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Breaking the Ice: Exploring the Link Between Glaciers and Mental Well-being

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ABSTRACT

Background Glaciers are integral in maintaining hydrological cycles, moderating oceanic levels, and preserving valuable ecosystems. Cryospheric regions are often overlooked in evaluating the environmental factors affecting mental health. This study investigates the potential influence of glacial presence and melt behaviour on global mental health, particularly among marginalized communities.

Methods National suicide rates of general population and specific age categories were gathered from World Health Organization between 2012-19. Glacial data was sourced from the World Glacier Monitoring Service, and Randolph Glacier Inventory. Wilcox testing was conducted to identify mean suicide rates across countries with and without glaciers. Pearson and Spearman correlation testing were employed to identify relationships between melt rate indicators and suicide rates.

Results Over the entire eight-year duration, countries with the existence of glaciers revealed a notably higher suicide rate (p-value of 0.0001). Children aged 5-15 years old demonstrated a consistently higher suicide rate amongst countries with glacial bodies (p-value between 0.020-0.037). A positive correlation between regional suicide rates and glacial area was revealed, except in low-latitude countries. Although melt rate variability showed no significant correlation with suicide statistics, Greenland was the only country to demonstrate a negative relation among all populations.

Conclusions To address the ongoing impacts of the climate crisis, further research is necessary to develop an inclusive framework that acknowledges the unique challenges faced by communities living in cryospheric regions. This study is the tip of the iceberg, recognizing the importance of inclusivity in addressing the mental health implications of climate change in these environments.

KEY WORDS: **glaciers, cryosphere, suicide rates, mental health, environmental factors, climate change**

1 | INTRODUCTION

The paper explores correlations between climate change and its potential impact on mental well-being, emphasizing the value of natural environments. Recent research highlights these associations, particularly in urban areas, and their broader effects on cognition and mood (Graddini, 2022; Nutsford et al., 2013 Maes et al., 2021; Bratman et al., 2012). Likewise, protected areas have been found to improve general well-being (Reining et al., 2021; Buckley et al., 2019; Wood et al., 2017). However, the rapid severity of climate change (Bellard et al., 2012; Dale et al., 2001) has led to increased negative consequences affecting both physical and mental health (Clayton, 2021; Cianconi et al., 2020; Berry et al., 2010). Solastalgia, or emotional distress due to environmental changes (Albrecht et al., 2007), exemplifies the complex interplay between mental health and climatic factors, with potential differential effects on populations.

Certain groups, including low socioeconomic individuals, women, children, and Indigenous populations are often disproportionately impacted by climate change (Cianconi et al., 2021; Benevolenza & DeRigne, 2019; Clayton & Manning, 2018). Youth are especially vulnerable to mental health challenges related to the climate crisis. Many studies have attributed this link to a fear of the unknown future and the incredible responsibility to devise a solution (Vergunst & Berry, 2022: Cianconi et al., 2021; Majeed & Lee, 2017). Shifts in societal values have encouraged environmental perspectives on mental health to inform policy (Lawrance et al., 2021; Cunsolo et al., 2016; Gagné et al., 2014). Earlier attitudes often downplayed or ignored the connections between environmental factors and mental health focussing primarily on the physical consequences of climate change and environmental degradation.

Cryospheric environments are crucial components of the Earth's planetary system, demonstrating complex relationships with global health and society (Stefánsson et al., 2021; Su et al., 2019; Rasul & Molden, 2019; Hovelsrud et al., 2011). Cryosphere is derived from the Greek roots *krýo* signifying cold and *sfaíra* meaning globe. These regions are categorized due to the predominance of frozen hydrology, seasonally or year-round, such as glaciers and sea ice. Approximately 13% of the Earth's surface is identified as cryospheric through remote sensing and field observations (Barry & Gan, 2022; IPCC, 2019). They are key in balancing many climatological processes, driving hydrological cycles, maintaining sea levels, and sustaining intricate ecosystems (Ren et al., 2019; DeBeer et al., 2016; Bentley, 1984). Cryospheric regions are also important in the greater network of water, acting as the largest storage of fresh water (Yonghian et al., 2020).

