Climate Change, Flooding and Mental Health

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Cover photo: Flooding in Bangkok, Thailand (Adobe Stock)

Introduction to Planetary Health

Planetary health is a multi-disciplinary approach that addresses the interconnections between the processes of environmental change and their impacts on human health and well-being, at scale. The planetary health concept builds on the ecological framing of planetary boundaries and supports the UN Sustainable Development Goals and the Paris Climate Change Agreement, both of which recognize the importance of regional and global coordination to solve complex environmental and development challenges.

Links between environmental change and human health are both direct (e.g. impact of air pollution on respiratory and cardiac functioning) and indirect (e.g. extreme weather events or sea-level rise leading to permanent displacement) but there is plausible connection between the change in natural systems and human well-being. The planetary health approach requires transboundary perspectives covering issues that one country cannot address in isolation. Solutions, however, may be local, national, regional or international.

The work of The Rockefeller Foundation Economic Council on Planetary Health, through its Secretariat based at the Oxford Martin School at the University of Oxford, aims to provide a policy-oriented, economic perspective to developing solutions. The central economic concept is that externalities – or costs and benefits to another party that are not priced, regulated or consented to – should better address planetary boundaries than at present. The analysis pays attention to equity and distributional issues, recognising how different people, institutions, countries and trajectories of development are affected by the impact of planetary health and the measures proposed to address it. This work seeks to target recommendations at global and national policy-makers.

A series of background papers has been developed by the Secretariat. These papers aim to illustrate where solutions might be identified and applied, diagnosing planetary health issues by highlighting drivers of change, significant environmental impacts and the resulting human health impacts.

This paper explores the linkages between climate change, flooding and mental health. It shows that the rapid mitigation of carbon emissions will slow the current rate of sea-level rise, thus allowing for a greater range of adaptation options to be implemented. Adaptation options include coastal protection to reduce vulnerability, which limits the potential for mental health impacts, while capital investment to increase mental healthcare quality and capacity will allow states to protect themselves against catastrophic floods. Education is critical to raise awareness of this planetary health issue, so as to improve preparedness and resilience in the wake of future change.

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The full set of papers can be accessed at: *www.planetaryhealth.ox.ac.uk/publications*.

Executive Summary

- Anthropogenic climate change is increasing the frequency and magnitude of extreme climate events while also changing historically stable mean climates. This applies especially to coastal flooding through sea-level rise, tides, storm-surges and wind-driven waves.
- While the impact upon and cost of protection/repair to physical assets and infrastructure has been well studied for coastal flooding, the effect of coastal flooding upon human being's mental health and the associated costs to the economy (direct and indirect) has had little attention.
- Reasons for this include a large number of confounding factors affecting people's mental health (such as prior disorders, level of preparedness, community support and degree of exposure) and the limited data available to test this type of causal pathway.
- Furthermore, high-resolution data sets recording clinical information that are representative of the population affected and long running to capture long-term impacts of mental health are sparse. Most clinical information on the mental health impacts of flooding are from Europe, North America or East Asia. There is a complete absence of mental health information from developing nations, including small island states, though some evidence exists that perceived risk (of a natural hazard) governs an individual's decision-making, which is likely to influence any flood-induced event.
- Equally, high-precision recording of coastal flood frequency and magnitude only occurs for a small number of globally accessible locations, making any causal empirical analysis difficult.
- Human factors affecting mental health risk are likely to influence planetary and socio-economic systems – the former through rising carbon emissions, the latter through socio-demographic behaviour and management/policy decisions.
- Solutions to these challenges can thus target planetary and socio-economic systems – the former through rapid, deep emissions reduction reducing the level of long-term climate change and slowing down the current rate of change, and the latter through varied forms of coastal protection and capital investment in mental healthcare quality, capacity and education to hedge against future uncertainty. Both solutions have numerous co-benefits to planetary and socio-economic systems.

Contents

1. Introduction

Anthropogenic climate change is very likely to exacerbate the stress upon health systems in all parts of the world. It will do this through an increase in the magnitude and frequency of short-lived extreme events (such as droughts, floods, heatwaves) and long-term changes in the climate system moving historically stable climatologies to new norms (including rising temperatures and sea level). Clearly, climate change in and of itself will not bring about health system stress, but its effect will be to increase vulnerability of people and infrastructures to the physical hazards and the induced stress upon people through fundamental socio-economic change (such as water availability and dietary shifts due to changes in aquacultural and agricultural productivity). The implied economic impact upon the global health system is complex and multifaceted, not least because of the multiple factors affecting health systems in general, but also because of the interplay of these factors; thus even attribution over the modern period, where climatological trends are present (such as rising temperature), is not straightforward.

That said, the rise in interest of this research field, both from the health and climate perspective demonstrates the underlying intuition of real causal pathways between our choice of greenhouse gas emissions and the resultant health impacts, both physical and economic. The planetary health approach to viewing this problem allows us consider issues upstream and downstream of the central issue – at how and why human activity is leading to environmental changes, which can then lead to probable/possible adverse human health outcomes.

We demonstrate this approach by focussing upon one particular causal strand, that of the impact of climate change upon mental health through the process of coastal flooding. Figure 1 shows a conceptual map of multiple factors and lines of interaction from human and planetary systems that converge to produce a series of risk factors from flooding leading to short- and long-term health and economic effects. While this is by no means exhaustive, it provides a framework to consider one planetary health issue.

Furthermore, this paper primarily describes the problem and pathway in a general sense. It is primarily qualitative, as a quantitative assessment of such a pathway is challenging in view of limited data and complex synergistic factors (represented by the connecting lines in Figure 1). Solutions are thus likely to be equally complex and multifaceted.

