$	Particulate Matter $\leq$ 2.5 Micrometers in Diameter
SD	Standard Deviation
SE	Standard Error
VIF	Variance Inflation Factor
WFS	Wildfire Smoke

Chapter 1. Introduction

1.1 Introduction

This chapter presents concepts that are foundational to this thesis. It begins with a brief overview of how the issue of climate change is a core societal concern that is causally related to the increasing frequency and severity of wildfires and, by extension, wildfire smoke (WFS), and how this may impact adolescents' health. An overview of three key concepts is then provided (climate change, mental health, and adolescence), followed by a discussion of how these concepts intersect. Finally, the relevance of this area of inquiry to the field of mental health care is outlined.

1.2 Background

Climate change is associated with warmer and drier conditions in regions across the globe (Clayton et al., 2023), which increases the severity and frequency of wildfires (Jain et al., 2024). Canada is included among the countries experiencing devastating wildfire seasons in recent years. For example, in 2023, over 200 Canadian communities were evacuated during a wildfire season that lasted for seven months (Jain et al., 2024). That year, the total area burned was approximately 15 megahectares, which more than doubled the previous record of 6.7 megahectares in the year 1989. A consequence of wildfires is the smoke they produce, which can extend beyond the region directly experiencing the wildfire. For instance, millions of North Americans were exposed to WFS during the Canadian wildfires of 2023 (Jain et al., 2024). Exposure to WFS can result in physical health consequences such as headache, cough, heart palpitations, stroke, and even death (Health Canada, 2024). An increase in poor mental health outcomes may also be associated with WFS exposure. However, this is an emerging area of

inquiry which has not been examined as much as the physical health effects of exposure to WFS (Eisenman & Galway, 2022).

The mental health of adolescents is an area of concern to health practitioners, policy makers, and young people themselves (Children First Canada, 2024). Today's adolescents experience relatively high rates of mental health problems compared to other age groups; for example, Canadian youth between 15 to 24 years are the age group most likely to meet criteria for an anxiety or mood disorder (Statistics Canada, 2024). Climate change may impact adolescent mental health and wellbeing through a variety of factors, including disruptions to education, increased family stress, displacement, and direct exposure to extreme weather events related to climate change (Clayton et al., 2023; McGushin et al., 2022). Approximately 1 billion children and adolescents worldwide are at risk of being impacted by climate change and related acute events (United Nations International Children's Emergency Fund [UNICEF], 2024).

1.3 Key Concepts

There are three key concepts that are foundational to this thesis: climate change (a phenomenon that relates to the increasing prevalence of WFS), mental health (a topic relating to this thesis' outcome variables of depression, anxiety, stress, and climate worry), and adolescence. The following subsections will: 1) define each concept, and 2) explore how these concepts intersect.

1.3.1 Climate Change

The phenomenon of climate change refers to the warming of our planet, a consequence of human-caused changes to earth's atmosphere; human activities, such as industrialization and the burning of fossil fuels, contribute to climate change by releasing greenhouse gases into the atmosphere, which trap heat and lead to global warming (Environment and Climate Change

Canada, 2020). Average temperatures are rising across the globe, with the ten warmest years in history having occurred since 1998 (Burke et al., 2018). This has led to increased rates of climate change related acute events that are hazardous to human health, such as wildfires, heatwaves, and floods (Burke et al., 2018). Climate change also leads to reduced air quality through a variety of mechanisms, including longer pollen seasons and wider distribution of certain plant species (Health Canada, 2024). In Canada, WFS is recognized as one of the most significant contributors to poor air quality related to climate change (Health Canada, 2024).

1.3.2 Climate Change and Wildfires

Wildfires can occur naturally in some forest ecosystems (Pausas & Keeley, 2021); however, the changing climate has increased the prevalence of extreme wildfire events (Coogan et al., 2019). Drought-like conditions are growing more common in regions around the globe due to warmer temperatures resulting from climate change, which may increase the fuel supply for wildfires (Pausas & Keeley, 2021). Wildfire events in Canada are expected to increase in frequency, severity, and duration; however, this trajectory will not occur equally across Canada depending on factors such as weather, climate, and availability of fuel for wildfires (Coogan et al., 2019).

1.3.3 Mental Health and Disorder

The World Health Organization (WHO, 2025a) defines mental health as “a state of mental well-being that enables people to cope with the stresses of life, realize their abilities, learn and work well, and contribute to their community” (para. 1). Mental health has also been conceptualized as part of a single continuum, whereby mental healthiness (a state of wellbeing in which individuals flourish) lies at one end of the continuum and mental disorder (a state of struggle or crisis stemming from clinically significant symptoms) at the other (Kelloway et al.,

2023). This single continuum model implies that mental health and mental disorder are mutually exclusive. In contrast, the dual-continuum model conceptualizes mental health and mental disorder as related yet distinct facets of mental functioning that can fluctuate independently from one another (Keyes, 2005). In this, more nuanced, conceptualization of mental health outcomes, the absence of mental disorder does not necessarily equate to the presence of mental health, and vice versa (Keyes, 2005).

Depression, anxiety, and stress, which are outcome variables in this thesis, are relatively common mental health problems (British Columbia Ministry of Health, 2024). Symptoms of depression may include feelings of sadness or hopelessness, a lack of interest in things one used to enjoy, lethargy, and low motivation (Lovibond & Lovibond, 1995). Anxiety may include physiological symptoms (e.g., trembling hands, sweatiness), worry about social situations, and feelings of panic or fear (Lovibond & Lovibond, 1995). Symptoms such as these may not necessarily reach a threshold of clinical significance (Vergunst et al., 2024); however, elevated symptom levels may result in diagnoses such as major depressive disorder and generalized anxiety disorder (American Psychiatric Association, 2022). For this reason, these outcomes are conceptualized as falling on the mental disorder continuum, rather than the mental health continuum.

In psychological research, the umbrella term of *stress* may be used to refer to different concepts or constructs, including *stressors* and *stress response* (Crosswell & Lockwood, 2020). When conceptualized as a negative emotional syndrome (Lovibond, 1998), stress may be characterized by the presence of symptoms such as irritability, difficulty relaxing, and agitation (Lovibond & Lovibond, 1995). In contrast, a stress response refers to the biological, emotional, and cognitive reactions individuals experience in response to stressful events (Crosswell &

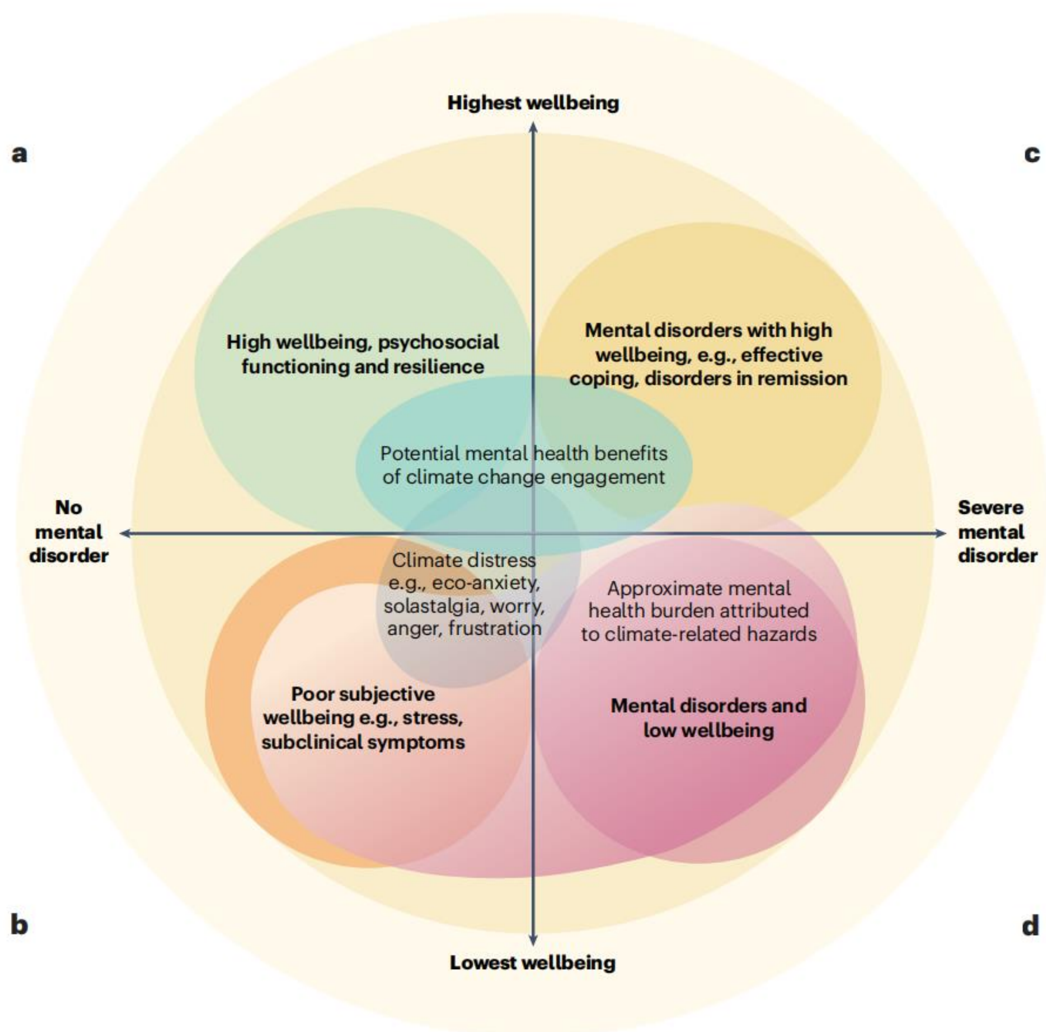
Lockwood, 2020). The WHO (2026) defined stress as a normal response to challenges in daily life and described that moderate amounts of stress may help individuals to overcome such challenges. However, according to Cohen et al. (2016), the psychological tradition tends to view stress as the overwhelm of an individual's capacity to cope with subjectively challenging or threatening situations. During a stress response, physiological changes, such as fluctuations in hormones (e.g., cortisol) and increased blood pressure, may occur; in the short term, these changes may be adaptive but chronic disturbances in physiological systems due to stress can negatively impact physical health (Cohen et al., 2016). Heightened or chronic stress may also increase symptoms of mental disorder (WHO, 2026); however, stress itself is not a disorder and may relate more to reduced mental wellbeing (Vergunst et al., 2024). As such, for this thesis the outcome of stress was conceptualized as aligning with the mental health continuum, rather than the mental disorder continuum.

1.3.4 Climate Change and Mental Health and Disorder

Climate change can impact levels of both mental health and disorder, as outlined in the framework developed by Vergunst et al. (2024). This framework (Figure 1) illustrates that the impacts of climate change can exist on each of the aforementioned continua. Different types of climate change related acute event exposures have different effects on a person's mental health; exposure to acute events (e.g., physical injury due to wildfire) may lead to severe mental health consequences while indirect exposure (e.g., displacement) or exposure to chronic environmental changes (e.g., loss of ecosystems) is associated with mental health outcomes that are less severe, relatively speaking (Vergunst et al., 2024).

Figure 1

Climate Change Impacts and the Dual-Continuum Framework



Source: "A Dual-Continuum Framework to Evaluate Climate Change Impacts on Mental Health" by F. Vergunst, R. Williamson, A. Massazza, H. L. Berry, and M. Olff, 2024, *Nature Mental Health, 2*(11), p. 4 (https://doi.org/10.1038/s44220-024-00326-x). Reused with permission of Springer Nature SNCSC.

Of note, worry about climate change is one form of distress that may occur as a result of climate change (Ojala, 2012), as shown in Figure 1. This concept, *climate distress,* is an

emerging area of interest related to emotional and psychological impacts of the knowledge of climate change, as well as the impacts of exposure to climate change related factors, such as extreme environmental events (Martin et al., 2023). *Climate worry*, an aspect of climate distress, is defined as worry about loss, damage, and devastation due to climate change (Ojala et al., 2021), particularly in relation to human wellbeing (self and/or others) and changes to the environment (Wullenkord & Ojala, 2023).

The experience of climate worry has been found to be associated with reduced mental wellbeing; as such, it lies along the continuum of mental health and wellbeing, rather than the mental disorder continuum (Vergunst et al., 2024). Following the framework proposed by Vergunst et al. (2024), climate worry was included as a dependent variable in this study relating to climate change related factors and mental health outcomes. As increased incidents of WFS are widely understood to be connected to climate change (Jain et al., 2024), it could be that those who perceive that they have been exposed to WFS would also be more worried about climate change generally.

1.3.5 Adolescence

Adolescence (10 to 19 years of age) is a period in the lifespan where individuals transition from childhood into adulthood (WHO, 2020). This period is marked by physical and psychosocial development, with individual variability in when specific milestones may occur (Sawyer et al., 2018; WHO, 2020). The start of adolescence is commonly viewed as the onset of puberty, while the end of adolescence is marked by the achievement of milestones of independence (Dumontheil, 2016; Sawyer et al., 2018). During puberty, hormonal shifts contribute to biological changes such as growth spurts and the development of sexual organs and characteristics (Sawyer et al., 2018). Significant brain development also occurs during

adolescence, which in turn leads to cognitive and emotional shifts and changes in social behaviours (Dumontheil, 2016). In the past century, social independence of adolescents has shifted to occur at older ages; milestones of financial independence, partnership, and parenting are occurring at ages beyond 19 years, on average, in many areas around the world (Sawyer et al., 2018). As such, the argument has been made to expand the age range up to 24 years to account for the current understanding and timing of role transitions, though the age range of 10 to 19 years is commonly utilized to define adolescence (Sawyer et al., 2018).

1.3.6 Climate Change and Adolescent Health

Climate change can impact all aspects of adolescent health and wellbeing, including physical health and nutrition, social connection, education and employment, and resiliency and sense of agency (McGushin et al., 2022). Acute events related to climate change, such as floods, storms, and heatwaves, may impact the health of young people through the increased prevalence of infectious diseases, such as pneumonia, cholera, and Lyme disease, and increased risk of non-communicable health concerns, such as asthma and heat stroke (UNICEF, 2024).

The mental health of adolescents can also be negatively impacted by climate change (Clayton et al., 2023); for example, exposure to climate change related acute events may increase rates of mental health problems such as anxiety and depression in this population (UNICEF, 2024). Despite the fact that climate change and related factors pose a health risk to youth, research trends indicate that there has been a decline in studies focusing on the impacts of climate change on adolescent health since 2018 (Meherali et al., 2024), indicating a need for more research in this area.

1.3.7 Climate Change and Mental Health Professionals

Various psychological associations are taking steps to raise awareness and address mental health challenges related to climate change. The American Psychological Association's (APA) Task Force on the Interface Between Psychology and Global Climate Change released policy recommendations with numerous suggestions, including increasing psychologists' knowledge relating to the mental health impact of climate change, and developing climate specific therapy materials for practitioners who serve clients impacted by climate change (APA, 2009). The Canadian Psychological Association (CPA) has a section (i.e., a designated group of psychologists with a shared interest) for environmental psychology, whose mission includes addressing questions related individual responses to exposure to extreme environmental conditions as well as environmental disasters (CPA, n.d.).

As the existence of the CPA section and APA task force indicates, a growing number of mental health professionals (MHPs), including counsellors, psychologists, and psychotherapists, view climate change as a phenomenon relevant to their field (Hoppe et al., 2023; Silva & Coburn, 2023). Furthermore, MHPs are noticing the impacts of climate change on the mental health of their clients (Hoppe et al., 2023). Despite this growing awareness, MHPs may not feel confident to broach the topic with their clients (Hoppe et al., 2023) and if they do, they may feel that they lack the knowledge or resources to support their clients who are experiencing the impacts of climate change (Hoppe et al., 2023; Silva & Coburn, 2023). If MHPs feel ill-equipped to support clients through their experiences of climate change, their clients who are impacted by climate change related acute events (such as WFS) may receive inadequate care. This possible gap in professional knowledge and practice is particularly salient when considering that WFS is becoming increasingly frequent and severe in regions across Canada. Research on the

associations between WFS and mental health outcomes is a necessary precursor to changes in both knowledge and practices in this area of health care.

1.4 Statement of the Problem

Wildfires are becoming increasingly common due to climate change. This means that WFS, which is a direct consequence of wildfires, is also a growing issue that extends to regions beyond the site of the fire. The physical health effects of WFS exposure are widely recognized (Rizzo & Rizzo, 2025); however, the mental health outcomes associated with WFS exposure are less understood (Eisenman & Galway, 2022). Adolescents are a population of interest due to relatively high rates of mental health problems (e.g., anxiety and depression) in comparison to other age groups (Statistics Canada, 2024; WHO, 2025b) and given that they are considered an at-risk group for health impacts of climate change (Clayton et al., 2023; McGushin et al., 2022; UNICEF, 2024).

1.5 Purpose

The purpose of this research is to explore if WFS relates to depression, anxiety, stress, and climate worry among Canadian adolescents. The impact of self-perceived exposure to WFS only is investigated, as well as the impact of WFS with multiple other climate change related acute events.

1.6 Research Question

This study seeks to answer the following question: Is there a relationship between self-perceived exposure to WFS and levels of depression, anxiety, stress, and climate worry among Canadian adolescents?

Chapter 2. Literature Review

2.1 Introduction

As outlined in Chapter 1, exposure to WFS has the potential to negatively impact a range of mental health outcomes; however, this area of inquiry is less well-researched than the physical health consequences of WFS exposure (Eisenman & Galway, 2022). Through a narrative review of the literature, associations between mental health outcomes and exposure to both WFS and wildfires were explored. This chapter discusses the review findings, including variations in study design and associated strengths and limitations, and ends with an outline of the research gaps that informed this thesis' research question.

2.2 Review Approach

For this thesis, an empirical integrative review was conducted. This type of review falls under the category of narrative review, which is an approach that allows researchers to explore broad or under-researched topics (Sukhera, 2022). Narrative reviews are appropriate when the goal is to identify research on key subthemes, rather than to address specific review questions (Demiris et al., 2019). Empirical integrative reviews focus on empirical studies with a diverse range of methodologies (Whittemore & Knafl, 2005). Though pre-determined inclusion and exclusion criteria may not be involved in narrative review approaches, a description of the research topics, search terms, and databases included in the review process is warranted (Sukhera, 2022).

This review focused on peer-reviewed articles, which were limited to the English language. Qualitative, quantitative, and review studies were included, and no date restriction was applied. The scholarly databases searched included PsycINFO, CINAHL, Science Direct, and Google Scholar. PsycINFO and CINAHL were chosen because they are health-related databases.

Science Direct was included as it focuses on numerous scientific areas, including health and the environment. Google Scholar is a popular academic search engine that can be useful when incorporated as a supplement to other databases (Haddaway et al., 2015). The key concepts included in this review were: wildfires, WFS, air pollution, adolescence, mental health, depression, anxiety, stress, and climate worry. The search terms evolved as the review was conducted, which aligns with the iterative process inherent to narrative reviews (Sukhera, 2022). Search terms and Boolean operators used are outlined in Appendix A.

2.3 Review Findings

The following sections outline the findings of this review as they pertain to the key themes of wildfires, WFS, and mental health outcomes. For this thesis, the outcomes of depression and anxiety are conceptualized as mental health problems (i.e., mental disorder continuum), while climate worry and stress relate to reduced wellbeing (i.e., mental health continuum). Due to the narrative approach of this review, study findings relating to other mental health outcomes are briefly discussed prior to the findings related to the outcomes of interest. The term “mental health outcomes” is used to refer to a broad range of outcomes pertaining to both mental health and disorder. No studies were found relating to exposure to WFS and/or wildfires and the outcome of climate worry; as such, this topic is briefly discussed at the end of this chapter.

2.3.1 Wildfire Exposure and Mental Health Outcomes

Wildfires and WFS are inherently linked, and those who experience wildfires may also experience WFS. Several studies found in this review noted that WFS exposure was an aspect of the wildfire experience for participants (Ducy & Stough, 2021; McDermott et al., 2005; Marshall et al., 2007; Montesanti et al., 2021). However, experiences specific to wildfire exposure may

not be shared by those who experience WFS only; for example, stressors associated with wildfire exposure include physical injury (Marshall et al., 2007), seeing flames (McDermott et al., 2005), loss of one's home (Townshend et al., 2015), and perceived threat to one's own life (McDermott et al., 2005; Papadatou et al., 2012; Yelland et al., 2010).

Research findings indicate that wildfire exposure is positively associated with a variety of poor mental health outcomes (Brown et al., 2019; Ducy & Stough et al., 2021; Emprasertsuk et al., 2025; McDermott et al., 2005; Marshall et al., 2007; Papadatou et al., 2012; Shalaby et al., 2024; Townshend et al., 2015; Yelland et al., 2010). Several studies focused on children, adolescents, and/or young adults (Ducy & Stough, 2021; McDermott et al., 2005; Papadatou et al., 2012; Townshend et al., 2015; Yelland et al., 2010), with some findings indicating that younger participants (i.e., children) may experience more severe symptoms (McDermott et al., 2005; Yelland et al., 2010) and more persistent symptoms of poor mental health (Yelland et al., 2010) in comparison to older (i.e., adolescent) participants.