Cryospheric environments as a source are often overlooked in evaluations of the effects of the environment on mental health. However, the consequential natural disasters, hydrological stresses, and rising sea levels tied to them are often highlighted (Talukder et al., 2021; Milner et al., 2017). The exclusion of this essential component illustrates a discrepancy in fully understanding the relationship between society, environment, and health. This demonstrates the importance of recognizing the cryosphere beyond a climate indicator and approaching environmental research with a comprehensive approach to avoid such limitations to the policies shaped by current research (Carey et al., 2016).

Many Indigenous cultures and alpine communities hold a unique relationship with the cryosphere through historical and spiritual significance. The Inuit in the Arctic have traditionally relied on ice and snow for food, shelter and transportation. Many Buddhist communities in Tibet consider mountains and glaciers sacred and are often sites of monasteries. Indigenous cultures in the Andes see glaciers as deities or protective entities and are central to spiritual ceremonies and rituals. This connection reaches beyond melt cycles and the natural repercussions of the changing

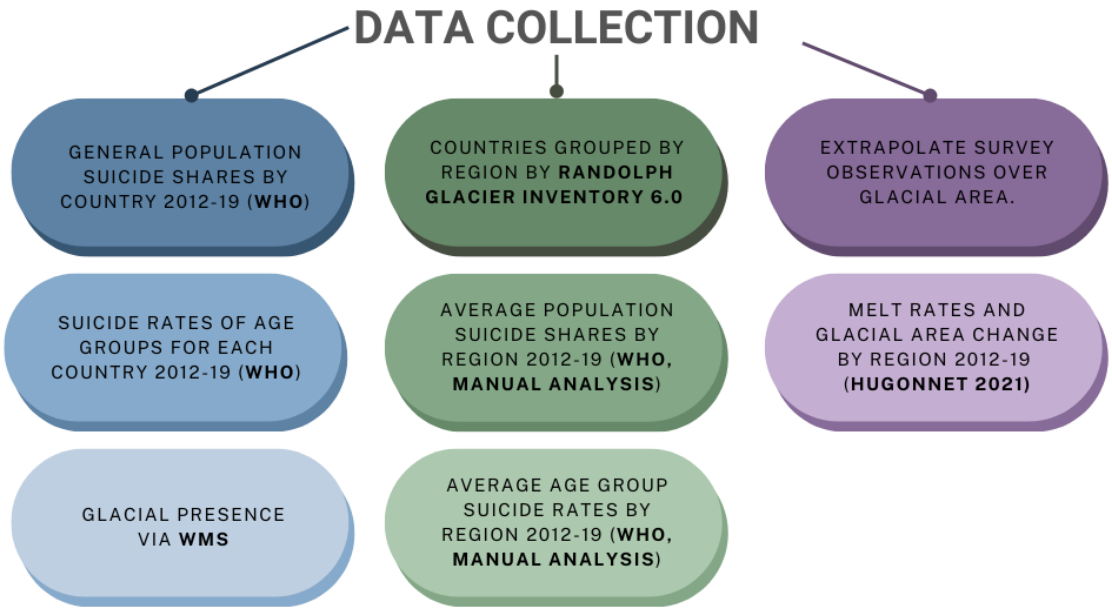


Fig.1: Data Collection. Included elements and associated sources of each data set. Blue corresponds to glacial presence, green to suicides rates corresponding to regional melt observations, and purple to the melt rate and glacial size extrapolation.

environment (Ruiz et al., 2020; Burnasheva, 2020; Allison, 2015; Cunsolo et al., 2015; Jurt et al., 2015). Furthermore, frozen regions are delicate ecosystems highly susceptible to the effects of climate change, magnifying the threats to nearby populations. Indigenous values are driven by their traditional way of life. The disappearance of the surrounding cryosphere jeopardizes their cultural identity by compromising food security, traditional customs, spiritual teachings, and physical health (Cunsolo et al., 2015; Cunsolo et al., 2013; Hovelsrud et al.; 2011; Dewailly et al., 1989). Understanding the relationships to cryospheric regions from Westernized **and** Indigenous perspectives is essential in understanding the complex influence of the climate crisis from a historical, scientific, economic, and sociocultural outlook on the environment. This carries the intricate relationship between nature and human life into developing reflective global policy and protecting the planet for a prosperous future (Gagné et al. 2014). It is worth acknowledging the limited research studies conducted on smaller Indigenous communities across Northern Canada that are directly affected by climatological implications in the cryosphere (Cunsolo et al., 2015; Cunsolo et al., 2013). However, current research has yet to bring meaningful policy change and raise awareness among the global population about the importance of this ecosystem. We hope this project can showcase the crucial role of frozen environments on a global scope and give a voice to these marginalized communities by encouraging discussions about environmental policy through mental health.