In simple terms, rapid mitigation of carbon emissions will slow the current rate of sea-level rise, thus allowing for a greater range of adaptation options to be implemented. Adaptation options will include coastal protection to reduce vulnerability and thus limit the potential for mental health impacts, while capital investment to increase mental healthcare quality and capacity will allow states to future-proof themselves against catastrophic floods. Finally, education of the population is critical to raise awareness of this planetary health issue, so as to improve preparedness and resilience in the wake of future change.

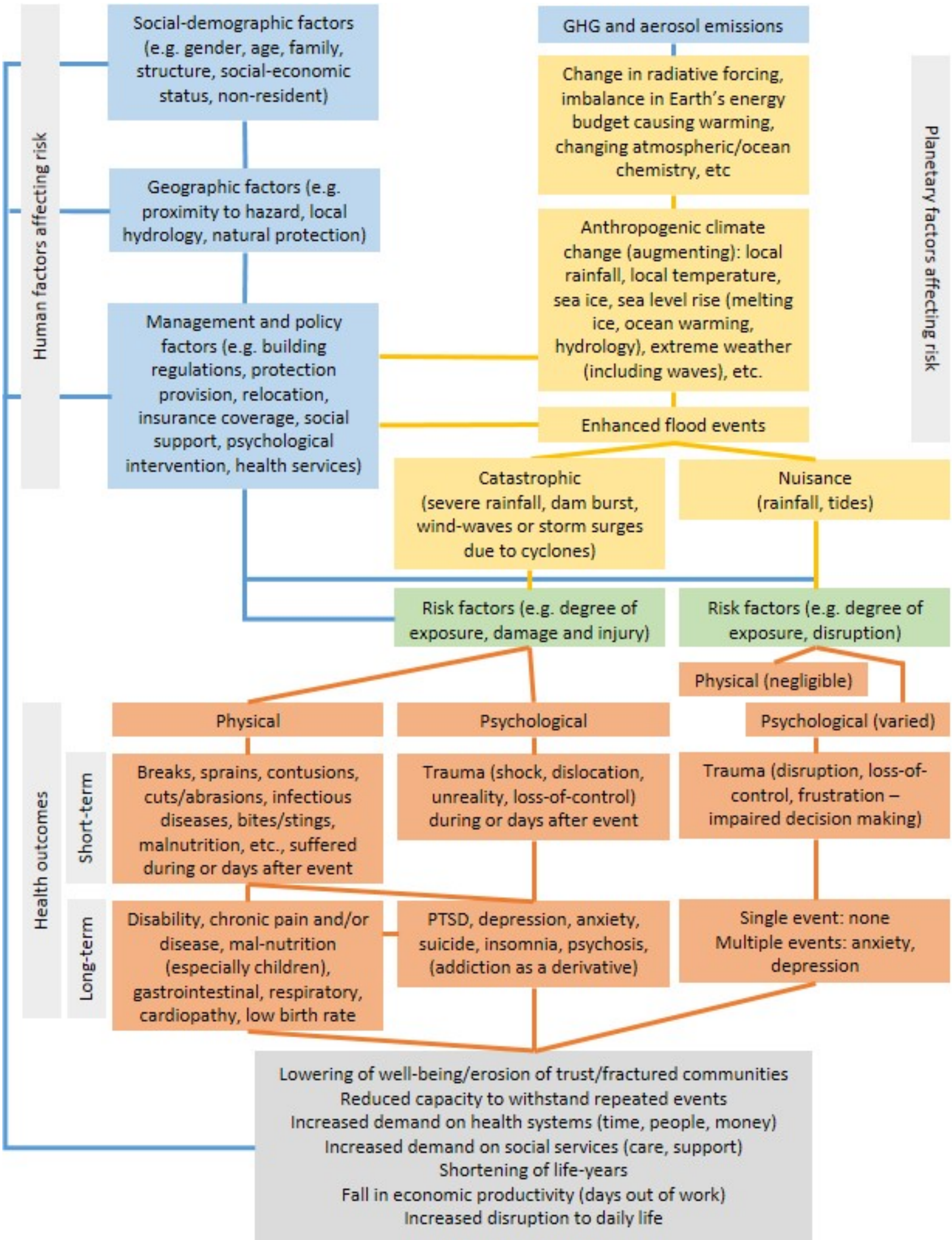

Figure 1: Conceptual map of human (blue) and planetary (yellow) factors impacting flood events. Interactions (connected lines) culminate in a series of risk factors (green) for a given event type, and these generate physical and psychological health outcomes (peach) at different time scales that may also interact, with a range of societal implications for said effects (grey). Examples of impacts/factors are not exhaustive and will vary widely by location, development status and pre-existing resilience. Adapted from Zhong et al. (2018)

2. Climate Change and Sea-Level Rise

From 20,000 to 6,000 years ago, the world's oceans rose on average by around 120 meters from deglaciation, and then effectively stopped. This plateau in sea level, coupled to a more widely stable planetary environment over the last 10,000 years, has facilitated the rise, development and expansion of modern civilisation (Rockström et al., 2009). However, the onset of recent human activity is impacting this environmental stability, including sea level. In the last 100 years, sea level has risen and is now rising faster than at any time in the last 2,000 years (at about 0.3 cm per year, Nerem et al., 2018). Sea level is the sum of a set of components, each one either changing the mass or volume of the ocean (Figure 2). Up to now, most of this rise is due to ocean warming (increasing the ocean volume) and melting glaciers (increasing the mass), but presently the contribution from ice sheets (increasing the mass) is around 36% and rising (Chen et al., 2017).