Research findings also indicate that positive associations exist between wildfire exposure and depression (Emprasertsuk et al., 2025; MacLeod et al., 2024; Marshall et al., 2007; Papadatou et al., 2012), anxiety (Agyapong et al., 2018; Caamano-Isorna et al., 2011; Emprasertsuk et al., 2025; MacLeod et al., 2024), and stress (MacLeod et al., 2024; Montesanti et al., 2021). For example, MacLeod et al. (2024) explored the associations between depression, anxiety, and stress in Australian adults from wildfire-affected and non-wildfire-affected regions. Participants were surveyed on their exposure experiences; for those affected by wildfires, exposure was categorized as low (e.g., provided professional services in response to fires, one or more community buildings destroyed), medium (e.g., lost income, experienced evacuation), or high (e.g., lost home, feared for own life, experienced significant injury). The authors found that

wildfire exposure was positively associated with levels of depression and anxiety, depending on the severity of exposure. Additionally, while participants with high exposure to wildfires were likely to have high levels of stress, the highest levels of stress were reported by participants with indirect exposure to wildfires (e.g., loss of income related to fire but not residing in region directly impacted by fire). It is possible that participants with indirect wildfire exposure still experienced WFS, which could indicate an association between WFS exposure and increased stress. However, a limitation of this study is that the survey did not ask participants whether they perceived exposure to WFS (MacLeod et al., 2024).

2.3.2 Wildfire Smoke Exposure

The smoke emitted from wildfires may negatively impact health; air pollution caused by WFS can travel hundreds of kilometers from the fire of origin, meaning these negative impacts can be widespread (Rizzo & Rizzo, 2025). WFS is composed of pollutants and chemicals such as particulate matter (PM), carbon dioxide, and carbon monoxide (Vicente et al., 2013). Some of these pollutants (not necessarily originating from WFS) have been linked to poor mental health outcomes. For example, increased exposure to $PM_{2.5}$ (particulate matter less than 2.5 micrometers in diameter) and carbon monoxide have been found to be associated with heightened risk of non-suicidal self-injury in adolescents (Liu et al., 2018), and increased levels of $PM_{2.5}$ correlate with increased emergency department presentations for mental health disorders among individuals eight to 24 years of age (Szyszkowicz et al., 2020).

Though WFS may share compositional similarities with other forms of air pollution, it is a distinct phenomenon. While the physical health consequences of WFS exposure are well researched, the impacts on mental health remain poorly understood in comparison (Eisenman & Galway, 2022). A recent scoping review explored the state of the literature pertaining to the

relationship between WFS exposure and mental health outcomes (Eisenman & Galway, 2022). Studies included in the review encompassed a broad range of outcomes, some of which were directly related to mental health and disorder (e.g., post-traumatic stress disorder, psychosomatic symptoms, depression, anxiety) and others that were indirectly related (e.g., increased domestic violence, sleep quality/quantity). The authors of the review described that their intention was to focus on WFS; however, they defined WFS as "smoke from the landscape including both wild lands and agricultural lands" (p. 2). This resulted in the inclusion of studies that focused on events that are not directly linked to WFS, such as coal mine fires (Eisenman & Galway, 2022). The narrative review for this thesis included studies from Eisenman and Galway's (2022) scoping review that: 1) were explicitly related to smoke from wildfires, and 2) focused on outcomes directly related to mental health and disorder. Recent studies that were published after the scoping review were also included.

2.3.2.1 Mental Health Outcomes

Some research indicates relationships between WFS exposure and mental health outcomes; however, generally the findings are mixed. For example, positive associations exist between WFS exposure and psychological symptoms of intrusion (e.g., recurring thoughts, nightmares), hyperarousal (e.g., irritability, poor concentration, hypervigilance), and avoidance (e.g., attempts to avoid reminders) (Ho et al., 2014), as well as increased risk of suicide in rural communities (Molitor et al., 2023). However, no association was found between WFS exposure and risk of suicide in urban populations (Molitor et al., 2023). Furthermore, one study found no relationship between mental health complaints (measured through physician billing records) and WFS exposure, which was quantified through PM levels (Moore et al., 2006). There are various factors that may explain the differences in findings among studies, including how WFS exposure

was determined and how mental health outcomes were measured. The next sections, which focus on the outcomes of depression, anxiety, and stress, describe study designs in greater detail as they relate to the topics under study in this thesis.

2.3.2.2 Depression

Studies exploring the relationship between WFS and depression have generally found that exposure to WFS is associated with increased depression (Emprasertsuk et al., 2025; Giles et al., 2024; Humphreys et al., 2022; Jung et al., 2025; Mirabelli et al., 2022; Mottershead et al., 2020; Rodney et al., 2021). During this review, it was noted that WFS was measured using different approaches that broadly fell under objective (i.e., quantifying concentrations of smoke) or subjective (i.e., self-reported participant exposure) methods. Further, within these two categories, variation was noted in how researchers chose to measure WFS.

In studies that used objective methods of WFS measurement, findings indicated that WFS exposure was related to increased depression in some populations (Emprasertsuk et al., 2025; Giles et al., 2024; Jung et al., 2025; Mirabelli et al., 2022). For example, a study conducted in the US found that youth (15-24 years) exposed to increased levels of WFS-specific $PM_{2.5}$ in the past seven days (differentiated from background $PM_{2.5}$ by computer models) were at increased risk of emergency department visits for depression (Jung et al., 2025). Annual levels of $PM_{2.5}$ were used to measure WFS in a study in Thailand, and increased $PM_{2.5}$ was found to be positively associated with the annual prevalence of diagnosed depression in adults; however, a limitation of this study was that general $PM_{2.5}$ was not differentiated from WFS-specific $PM_{2.5}$, despite the authors' intention to examine the impacts of $PM_{2.5}$ originating from wildfires (Emprasertsuk et al., 2025). In a Canadian study, $PM_{2.5}$ measurements were utilized to corroborate participants' perceived exposure to WFS (which was self-reported through surveys); though the authors

measured $PM_{2.5}$ during a period of increased WFS, they did not separate general $PM_{2.5}$ from WFS-specific $PM_{2.5}$ (Giles et al., 2024). Participants (age >18 years) were surveyed on two occasions: during a period of heightened WFS, and during a period without WFS. Symptoms of depression (measured through the Depression, Anxiety, and Stress Scale [DASS]) were found to be higher during periods of WFS exposure when compared to periods with no WFS (Giles et al., 2024). Objective measures other than $PM_{2.5}$ may also be used to measure WFS; for instance, Mirabelli et al. (2022) used satellite imaging to determine WFS plume density (light, medium, or heavy) to explore the relationship between WFS exposure and adult mental health outcomes (measured through data gathered from an annual telephone survey). The authors found that exposure to ≥4 weeks of heavy WFS in the past year (compared to <2 weeks exposure) was associated with a 4% increase in the likelihood of ever having had a depressive disorder (Mirabelli et al., 2022).

Studies that utilized subjective measures also found positive associations between WFS exposure and symptoms of depression (Humphreys et al., 2022; Mottershead et al., 2020; Rodney et al., 2021). In an Australian study, adults who lived in an area during a period of severe WFS were surveyed (Rodney et al., 2021). The authors found that 21.4% of participants felt depressed (which participants attributed to the WFS) and that individuals with pre-existing physical or mental health problems were at greater risk of depression. Some individuals reported that they had been directly exposed to wildfires in addition to WFS. Participants were asked to focus on the impact of WFS specifically; however, the authors acknowledged that some participants were likely unable to separate the impacts WFS specifically from the impacts of wildfires (Rodney et al., 2021). Participants in studies that utilized interviews (Mottershead et al., 2020) and focus groups (Humphreys et al., 2022) voiced increased depression related to WFS

exposure. Possible mechanisms through which this occurs were identified by Mottershead et al. (2020); they studied the experiences of adult members of the Dene Tha' First Nation, who were evacuated from their community due to WFS severity. One participant described that increased depressed feelings resulted from staying indoors to avoid WFS, which also contributed to a sense of isolation and a lack of routine (Mottershead et al., 2020). Similarly, increased feelings of depression were described by adults in a rural US community who experienced periods of severe WFS in recent years (Humphreys et al., 2022). One participant who worked in healthcare voiced that many of their patients with diagnosed depression requested higher doses of antidepressant medications during periods of severe WFS. This could indicate that WFS exposure may exacerbate symptoms in individuals with pre-existing depression (Humphreys et al., 2022).

2.3.2.3 Anxiety

From this review, the findings were mixed among studies that explored the association between WFS exposure and anxiety. However, numerous studies found that WFS may contribute to increased anxiety (Dodd et al., 2018; Giles et al., 2024; Humphreys et al., 2022; Jung et al., 2025; Mirabelli et al., 2022; Rodney et al., 2021; Zhu et al., 2024). Two qualitative studies found in this review discussed possible mechanisms that underlie the association between WFS exposure and increased anxiety (Dodd et al., 2018; Humphreys et al., 2022). In one of these studies, adults in a rural US community affected by severe WFS in recent years were interviewed; the authors found that WFS exposure contributed to heightened concern for one's own health and the health of one's children, which may in turn increase feelings of anxiety (Humphreys et al., 2022). Participants also described that increased anxiety stemmed from social isolation and decreased time outdoors during periods of severe WFS (Humphreys et al., 2022). In a study of four different rural or remote Indigenous communities in Canada impacted by

prolonged, severe WFS, the authors found that some participants (total *n*=30, one of whom was described as *youth*) described that WFS exposure increased the perceived threat of encroaching wildfires and the fear of possible evacuations, which contributed to increased feelings of anxiety (Dodd et al., 2018).

Quantitative studies utilizing subjective measures of mental health outcomes (e.g., surveys) also found that exposure to WFS may increase anxiety (Giles et al., 2024; Rodney et al., 2021). In the Canadian study of adults by Giles et al. (2024), participants self-reported their levels of anxiety through the DASS questionnaire, and exposure to WFS within seven days was found to be significantly associated with increased anxiety compared to levels of anxiety during a period with no WFS. The authors of an Australian study used a survey to gather self-reported data about adult participants' anxiety symptoms, and found that 45.3% of participants who lived in areas impacted by wildfires and WFS reported increased anxiety attributed to WFS exposure; however, the authors acknowledged that some participants were exposed to wildfires as well as WFS and may have been unable to separate the impacts of these phenomena (Rodney et al., 2021). Secondary survey data (gathered from an annual telephone survey) was utilized by Mirabelli et al. (2022) to measure mental health outcomes in US adults, and it was found that participants who experienced heavy WFS density for >4 weeks of the year had a 34% increase in the prevalence of feeling "nervous, anxious, or on edge more than half the time during the past 2 weeks" (p. 3) in comparison to those who experienced <2 weeks of heavy WFS in the past year.

Among quantitative studies that utilized objective measures of mental health outcomes (e.g., hospital records), findings pertaining to WFS exposure and anxiety were mixed. Some of these studies found positive associations between WFS exposure and anxiety (Jung et al., 2025; Zhu et al., 2024). For example, two US studies exploring the relationship between WFS-specific

$PM_{2.5}$ and anxiety found that certain populations were at increased risk of presenting to emergency departments for anxiety disorders after exposure to WFS (Jung et al., 2025; Zhu et al., 2024). Jung et al. (2025) found that, within four days of exposure to increased WFS, children (0-14 years) and youth (15-24 years) were at greater risk of presenting to emergency departments for anxiety disorders compared to males and older individuals, and Zhu et al. (2024) found that exposure to a smoke event (WFS-specific $PM_{2.5}$ contributing to ≥25% of the total $PM_{2.5}$ in the past 48 hours) was positively associated with an increased risk of emergency department visits for anxiety disorders in girls (5-17 years). There are numerous pathways through which exposure to WFS could increase symptoms of anxiety in these populations; for example, it is possible that the inhalation of compounds found in WFS causes physiological changes (such neurological inflammation) that exacerbate symptoms of anxiety (Zhu et al., 2024).

Other quantitative studies utilizing objective measures for mental health outcomes found negative associations between WFS exposure and anxiety (Emprasertsuk et al., 2025; Zhu et al., 2024). For instance, though Zhu et al. (2024) found that girls (5-17 years) exposed to a smoke event were at increased risk of emergency department visits for anxiety, they also found that exposure to a major smoke event (WFS-specific $PM_{2.5}$ contributing to ≥75% of the total $PM_{2.5}$ in the past 48 hours) was negatively associated with risk of emergency department visits for anxiety among girls, as well as children and adolescents generally (5-17 years). Further, a study in Thailand found a negative association between annual average $PM_{2.5}$ levels and the national prevalence of diagnosed anxiety disorders in adults (Emprasertsuk et al., 2025). However, these findings may have been impacted by a limitation in terms of WFS measurement. While the authors described their intent to examine $PM_{2.5}$ originating from wildfires, they did not differentiate between general $PM_{2.5}$ and WFS-specific $PM_{2.5}$ (Emprasertsuk et al., 2025). Though

Zhu et al. (2024) did not discuss possible explanations for the negative association they found, Emprasertsuk et al. (2025) posited that this counter-intuitive association between anxiety and WFS exposure may result from decreased treatment engagement stemming from exacerbation of anxiety symptoms.

2.3.2.4 Stress

In comparison to the number of studies examining depression and anxiety, this review found relatively few studies examining stress. However, some study findings indicate a relationship between WFS exposure and increased stress (Dodd et al., 2018; Giles et al., 2024). The qualitative study focused on four Indigenous communities in Canada found that some participants experienced increased stress during times of WFS exposure (Dodd et al., 2018). Several mechanisms through which heightened stress may occur were identified; for instance, the presence of WFS may serve as a constant reminder of relatively nearby wildfires and may contribute to a state of uncertainty about if or when an evacuation could occur. Further, the authors found that poor air quality due to WFS may lead to increased time indoors; as a result, stress may increase due to feelings of social isolation (Dodd et al., 2018). A similar mechanism by which WFS may increase stress was identified by Giles et al. (2024). The authors utilized the DASS to measure stress levels among Canadian adults, both during a period of heightened WFS and during a period without WFS. Study findings indicated that stress was significantly increased during the period of heightened WFS compared to the period with no WFS, which the authors argued may be due to increased time indoors and decreased physical exercise during periods of WFS (Giles et al., 2024).

2.3.3 Wildfire Exposure in Wildfire Smoke Exposure Studies

During this narrative review, it was noted that some studies focusing on WFS exposure and mental health outcomes acknowledged that participants may have been exposed to wildfires in addition to WFS, and that this could have impacted the findings related to mental health outcomes (e.g., Emprasertsuk et al., 2025; Jung et al., 2025; Rodney et al., 2021; Zhu et al., 2024). However, numerous studies did not explicitly account for possible wildfire exposure among participants (e.g., Giles et al., 2024; Ho et al., 2015; Mirabelli et al., 2022; Molitor et al., 2023; Moore et al., 2006). Considering that WFS and wildfires are inherently linked, it may be possible that participants in studies purporting to focus on WFS exposure were also exposed to wildfires. Wildfire exposure is an experience that can differ from WFS exposure in numerous ways; for example, individuals exposed to wildfire may fear for their lives (McDermott et al., 2005) and may experience damage to or destruction of their home (Townshend et al., 2015). As such, studies that wish to determine the impacts of WFS only on mental health outcomes should either: 1) seek to study participants that have only experienced WFS, or 2) explicitly account for possible wildfire exposure in their study design.

2.3.4 Wildfire and Wildfire Smoke Exposure and Climate Worry

Some studies found in this review indicated that exposure to wildfires and/or WFS may be associated with increased worry. For example, Humphreys et al. (2022) found that some participants described worry related to concerns about WFS impacting their children’s health, and Mirabelli et al. (2022) found that participants exposed to medium or heavy WFS plumes for $\geq$6 weeks in the past year were at increased risk of worry-related symptoms compared with participants exposed to $\leq$4 weeks of medium or heavy WFS in the past year.

It remains unclear whether exposure to WFS or wildfires is associated with climate change specific worry, as this review found no studies directly examining these relationships. However, worry related to wildfires was identified among Canadian adolescents in the thematic results of a qualitative study that analyzed responses to an open-ended survey question (Tiwari et al., 2025). The study explored how the impacts of climate change on mental health were perceived by Canadian adolescents; though the authors did not focus on climate worry, wildfires, or WFS in their study, some participant responses included descriptions of wildfires or WFS (Tiwari et al., 2025). For example, when asked the question “Based on your experience, how is climate change impacting your mental health?” one participant wrote “it [climate change] is impacting my mental health as I am worried about wildfires” (p. 7). Another participant noted the physiological impacts of WFS in their response, describing that “the fires this summer made it hard to breathe” (Tiwari et al., 2025, p.10). Participant responses such as these indicate that experiences related to wildfires and WFS may increase Canadian adolescents’ worry about the impacts of climate change.

2.4 Gaps in the Research

From this review of the literature, four key research gaps were identified:

1) Relatively few quantitative studies found in this review used self-reported data to measure mental health outcomes. Numerous quantitative studies relied on administrative health data (e.g., hospital records); however, not all individuals experiencing mental health symptoms will seek formal health care, so use of these data sources may result in an underestimation of the prevalence of mental health problems (Zhu et al., 2024). Using survey data to measure levels of depression, anxiety, and stress may help to illuminate a broader range of participant experiences

related to these mental health problems. Thus, further quantitative research utilizing survey data to measure such outcomes is warranted.

2) There was a general lack of research focusing on adolescent populations, and no studies were found that focused on adolescents as the sole population of interest in relation to WFS exposure and mental health outcomes. This is notable when considering the numerous ways in which climate change related acute events, including wildfires and WFS, can impact young people (as noted in Chapter 1). As such, research focusing on the relationship between adolescent mental health outcomes and climate change related acute events (particularly WFS) is needed.

3) Few studies were found that explicitly focused on participants who had experienced only WFS (e.g., not in addition to, or with unknown, exposure to wildfires). Though WFS and wildfires are related phenomena, exposure to wildfires can be uniquely devastating, with possible consequences of direct exposure including loss of one's home and fear for one's life (e.g., McDermott et al., 2005; Townshend et al., 2015). Studies that intend to focus solely on WFS but do not account for possible wildfire exposure among participants risk misattributing mental health findings to the incorrect acute event related to climate change. Thus, there is value in research that explicitly separates participants who experienced WFS only from those who also experienced wildfires.

4) No studies were found directly examining the relationships between WFS and/or wildfire exposure and climate worry. However, previous research indicates that exposure to periods of heightened WFS may contribute to worry for oneself and others (Humphreys et al., 2022), and that some Canadian adolescents may feel worried about exposure to wildfires and WFS as it relates to the mental health impacts of climate change (Tiwari et al., 2025).

Considering that climate worry includes concern about the impacts of climate change on oneself, others, and the environment (Wullenkord & Ojala, 2023), it may be that WFS exposure increases climate worry. Further research is needed to explore this area of inquiry.

Chapter 3. Theoretical Frameworks

3.1 Introduction

As indicated in the narrative review of the literature, there is currently limited research on the relationship between mental health outcomes and WFS among adolescents. However, existing frameworks support the notion that this population may experience adverse mental health outcomes related to climate change factors, including exposure to WFS. The theoretical foundation of this thesis draws upon three frameworks relating to climate change, WFS, and mental health outcomes, and the details of these frameworks are outlined in this chapter.