This research project assesses the potential influence of glacial presence and melt tendency on suicide rates across the world. We analysed suicide rates from 2012-19 to avoid potential skew due to elevated mental health challenges caused by the COVID-19 pandemic. Suicide rates are a quantitative measure requiring a level of categorization and investigation in contrast to a diagnosis process. As with other conditions, the reliability of statistics is highly linked to the quality and accessibility of resources and national perspectives on mental health (Tøllefsen et al., 2012). We looked at various age groups (>70 yrs., 50-70 yrs., 15-50 yrs., 5-15 yrs.) to gain insight into the consequences on specific populations, particularly vulnerable individuals such as youth. We expect a continuation of the witnessed negative trend in mental health due to environmental factors linked to climate change. This may be particularly detrimental to younger generations, due to a sense of responsibility to create a solution for climate change or anxiety associated with an uncertain future. We believe this association is likely to be more prevalent among the cryospheric regions, as they are incredibly delicate environments and highly susceptible to climatological evolution. They also act as indicators of the deteriorating condition of our planet and exhibit accelerated rates of change (Haeberli et al., 2007). Researchers have noted changes in the role they play in ecological balance and human life across all domains (Talukder et al., 2021; Milner et al., 2017, Allison, 2015). Human populations are expected to adapt to this change in their surroundings often without warning or direction (Kääb et al., 2005, Cunsolo et al., 2015; Cunsolo et al., 2013). This could also amplify the perception of climate change and begin to outweigh their beauty. To the best of our knowledge, there is no current research evaluating the impact of cryospheric regions on mental health, particularly with respect to glacial bodies. Limited research has tied negative effects of the changing cryosphere to the mental well-being of Indigenous populations in Northern Canada (Cunsolo et al., 2015; Cunsolo et al., 2013). This study seeks to fill the gap in the literature, providing insights into the potential mental health consequences of cryospheric changes in populations worldwide. It is crucial to recognize the essential role of these environments and the effects on vulnerable populations to investigate the implications of climate change, from its origins to its outcomes. Embracing an inclusive approach that considers the intricacies between nature and humans is key to developing sustainable policies for a hopeful future.

2 | METHODS

Data Collection

We compiled data sets and completed the initial analysis using Excel following the process outlined in Figure 1 . To investigate the potential impact of glacier presence on global mental health, we compared suicide rates of countries across the world with and without glacial formations. We gathered data from the World Health Organization (WHO), including annual suicide shares for nearly every country and US territory worldwide between 2012-19. Additionally, we used suicide rates from various age groups provided by WHO (70 + yrs, 70-50 yrs, 50-15 yrs, and 15-5 yrs) to identify trends amongst these specific populations. We manually confirmed the existence of glaciers through the World Glacier Monitoring Service (WGMS) database and the Randolph Glacier Inventory (Pfeffer et al., 2014). Our objective to address the relationship between glacial melt behaviour and