Figure 2: Illustration showing the different components contributing to local mean sea level. Each icon represents, from left to right, local mean sea level, ocean warming (thermo-steric), ocean dynamics (currents), glaciers, Greenland, Antarctica, land-water storage, and vertical land movement (natural and anthropogenic).

Sea level responds slowly and over long periods to changes in atmospheric forcing, the latter affected directly by cumulative emissions (Figure 1). Consequently, using scenarios that follow different emissions pathways can be informative for future planning. Projections of global sea-level rise under a Paris-like agreement (1.5°C) are likely to reach 44cm by 2100 (Jackson et al., 2018), compared to a business-as-usual scenario (4.3°C) of 84cm by 2100 (Jackson & Jevrejeva, 2016). Projections are uncertain leading to possible rises of up to 70cm and up to 180cm by 2100 for Paris and business-as-usual scenarios, respectively (Jevrejeva et al., 2018). The sources of uncertainty lie in incomplete knowledge and natural variability of the Earth's system, both of which are reflected in the range of responses from numerical simulations of each sea-level component.

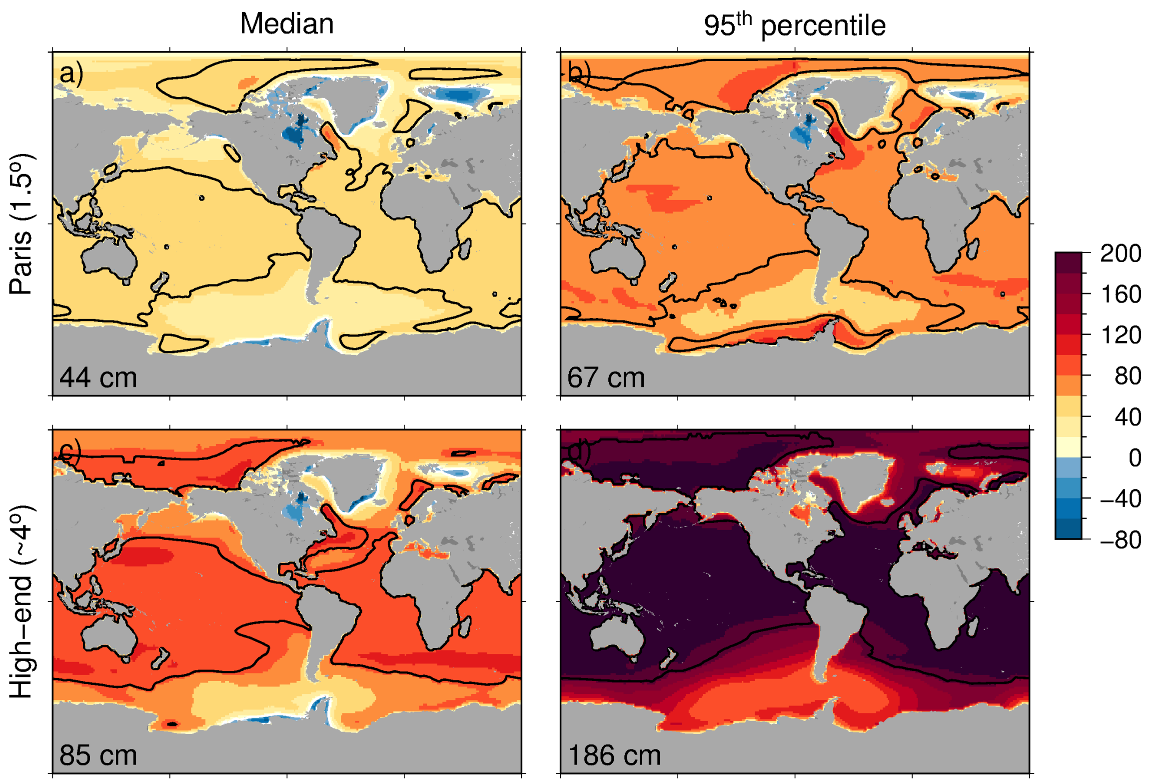

Figure 3: Relative sea-level projections by 2100 for median (50th percentile, LHS) and 95th percentile (RHS) probability for (a-b) Paris-like agreement (Jackson et al., 2018) and (c-d) high-end scenarios (Jackson & Jevrejeva, 2016). Black contour shows the global average sea-level projection, whose value is labelled in each plot (e.g. 44cm).

Sea level is not the same everywhere, and local areas can expect differences in projected sea-level rise of up to ±20% of the global average (Figure 3, Jackson & Jevrejeva, 2016). This is because each component has its own global pattern (the way it is distributed through the ocean) due to the rotation and gravitation of the Earth (Mitrovica et al., 2001).

The importance of the Paris climate change accord

Future sea-level change is strongly dependent upon the emissions pathway we follow. An emissions pathway that reaches the Paris 1.5°C target late in the century via a temperature overshoot and subsequent fall will "lock in" further sea-level rise well beyond 2100. The long-term median sea-level rise (in 2300) is roughly proportional to the duration of overshoot for net-zero greenhouse gas scenarios where sea-level rises roughly 4cm per 10 years of overshoot above 1.5°C (Mengel et al., 2018). Obviously, strong mitigation will slow down the rate of rise, which will allow for an increase in the time available for adaptation. This is a key reason to achieve the temperature targets committed to in Paris (United Nations, 2015) from below, with no overshoot, particularly in the context of coastal flooding where seemingly small increases in sea level can result in dramatic changes to exposure, placing even greater numbers of people at risk than would be otherwise.