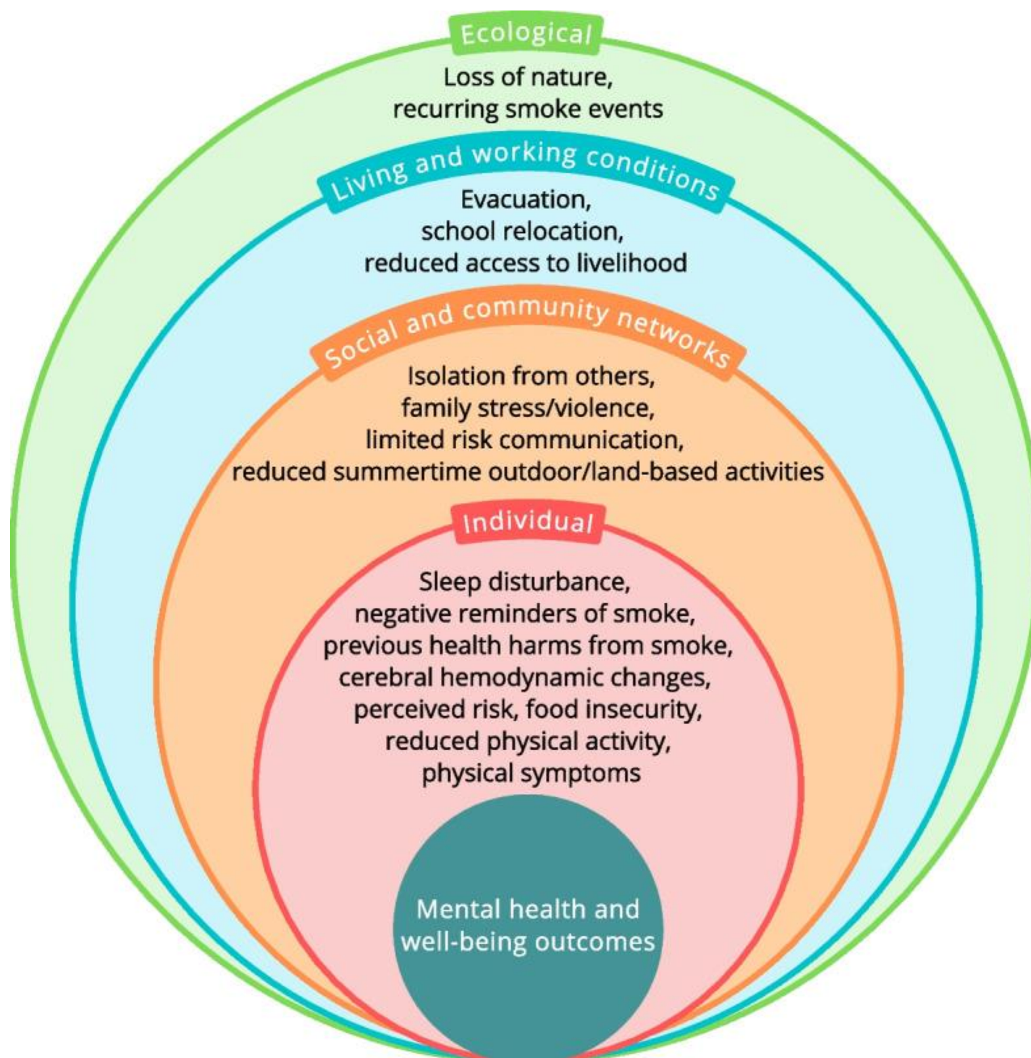
3.2 Theoretical Frameworks

3.2.1 Impacts of Wildfire Smoke on Mental Health and Wellbeing Framework

The first framework that informs the theoretical foundation of this thesis was adapted from Lawrance et al.'s (2022) Climate Change Impacts on Mental Health and Wellbeing Framework, which was based on Bronfenbrenner's Socioecological model (1977). In his model, Bronfenbrenner (1977) proposed that individuals exist within interrelated systems: the microsystem (immediate relationships and environment), the mesosystem (interconnected microsystems), the exosystem (social structures, such as the government and media), and the macrosystem (cultural ideologies and values). Each of these systems interact with each other and are thought to influence individuals' development throughout the lifespan (Bronfenbrenner, 1977). Lawrance et al. (2022) adapted this model to be specific to the climate change impacts on mental health and wellbeing, which was then adapted by Eisenman and Galway (2022) to outline the impacts of exposure to WFS specifically (Figure 2).

Figure 2

Impacts of WFS on Mental Health and Wellbeing Framework



Source: From "The Mental Health and Well-Being Effects of Wildfire Smoke: A Scoping Review," by D. P. Eisenman and L. P. Galway, 2022, *BMC Public Health, 22*(1)*,* p. 12 (https://doi.org/10.1186/s12889-022-14662-z). Reused with permission of the copyright holder under creative commons license (https://creativecommons.org/licenses/by/4.0/).

As shown in Figure 2, WFS can negatively impact an individual's mental health and wellbeing through various mechanisms that exist at numerous levels (Eisenman & Galway,

2022). At the individual level, mental health may be impacted by WFS through factors such as perceived risk of danger and negative reminders of previous events (e.g., evacuations due to wildfires) related to WFS. Mechanisms of mental health impacts at the social and community level may relate to factors such as social isolation, increased stress among families, and decreased time outdoors. In relation to living and working conditions, mental health may be reduced through disruptions in education, as well as experiences such as evacuations (Eisenman & Galway, 2022) which can occur in some communities due to severe WFS (Mottershead et al., 2020). Finally, at the ecological level, repeated exposure to WFS may negatively impact mental health through feelings of loss or grief for the natural world (Eisenman & Galway, 2022).

It is possible that the Canadian adolescents in this study who perceived exposure to WFS experienced some or all of these impacts related to WFS; for example, experiences such as evacuations, disruptions to schooling, social isolation, and increased family stress are likely to impact adolescents as well as children and adults. As such, Eisenman and Galway's (2022) framework supports the notion that participants in this study could experience decreased mental health in relation to perceived WFS exposure.

3.2.2 Climate Change Impacts on Adolescent Wellbeing Framework

The Adolescent Wellbeing Framework was first developed by Ross et al. (2020). The authors defined wellbeing as the ability to thrive and reach one's full potential. They argued that adolescent wellbeing is multidimensional and comprised of both objective (e.g., access to education) and subjective (e.g., feelings of fulfillment) measures of wellbeing that fall under five dimensions: 1) good health and nutrition, 2) connection, positive values, and societal contributions, 3) a safe and supportive environment, 4) learning, education, competence, skills, and employability, and 5) resiliency and agency (Ross et al., 2020).

Ross et al.'s (2020) Adolescent Wellbeing Framework was adapted by McGushin et al. (2022) to outline ways in which climate change can impact adolescent wellbeing, as well as ways in which health professionals and the greater community can collaborate with and be supportive of adolescents (Figure 3). This framework outlines that climate change can impact each of the dimensions relating to adolescent wellbeing, including mental wellbeing. For example, exposure to climate change related acute events can disrupt an adolescent's living environment, interrupt education due to school closures, and increase feelings of concern about future exposures (McGushin et al., 2022). As outlined in the previous framework, some of these impacts may result from WFS exposure, including evacuation and disruption to education (Eisenman & Galway, 2022).

Figure 3

Climate Change Impacts on Adolescent Wellbeing Framework

Source: From "Adolescent Wellbeing and Climate Crisis: Adolescents Are Responding, What About Health Professionals?" by A. McGushin, G. Gasparri, V. Graef, C. Ngendahayo, S. Timilsina, F. Bustreo, and A. Costello, 2022, *British Medical Journal, 379,* p. 2 (https://doi.org/10.1136/bmj-2022-071690). Reused with permission of the copyright holder under creative commons license (https://creativecommons.org/licenses/by-nc/3.0/igo/).

3.2.3 Climate Change Impacts and the Dual-Continuum Framework

The third framework foundational to this thesis relates to climate change impacts and the dual-continuum model (Figure 1), which was introduced in Chapter 1 (Vergunst et al., 2024). When developing this framework, Vergunst et al. (2024) drew on Keyes' (2005) dual-continuum model of mental health and disorder, which posits that mental health and mental disorder are two related yet distinct phenomena that exist on separate continua. As outlined in Vergunst et al.'s (2024) framework, exposure to climate change related acute events is associated with impacts to both mental health and mental disorder. For the purpose of this thesis (as described in Chapter 1), the outcomes of depression and anxiety are conceptualized as falling on the mental disorder continuum, while stress and climate worry relate more to the mental health and wellbeing continuum. Vergunst et al.'s (2024) conceptualization of the impacts of climate change related factors existing on two continua (i.e., mental health and disorder) supports the use of continuous measures for mental health outcome variables, as was done in this thesis.

3.2.4 Framework Development and Mechanisms of Impact

The theoretical frameworks that underpin this thesis were adapted from existing frameworks and models, and were informed by the findings of empirical research (Eisenman & Galway, 2022; McGushin et al., 2022; Vergunst et al., 2024). However, these frameworks are somewhat theoretical in nature, which may indicate that this area of inquiry is relatively understudied and further research is warranted. For example, Eisenman and Galway (2022) acknowledged that the research relating to WFS exposure and mental health outcomes is both limited and inconsistent, and that their framework should be considered with this context in mind. Further, Vergunst et al. (2024) developed their dual-continuum framework in response to a lack of clarity related to conceptualizations of climate change impacts on mental health

outcomes, which they argued has negatively impacted attempts to explore mechanisms of impact in previous research.

Both McGushin et al.'s (2022) framework relating to adolescent wellbeing and Eisenman and Galway's (2022) framework relating to the impacts of WFS exposure highlight possible mechanisms through which exposure to climate change related factors such as acute events may impact mental health and wellbeing. Further, in their study, Vergunst et al. (2024) discussed a variety of pathways through which exposure to climate change related acute events may impact mental wellbeing and/or mental disorder. However, the purpose of this thesis is to explore associations between WFS exposure and mental health outcomes in adolescents, rather than mechanisms of impact.

3.3 Summary

The frameworks that underpin this thesis are relatively theoretical in nature; this may relate to the presence of gaps in the research, inconsistent evidence, and an absence of clarity in terms of the conceptualization and measurement of constructs in this area of inquiry (Eisenman & Galway, 2022; Vergunst et al., 2024). As such, these frameworks outline possible mechanisms of impact, while also highlighting the need for further research on exposure to climate change related acute events and mental health outcomes. This thesis explores associations between WFS exposure and mental health outcomes, rather than mechanisms of impact. Taken together, the frameworks described in this chapter indicate that reduced mental wellbeing and/or increased symptoms of mental disorder may occur in adolescents who perceive exposure to WFS.

Chapter 4. Methodology

4.1 Study Design

This is a cross-sectional study utilizing secondary survey data from a larger project titled *Canadian Adolescents and Climate Change: Emotional Responses and Coping Strategies.* The survey instrument was developed by a team of individuals that included youth researchers (high school aged) and academics from various disciplines (Tiwari et al., 2025). Focus groups (with participants aged 15-18) were utilized during survey development to examine questions used in previous studies, and cognitive interviews (with participants aged 13-18) were used to ensure that key questions were clear to prospective participants (Tiwari et al., 2025).

Through an online survey platform (Qualtrics), data were collected between October and November of 2023 (Tiwari et al., 2025). A non-probability quota sampling approach was used with the intent to recruit a minimum of 100 participants from each Canadian province/territory, a minimum of 300 adolescents living in non-urban areas, at least 300 cis-boys and 300 cis-girls, and equal numbers of younger participants (13-15 years) and older participants (16-18 years) (Martin et al., 2025). Each of these quotas were met, except for the regional quota for the Northwest Territories (Martin et al., 2025). There was a total of 804 participants after data quality checks, which were completed by both the research team and by Qualtrics (Tiwari et al., 2025).

4.1.1 Participants

Participants had to be 13 to 18 years of age and living Canada to be eligible to complete the survey (Tiwari et al., 2025). The survey was available in English, and participants needed internet access to complete it (Martin et al., 2025). Recruitment was conducted by Qualtrics (Tiwari et al., 2025), where participants were pre-registered for survey research on a research panel (Qualtrics, 2020a).

4.1.2 Ethics

The *Canadian Adolescents and Climate Change: Emotional Responses and Coping Strategies* research project received ethics approval (REB #25013) from Athabasca University's Research Ethics Board (Martin et al., 2025). Qualtrics obtained parent/guardian approval before administering the survey to participants under the age of 18 (Martin et al., 2025). Participants chose to complete the survey after receiving a Letter of Information, which informed them of the content and length of the survey, that participation was voluntary, and that confidentiality and anonymity would be maintained (Martin et al., 2025). Qualtrics compensated participants for their time, which can include incentives such as earning points towards a reward (Qualtrics, 2020b). The Research Ethics Officer at Athabasca University confirmed that further ethics approval was not required for secondary use of the data (Appendix B).

4.1.3 Measures

4.1.3.1 Independent Variables

Wildfire Smoke (Variable of Interest). Exposure to WFS was the primary independent variable of interest. Participants were asked the question: "Now thinking about where you live: in the last 12 months, have you experienced the following in the area where you live?" Participants could answer "yes," "no," or "I don't know" for the following: "heat wave," "wildfire/forest fire in or near my community," "poor air quality from forest fire" (which was used to determine WFS exposure for this study), "drought (a longer than normal period without rain or snow)," "snowstorm," "flood," "hurricane/tropical storm," "tornado," "earthquake," and "I have noticed a change in the natural environment (for example, weather patterns, changes in the plants and animals)." For this thesis, the focus was on well-established, acute events related to climate change; as such, exposure to earthquakes (a geophysical disaster) and noticing gradual

changes in the environment (a non-acute exposure) were not considered when developing the WFS exposure variable.

This measure was coded into six categories: 1) no exposures, 2) WFS only, 3) WFS +1 other climate change related acute event (including wildfires and other acute events), 4) WFS +2 other acute events, 5) WFS +3 other acute events, and 6) WFS + ≥4 other acute events. The rationale for this categorization is outlined in Chapter 5. The reference category was the "no exposures" group. There were 626 participants with a valid measure on this variable. Of the 804 participants, those who said "I don't know" to experiencing WFS (n=48), those who said "no" to WFS exposure but reported "yes" to other acute event exposures (n=126), and those with missing values on WFS exposure (n=4) were excluded.

Covariates.

The covariates included in adjusted models are known to relate to mental health outcomes: age, gender, perceived family wealth (Halladay et al., 2025) and urbanicity (Weeks et al., 2023). Covariates are factors outside of the variables of interest that may be associated with the outcome variables; as such, associations between the variables of interest may be more accurately determined when covariates are adjusted for in statistical models (Halladay et al., 2025). In some instances, covariates can be controlled for through study design (Thomas, 2020); for example, a study on WFS exposure could compare participants from a WFS-exposed town and a non-WFS-exposed town and intentionally have equal representation of cis-boys and cis-girls in the sample. However, as this study did not control through study design, there may (for example) be more cis-girls who perceived WFS exposure compared to other gender identities. As such, statistical controls were utilized, meaning that covariates were included in adjusted models (Thomas, 2020).

Age. Participants' ages ranged from 13 to 18 years of age. This variable was treated as continuous in statistical models.

Gender. The survey included one question pertaining to gender: "What gender do you identify as? (Select ALL that apply)." The response options were: "agender," "boy/man," "gender fluid," "girl/woman," "non-binary," "trans boy/trans man," "trans girl/trans woman," "two-spirit," "prefer not to answer," and "another identity not listed." If a participant selected "another identity not listed," they could specify with a typed response. For this thesis, participants who chose only "boy/man" were categorized as cis-boy and participants who chose only "girl/woman" were categorized as cis-girl. Participants who preferred not to select an answer, who selected an identity other than "boy/man" or "girl/woman", or who selected numerous gender identities were placed in one category: "gender diverse." This variable was treated as categorical.

Urbanicity. Participants responded to the question: "What phrase best describes the area where you currently live?" The response options were: "a city," "a small town," or "a rural or remote area." This variable was treated as categorical.

Family Wealth. Participants responded to the question: "How financially well off do you believe your family is?" The five-point response scale ranged from 1 ("very well off") to 5 ("not at all well-off") with 3 indicating "average." For analysis, "very well-off" and "quite well-off" were combined into one category ("above average"), and "not very well-off" and "not at all very well-off" were combined into one category ("below average"). The reference group in statistical models was "average." This variable was treated as categorical.

4.1.3.2 Dependent Variables

The dependent variables of depression, anxiety, and stress were measured through The Depression Anxiety Stress Scales for Youth (DASS-Y). This psychometric tool is the adapted version of the adult DASS, in that it uses simplified wording that is more appropriate for young people (Szabo & Lovibond, 2022). Similar to the DASS, the DASS-Y is intended to assess negative emotional states in the respondent and consists of three subscales: depression, anxiety, and stress. The DASS-Y tool has been validated for use in children and youth ages seven to 18 years (Szabo & Lovibond, 2022). In the survey, the DASS-Y questions had the following preamble: "We would like to find out how you have been feeling in the past week. There are some sentences below. Please select the statement which best shows how TRUE each sentence was about you during the past week." The full DASS-Y questionnaire can be found in Appendix C. All scale items were treated as continuous in the models.

Depression. Seven questions pertained to the depression subscale. Participants were asked whether they had experienced certain symptoms during the past week, such as "I did not enjoy anything" and "I could not stop feeling sad." Feedback from youth co-researchers during survey development prompted a change in wording for one item, from "I hate myself" to "I don't like myself" (Martin et al., 2025). There was a four-point scale response that ranged from 0 ("not true") to 3 ("very true"). A variable was computed that calculated each participant's mean score for the depression subscale. A participant had to answer >80% (six or more) of the subscale items for their score to be included in analysis (Downey & King, 1998).

Anxiety. There were seven questions in the anxiety subscale, including whether the respondent's "hands felt shaky" or they "felt scared" in the past week. Participants responded with the same four-point scale as for the depression questions, and a variable was computed that

calculated each participant's mean anxiety score. Participants who answered fewer than six of the items were excluded from analysis.

Stress. Seven questions pertained to the stress subscale. Participants were asked if, in the past week, they felt "easily irritated" or "found it difficult to relax," for example. The same four-point scale was used as with depression and anxiety questions. A variable was computed that calculated the mean stress score for each participant, and participants who answered fewer than six of the items were not included in the analysis.

Climate Worry. Participants answered a total of five questions related to climate worry (Martin et al., 2025), which were adapted from a scale previously developed for adolescents in Sweden (Ojala, 2012). The questions asked how worried participants were about the impact of climate change for themselves, their friends and family, future generations, people in different countries, and animals and nature. A four-point scale response ranged from 1 ("not worried at all") to 4 ("very worried").

As done in other studies (e.g., Wullenkord & Ojala, 2023), concern about oneself or one's friends and family constituted micro worry (mean score on these two items), while concern about future generations, people in other countries, or plants and animals constituted macro worry (based on mean scores). Any respondents who did not answer all items for each scale were excluded from analysis. The climate worry questions were not asked of participants who did not believe that climate change was happening (n=17), given that those questions may have seemed irrelevant to or could have been interpreted differently by such individuals (Martin et al., 2025).

4.1.4 Data Analysis

The survey data was analyzed with IBM SPSS Statistics software (version 29). First, bivariate linear regression analyses were completed to assess model fit and examine the

relationships between climate change related acute event exposure categories and the various mental health outcomes. Then, multiple linear regression analyses were performed that included the demographic covariates of age, gender, urbanicity, and perceived family wealth. Multiple linear regression was used because the outcome variables were continuous and there were both continuous and categorical independent variables (Laerd Statistics, n.d.). All models used a significance level of .05, a common threshold for confidence in quantitative research (Field, 2017).

Multiple linear regression has six assumptions of the data: linearity, no outliers, no multicollinearity, normality of residuals, independence of residuals, and homoscedasticity (Field, 2017). Assumptions were checked using a series of approaches outlined in Appendix D. During this process, a few concerns regarding the assumptions were noted, specifically with normality and independence of residuals. Normality was assessed by generating histograms of residuals; to account for non-normal distributions (as evidenced in Appendix F), bias corrected and accelerated (BCa) bootstrap (95%) confidence intervals (CI) were utilized in all statistical models (Field, 2017).

Scatterplots were generated to assess for independence of residuals (Appendix G). Visual inspection indicated that non-independence may be present for the outcome variables of climate micro and macro worry, as evidenced by clustering of scatterplot points (Field, 2017). Non-independence of residuals may impact the validity of standard errors, which can in turn impact the validity of CIs and significance tests (Field, 2017). Various options for addressing non-independence of residuals were considered, including other statistical models (Columbia University, n.d.; Mehta, 2023), robust standard errors (IBM, 2024; Mansournia et al., 2021), and the transformation of data (Field, 2017); however, these approaches were inappropriate for the

data structure. As such, multiple linear regression remained the statistical model of choice for data analysis. The results for the outcomes of climate micro and macro worry, particularly the CIs and p-values, should be considered with this context in mind.

Chapter 5. Acute Event Exposure Group Conceptualization

5.1 Introduction

As the review of the literature outlined, there are numerous ways that WFS exposure can be measured, and this can impact interpretation of the findings. Further, as we see the effects of climate change manifest, studies that seek to explore the impacts of a single form of climate change related acute event need to consider that in present society many people are experiencing multiple types of events. This chapter outlines the decision process as it related to classifying exposures to climate change related acute events reported by participants to provide a rationale for the categorization that was utilized in analysis.

5.2 Exposure Classification

The first step in conceptualizing climate change related acute event exposure classifications was determining the number of participants who reported exposure to WFS smoke. Preliminary data analysis indicated that over half of participants responded “yes” to experiencing WFS in the prior 12 months (497/804, 61.8%). Further analysis revealed that many of these participants reported exposure to one or more other acute events related to climate change, in addition to WFS (Table 1). As such, while many participants reported WFS exposure, only 40 participants reported that WFS was the only acute event they had experienced. These results indicated that studying the mental health consequences of WFS in isolation may be challenging.

Table 1

Number of Acute Events Experienced by Participants Who Reported WFS Exposure (n=497)

Number of Exposures	“Yes” to WFS Exposure in Prior 12 Months
1 (WFS only)	40 (8.0%)
2 (WFS +1)	106 (21.3%)
3 (WFS +2)	136 (27.4%)
4 (WFS +3)	126 (25.4%)
5 (WFS +4)	58 (11.7%)
6 (WFS +5)	24 (4.8%)
7 (WFS +6)	7 (1.4%)

Four key factors were considered when conceptualizing how to classify climate change related acute event exposures for data analysis: 1) centering WFS as the acute event of interest, 2) considering that WFS exposure may occur to people who have experienced other acute events, 3) conceptualizing an appropriate comparison group, and 4) sample size. These considerations informed four options related to the categorization of participant exposures (Table 2).