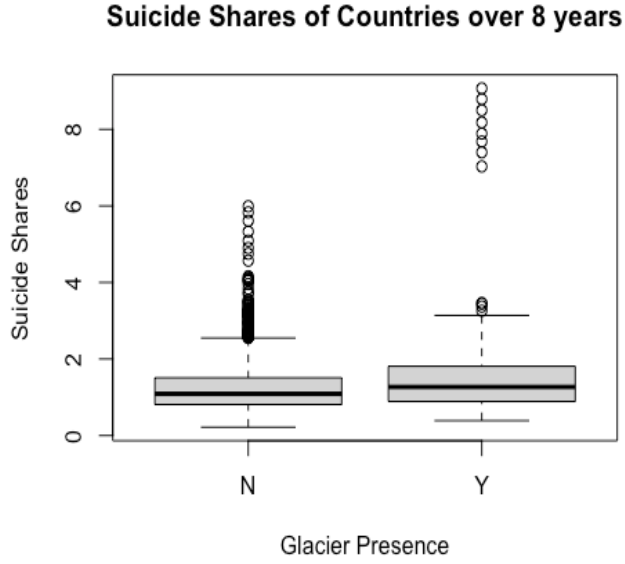
the mental health of the related region involved a more extensive analysis. We organized countries by region categorized by the Global Terrestrial Network for Glaciers (GTN-G) Glacier Regions, see Figure 1 of the Appendix. For ease of analysis, multiple glacial regions may have been combined into a single data set, see Table 1 of the Appendix for affected areas. The annual melt rate and glacier area loss data were sourced from a recent Nature publication (Hugonnet et al., 2021). This data employed field observations, satellite data, and extrapolation techniques to analyze decades worth of melt data. We used the rates aligning with the 2012-19 period to match our WHO suicide data. We calculated the average suicide rates for the overall population and individual age groups across all included nations for each year. In data sets consisting of multiple regions, the glacial data was averaged.

Ethics

Considering ethical implications, this study aims to minimize negative effects on communities impacted by suicide through reporting and disseminating information responsibly and sensitively. From an ethical standpoint, this study would like to consider the individuals we may affect. Additionally, we prioritize the well-being of communities in proximity to glaciers, striving to avoid further marginalization and harm. Our ethical conduct prioritizes the benefit of these populations and amplifies their valuable perspective throughout this study. We also hope to encourage conversations around frozen environments and mental health through the inclusion of these groups.

Data Analysis

We used the R programming language with tidyverse, ggpubr, dplyr, ggsignif packages for statistical analysis following the pipeline visualized in Figure 2. We began by conducting Levene and Shapiro testing for annual suicide data of the overall population and each age category to identify equal variance and normality. We performed a non-parametric Wilcox test to analyze the mean suicide rate between countries with and without glaciers. This process was repeated for each age group annually. The eight-year period of each nation's general population suicide shares was combined into a single data set to investigate an overall trend across a greater temporal scale. A p-value of <0.05 was used to determine the statistical significance between means. Box plots were generated to visualize the relationship. We calculated the average glacial melt rate by extrapolating the rate of a smaller observed region to the entire glacier area. Pearson and Spearman correlation testing was conducted between averaged suicide data and indicators of glacial melt behaviour for each region across the eight-year duration. Depending on the distribution of the data set, we performed the appropriate test across the overall population rates and individual age groups with the glacial area loss and calculated melt rates. A p-value of <0.05 was considered significant and the correlation variable determined whether the variables were positively or negatively related. The results were plotted to demonstrate the relation between variables.



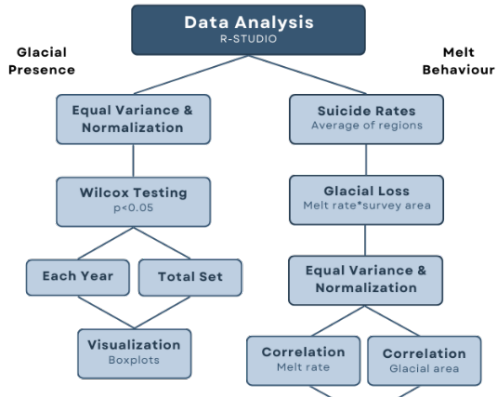


Fig. 2: Data Analysis. A flowchart illustrating the analysis process followed using R to determine results for each data set.

3 | RESULTS

Wilcox testing of annual death shares (the proportion or percentage of total deaths within the

Fig. 3. Box plot illustrating significantly higher mean suicide shares of countries with glaciers across the entire 8-year period 2012-19.

population attributed to suicide) insignificant results. The compiled data set containing suicide shares (the proportion of total deaths attributed to suicides within a specific population) of countries during the entire eight-year period demonstrates a statistically higher mean in suicide rates of countries **with** glacial formations holding a p-value of **0.0001**. Suicide rates refer to a specific measure of the frequency of suicides within a population, often expressed per a certain unit of population and provides a standardized metric for understanding the prevalence of suicide in a way that accounts for differences in population sizes. Figure 3 illustrates these results as a box plot.