Increasing coastal hazard from future sea-level rise

Sea-level rise does not occur in isolation. It will combine with enhanced tides, wind-driven waves and storm surges to increase the height and frequency of coastal floods: termed "extreme sea level". (Figure 4, Vousdoukas et al., 2018). By the end of the century, the global average 1-in-100 year coastal flood event is likely to be 58-172cm higher than today under a business-as-usual scenario, thus rendering a large part of the tropics exposed annually to the present-day 1-in-100 year event around 2050 (Vousdoukas et al., 2018). Northern European and American cities are likely to see an increase of exposure from the present-day 1-in-100 year event by a factor of 5 to around 1-in-20 years by 2050.

Figure 4: Illustration showing the different components contributing to coastal extreme sea level. Each icon represents, from left to right: local extreme sea level, local mean sea level (Figure 3), tides, wind waves and storm surges.

In addition, as the climate warms the atmosphere has a greater capacity to hold water, meaning that extreme rainfall inland may occur simultaneously with "extreme sea level" to cause enhanced inland flooding downstream of river catchments (Muis et al., 2015). This combined effect places numerous coastal towns and cities at even higher risk than were one extreme to occur on its own.

While a single coastal extreme event can cause catastrophic damage to infrastructure, loss/injury to life and numerous negative mental health impacts (Figure 1), frequent coastal flood events of far lower magnitude and intensity may also generate mental health outcomes. Coastal flooding caused by high tides augmented by a rise in mean sea level are termed "nuisance floods" (Figure 1) and cause local, temporary (a few hours) disruption to local services, transport and communication networks. Repeated exposure to such flooding may have negative impacts to mental health through stress associated with such disruption occurring on a weekly or daily basis, or may have positive impacts due to individuals being confronted by a "soft" climate-change induced event resulting in improved resilience and greater awareness (Jamero et al., 2017).

Economic impact of flood damages

From 1998 to 2017, climate-related and geophysical disasters killed around 68,400 people per year and left 231.5 million people per year injured, homeless, displaced or in need of emergency assistance (CRED, 2018). In the latter statistic, individuals are included multiple times representing multiple events they may have experienced. Most reported deaths were due to geophysical events (such as earthquakes). Statistically, though, 91% of all disasters were climate-related (floods, storms, heatwaves, other extremes), of which floods and storms accounted for 43.4% and 28.2%, respectively (CRED, 2018). Damages from coastal flooding are often difficult to discern from pre-existing data sets because they may be recorded as either hydrological (flood) or meteorological (storm) events. With this in mind, flood and storm disasters accounted for 46% and 23% of total recorded, insured economic losses from 1998-2017 of US$2.9 billion (CRED, 2018).

Whether or not these damages have increased discernibly from climate change is extremely difficult to establish, but these losses do amount to a 9% increase from those reported in the previous 20 year period. On the other hand, 20 years of economic growth have greatly increased the value of potential damages. For context, global temperature and global sea level have risen around 0.37°C (Morice et al., 2012) and 5.5cm (Church and White, 2011), respectively, between the 1978-1997 and 1998-2017. Total damage estimates are likely to be skewed on account of limited reporting of events across income groups. For example, low-income countries only reported losses for 13% of climate-related disasters while high-income countries only reach 52% in that category (CRED, 2018).

In the UK context, the winter of 2013–2014 caused widespread river, coastal and surface water flooding after a period of heavy rainfall, which resulted in total economic damages estimated at £1.3 billion (Environment Agency, 2015). Roughly 25% of the cost was for the repair of damage to an estimated 10,465 residential properties, while public health and welfare costs amounted to approximately 2% of the total. Most of the residents affected had not previously experienced household flooding and many suffered symptoms of depression, anxiety and post-traumatic stress disorder (PTSD) more than 1 year after flooding, especially those displaced for more than six months (Munro et al., 2017). These symptoms were often exacerbated for those who lost livelihoods to the flood events as well as their homes. A best estimate of £50 million was spent on temporary accommodation for people who were evacuated or displaced (Environment Agency, 2015).

While it is useful to examine globally insured damages, it is difficult to attribute losses to climate change. Put simply, the natural variability in year-to-year damages coupled with adaptation to infrastructure, improvements to disaster preparedness from frameworks such as that adopted at Sendai (United Nations, 2015) and data sparsity make estimating trends in losses difficult. An alternative approach that has been taken is the counter-factual approach, which essentially asks "what would have happened (to a past event), had X not happened, holding everything else fixed". This approach was taken to assess the impact of 20th-century sea-level rise in New York City on losses due to Hurricane Sandy. The analysis found that 60,000 more people, 26,000 more houses and an extra US$2 billion in flood damages occurred as a result of a 20cm sea-level rise (Leifert, 2015).

Coastal flood damages from future sea-level rise

In the scientific literature, future coast flood damages are generally estimated by analysing the current distribution of population by elevation, scaling it by forecasts of population growth and converting it to asset value to provide exposure for any elevation. These exposures are assessed according to projected extreme sea levels to evaluate the degree of risk.