Table 2

Considerations Related to Acute Event Exposure Classification

Classification Options	Strengths	Drawbacks
Approach A		
Group 1 = "Yes" to WFS Group 2 = All other participants as comparison	Focus on WFS as event of interest Full sample	Does not account for experience of other climate change related acute events
Approach B		
Group 1 = "Yes" to WFS only Group 2 = No exposures as comparison group - Remove participants who experienced WFS and another climate change related acute event - Remove participants who experienced a climate change related acute event who reported no WFS	Focus on WFS as event of interest Separation of WFS from exposure to other climate change related acute events through use of "no exposures" group as comparator	Excluding participants who said "yes" to wildfires if they had another exposure removes many participants exposed to the phenomenon under study Reduced sample size

Classification Options	Strengths	Drawbacks
Approach C		
Group 1 = “Yes” to WFS only Group 2 = “Yes” to WFS and wildfire Group 3 = No exposures as comparison group - Remove participants who experienced WFS and another climate change related acute event (not wildfire) - Remove participants who experienced a climate change related acute event and reported no WFS	Focus on WFS as event of interest Acknowledges that WFS and wildfires are linked as acute events related to climate change	Removes participants who experienced WFS if they also experienced another climate change related acute event (other than wildfire), thus removing participants with exposure to the phenomenon under study Reduced sample size
Approach D		
Group 1 = “Yes” to WFS only Group 2 = “Yes” to WFS plus any other exposures (including wildfire) Group 3 = No exposures as comparison group	Focus on WFS as event of interest Acknowledges possible impact of exposure to numerous climate change related acute events Retains all participants who experienced WFS (sample size is reduced but still large)	All combinations of climate change related acute events are not accounted for (e.g., flood + WFS; flood + heatwave + WFS), so it is difficult to disentangle impacts of such events in addition to WFS

As outlined in Table 2, each option for exposure groupings had both strengths and drawbacks. Ultimately, the decision was reached to use approach D with six groupings: 1) no exposure to climate change related acute events (comparison group), 2) WFS only, 3) WFS +1

other acute event, 4) WFS +2 other acute events, 5) WFS +3 other acute events, and 6) WFS + ≥4 other acute events. This approach had four benefits. First, the central focus of this thesis (examining the impact of exposure to WFS) was upheld. Second, by using "no exposures" as the comparison group, the possible mental health impacts of exposure to only WFS were isolated from impacts of other climate change related acute events (though findings remain correlational, rather than causal). Third, all participants who perceived exposure to WFS were included. Fourth, the potential for exposure to other climate change related acute events in addition to WFS was acknowledged.

5.3 Summary

Many participants in the sample reported experiencing multiple climate change related acute events, which complicated the conceptualization of WFS exposure groupings for this study. This may reflect the reality for people living in areas impacted by climate change and should be a consideration of studies that seek to isolate health impacts of exposures to specific acute events. Numerous categorization options were considered, each with strengths and drawbacks. The approach that this study utilized maintained WFS exposure as the independent variable of interest, while acknowledging the possible impact of exposure to multiple acute events related to climate change.

Chapter 6. Results

6.1 Descriptive Statistics

Eight hundred and four participants completed the survey; descriptive statistics for the key variables in this study and demographic characteristics of participants are presented Table 3. Approximately half of participants identified as cis-girl (50.6%) while 46.1% identified as cis-boy and 3.2% identified as gender diverse. The mean age of participants was 15.6 years (standard deviation [SD] = 1.65). The majority of participants lived in a city (68.4%), and approximately half of participants perceived their family wealth as average (47.9%). The mean depression and anxiety score among participants was 0.8 (SD = 0.86 and 0.80, respectively), while the mean stress score was 1.2 (SD = 0.85). Mean climate macro worry (3.1, SD = 0.76) was slightly higher than mean climate micro worry (2.8, SD = 0.83).

Table 3

Participant Demographics and Variable Characteristics

Variable	*n* (%) / Mean (SD), Min, Max
Age (*n*=804)	15.6 (±1.65), 13, 18
Gender (*n*=804)	
Cis-girl	407 (50.6%)
Cis-boy	371 (46.1%)
Gender diverse	26 (3.2%)
Urbanicity (*n*=804)	
A city	550 (68.4%)
A small town	187 (23.3%)
A rural/remote area	65 (8.1%)
Perceived family wealth (*n*=804)	
Worse off than average	118 (14.7%)
Average	385 (47.9%)
Better off than average	299 (37.2%)
Depression subscale (*n*=789)	0.8 (±0.86), 0, 3
Anxiety subscale (*n*=787)	0.8 (±0.80), 0, 3
Stress subscale (*n*=790)	1.2 (±0.85), 0, 3
Climate micro worry (*n*=785)	2.8 (±0.83), 1, 4
Climate macro worry (*n*=781)	3.1 (±0.76), 1, 4
Acute event exposure groups (*n*=626)	
No exposures	129 (20.6%)
WFS only	40 (6.4%)
WFS +1 other climate change related acute event	106 (16.9%)
WFS +2 other climate change related acute events	136 (21.7%)
WFS +3 other climate change related acute events	126 (20.1%)
WFS + ≥4 other climate change related acute events	89 (14.2%)

Note. SD = standard deviation; Min = minimum; Max = maximum. Some percentages may not total 100 due to rounding. Depression, anxiety, and stress scale response options = 0 for “not true” to 3 for “very true.” Climate worry scale response options = 1 for “not worried at all” to 4 for “very worried.”

Table 4 outlines the frequencies of other types of climate change related acute event exposures that were perceived by participants who were included in analyses. In the group who experienced WFS plus one other acute event, wildfire exposure was most frequently reported in comparison to other types of acute event exposures (31.1%). In contrast, exposure to heat wave was most frequently reported by participants in the other groups: WFS plus two other acute events (62.5%), WFS plus three other acute events (83.3%), and WFS plus four or more other acute events (89.9%). Percentages for those who experienced WFS plus two or more other climate change related acute events do not equal 100 (Table 4), as there was overlap between multiple types of acute event exposures.

Table 4

Frequencies of Climate Change Related Acute Event Exposures in Exposure Groups

	WFS +1 (*n*=106)	WFS +2 (*n*=136)	WFS +3 (*n*=126)	WFS + ≥4 (*n*=89)
Wildfire	33 (31.1%)	62 (45.9%)	82 (65.1%)	76 (85.4%)
Heat Wave	25 (23.6%)	85 (62.5%)	105 (83.3%)	80 (89.9%)
Drought	12 (11.4%)	30 (22.1%)	39 (31.0%)	41 (46.6%)
Snowstorm	30 (28.6%)	64 (47.4%)	82 (65.1%)	69 (77.5%)
Flood	2 (1.9%)	10 (7.4%)	18 (14.3%)	59 (67%)
Hurricane/ Tropical Storm	2 (1.9%)	11 (8.1%)	12 (9.5%)	40 (45.5%)
Tornado	2 (1.9%)	10 (7.4%)	40 (31.7%)	29 (33.3%)

Note. Values displayed as *n* (%) and reflect participants who responded “yes” to experiencing other climate change related acute events in addition to WFS in the past 12 months.

6.2 Bivariate Linear Regression Analysis

Bivariate linear regression analyses (unadjusted for covariates) were conducted to explore model fit and the relationships between WFS exposure and the outcome variables: depression, anxiety, stress, climate micro and macro worry (Table 5).

Table 5

Bivariate Regression Analyses of Acute Event Exposure and Mental Health Outcomes

	Depression (*n*=616) R^2=0.01	Anxiety (*n*=615) R^2=0.03	Stress (*n*=615) R^2=0.03	Climate Micro Worry (*n*=612) R^2=0.03	Climate Macro Worry (*n*=610) R^2=0.02
Intercept	0.79 (0.65, 0.93)*** SE=0.08	0.71 (0.57, 0.86)*** SE=0.07	1.14 (0.99, 1.28)*** SE=0.08	2.64 (2.47, 2.79)*** SE=0.07	3.00 (2.85, 3.15)*** SE=0.08
Exposure (ref=no exposures)					
WFS Only	-0.06 (-0.42, 0.31) SE=0.17	-0.10 (-0.35, 0.17) SE=0.14	-0.03 (-0.35, 0.29) SE=0.15	-0.20 (-0.51, 0.09) SE=0.16	-0.05 (-0.39, 0.27) SE=0.16
WFS +1	-0.00 (-0.24, 0.25) SE=0.11	-0.03 (-0.21, 0.17) SE=0.10	0.11 (-0.11, 0.34) SE=0.11	0.24 (0.05, 0.45)* SE=0.11	0.14 (-0.08, 0.36) SE=0.11
WFS +2	-0.08 (-0.29, 0.15) SE=0.10	-0.03 (-0.21, 0.17) SE=0.10	0.05 (-0.16, 0.25) SE=0.10	0.08 (-0.12, 0.29) SE=0.11	0.11 (-0.14, 0.34) SE=0.11
WFS +3	-0.03 (-0.24, 0.19) SE=0.11	-0.01 (-0.20, 0.18) SE=0.10	0.10 (-0.10, 0.30) SE=0.10	0.13 (-0.07, 0.35) SE=0.10	0.17 (-0.03, 0.36) SE=0.10
WFS +≥4	0.25 (0.02, 0.51)* SE=0.13	0.38 (0.13, 0.62)*** SE=0.12	0.41 (0.18, 0.64)** SE=0.12	0.35 (0.13, 0.57)** SE=0.12	0.29 (0.07, 0.52)* SE=0.11

Note. SE = standard error. Ref = reference. Values reflect unstandardized coefficients and upper and lower 95% CI values. Results are bootstrapped and based on 1,000 bootstrap samples.
* $p<.05$; ** $p<.01$; *** $p<.001$.

The bivariate linear regression models were statistically significant for anxiety ($F(5, 609) = 4.183$, $p = <.001$), stress ($F(5, 609) = 3.110$, $p = .009$), and climate micro worry ($F(5, 606) = 3.539$, $p = .004$). However, the models were not significant for depression ($F(5, 610) = 1.780$, $p = .115$) or climate macro worry ($F(5, 604) = 1.878$, $p = .096$).

Participants who perceived exposure to WFS only in the last 12 months had, on average, the same mean level of each mental health outcome as participants who perceived no exposure to acute events related to climate change. Increased climate micro worry was significantly higher for those exposed to WFS plus one other climate change related acute event ($\beta = 0.24$, $p = .025$) and WFS plus four or more other climate change related acute events ($\beta = 0.35$, $p = .002$) compared to those with no exposures. Mean levels of each outcome variable (depression [$\beta = 0.25$, $p = .045$], anxiety [$\beta = 0.38$, $p <.001$], stress [$\beta = 0.41$, $p = .003$], climate micro worry [$\beta = 0.35$, $p = .002$], climate macro worry [$\beta = 0.29$, $p = .012$]) were significantly higher among those exposed to WFS plus four or more other climate change related acute events compared to those with no perceived exposures.

6.3 Multiple Linear Regression Analysis

Following the bivariate analyses, multiple linear regression analyses were conducted that were adjusted for demographic covariates (age, gender, urbanicity, perceived family wealth; Table 6).

Table 6

Multiple Regression Analyses of Acute Event Exposure and Mental Health Outcomes

	Depression (*n*=614) R^2=0.09	Anxiety (*n*=613) R^2=0.15	Stress (*n*=613) R^2=0.14	Climate Micro Worry (*n*=608) R^2=0.05	Climate Macro Worry (*n*=611) R^2=0.04
Intercept	0.35 (0.10, 0.62)** SE=0.12	0.20 (-0.01, 0.41) SE=0.11	0.64 (0.41, 0.88)*** SE=0.12	2.65 (2.41, 2.87)*** SE=0.12	2.84 (2.58, 3.09)*** SE=0.13
Exposure (Ref=no exposures)					
WFS Only	-0.04 (-0.33, 0.28) SE=0.17	-0.08 (-0.36, 0.24) SE=0.15	0.00 (-0.29, 0.31) SE=0.14	-0.21 (-0.52, 0.10) SE=0.17	-0.07 (-0.38, 0.29) SE=0.16
WFS +1	0.05 (-0.17, 0.28) SE=0.11	0.02 (-0.18, 0.20) SE=0.10	0.19 (-0.03, 0.38) SE=0.10	0.24 (0.01, 0.45)* SE=0.11	0.17 (-0.05, 0.39) SE=0.11
WFS +2	-0.06 (-0.25, 0.12) SE=0.10	-0.02 (-0.20, 0.16) SE=0.09	0.07 (-0.13, 0.28) SE=0.10	0.07 (-0.13, 0.27) SE=0.11	0.11 (-0.13, 0.35) SE=0.11
WFS +3	-0.04 (-0.23, 0.14) SE=0.10	-0.03 (-0.23, 0.18) SE=0.10	0.09 (-0.12, 0.28) SE=0.10	0.11 (-0.08, 0.31) SE=0.10	0.16 (-0.03, 0.36) SE=0.10
WFS +≥4	0.23 (-0.04, 0.48) SE=0.13	0.36 (0.12, 0.61)** SE=0.12	0.39 (0.18, 0.61)** SE=0.11	0.31 (0.07, 0.54)** SE=0.12	0.26 (0.04, 0.49)* SE=0.11
Age	0.06 (0.02, 0.10)** SE=0.02	0.06 (0.02, 0.10)** SE=0.02	0.05 (0.01, 0.09)** SE=0.02	-0.03 (-0.08, 0.01) SE=0.02	0.01 (-0.03, 0.05) SE=0.02
Gender (Ref=cis-boy)					
Cis-Girl	0.24 (0.09, 0.38)** SE=0.07	0.33 (0.21, 0.45)*** SE=0.06	0.37 (0.24, 0.50)*** SE=0.06	0.16 (0.02, 0.30)* SE=0.07	0.22 (0.08, 0.35)** SE=0.07

	Depression (n=614) R^2=0.09	Anxiety (n=613) R^2=0.15	Stress (n=613) R^2=0.14	Climate Micro Worry (n=608) R^2=0.05	Climate Macro Worry (n=611) R^2=0.04
Gender Diverse	0.34 (-0.02, 0.70) SE=0.18	0.80 (0.44, 1.17)*** SE=0.19	0.37 (-0.04, 0.74) SE=0.20	0.20 (-0.27, 0.60) SE=0.21	0.34 (0.09, 0.60)** SE=0.14
Urbanicity (Ref=city)					
Small Town	0.10 (-0.06, 0.25) SE=0.08	0.03 (-0.11, 0.18) SE=0.08	0.24 (0.09, 0.40)** SE=0.08	-0.03 (-0.21, 0.13) SE=0.08	-0.02 (-0.17, 0.13) SE=0.08
Rural/ Remote	0.50 (0.22, 0.80)*** SE=0.15	0.45 (0.19, 0.71)*** SE=0.14	0.58 (0.33, 0.84)*** SE=0.12	-0.06 (-0.33, 0.22) SE=0.14	-0.02 (-0.28, 0.21) SE=0.12
Family Wealth (Ref= average)					
Above Average	-0.04 (-0.19, 0.10) SE=0.08	0.08 (-0.05, 0.20) SE=0.07	-0.05 (-0.19, 0.08) SE=0.07	0.07 (-0.10, 0.22) SE=0.07	-0.01 (-0.14, 0.12) SE=0.07
Below Average	0.14 (-0.09, 0.37) SE=0.11	0.16 (-0.02, 0.36) SE=0.10	0.06 (-0.13, 0.26) SE=0.10	0.17 (-0.03, 0.40) SE=0.10	0.08 (-0.11, 0.25) SE=0.10

Note. SE = standard error. Ref = reference. Values reflect unstandardized coefficients and upper and lower CI values. Results are bootstrapped and based on 1,000 bootstrap samples. * p<.05; ** p<.01; *** p<.001.

All multiple regression models were statistically significant: depression (F(12, 601) = 4.698, p = <.001), anxiety (F(12, 600) = 8.669, p = <.001), stress (F(12, 600) = 7.983, p = <.001), climate micro worry (F(12, 598) = 2.359, p = .006), and climate macro worry (F(12, 595) = 2.110, p = .015). Positive, significant associations were found between age and the outcomes of depression (β = 0.06, p = .005), anxiety (β = 0.06, p = .005), and stress (β = 0.05, p = .008). This shows that as participant age increased, depression, anxiety, and stress also

increased. In comparison to identifying as a cis-boy, individuals who identified as cis-girl had higher scores on each outcome variable (depression [$\beta = 0.24$, $p = .002$], anxiety [$\beta = 0.32$, $p < .001$], stress [$\beta = 0.37$, $p < .001$], climate micro worry [$\beta = 0.16$, $p = .025$], climate macro worry [$\beta = 0.22$, $p = .002$]). Those who identified as gender diverse had higher levels of anxiety ($\beta = 0.80$, $p < .001$) and climate macro worry ($\beta = 0.34$, $p = .009$) compared with those who identified as cis-boy.

Significantly higher stress was found for those living in a small town ($\beta = 0.24$, $p = .002$) or rural or remote area ($\beta = 0.58$, $p < .001$) compared to individuals who lived in a city. Participants who reported living in a rural or remote area also had higher levels of depression ($\beta = 0.50$, $p < .001$) and anxiety ($\beta = 0.45$, $p < .001$) than city-dwellers. Perceiving one's family wealth as above or below average was not significantly associated with mental health outcomes when compared with individuals who perceived their family wealth to be average in the adjusted models.

As with the bivariate regression analyses, individuals with perceived exposure to WFS only did not have significantly different levels of depression ($\beta = -0.04$, $p = .841$), anxiety ($\beta = -0.08$, $p = .623$), stress ($\beta = 0.00$, $p = .985$), climate micro worry ($\beta = -0.21$, $p = .229$), or climate macro worry ($\beta = -0.07$, $p = .659$) than those with no perceived exposures. Climate micro worry was higher for those exposed to WFS plus one other climate change related acute event ($\beta = 0.24$, $p = .034$) and WFS plus four or more other climate change related acute events ($\beta = 0.31$, $p = .008$) compared to those with no self-perceived exposures to acute events. The results for climate micro worry were largely unchanged from the bivariate regression analysis and indicate that individuals with perceived exposure to WFS plus two or three other climate change related

acute events in the last 12 months have similar levels of climate micro worry compared to individuals with no perceived exposures.

Similar to the bivariate regression analyses, multiple linear regression findings showed that those who perceived they were exposed to WFS plus four or more other climate change related acute events had higher anxiety ($\beta = 0.36$, $p = .003$), stress ($\beta = 0.39$, $p = .002$), climate micro worry ($\beta = 0.31$, $p = .008$), and climate macro worry ($\beta = 0.26$, $p = .019$) than those with no exposures. However, the difference in levels of depression between those with exposure to WFS plus four or more other climate change related acute events and those with no exposures was no longer significant when demographic covariates were adjusted for in analysis ($\beta = 0.23$, $p = .069$).

6.4 Summary

Both the bivariate and multiple regression analyses found that perceived exposure to WFS only was not significantly associated with mental health outcomes compared to participants with no perceived exposures to climate change related acute events. However, participants with perceived exposure to WFS plus four or more other acute events had significantly higher anxiety, stress, climate micro worry, and climate macro worry than those with no exposures. These findings are discussed in the next chapter.

Chapter 7. Discussion and Conclusion

7.1 Wildfire Smoke Exposure and Depression, Anxiety, and Stress

The findings from this research suggest that Canadian adolescents who perceive no exposures to climate change related acute events in the last 12 months may have similar levels of depression, anxiety, stress, climate micro worry, and climate macro worry as those who perceive exposure to WFS only. These findings were unexpected considering that previous studies (see Chapter 2) have found that WFS exposure is associated with increased depression and stress (Dodd et al., 2018; Emprasertsuk et al., 2025; Giles et al., 2024; Humphreys et al., 2022; Jung et al., 2025; Mirabelli et al., 2022; Mottershead et al., 2020; Rodney et al., 2021), with mixed findings for the outcome of anxiety (Dodd et al., 2018; Emprasertsuk et al., 2025; Giles et al., 2024; Humphreys et al., 2022; Jung et al., 2025; Mirabelli et al., 2022; Rodney et al., 2021; Zhu et al., 2025). However, several key differences in study design could explain this study's findings.

First, this thesis utilized self-reported measures of WFS exposure, whereas some previous studies used objective measures (e.g., Jung et al., 2025; Mirabelli et al., 2022; Zhu et al., 2024). Through the use of methods such as measurement of WFS-specific $PM_{2.5}$ (Jung et al., 2025; Zhu et al., 2024) or satellite-imaging of WFS plume density (Mirabelli et al., 2022), researchers in previous studies were able to determine the severity of WFS at specific times and in specific locations. It is possible that objective methods such as these more accurately determine the level and duration of exposure that participants experienced in comparison to self-reported exposure data.