The plot in Figure 4A demonstrates a slightly higher mean suicide rate of individuals 70 years old and above in countries **without** glaciers consistent each year, however, Wilcox testing concluded this difference was insignificant. This discrepancy began to **equalize** in the population aged 50-70 years old, with an insignificant difference between suicide rates demonstrated by Figure 4B. Though statistically insignificant, Figure 4C illustrates a slightly higher mean amongst individuals ages 15-50 years old for countries **with** glacial bodies visually verified each year. The youngest population aged 5-15 years old indicated a statistically significant **p-value between 0.037-0.020** each year. As displayed in Figure 4D, a higher mean suicide rate was identified among countries **with** glacial formations.

Overall, each country demonstrated a unique relationship between melt behaviour and suicide rates with many inconsistencies present amongst different age groups. Melt tendencies were analysed based on two factors, glacial area size in and the annual melt rate in . No prevalent trends could be identified regarding annual melt variability. Greenland was the only nation to demonstrate a negative correlation between glacial melt rates and suicide rates amongst each population, however, considered statistically insignificant by Pearson correlation testing. This is illustrated by linear plots, corresponding to each population, shown in Figure 5.

Each region consistently revealed a statistically significant relationship positively correlating glacial area with suicide rates of the general population, excluding the region of low latitudes. This relationship was prevalent throughout many of the age categories, with few exceptions. Figure 6 demonstrates the results of each region.

4 | DISCUSSION

As the climate crisis worsens, humans are experiencing a growing negative influence on their mental health. While for many, nature has traditionally acted as a sanctuary of safety and peace, the deteriorating state of our

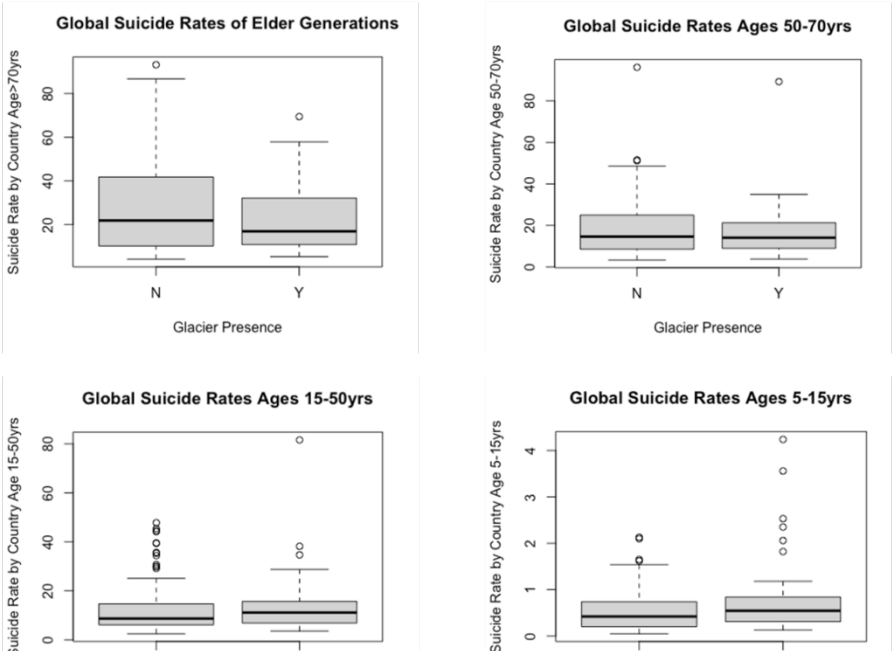


Fig. 4A-D. Box plot of illustrating mean suicide rates of various age groups between countries with and without glacial bodies in 2015, representative of trends present each year.