In the absence of further adaptation, per capita flood damage costs by 2050 in the top ten most vulnerable megacities are at least double for the likely sea-level rise under a business-as-usual scenario, compared to scenarios where the Paris agreement is implemented. Under the low probability scenario with higher sea-level rises, per capita flood damage costs by 2050 in the ten most vulnerable megacities would triple compared to the Paris implementation scenario. From the point of view of global coastal damages, costs under a no-adaptation scenario for a Paris-like scenario could reach US$10.2 trillion per year (1.8% of global GDP), while under a business-as-usual scenario this could reach US$14 trillion per year extending to US$27 trillion per year for a low-probability (95th percentile) outcome (Jevrejeva et al., 2018). Adaptation is certainly a worthwhile investment as costs could decrease for all scenarios by more than a factor of ten.

3. Flood Impacts upon Human Health

As mentioned, current models of coastal flood impacts do not account for the impact to society or people. While they may be helpful for decision-makers doing a cost-benefit analysis of various mitigation or adaptation options for tangible assets (such as buildings, roads, energy and communication systems), their lack of accounting for human impact, especially health, is a serious omission – though one that is admittedly a challenge to address (some have questioned whether it should even be addressed, but that tangible and intangible costs should be estimated separately, see Whitmarsh, 2008). Understanding the social determinants impacted by governmental and business decisions, education and local environmental changes that may in turn impact determinants of health is likely to inform local/community-based adaptation and resilience solutions (and their costing/payoff).

Quantitative and qualitative assessments of the relationship between flooding and human health are numerous (Alderman et al., 2012, Zhong et al., 2018). These assessments and their recommendations are useful for policy-makers when viewed as complementary to population asset-based analyses. In general, health outcomes have been categorised into short and long term, and typically depend upon the characteristics of the flood event and people's vulnerability. While the characteristics of a flood event may be established scientifically, for example using hourly tide gauge measurements to estimate the occurrence time of a given water level (referred to as a return period), or combining high-resolution topography of a populated delta with a hydrological model to explore where floods might flow, quantitatively establishing human vulnerability is less straightforward. Certainly, modelling different types of flooding for a specific region allows one to estimate exposure of assets, homes, transport and communication networks, and thus a certain degree of risk to people, but there is significant evidence that health at time of flood, particularly any pre-existing conditions (especially psychological), strongly impact health outcomes (Tapsell et al., 2002, Bourque et al., 2006, Berry et al., 2010, Lamond et al., 2015).

Short-term effects

Short-terms impacts of flooding upon human health are those occurring during the event, or in the days soon afterwards. The majority of immediate fatalities occur in flash and coastal flood events, often due to drowning and acute trauma (Alderman et al., 2012), though there is a propensity for higher numbers in low-income developing countries due to limited adaptation capacity. Non-fatal injuries include lacerations, abrasions/contusions, sprains and fractures (Bourque et al., 2006), and also (though rarely) communicable diseases such as dermatitis, conjunctivitis and ear-nose-throat infections (Alderman et al., 2012).

Short-term mental health trauma can also occur through stress, which arises from the difference between the perceived demands the event places upon the individual and the resources the individual can draw upon to adapt to that demand (Green, 1988). The “distance” between the event and the individual’s experience of it will strongly impact the extent to which short-term trauma may be obviously manifested. For example, if death occurs following the impact of a flood event, close friends and family of the deceased constitute a population at risk as their degree of loss, which includes loved ones, property, community, employment and unfamiliar surroundings, may overwhelm their coping capacity (Cohen, 2002). As the individual event “distance” increases, impaired mental health resulting from anxiety, distress and the inability to cope may not present obvious symptoms (Rick et al., 1998).

Long-term effects

Long-term mortality and morbidity may be attributed to floods directly (e.g. impacting sanitation) in low-income countries, or indirectly by affecting health, food and economic systems that enhances poverty, malnutrition and non-communicable diseases (Alderman et al., 2012). From a physical perspective, chronic disease, malnutrition and pre-existing illness can all be worsened by a flood event, even months to years afterwards, thus permanently increasing a person's vulnerability in the future (Sharma et al., 2008).

The psychological disorders most commonly found in people affected by flood events are PTSD, followed by depression and anxiety (Liu et al., 2006; Mason et al., 2010; Norris et al., 2005). Studies of floods report prevalence of mental health disorders ranging from 8.6% (Liu et al., 2006) to 53% (Heo et al., 2008) in the first two years following floods. Psychological distress may also account for a portion of the physical illness experienced following floods (Reacher et al., 2004) and together these have a lasting impact on the quality of life of survivors. Evidence from focus group discussions following flood events in the United Kingdom indicates that the greater the damage, tangible losses (like personal items) and inconvenience caused, the greater the stresses suffered by victims are likely to be (Tapsell et al., 2002). In the midst of these negative outcomes, limited evidence points towards an increase in community spirit and the use of humour to help victims cope (Tapsell et al. 2002).

The duration of psychological disorders arising from flood events is difficult to establish quantitatively, but surveys indicate that marginal effects can still occur in significant numbers of victims at least six years post-flood (56% of respondents, Lamond et al., 2015) and these effects result in long-term impacts to well-being as well. In addition to the long-lived nature of these conditions, there is strong evidence of co-morbidity, where multiple, related conditions occur in the same individual (Lamond et al., 2015).

The health of new born children may also be affected by the physical and mental health of pregnant mothers and their access to health services. Pregnant women exposed to extreme events have shown high levels of prenatal stress and thus poor pregnancy outcomes (Tong et al., 2011), while children may also be negatively affected with symptoms including behavioural and psychiatric problems (Kinney et al., 2008).