Second, it may be that the mental health impacts of WFS exposure exist during a relatively short period of time after the exposure occurs, which could be why this study found

similar mental health outcomes between participants exposed to WFS only and those with no exposures. Previous studies have found that the impacts of WFS exposure on mental health outcomes were present within hours or days of the exposure; for example, Zhu et al. (2024) found associations within 48 hours of exposure, and Giles et al. (2024) found associations within seven days of exposure. In the survey data used for this study, participants self-reported whether exposures had occurred during the last 12 months; as such, there may have been a wide range of participant experiences in terms of how recently they perceived WFS exposure (e.g., 12 months ago versus 3 days ago).

Third, while some previous studies considered that participants may have been exposed to wildfires in addition to WFS (e.g., Jung et al., 2025; Rodney et al., 2021; Zhu et al., 2024), no studies found in the literature review explicitly considered that participants may have been exposed to climate change related acute events apart from WFS and wildfires (e.g., heat waves, storms); as such, the findings of those studies may have been impacted by participant exposures to climate change related acute events outside of the exposures under study. In contrast, the acute event exposure categories in this study separated participants who perceived exposure to WFS only from those who perceived exposures to other climate change related acute events, which could contribute to the difference in study findings.

Though this study found that participants exposed to WFS only had similar mental health outcomes compared to non-exposed individuals, it was also found that participants who were exposed to WFS plus four or more other climate change related acute events had elevated anxiety and stress compared to those with no exposures. This supports the notion that adolescents exposed to multiple different climate change related acute events may suffer negative health consequences; previous studies have found that adolescents exposed to multiple acute events

experienced poor mental health outcomes, such as increased risk of suicidal thoughts (Edwards et al., 2024) and increased risk of conduct problems like bullying others (Campbell et al., 2025). Both Campbell et al. (2025) and Edwards et al. (2024) studied Australian adolescents (aged 10-17 years and 14-20 years, respectively) and utilized subjective measures of both natural disaster exposure (reported by participants' caregivers) and mental health outcomes (reported by participants). Some of the natural disasters included in these studies were also acute events under study in this thesis, such as wildfires, floods, and droughts; however, WFS was not included as a form of natural disaster (Campbell et al., 2025; Edwards et al., 2024). Of note, Campbell et al. (2025) and Edwards et al. (2024) found that exposure to two or more natural disasters in the last 12 months negatively impacted mental health outcomes, whereas this study found that exposure to five or more climate change related acute events (WFS plus four or more other acute events) impacted mental health outcomes. One possible explanation for this difference in findings is variations in the self-reported measures for adolescent mental health outcomes. In their studies, both Campbell et al. (2025) and Edwards et al. (2024) asked participants about mental health symptoms they experienced within a relatively broad timeframe (the past six months and the past 12 months, respectively), while this study utilized a measure (the DASS-Y) that inquired about participants' mental health symptoms from the past week. As such, it could be that the mental health impacts of perceived exposure to WFS plus one, two, or three other climate change related acute events within the past 12 months are not detected by a tool such as the DASS-Y.

This study was not meant to evaluate possible mechanisms through which mental health outcomes are impacted; however, as discussed in Chapter 3, there are numerous ways in which participants may have been impacted by their perceived exposures (Eisenman & Galway, 2022; McGushin et al., 2022; Vergunst et al., 2024). For example, direct exposure to acute events may

have resulted in impacts such as physical injury and/or illness, displacement (McGushin et al., 2022; Vergunst et al., 2024), worry about future exposures, and/or disruptions to education (McGushin et al., 2022). In terms of exposure to WFS, participants may have been impacted through mechanisms such as decreased physical activity (Giles et al., 2024), social isolation (Dodd et al., 2018; Humphreys et al., 2022), and/or physiological disruptions, such as hormone fluctuations or neurological changes (Jung et al., Zhu et al., 2025).

Though exposure to WFS only did not significantly increase the risk of poor mental health outcomes among participants in this study, exposure to WFS plus multiple other acute events did. It may be that impacts of WFS exposure (e.g., feelings of social isolation) increase an adolescent's risk of poor mental health outcomes related to other acute event exposures; for example, feeling socially isolated could decrease the efficacy of coping skills related to social support from peers and other community members. Further, exposure to repeated climate change related acute events may in and of itself increase the risk of mental disorder and reduced mental health; this aligns with Campbell et al.'s (2025) finding that adolescents exposed to multiple natural disasters had worse mental health outcomes than those exposed to a single disaster. These findings support the notion that stress resulting from exposure to climate change related acute events may increase an individual's psychological vulnerability to future stressful events, placing affected individuals at higher risk for increased symptoms of mental disorder and further reduced mental wellbeing (Vergunst et al., 2024).

7.2 Wildfire Smoke Exposure and Climate Worry

There is currently a paucity of research directly exploring the relationship between climate worry and exposure to WFS (see Chapter 2). However, previous studies have found that exposure to WFS may be linked to increased worry (e.g., Humphreys et al., 2022; Mirabelli et

al., 2022). This study found that participants who perceived exposure to WFS plus one other climate change related acute event had higher climate micro worry than those with no exposures; further, those who perceived exposure to WFS plus four or more other climate change related acute events had elevated climate micro and macro worry compared to non-exposed participants. These findings suggest that, while exposure to multiple climate change related acute events may increase climate micro and macro worry in Canadian adolescents, perceived exposure to WFS only may not result in increased climate worry.

It is curious that exposure to WFS plus one other climate change related acute event appears to contribute to increased climate micro worry, while exposure to WFS plus two or three other acute events does not. A drawback of this study's approach is that it is difficult to tease out acute event exposure combinations, so conclusions cannot be drawn about the impacts of specific exposure types and combinations on climate micro worry. One mechanism through which exposure to climate change related acute events may increase climate micro and macro worry is decreased psychological distance from climate change. Psychological distance from climate change refers to how direct or immediate the effects of climate change feel to an individual; one study found that climate change worry increased when psychological distance decreased among university students (Stewart et al., 2024). Taken with these findings, it may be that perceived exposure to WFS plus four or more other climate change related acute events reduces psychological distance from climate change, thereby increasing climate micro and macro worry.

7.3 Relevance of Findings to the Field of Counselling

There is mounting empirical evidence indicating that climate change and related factors can negatively impact mental health outcomes, and the mental health field must prepare for a likely increase in demand for mental health services due to such factors (Clayton & Crandon,

2025). This study found that exposure to WFS plus multiple other climate change related acute events may negatively impact the mental health of Canadian adolescents, which supports the notion that acute events related to climate change are relevant to the field of mental health care. Clayton and Crandon (2025) recommended numerous ways in which the mental health care field can prepare to better support individuals and communities impacted by climate change. In their recommendations, they discussed the need for increased training of MHPs related to the mental health impacts of climate change, as well as the importance of serving clients who may be experiencing poor mental health linked to climate change and related factors (Clayton & Crandon, 2025). The findings of this thesis relate to Clayton and Crandon's (2025) recommendations by highlighting the importance of: 1) the education and training of counsellors about the mental health impacts of climate change and related acute events, and 2) providing counselling services to adolescents who have been exposed to WFS and multiple other climate change related acute events.

Many counsellors today may feel ill-equipped to support clients experiencing mental health impacts related to climate change factors (Hoppe et al., 2023) and may desire increased guidance from professional bodies (Silva & Coburn, 2023). With this in mind, it could be valuable for graduate counselling programs to incorporate the topic of climate change in existing courses, and for academic institutions and professional organizations to offer continuing education and/or specialized training programs related to mental health and climate change factors. If existing courses in counselling programs were to include the topic of climate change and mental health, the relationship between exposures to climate change related acute events and adolescent mental health could be included as a sub-topic. For example, at the time of writing, Athabasca University's (n.d.) Master of Counselling program includes a course titled

Sociocultural and Systemic Influences on Counselling, which could feasibly include a subsection that pertains to mental health outcomes and climate change related factors such as acute event exposures. An addition such as this to counselling program curricula could raise awareness of the relevance of climate change related factors to the field of mental health care. Counselling students could then choose whether to pursue additional education and/or training related to this topic. These steps could help to improve the confidence and competence of counsellors serving young clients impacted by climate change and related acute events.

In addition to raising awareness of the impact of climate change factors on mental health outcomes, similarities and differences between exposure to climate change related acute events (i.e., WFS, wildfires) and exposure to other stressful experiences (i.e., earthquakes, gun violence) could be explored. For example, practitioners should be aware that exposure to climate change related acute events may result in mental health problems that are not specific to climate change, such as post-traumatic stress disorder (Clayton et al., 2023; Vergunst et al., 2024), and that existing evidence-based counselling interventions focused on treating such mental health problems (as well as techniques to bolster coping mechanisms) may be beneficial (Clayton & Crandon, 2025). In terms of this thesis' findings, this means that adolescents with increased anxiety and stress resulting from exposure to WFS and other acute events may benefit from existing interventions and treatment modalities. However, the findings of this thesis also indicate that exposure to climate change related acute events could reduce wellbeing in ways specific to the phenomenon of climate change (i.e., increased climate worry); as such, counsellors may benefit from education and training pertaining to climate change emotions, which may be a knowledge gap for today's MHPs (Hoppe et al., 2023). Climate worry is not a disorder (Vergunst et al., 2024) and is in fact linked to positive actions, such as pro-environmental behaviours

(Wullenkord & Ojala, 2023). As such, counsellors must be educated in order to avoid pathologizing climate worry and related climate change emotions, and to learn about approaches that may assist adolescents in coping effectively. For example, existing counselling models, such as acceptance and commitment therapy, may help to uncover adolescents' values related to the environment and to identify which actions are aligned with those values (Clayton & Crandon, 2025).

The findings of this thesis indicate that adolescents in regions impacted by WFS and multiple other climate change related acute events within the past 12 months may benefit from counselling support, as they could be at higher risk of poor mental health outcomes compared to non-exposed adolescents. It may be prudent for counsellors living in regions at risk of multiple climate change related acute events to be offered specialized training related to supporting adolescents impacted by multiple acute events. Further, at-risk regions with fewer available clinicians could potentially bolster access to counselling care by incorporating virtual services from counsellors who are already competent in this area of practice. By increasing both the competency and availability of practitioners who serve adolescents impacted by WFS and multiple other climate change related acute events, young clients may be better supported through experiences of increased anxiety, stress, and climate worry.

7.4 Strengths and Limitations

Through secondary data analysis, this thesis used survey data to explore the relationships between the dependent and independent variables. One strength of this study was the use of self-reported data, particularly in terms of mental health outcomes. As discussed in Chapter 2, administrative mental health data (e.g., such as hospital records) may inaccurately represent the prevalence of mental health problems, as not everyone experiencing symptoms of poor mental

health will seek a physician or go to a hospital (Szyszkowicz et al., 2020; Zhu et al., 2024). Instead, self-reported measures (e.g., surveys) may capture the symptom levels of participants who may or may not have sought formal mental health support. In this study, self-reported data was also used to determine whether participants perceived exposure to WFS. In contrast, reliance on objective measures of WFS exposure does not necessarily account for participant travel and may not accurately determine whether participants were exposed to WFS (Zhu et al., 2024).

Furthermore, the possible impacts of exposure to climate change related acute events other than WFS were considered and informed the study design for this thesis. Specifically, acute event exposure categories were created that intentionally separated participants who perceived exposure to WFS only. This group of participants was compared to those with no perceived exposures, which facilitated the exploration of how exposure to WFS in the absence of exposure to other climate change related acute events may relate to mental health outcomes.

This study had limitations that should be considered. Though the use of self-reported WFS exposure data may help to confirm whether participants were indeed exposed to WFS, this approach may also introduce errors. For example, recall bias could lead to participants inaccurately recalling whether they were exposed to WFS or how recently the exposure occurred. In addition, participants were asked about whether WFS exposure was perceived (yes or no) but not about the severity or duration of exposure.

Due to the cross-sectional study design, conclusions about causality cannot be drawn (Weng & Chang, 2020). The survey instrument was web-based and in English, so adolescents in Canada who were not fluent in English and/or did not have internet access were unlikely to be represented in the sample (Tiwari et al., 2025). Further, the sample was not representative of the general population due to the non-probabilistic quota approach that was used (Martin et al.,

2025), so study findings are not necessarily representative of the whole population (McCombes, 2019); for example, claims cannot be made about the percentage of Canadian adolescents who perceive exposure to WFS within the last 12 months.

Prospective participants were informed of the nature of the survey before completing it (Tiwari et al., 2025); this could mean that adolescents who chose to complete the survey were especially concerned about the impacts of climate change (e.g., climate worry) and may have been more likely to perceive that they were exposed to climate change related acute events. Further, the survey did not ask participants whether they had a previous mental health diagnosis; this would have been an important covariate to include in adjusted models, as individuals with pre-existing mental health problems may be at increased risk of mental health impacts from WFS exposure (Humphreys et al., 2022; Rodney et al., 2021). In addition, the DASS-Y may not have been the most appropriate measure for participants' stress responses in relation to climate change related acute event exposure; the developers of the DASS (from which the DASS-Y was adapted) intended for their tool to measure stress as a negative emotional syndrome (Lovibond, 1998), rather than as a stress response to a threatening event.

7.5 Recommendations for Future Research

Theoretical frameworks indicate that WFS exposure has the potential to negatively impact the mental health of adolescents (Eisenman & Galway, 2022; McGushin et al., 2022), and some research findings have supported this notion (e.g., Jung et al., 2025; Zhu et al., 2024). However, there remains a lack of empirical research in this area of inquiry and further research on this topic may be warranted. It could be valuable for studies examining WFS exposure and adolescent mental health outcomes to focus on a window of time shortly after exposure occurs (e.g., within seven days). Further, both quantitative and qualitative research could explore the

different WFS exposure experiences that adolescents have, and how these relate to mental health outcomes; for instance, researchers utilizing self-reported measures of WFS exposure could ask participants how recently the exposure occurred, how severe the exposure was, and whether they were exposed to WFS more than once. In addition, the use of objective measures of WFS exposure to corroborate self-reported exposure may increase the accuracy with which researchers can determine the degree of WFS exposure experienced by participants.

Future studies should continue to explore the impacts of exposure to multiple climate change related acute events on adolescent mental health outcomes. This area of research may become increasingly relevant in future years, as the number of exposures to climate change related acute events that individuals experience is projected to trend upwards for future generations; for instance, a person born in 1960 will experience an average of four heat waves in their lifetime, while a child born in 2020 may experience an average of 30 heatwaves in their lifetime (Thiery et al., 2021). If associations between exposure to multiple climate change related acute events and adolescent mental health were better understood, this information could be utilized in the education and training of counsellors. Continued research focused on counselling practices that support adolescents exposed to multiple climate change related acute events (e.g., the development of new counselling interventions, or research on the efficacy of existing interventions for this population) would also be valuable to practitioners, as well as to adolescent clients who stand to benefit from competent counselling care.

7.6 Conclusion

WFS is an acute environmental event related to climate change; Canada has experienced periods of prolonged and severe WFS in recent years, which may continue to worsen due to climate change factors (Jain et al., 2024). The findings of this thesis indicate that Canadian

adolescents who perceive exposure to WFS only in the last 12 months may have similar mental health outcomes to those with no perceived exposures in that timeframe. However, this study found higher levels of anxiety, stress, and climate worry among participants who perceived exposure to WFS plus four or more other climate change related acute events compared to non-exposed participants. Further research is warranted to continue exploring the relationship between WFS exposure and adolescent mental health outcomes.

There is also value in continued exploration of the ways that exposure to multiple climate change related acute events impacts adolescent mental health, as the average number of acute events that an individual experiences in their lifetime is likely to increase in the coming decades (Thiery et al., 2021). Considering that climate change and related factors (such as exposure to acute events) may increase the demand for mental health services in the future (Clayton & Crandon, 2025), it is crucial for counsellors to have the knowledge and skills to support young clients who are at risk of exposure to WFS as well as multiple other climate change related acute events. Future work should support this by researching how counsellors can best serve adolescents exposed to multiple acute events, by incorporating education on climate change into counselling programs, and by developing specialized training that supports counsellors in providing competent care to this population.

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Appendix A

Literature Review Search Terms

Table A

Narrative Literature Review Concepts and Search Terms

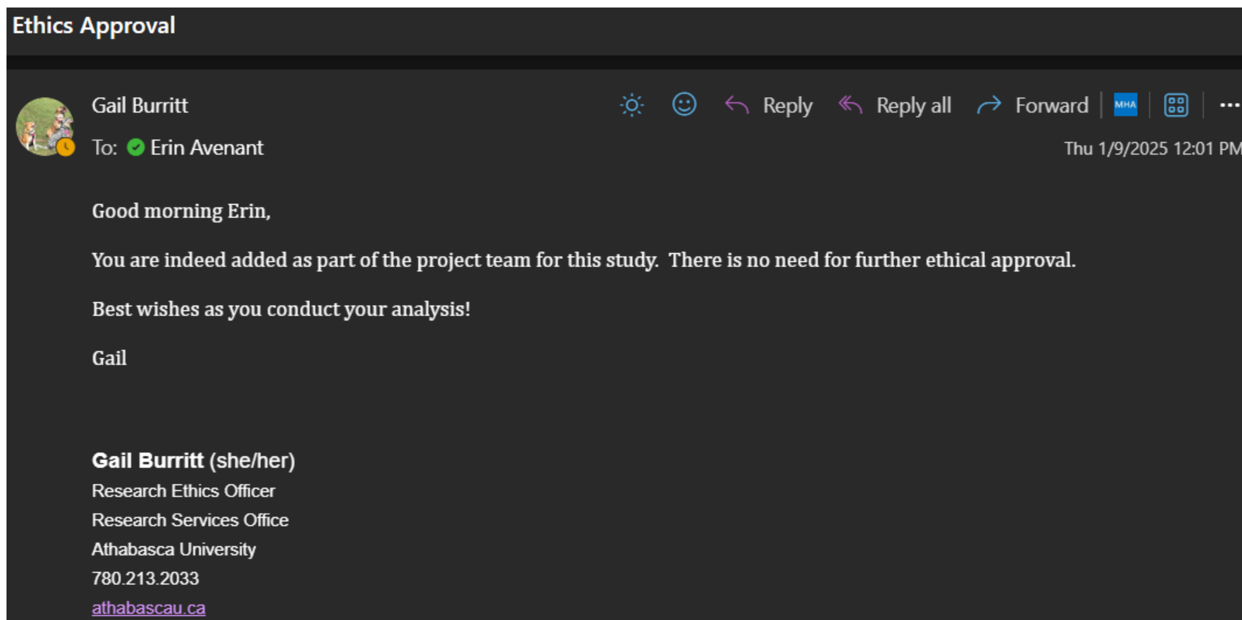
Concept	Search Terms
Wildfires	(wildfire* OR “wild fire*” OR “forest fire*” OR bushfire* OR “bush fire*” OR brushfire* OR “brush fire*”)
Wildfire smoke	(wildfire* OR “wild fire*” OR “forest fire*” OR bushfire* OR “bush fire*” OR brushfire* OR “brush fire*”) AND smoke
Air pollution	(“air quality” OR “air pollution”)
Mental health outcomes	(“mental health” OR “mental illness” OR “mental disorder” OR wellbeing OR well-being OR “well being” OR psycholog*)
Depression, anxiety, and stress	(depress* OR anxiousness OR anxiet* OR stress)
Climate worry	(“climate worry” OR “climate change worry” OR “climate-change worry”)
Adolescence	(adolescen* OR teen* OR youth)

Appendix B

Ethics Approval Correspondence

Figure B

Screenshot of E-mail Confirmation of Ethical Approval to Proceed with Analysis



Ethics Approval

Gail Burritt

To: Erin Avenant

Thu 1/9/2025 12:01 PM

Good morning Erin,

You are indeed added as part of the project team for this study. There is no need for further ethical approval.

Best wishes as you conduct your analysis!

Gail

Gail Burritt (she/her)
Research Ethics Officer
Research Services Office
Athabasca University
780.213.2033
athabascau.ca

Appendix C

Depression Anxiety Stress Scale (Youth Version) Questionnaire

Table C

DASS-Y Questions on Survey

DASS-Y Subscale	Survey Question
Depression	I hated my life.
	I didn't like myself.
	I felt that life was terrible.
	I felt like I was no good.
	I could not stop feeling sad.
	I did not enjoy anything.
	There was nothing nice I could look forward to.
Anxiety	I felt like I was about to panic.
	I felt terrified.
	I felt scared for no good reason.
	I could feel my heart beating really fast even though I hadn't done any hard exercise.
	I had trouble breathing (e.g., fast breathing), even though I wasn't exercising and I was not sick.
	My hands felt shaky.
	I felt dizzy, like I was about to faint.

DASS-Y Subscale	Survey Question
Stress	I got upset about little things.
	I was easily irritated.
	I found myself overreacting to situations.
	I was easily annoyed.
	I was stressing about lots of things.
	I got annoyed when people interrupted me.
	I found it difficult to relax.

Note. In the survey, the DASS-Y questions had the following preamble: “We would like to find out how you have been feeling in the past week. There are some sentences below. Please select the statement which best show how TRUE each sentence was about you during the past week.”

Appendix D

Assumptions of Multiple Linear Regression

No Outliers

No outliers were present in the data used for analysis. The continuous variables (age, depression, anxiety, stress, climate micro worry, and climate macro worry) had response options that were bound by upper and lower limits.