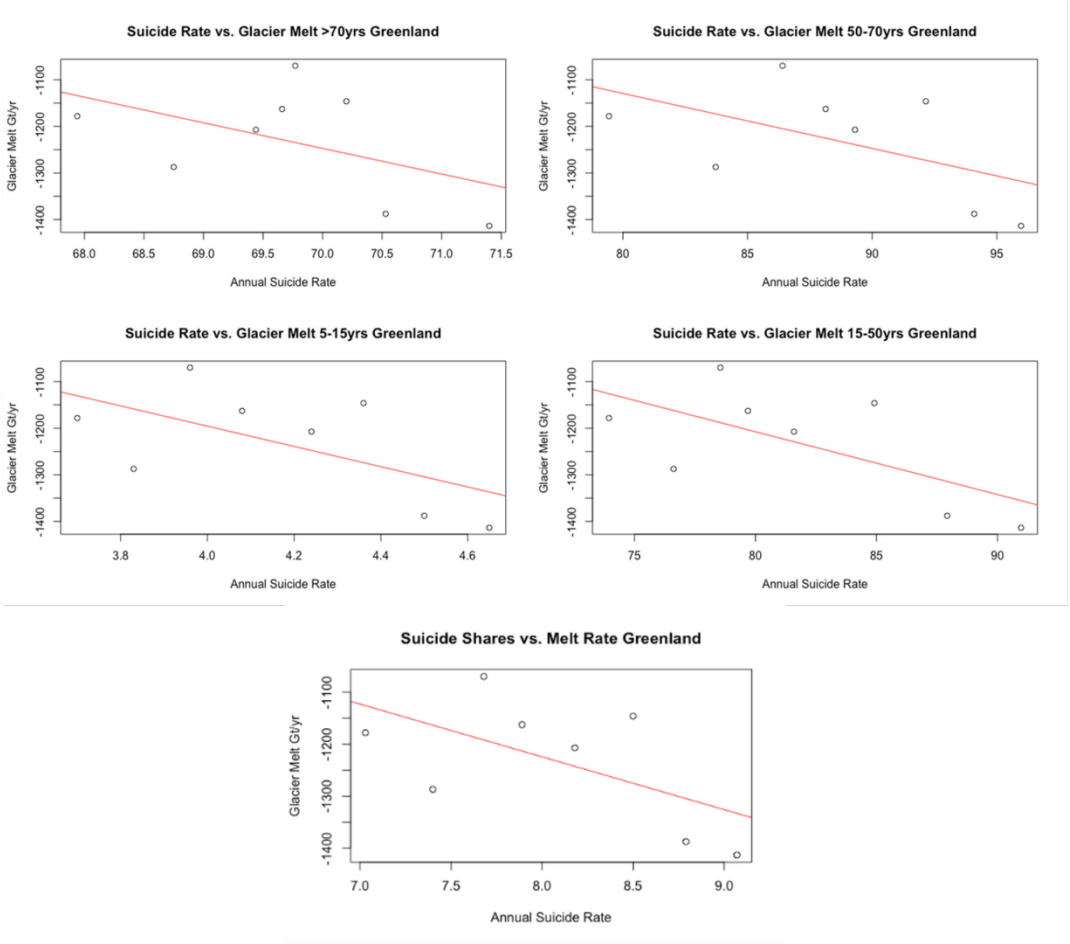


Fig. 5A-E. Linear plots demonstrating the statistically insignificant negative correlation between melt rate variability and suicide rates consistent amongst the general population and age groups in Greenland between 2012-19.

planet is threatening our physical, emotional, and mental well-being (Clayton, 2021; Cianconi et al., 2020; Berry, et al., 2010). Communities living in cryospheric environments are particularly vulnerable to the complex challenges to their physical and mental health related to rapid changes in their surroundings (Cunsolo et al., 2015; Cunsolo et al., 2013). The regions they inhabit are incredibly fragile, resulting in unpredictable weather patterns, natural disasters, food and water insecurity, and loss of traditional ways of life. It is essential to include these cryospheric regions in the evaluation of mental health in the context of climate change. By including these perspectives and experiences, we can gain insight into the direct challenges these populations face and how frozen features potentially affect the global population. This understanding can support sustainable and inclusive policy development for a prosperous future (Lawrance et al., 2021; Cunsolo et al., 2016; Gagné et al., 2014).