Solastalgia and biophilia are terms coined to describe distress caused by environmental degradation, loss of home or sense of belonging, and the important relationship between human well-being and their local environment (sense of place), respectively (Berry et al., 2010). These mental health impacts via the physical environment can also be felt in the social environment where social capital is eroded by the economic and logistical challenges following a flood event. If forced movement is necessary – whether temporary evacuation or permanent due to destruction or inundation – this can exacerbate adverse impacts on mental health (Berry et al., 2010). People relocated for six months or more post-flood are six times more likely to report mental health deterioration than those not relocated at all (Lamond et al., 2015).

Nuisance flooding – an unseen problem for mental health?

In Figure 1 and Section 2, we defined two types of coastal flood: a catastrophic event and a nuisance flood. The existing literature has focused upon mental health impacts of catastrophic flood events for good reasons. They are destructive enough to identify and are likely to have a measurable effect upon people, in terms of loss of home, livelihood, perhaps even members of the community.

Conversely, nuisance floods are just that. They are short-lived and cause annoyance and frustration to the general public. They may result in temporary road closures, burst water mains or power outages that cause a reduction in productivity through delays getting people and products from one place to another. While these issues appear initially trivial, they may mount up. Scientific evidence points in only one direction on this issue; nuisance flooding will become more frequent and increasingly disruptive. In fact, it has been estimated that the cumulative cost of nuisance floods over time may exceed the costs of the extreme but infrequent events for which societies typically prepare (Moftakhari et al. 2017). From a mental health perspective, continuous low-level stress can accumulate and have many long term negative impacts such as general affective distress, anxiety and depression (Charles et al. 2013).

Case study: Kiribati

Sea-level rise is a critical climate change factor for Kiribati that threatens its future sovereignty and national identity through coastal flooding, food security and water salinization, amongst other factors. The effect of climate change on the mental health of *i-Kiribati* communities is uncertain. Some indication as to the Kiribati context may be drawn from a key review of the impact of extreme weather events in developing countries by Rataj et al. (2016). PTSD and depressive disorders were prevalent in 1-53% of victims of flooding (from rainfall) and tropical cyclones experienced in the Caribbean, Indian Ocean and South-East Asia (17 events analysed in total).

Many Least Developed Countries and Small Island Developing States have developed formal national adaptation programmes. Kiribati was one of the first Pacific island states to prepare a National Adaptation Programme of Action (NAPA). Following on from the NAPA, the World Health Organisation (WHO) and the Kiribati Ministry of Health and Medical Services (MHMS) undertook a more rigorous climate change and health vulnerability assessment. This led to the development of a National Climate Change and Health Action Plan (NCCHAP), as the health sector's formal contribution to the cross-sectoral national adaptation planning process in Kiribati. A key focus is on motivating households to adapt in anticipation of climate change through pilot community projects (Kuruppu & Liverman, 2011).

As of 2013, 44% of the population of Kiribati live in urban areas. In particular, the island of South Tarawa experiences overcrowding leading to high levels of unemployment, poor housing conditions and health outcomes leading to a deteriorating social environment. With limited data available, Oten et al. (2013) estimate of the number of adults currently experiencing mental illness is between 650 (based on disability survey) and approximately 10,000 (assuming WHO (2004) estimate of 13% of total population). Furthermore, assuming the high value prevalence and that 364 people were recorded as accessing some form of treatment in 2011, the treatment gap would be 63.6%.

The limited availability of mental healthcare in the public health system is underlined by the fact that mental health expenditure comprises 0.8% of the total health budget (Oten et al. 2013). The sole psychiatric unit for the country has no psychiatrists and five nurses, only two of whom have specialist mental health/psychiatric training (Oten et al. 2013). Beyond this facility, there are no formal community mental health services and it would appear that much of the care provided to individuals is from family members (Oten et al. 2013).

The limited data and literature for mental health in small islands and developing countries is clearly an issue that urgently needs to be addressed (McIver et al., 2014) and though some inferences may be made from the evidence in developed nations, the challenges and needs of island and poor communities will be different, thus posing a series of alternative mental health questions.

Perceived risk and climate beliefs

The IPCC assessment reports (IPCC, 1990, 1995, 2001, 2007, 2013) and most recently the Special Report for 1.5°C (IPCC, 2018) have all presented the scientific basis for climate change, the projected impacts, and potential solutions for mitigation and adaptation. This summary of scientific knowledge effectively spells out the risk, as far as science can tell us, to the planet – both human and natural systems from climate change. On the other hand, individuals need to think about the concept and be able to relate to and understand the term; only then can behavioural change follow (Kuruppu & Liverman, 2011).

If, for the sake of argument, we describe this product as the "true" risk then there is also the risk to the planet as perceived by individuals, often in their local context. People's decision-making and behaviour is related to the risk they perceive, rather than the "true" risk. If the two align, then responses to climate change or natural hazards are a product of multiple socio-economic-environmental factors (Whitmarsh, 2008): people may decide to respond to a flood by staying put, but the reason would not be for lack of "true" information about the hazard. If the two are misaligned, then responses are made relative to their perceived risk rather than the "true" risk. This misalignment in any individual has been described as psychological distance (Liberman and Trope, 2008), where distance from climate change related events includes distant in time, space and from affected people.

It has been shown in other climate contexts (e.g. agricultural practices) that psychological distance alters peoples' ability to regulate emotions and mental distress to climate extremes – for example, an accepting attitude of living in a drought-prone region affected by climate change that can limit a farmer's productivity tends to increase emotional resilience and reduce mental distress (Acharibasam & Anuga, 2018). This is supported by studies identifying direct experience of a climate extreme as having a strong influence on risk perception (Hinchliffe, 1996).