No Multicollinearity

A variance inflation factor (VIF) less than four indicates that multicollinearity is not present (Pennsylvania State University, 2018). For each of the analyses, the average VIF was between 1.0 and 2.0 (Appendix E).

Normality of Residuals

Histograms of the distribution of residuals were generated for all multiple linear regression models and visually inspected for normality (Appendix F). The models with stress and climate micro worry as the outcome variables were approximately normally distributed. However, skewed distributions were observed for the models with depression, anxiety, and climate macro worry as the outcome variables. When concerns are noted for this assumption, BCa bootstrapping can be used (Field, 2017). For consistency, BCa bootstrapping was utilized for all statistical models.

Independence of Residuals

Independence of residuals can be assessed by examining the plots of predicted values and residuals, also known as a *zpred* vs. *zresid* plot (Field, 2017). If this assumption is met, the plots should display a random scatter of plot points (JMP Statistical Discovery, n.d.). However, the plots generated during analysis showed varying degrees of random scattering, with clustered plot

points noted for climate micro and macro worry (Appendix G). As discussed in Chapter 4, various paths forward were considered. The decision was made to proceed with multiple linear regression.

Homoscedasticity

Homoscedasticity was also assessed by examining the *zpred vs. zresid* plots (Field, 2017). None of the scatterplots displayed a funnel- or fan-like pattern (Appendix G), indicating that the assumption of homoscedasticity was met.

Linearity

Age and perceived family wealth were the only continuous independent variables. To assess whether a linear relationship existed between each of these variables and each dependent variable, *zpred* vs. *zresid* plots were created and fitted with a Loess curve, shown in Appendix H (UCLA: Statistical Consulting Group, n.d.). For the variable of age, the Loess curves approximated a horizontal line at zero, indicating a linear relationship (UCLA: Statistical Consulting Group, n.d.). However, this was not the case for the variable of perceived family wealth plots. As such, family wealth was converted to a categorical variable.

Appendix E

Variance Inflation Factor (VIF) Values (Assumption of No Multicollinearity)

Table E1

VIF Values for Multiple Linear Regression Analysis with Outcome Variable of Depression

Variable	VIF
Age	1.044
Gender	
Cis-girl	1.063
Gender diverse	1.059
Urbanicity	
Small town	1.056
Rural or remote area	1.049
Family wealth	
Worse off than average	1.151
Better off than average	1.146
Exposure group	
WFS only	1.241
WFS +1 other climate change related acute event	1.541
WFS +2 other climate change related acute events	1.625
WFS +3 other climate change related acute events	1.597
WFS + ≥4 other climate change related acute events	1.484

Table E2

VIF Values for Multiple Linear Regression Analysis with Outcome Variable of Anxiety

Variable	VIF
Age	1.047
Gender	
Cis-girl	1.065
Gender diverse	1.059
Urbanicity	
Small town	1.056
Rural or remote area	1.049
Family wealth	
Worse off than average	1.152
Better off than average	1.146
Exposure group	
WFS only	1.246
WFS +1 other climate change related acute event	1.541
WFS +2 other climate change related acute events	1.622
WFS +3 other climate change related acute events	1.596
WFS + ≥4 other climate change related acute events	1.480

Table E3

VIF Values for Multiple Linear Regression Analysis with Outcome Variable of Stress

Variable	VIF
Age	1.047
Gender	
Cis-girl	1.067
Gender diverse	1.061
Urbanicity	
Small town	1.057
Rural or remote area	1.048
Family wealth	
Worse off than average	1.149
Better off than average	1.144
Exposure group	
WFS only	1.241
WFS +1 other climate change related acute event	1.546
WFS +2 other climate change related acute events	1.624
WFS +3 other climate change related acute events	1.596
WFS + ≥4 other climate change related acute events	1.474

Table E4

VIF Values for Multiple Linear Regression Analysis with Outcome Variable of Climate Micro Worry

Variable	VIF
Age	1.052
Gender	
Cis-girl	1.070
Gender diverse	1.066
Urbanicity	
Small town	1.053
Rural or remote area	1.048
Family wealth	
Worse off than average	1.145
Better off than average	1.142
Exposure group	
WFS only	1.260
WFS +1 other climate change related acute event	1.559
WFS +2 other climate change related acute events	1.657
WFS +3 other climate change related acute events	1.627
WFS + ≥4 other climate change related acute events	1.508

Table E5

VIF Values for Multiple Linear Regression Analysis with Outcome Variable of Climate Macro Worry

Variable	VIF
Age	1.054
Gender	
Cis-girl	1.072
Gender diverse	1.066
Urbanicity	
Small town	1.055
Rural or remote area	1.049
Family wealth	
Worse off than average	1.146
Better off than average	1.142
Exposure group	
WFS only	1.260
WFS +1 other climate change related acute event	1.558
WFS +2 other climate change related acute events	1.655
WFS +3 other climate change related acute events	1.619
WFS + ≥4 other climate change related acute events	1.505

Appendix F

Histograms (Assumption of Normality of Residuals)

Figure F1

Histogram with Depression as Outcome Variable (n=614)

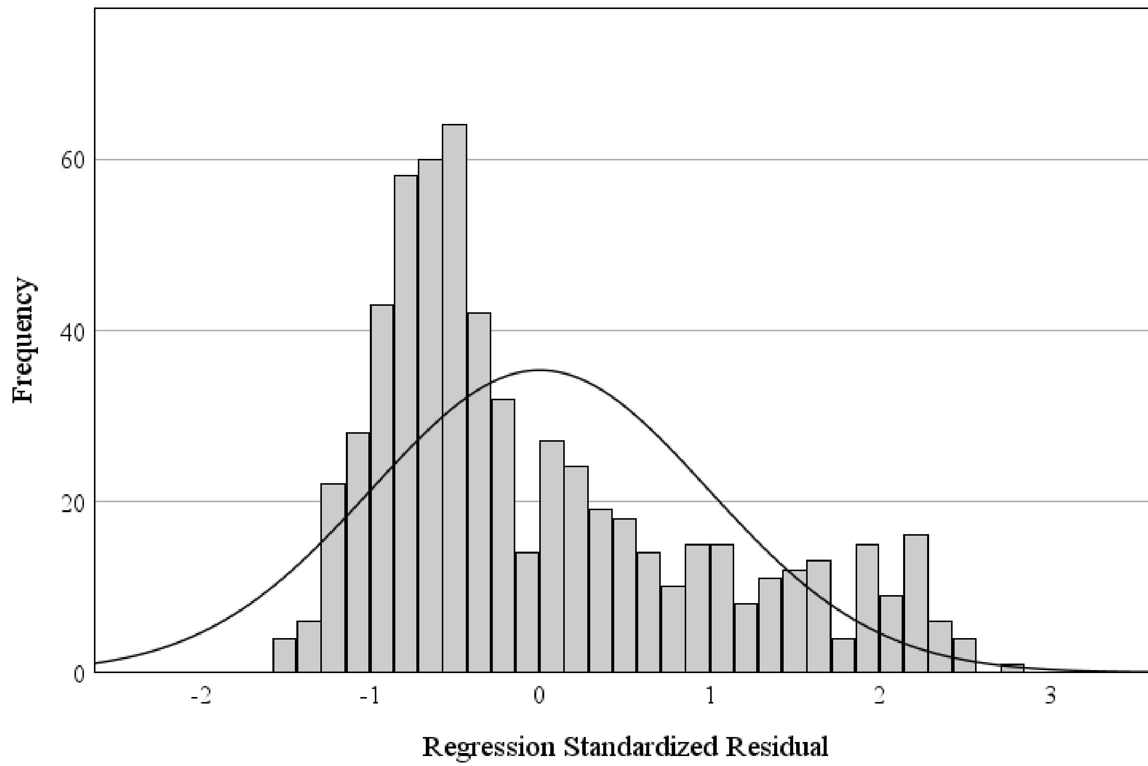


Figure F2

Histogram with Anxiety as Outcome Variable (n=613)

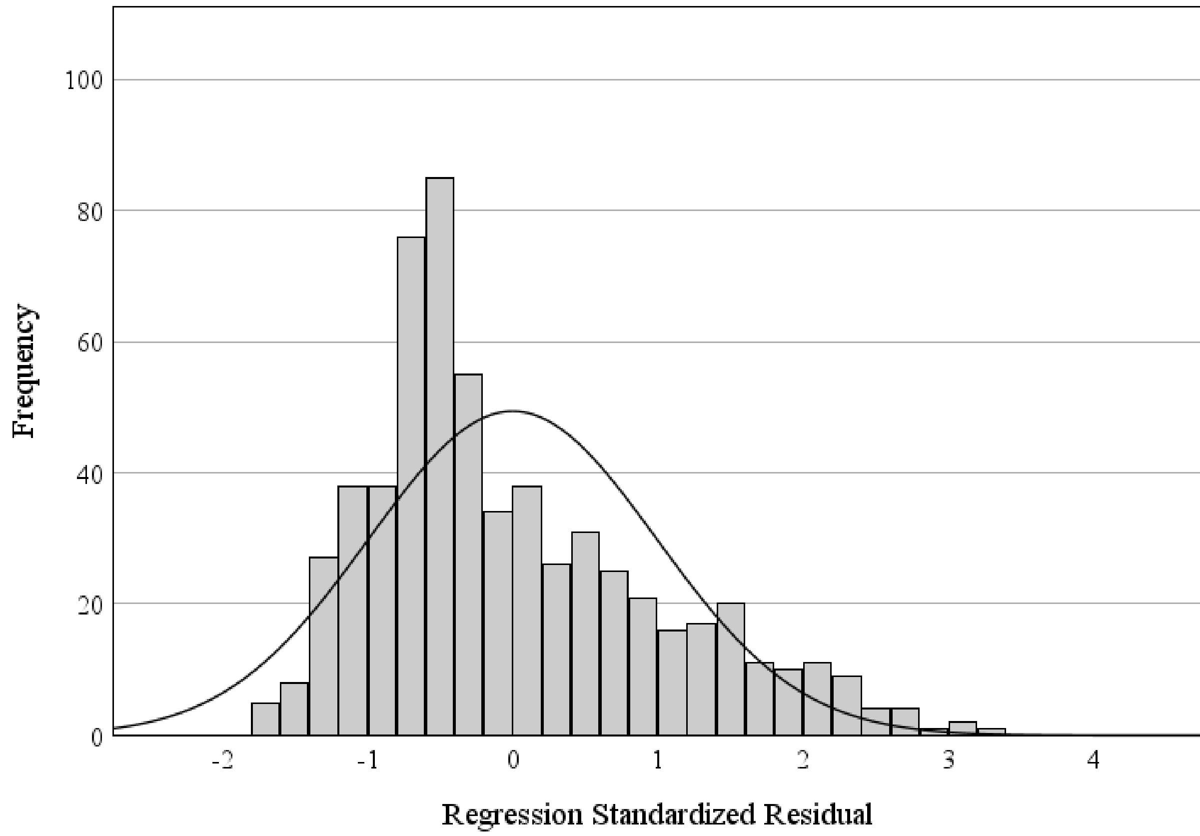


Figure F3

Histogram with Stress as Outcome Variable (n=613)

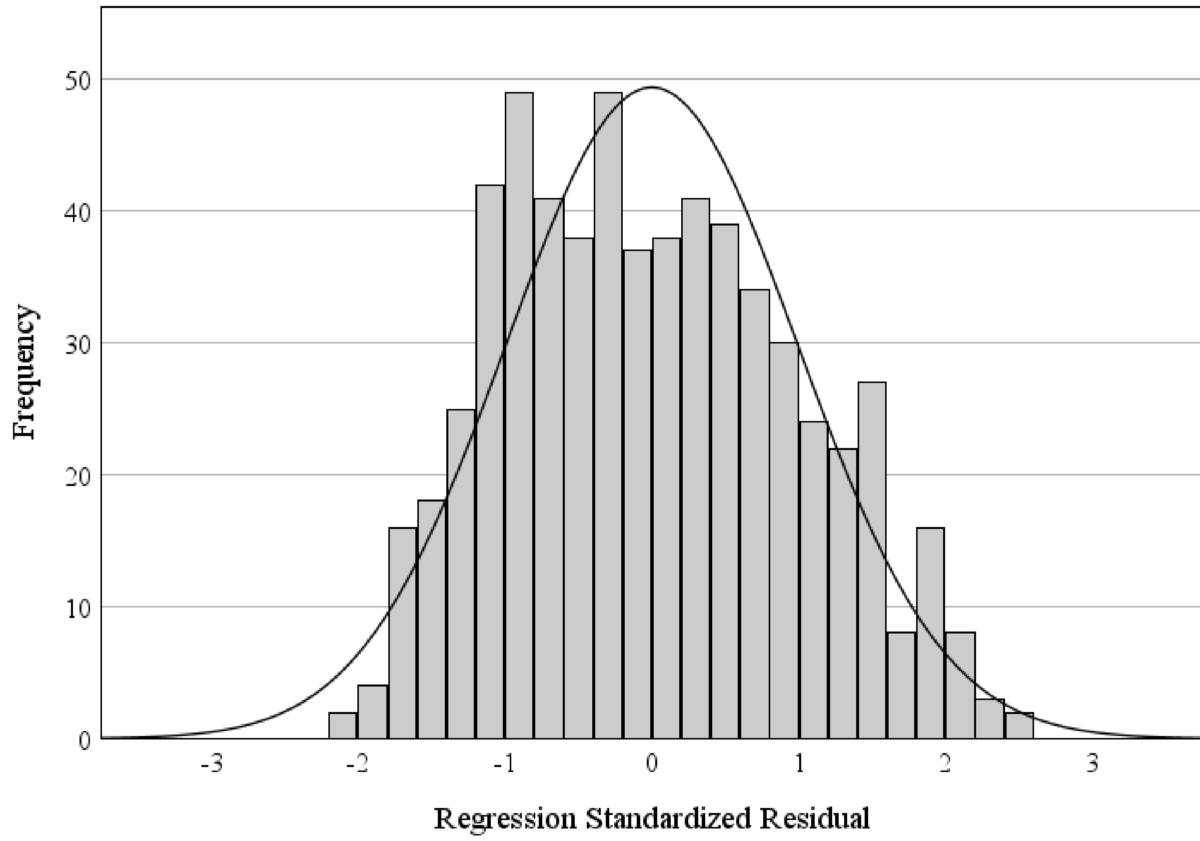


Figure F4

Histogram with Climate Micro Worry as Outcome Variable (n=611)

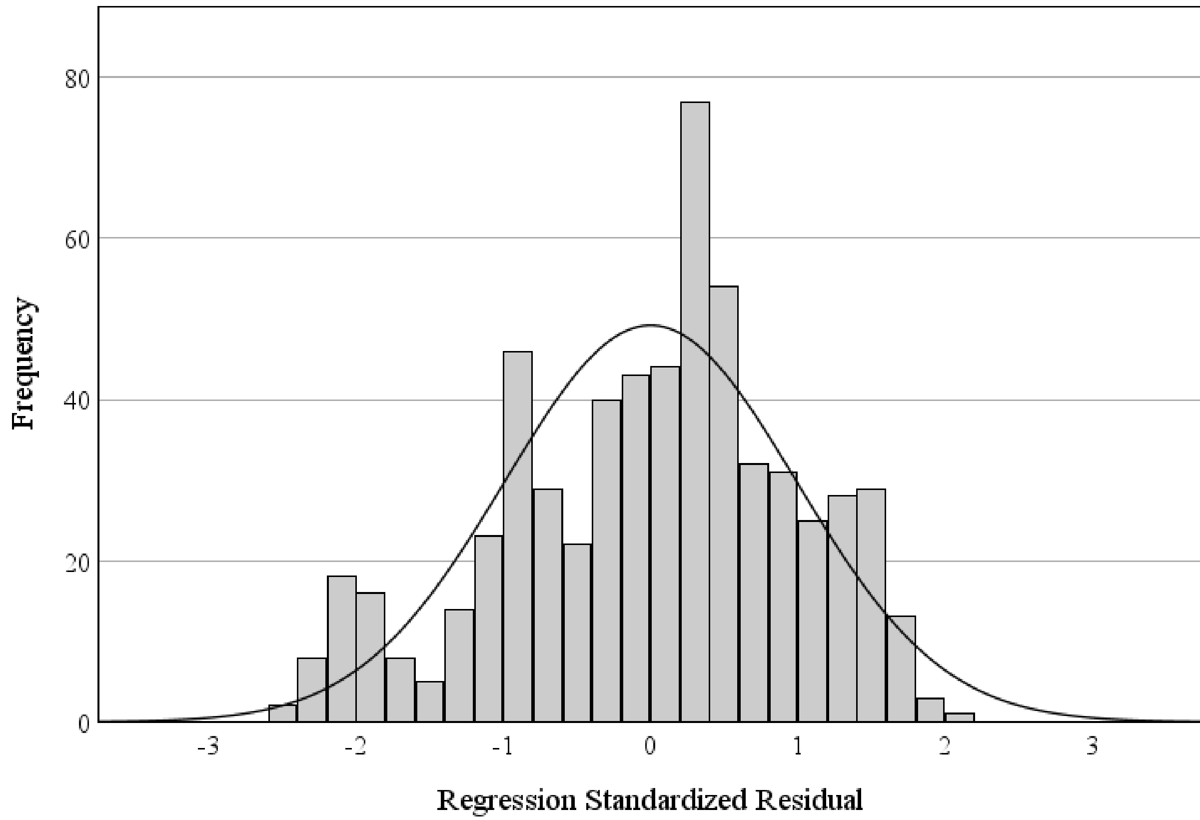
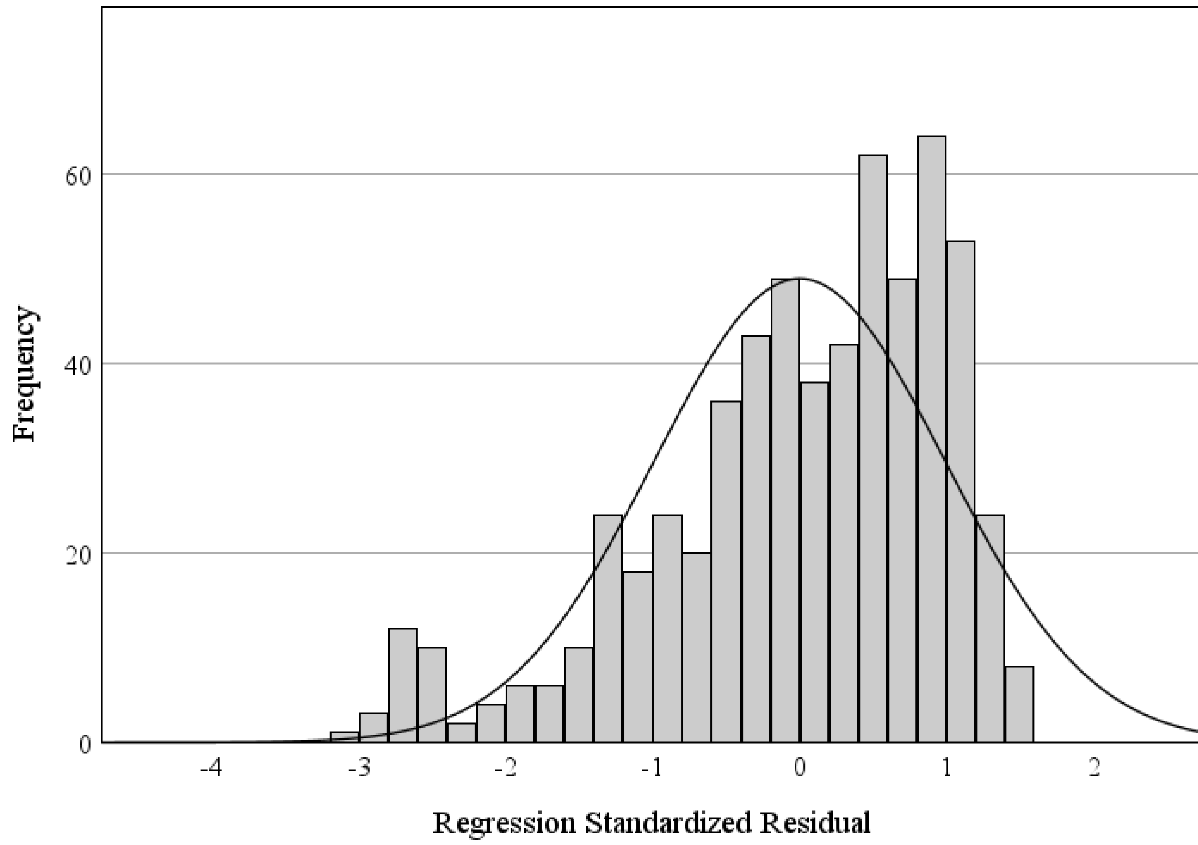


Figure F5

Histogram with Climate Macro Worry as Outcome Variable (n=608)



Appendix G

Zpred vs. *Zresid* Plots (Assumptions of Homoscedasticity and Independence of Residuals)