This study suggests that the presence of glaciers may have a negative impact on global mental health over a longer period, particularly among youth. We believe this could be due to various factors such as amplified losses associated with these highly vulnerable climatological indicators, the disastrous consequences resulting from unforeseeable changes in this environment, and the vital role these features play in human society. It is important to acknowledge the unique cultural connection between glaciers and their nearby population, whether it is spiritually recognized by Indigenous peoples in Northern Canada, or a source of national identity like in Iceland, where a funeral was held for a melted glacier (Guardian News and Media, 2019). Our results show a notable rise in suicide rates in children ages 5-15 years old with glacial formations each year. This supports previous research identifying the disproportional effects of climate change on youth (Vergunst, F., & Berry, H. L.,2022). This is concerning as children are highly susceptible to

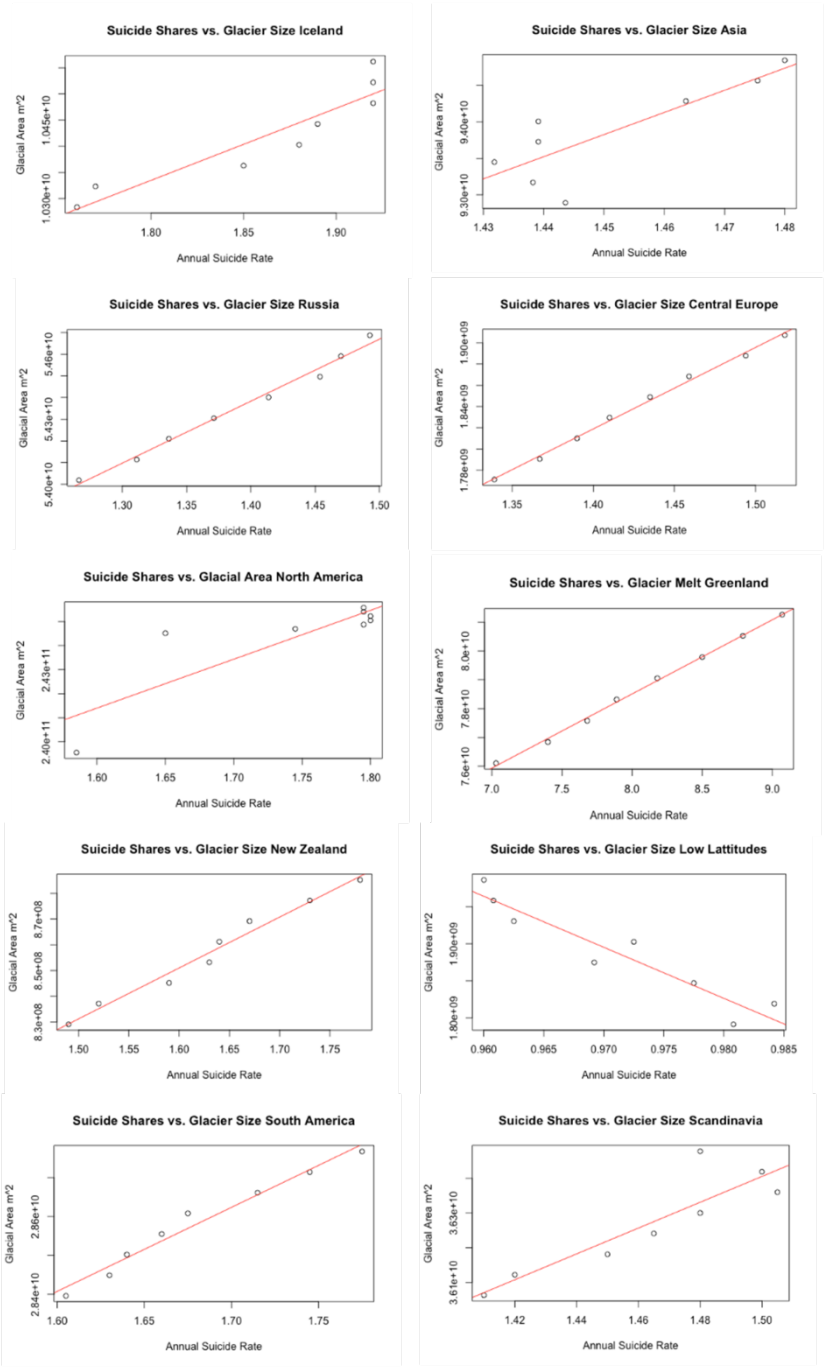


Fig. 6A-J. Linear plots demonstrating significant correlation relationships between glacial area and suicide rate between 2012-19 for each glacial region.