Conversely, psychological distance can be affected by climate itself. Recent work studying patterns of belief in climate change in the United States found that that scepticism about whether the Earth is warming is greater in areas exhibiting cooling relative to areas that have warmed and that recent cooling can offset historical warming (Kaufmann et al. 2016). Curiously, flooding is rarely associated with climate change amongst the public, even those who have experienced it first-hand (Whitmarsh, 2008). While little is known about the extent of protective actions taken in response to climate change, Environment Agency (2002) research shows only 5% of people in the UK take any action (e.g. erecting sandbags or flood boards, moving valuables to higher ground, turning off power supply) to prepare for floods (Whitmarsh, 2008). The lack of connection between climate change, flooding (including coastal flooding through sea level rise) and an individual's perceived risk may well contribute towards limited coping capacity and the desire to act in a preventative manner until it becomes too late.

4. Impact of Health on Society

Days out of role because of health problems are a major source of lost human capital. Studies estimate that there are 3.6 billion annual health-related days out of role in the United States (Merikangas et al., 2007). Common health conditions (pain, cardiovascular, depression and migraine), including mental disorders, make up a large proportion of the number of days out of role across a wide range of countries. The occurrence of co-morbidity appear to be common with more than half of people reporting two or more health conditions, often all physical or psychological (Alonso et al., 2011). Across 24 countries in the WHO World Mental Health Survey, three mental health disorders, panic, PTSD and generalised anxiety disorder were among the key reasons provided for days out of role. This is coupled to evidence that indicates that the first two disorders (panic and PTSD) each cause an average of around 43 days out work per year in individuals with those conditions (Alonso et al., 2011).

Cost of mental health

As mentioned above, mental health disorders have a high share of days out of role, but mental illness more widely accounts for nearly 25% of disability-adjusted life years (Kaplan and Laing, 2004). Furthermore, when compared with other diseases (e.g. diabetes and cancer), they appear to be most costly to society (Andlin-Sobocki et al., 2005).

A detailed analysis of the cost of psychological disorders in Europe in 2004, where direct and indirect costs were established for each disorder by country and scaled by the number of cases of each disorder, found that around 4% and 9% of the population had an affective (depression and bipolar) or anxiety (panic, phobia, OCE, GAD) disorders, respectively (Andlin-Sobocki et al., 2005). These percentages translated into total costs (for 2004) to the European economy of €106 billion and €41 billion, respectively.

Cost of mental health from flooding

We have loosely estimated the average annual cost of mental health from flooding to the European and US economies to be €0.20-1.23 billion and US$1.9-12.1 billion, respectively, from 1998-2017. This range draws upon a number of studies referred to in previous sections of this report and makes a series of extremely strong assumptions (see Table 1 for calculation). Given the assumptions, we would not speculate upon the validity of this range, however, it is useful in providing a sense of the impact of mental health issues arising from flooding on the wider economy, underlining the importance of this issue when looking forwards to a changing climate where greater numbers of people are likely to be affected in the future.

	Europe	United States	Reference
Number of people affected by flooding worldwide (1998-2017)	2 billion		CRED (2018)
Percentage of people affected by climate-related disasters (1998-2017)	1%	<2%	CRED (2018)
Number of people affected by flood (1998-2017)	20 million	<40 million	This study
Percentage of those affected by flood reporting mental disorder (global)	8.6 – 53%		Liu et al. (2006), Heo et al. (2008)
Number of people affected by flood reporting mental disorder (1998-2018)	1.72 – 10.6 million	3.44 – 21.2 million	This study
Number of people affected by flood reporting mental disorder per year	0.09 – 0.56 million	0.18 – 1.12 million	This study
Average cost per case of depressive disorders (2004 in Europe, 2005 in USA)	€2,200[a]	US$10,800[b]	Europe: Andlin-Sobocki et al. (2005), USA: Greenberg et al. (2015)
Average annual cost of mental disorders due to flooding (1998-2017)	€0.20 – 1.23 billion	US$1.9 – 12.1 billion	This study

a. Calculated as average of total cost per case of GAD (€1,804), panic (€967) and depressive disorders (€3,826)
b. Calculated as incremental direct cost per patient ($5,707) multiplied by additional cost of disorder (1.9) to give cost per case

Table 1: Published statistics and the authors' estimates leading to average annual cost of mental health from flooding in Europe and the United States (1998-2017). Final values predicated upon accuracy of flood affected populations (only given as a percentage in CRED (2018)) and percentage of those affected reporting mental disorder (global estimate).

Building healthcare resilience anywhere

The above estimate made for the average annual cost of mental health from flooding in Section 4 illustrates the critical importance of health systems being able to provide capacity. In the context of a changing climate where flooding in general, and coastal flooding in particular, will become more frequent and more intense through the inevitable rise of sea level, health systems must be in a position to cater for greater numbers of victims (though perhaps fewer fatalities as protection improves).

The evidence of present-day flooding shows that health systems are often placed under severe strain during and in the aftermath of a major flood event. For example, short-term hospital admissions rise significantly on the day or day after cyclones make landfall (e.g. USA, Bourque et al., 2006). A key cause of post-flood related deaths is the inability of the health system to maintain a constant medication uptake for those suffering chronic disease and related conditions (e.g. Hurricane Katrina and Rita and Japanese 2006 flood).

Vulnerability to natural disasters has two sides: the degree of exposure to dangerous hazards (susceptibility) and the capacity to cope with or recover from disaster consequences (resilience). Vulnerability reduction programs reduce susceptibility and increase resilience, while susceptibility to disasters is reduced largely by prevention of, and planning for emergencies (Keim, 2008). Emergency preparedness and response and recovery activities – including those that address climate change – increase disaster resilience. Some evidence indicates that the way a flood disaster response is handled by community and professional agencies can have a significant effect on mental health outcomes, and lower illness burdens (Tunstall et al., 2006).