Figure G1

Zpred vs. Zresid Plot with Depression as Outcome Variable

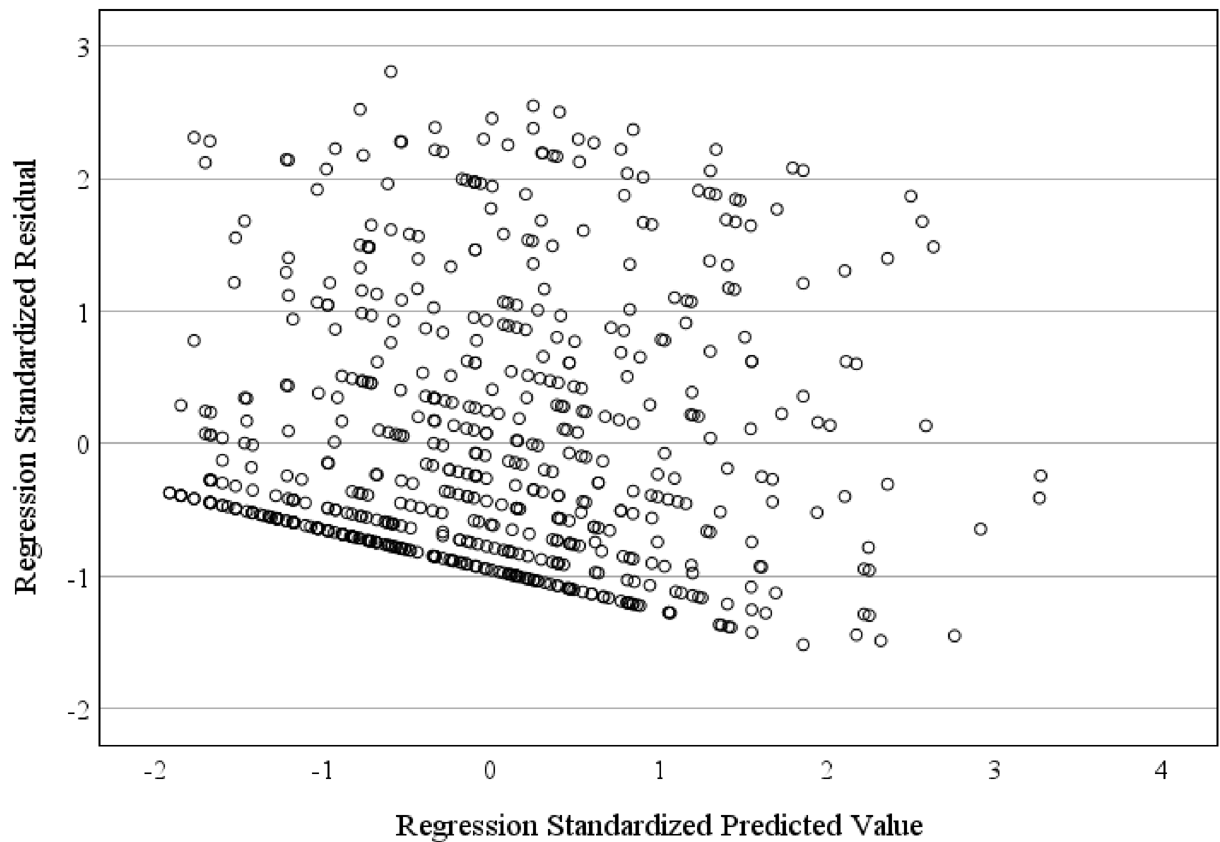


Figure G2

Zpred vs. Zresid Plot with Anxiety as Outcome Variable

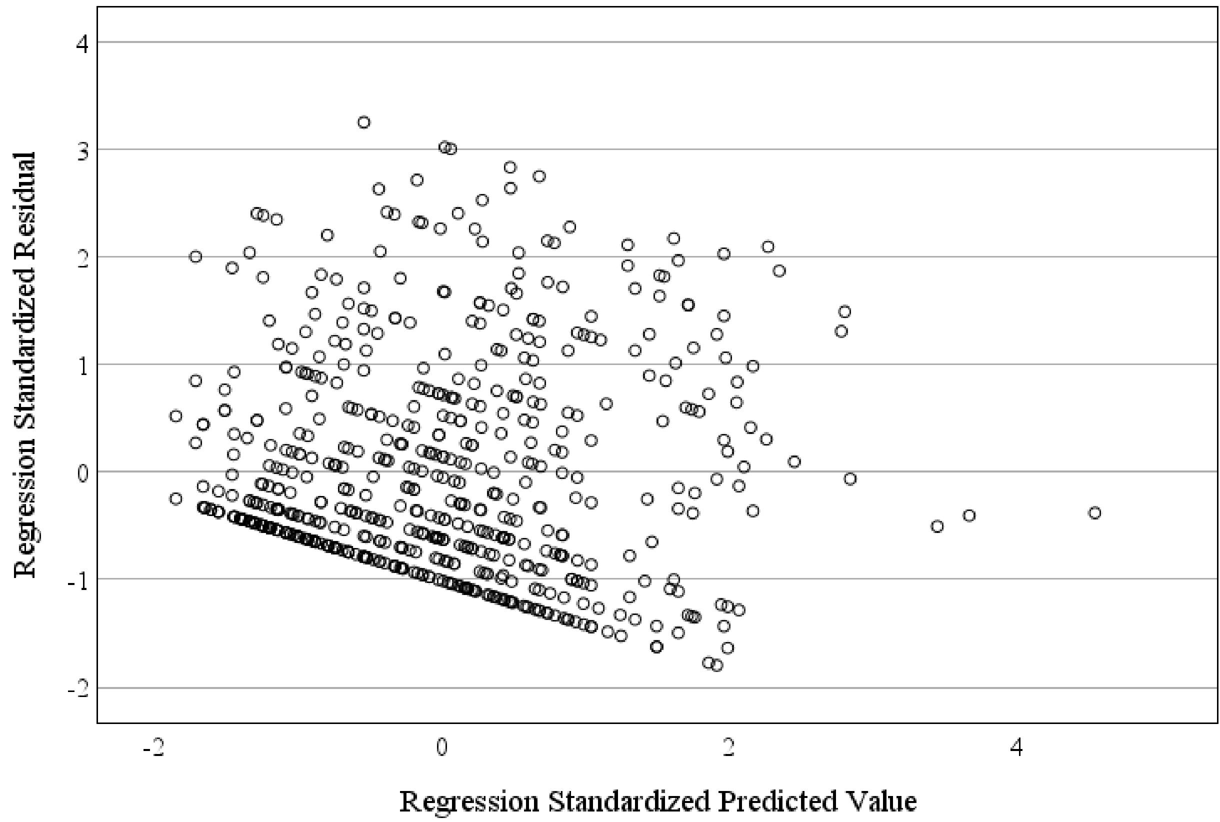


Figure G3

Zpred vs. Zresid Plot with Stress as Outcome Variable

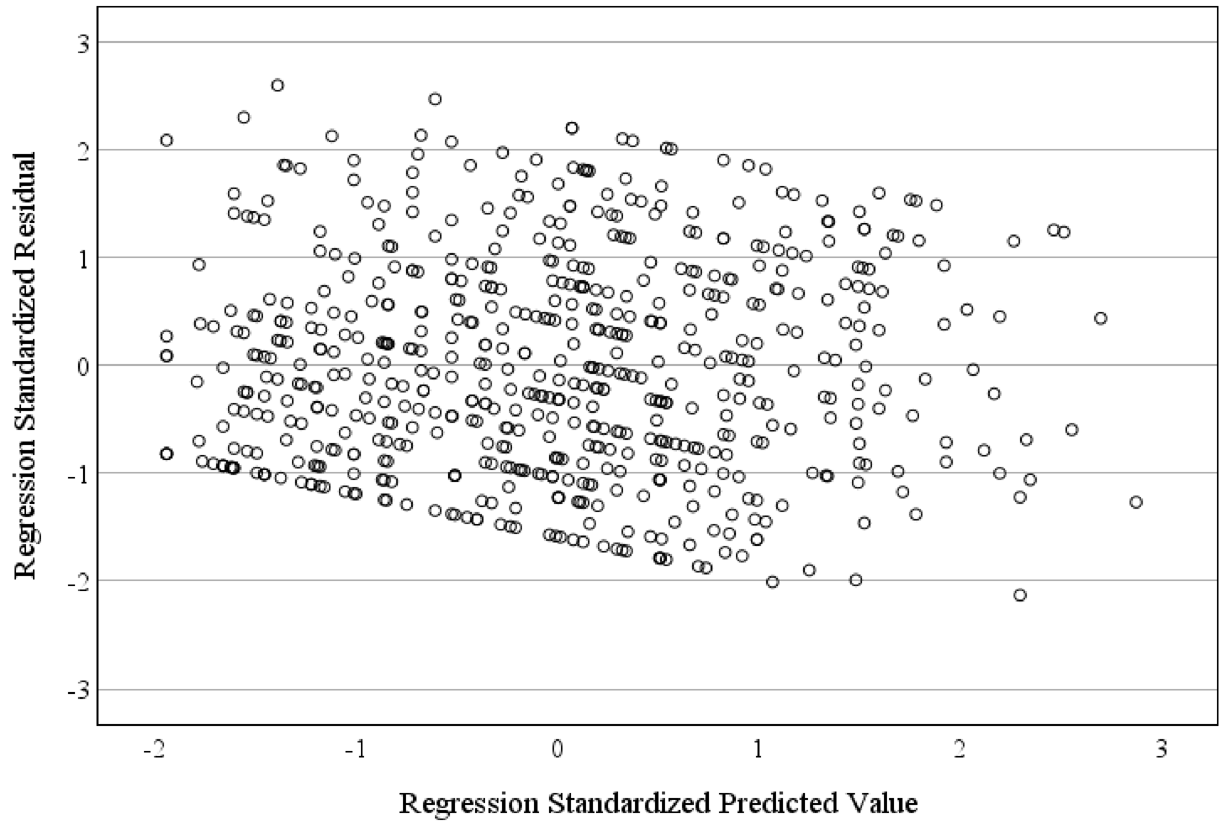


Figure G4

Zpred vs. Zresid Plot with Climate Micro Worry as Outcome Variable

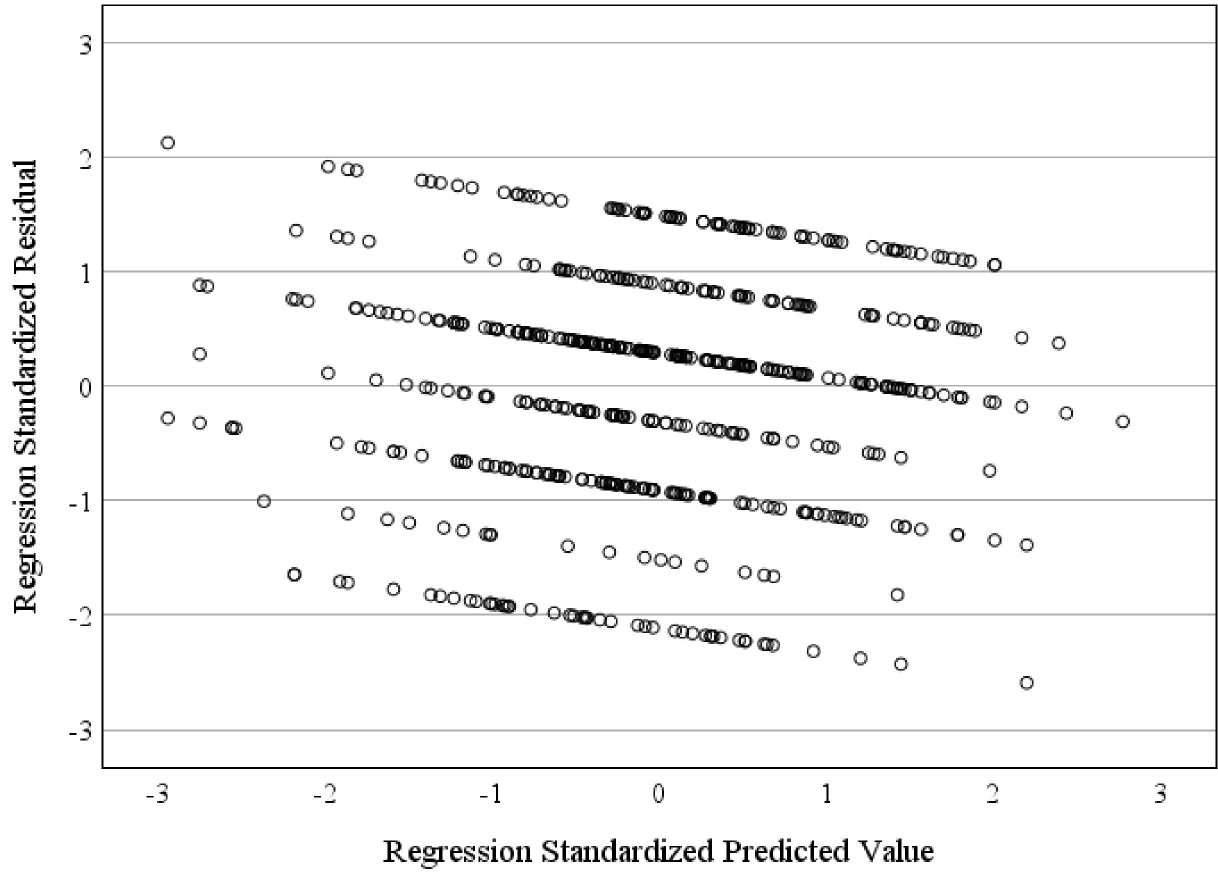
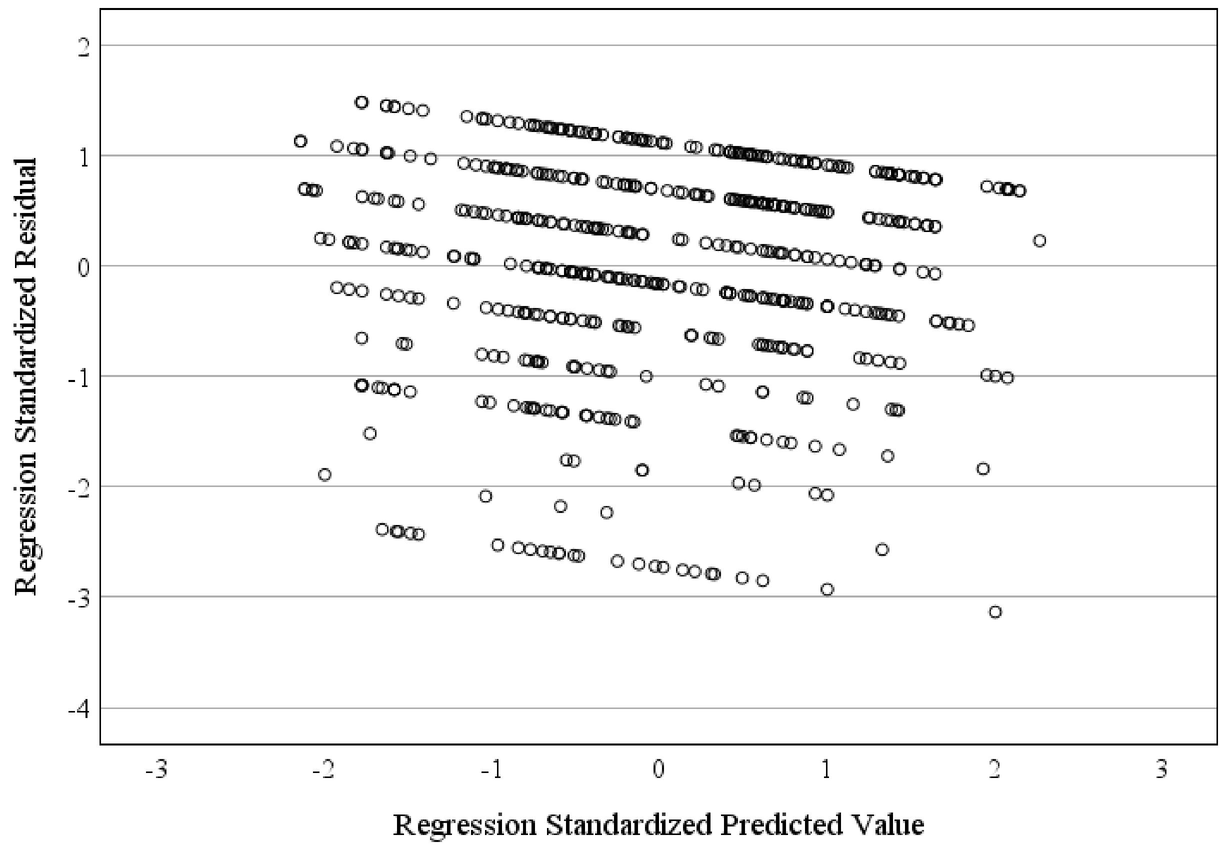


Figure G5

Zpred vs. Zresid Plot with Climate Macro Worry as Outcome Variable



Appendix H

Loess Curves (Assumption of Linearity)