changes in their environment lacking the coping mechanisms, knowledge, and resources to manage the stress and mental distress associated with the changing climate. The positive correlation identified between suicide rates and glacial areas of many of the analyzed regions is likely due to unrelated trends in decreasing suicide rates globally through public health efforts specifically aimed at improving mental health and reducing incidence of suicide (Naghavi, 2019). Concurrent to suicide rates, climate change is worsening at alarming rates resulting in accelerated glacial loss. This is an

example of where correlation does not imply causation as the correlation is a result of external variables we could not account for in our statistical framework due to the scope of our study. The region consisting of nations at low latitudes demonstrated the reverse relationship; this should be investigated further. Greenland showed a negative correlation variable between melt tendency and suicide rates across the general population and specific age groups. Though statistically insignificant, this trend is potentially due to the significance glaciers have to national identity and the population's proximity to frozen regions. Overall, these interpretations offer initial insights into the potential influence of glaciers on mental health across the world.

Limitations

While research has explored the indirect consequences of the cryosphere, the direct impacts on individuals and marginalized communities worldwide should not be overlooked. In light of these considerations, this study identifies several key limitations that deserve attention when interpreting its findings. First, the reliance on suicide data collected by the World Health Organization introduces potential limitations in capturing the full scope of suicide rates worldwide. Inconsistent data quality, as evident in Figure 2 of the Appendix, except for Greenland, was present in the final dataset. Additionally, the quality and accessibility of mental health resources and individual countries' approaches to reporting may lead to variations in the accuracy of data. These disparities in data quality pose challenges that are difficult to address comprehensively within the scope of this initial evaluation. It's crucial to note that suicide rates are not the sole indicators of mental health, emphasizing the importance of including all mental health conditions in policy advocacy, resource allocation, and stigma reduction efforts.

Second, the unique nature of cryospheric regions, often remote and hostile, limits the consistency and availability of data. These environments require a deep understanding of geomorphology and the broader systems influencing glacial behavior, making it challenging to generalize findings from limited field observations to a global context. Furthermore, while satellite data is valuable for assessing large-scale and long-term changes, it lacks the precision to account for the intricate internal dynamics of cryospheric environments. The study could not consider numerous variables related to these environments, such as their specific economic, industrial, societal, and cultural connections, which might impact the results. While this quantitative analysis couldn't pinpoint the explicit causes of reported mental health outcomes, it does highlight potential relationships that warrant further investigation

To address limitations of this study, we suggest conducting a focused study across a region with a well-researched glacial body such as the Juneau Icefield. This would ensure consistent field observations with a comprehensive understanding of the geomorphology dictating melt behaviour and standardized access to adequate mental health resources and diagnosis procedures. This design would enable researchers to interview the nearby population and determine the factors directly impacting communities, thus providing more reliable mental health statistics and informing scientists for accurate interpretations. We would recommend investigating whether years of increased melt affect mental health instability in later years, to identify a potential trickle-down effect that takes time to reach a noticeable impact. To mitigate bias, analysis strategies should account for external factors and alternative environmental variables. A holistic approach should examine the environment as a larger system, exploring how each element could lead to potential influences on mental health. This framework could be employed on a national scale and applied globally to identify trends and study the effects on various regions. A larger systemic perspective is important when it adequately represents individuals. Asking inhabitants of countries containing substantial glacial formations directly if and how glacial melt and climate change affects their mental health would be valuable in establishing the validity of these claims. This complex issue of glacier impact on mental health is often overlooked due to the challenges associated with cryospheric regions. Through focused design accommodating diverse populations, we can develop policy strategies to address environmental conservation in the context of mental health.

5 | CONCLUSION

This study aims to highlight the importance of including frozen regions and marginalized populations in assessing the impact of the climate crisis on mental health. These regions are essential in sustaining life on Earth and represent a component of human identity. By conducting initial studies such as this, we hope to encourage prioritizing cryosphere research and informing policies to protect these

environments as part of our human identity. The cryosphere deserves as much reverence as forests and oceans, despite seeming untouched and remote. Future research studies are not only an academic pursuit but an ethical imperative, as they must give voice to marginalized populations, shedding light on the unique and disproportionate mental health burdens they bear in the face of climate change.

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