While it is easy to point out that a more robust healthcare system with capacity for disaster response including mental health disorders would place vulnerable countries in a better position of preparedness, the present state of government mental health expenditure varies widely (Figure 5). Median global mental health expenditure per capita is US$2.5 per year, which is less than 2% of overall global health expenditure (WHO, 2018). Regionally, European and Pan-American investment in mental health is ~220 and 120 times higher than African and South-East Asian regions. This picture of investment in mental health is also reflected in the grey literature discussing many of the symptoms of mental health due to flooding. As shown in previous sections, epidemiological studies are focussed upon developed nations while almost nothing is known of the mental health effects of coastal flooding in developing nations. Ironically, it is in these locations that sea-level rise induced extremes will be felt worst due to limited adaptation capacity.

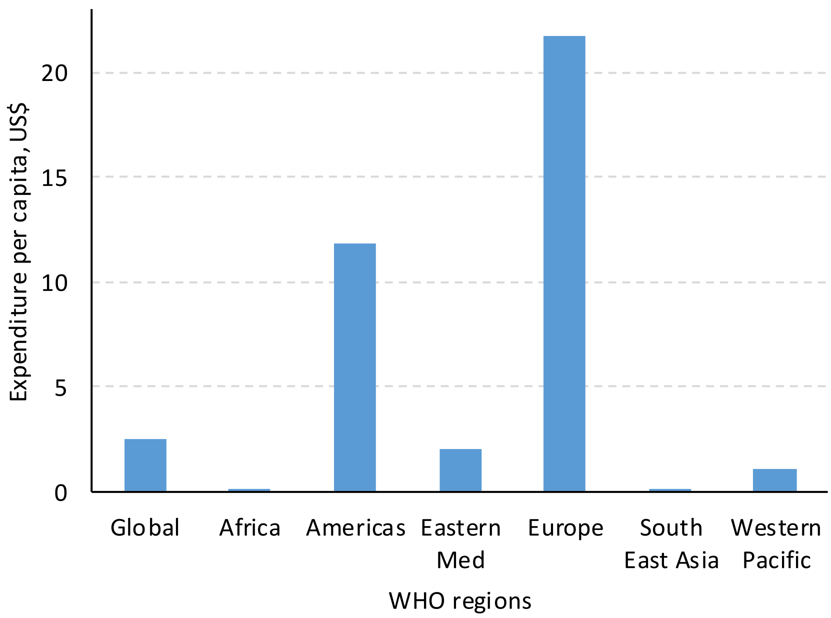

Figure 5: Government mental health expenditure per capita, US$, by WHO region. Figure reproduced from Fig 3.1.1 in WHO (2018).

5. Conclusions

Sea-level rise is a key bi-product of anthropogenic climate change. As GHG emissions continue to rise, the Earth's energy imbalance results in warming – which causes an increase in ocean volume (through thermal expansion) and ocean mass (through melting of land-ice) – thus causing sea level to rise. The rise refers to the global average; however, coastal sea-level change will be impacted by multiple factors, both physical and anthropogenic (i.e. subsidence), and will thus deviate by ±20% from the global value, and perhaps even more depending upon whether a city (like Jakarta) elects to halt groundwater extraction activity.

The rise in sea level will increase the frequency and occurrence of coastal flood events generated by tides, wind waves and storm surges (from tropical cyclones). These future changes will impact both physical infrastructure for which a significant literature exists in terms of economic damages, and human well-being for which there is a small, but growing body of evidence. A key aspect of well-being that remains underresearched is that of mental health, especially outside of data-rich locations such as Northern Europe and the US.

In Figure 1, we presented a conceptual diagram illustrating the causal pathways leading from planetary health to well-being outcomes via coastal flooding. Through this report, we have come to the point of estimating (very loosely) the cost of mental health from flooding to Europe for a specific year. This says nothing about the long-term change in climate, or the impact of climate upon this value. However, circumstantial evidence points to the fact that over a period of 40 years insured damages have risen by 9% while over the same period global temperature and global sea level have risen around 0.37°C and 5.5cm. Furthermore, causal links between different parts of Figure 1 have been clearly demonstrated, and there is a body of research considering at least qualitatively the causal change from climate change to mental health (e.g. Berry et al., 2018).

Mental health impacts from flooding can be long-lived and affect every aspect of an individual's life. Health systems have a clear role to play in supporting those dealing with these issues; however, the problem is not just one of care to victims. A systems-based approach that is cross-sectoral in assessing the impacts of this key health issue across society is a more pragmatic solution than isolated, and thus limits policy intervention (Berry et al., 2018).

Decision-makers have all the tools at their disposal to develop preventative measures and reduce the number of future cases of mental health disorders from flooding. The main challenge to implementation is designing a workable strategy that captures multiple benefits across economic, societal and environmental settings, that is based upon a prior understanding of a local community's resilience and sustainability priorities, and that identifies a set of key metrics to use in practise with which to measure success.

In the context of coastal flooding, a key message is one of rapidly curbing GHG emissions to slow down the rate of sea-level rise. A second message is to plan for uncertainty since sea-level projections, and thus coastal flood events, have a degree of uncertainty about where they end up for any given climate scenario. A third is to build in capacity to existing health systems and community healthcare workers so that a sudden coastal flood event does not leave a region reeling.

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