Figure H1

Zpred vs. Zresid Plot for Age with Depression as Outcome Variable

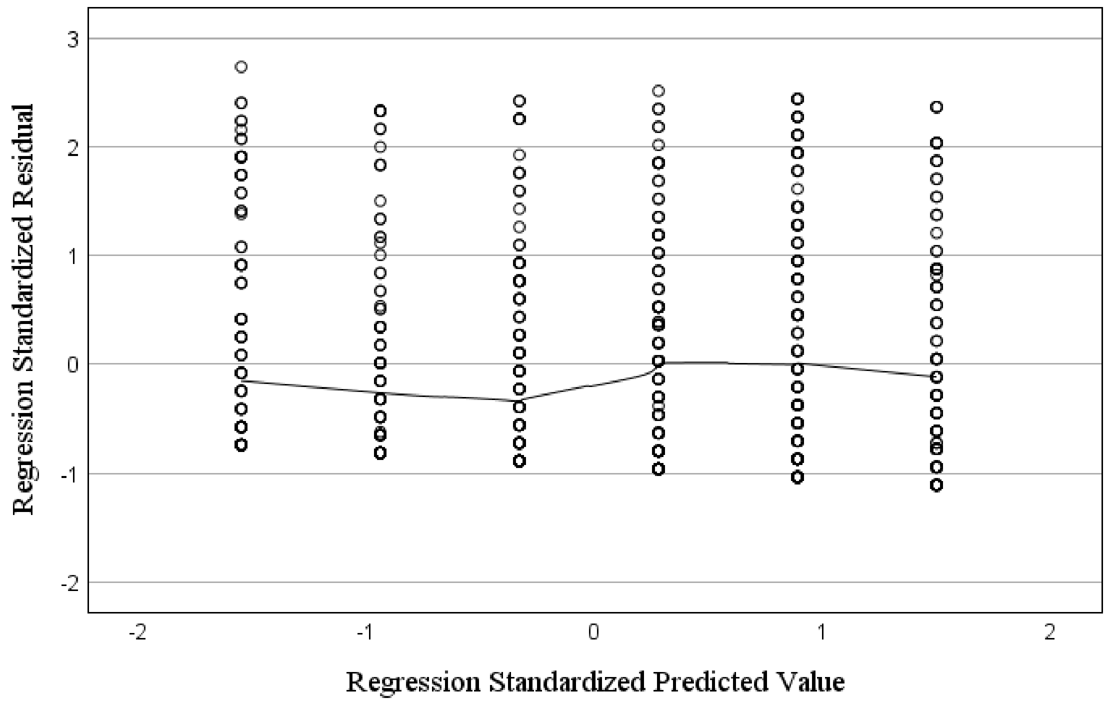


Figure H2

Zpred vs. Zresid Plot for Age with Anxiety as Outcome Variable

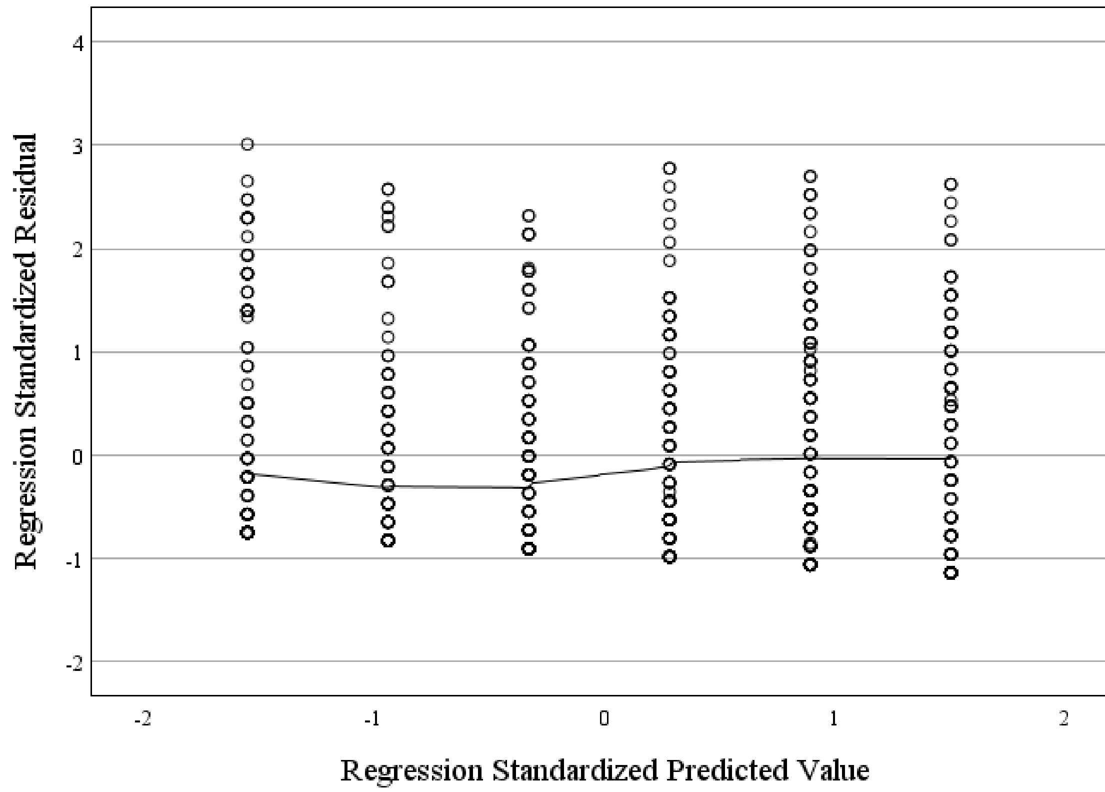


Figure H3

Zpred vs. Zresid Plot for Age with Stress as Outcome Variable

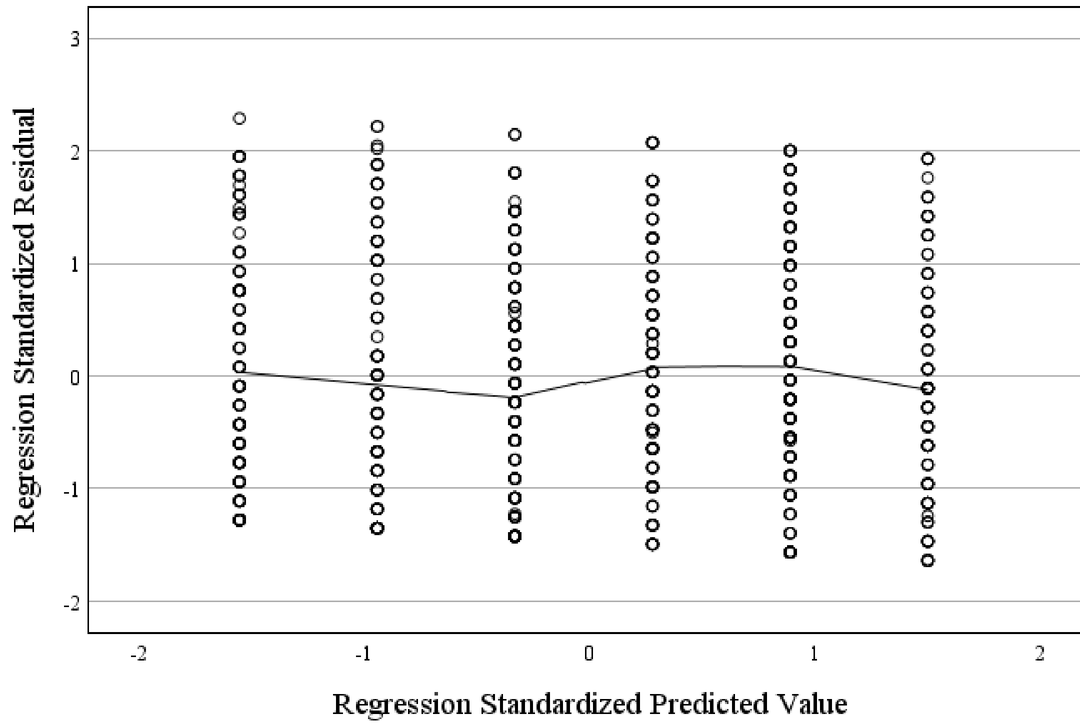


Figure H4

Zpred vs. Zresid Plot for Age with Climate Micro Worry as Outcome Variable

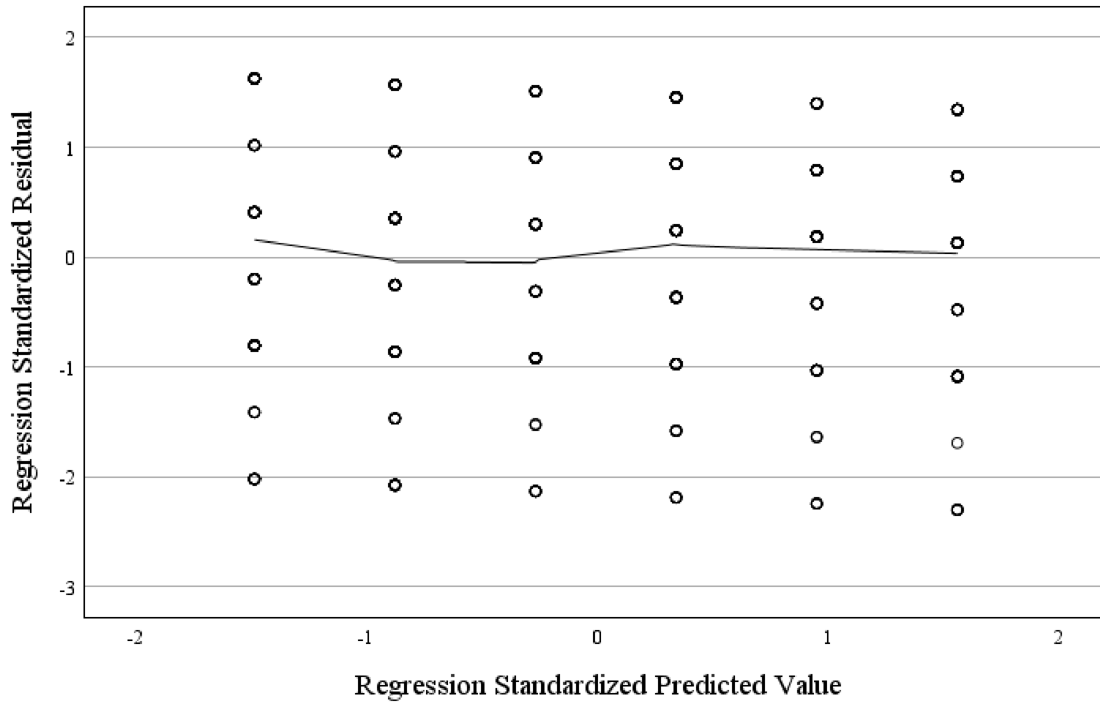


Figure H5

Zpred vs. Zresid Plot for Age with Climate Macro Worry as Outcome Variable

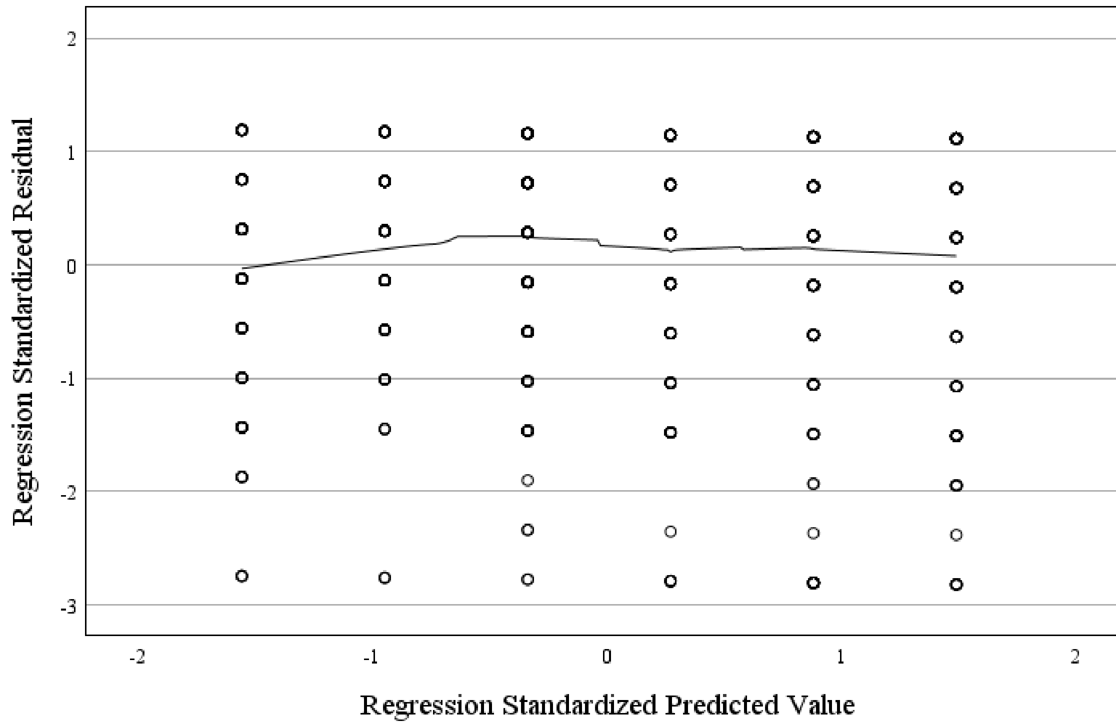


Figure H6

Zpred vs. Zresid Plot for Family Wealth with Depression as Outcome Variable

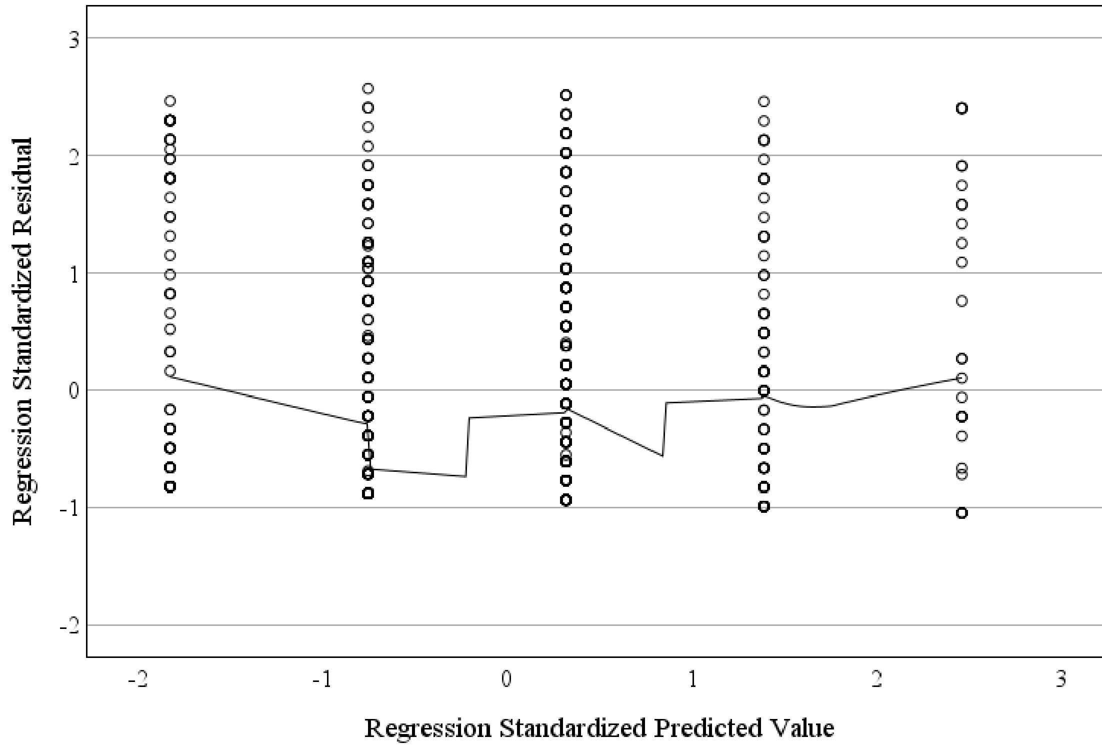


Figure H7

Zpred vs. Zresid Plot for Family Wealth with Anxiety as Outcome Variable

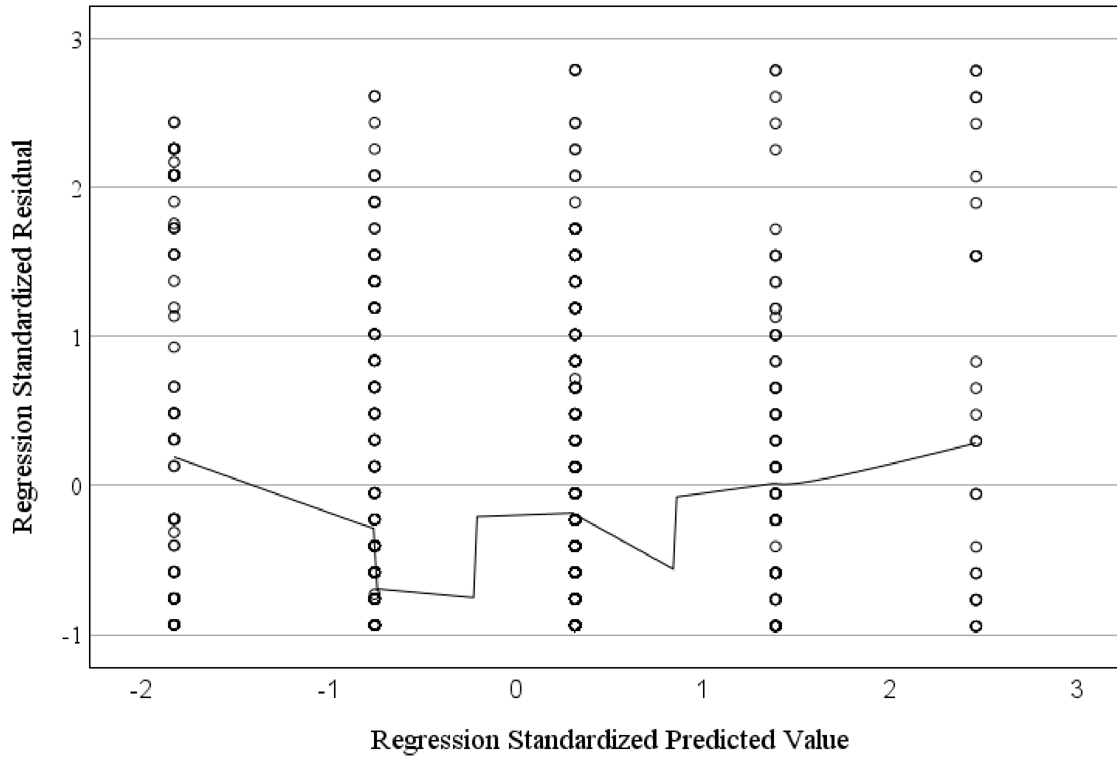


Figure H8

Zpred vs. Zresid Plot for Family Wealth with Stress as Outcome Variable

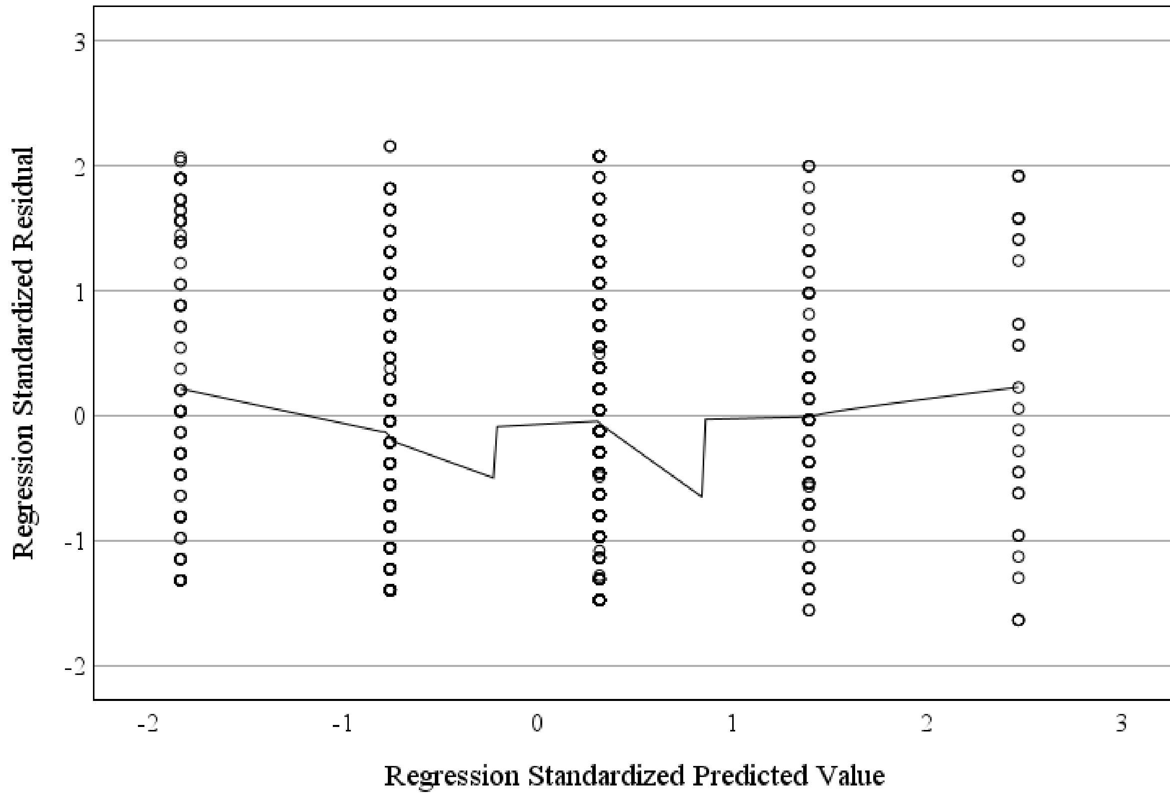


Figure H9

Zpred vs. Zresid Plot for Family Wealth with Climate Micro Worry as Outcome Variable

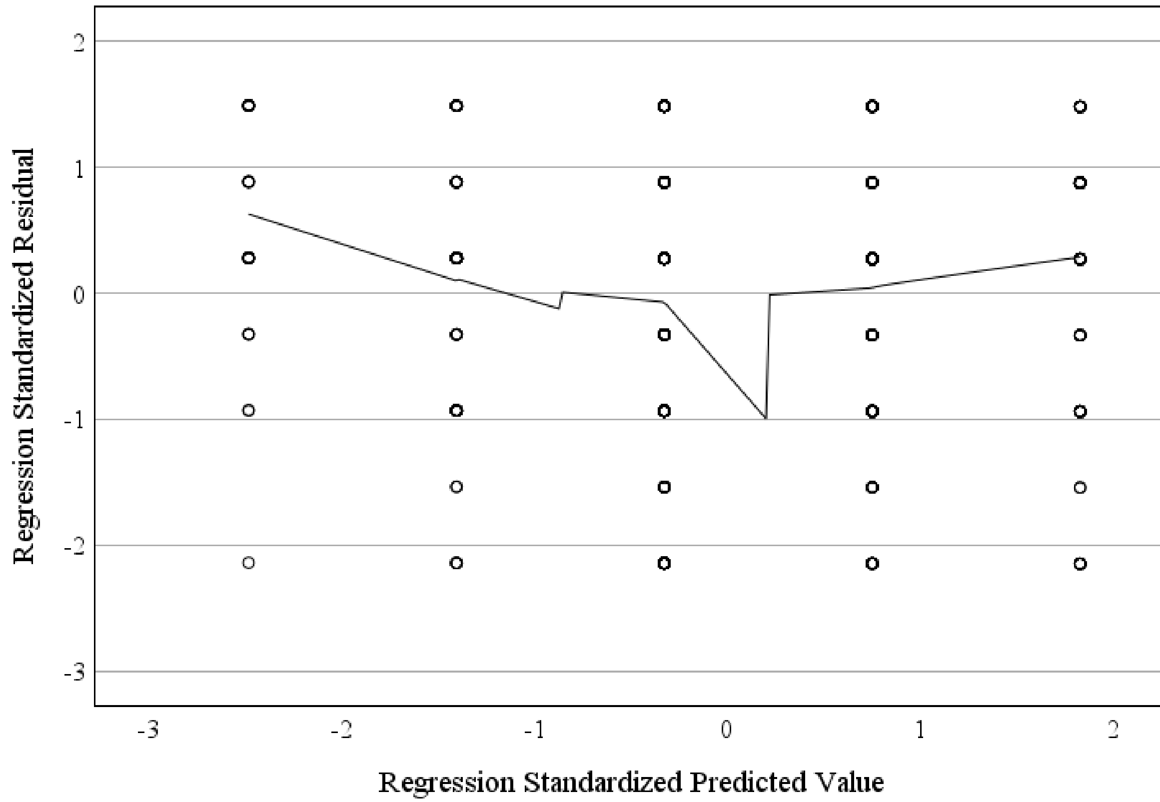


Figure H10

Zpred vs. Zresid Plot for Family Wealth with Climate Macro Worry as Outcome Variable