The association between weather and crime in a township setting in South Africa

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Abstract

The association between various meteorological parameters and crime is well-established in developed contexts. In contrast in this study, we investigated the association between three weather parameters (temperature, relative humidity and rainfall) and three categories of crime in the developing township of Khayelitsha, in the Western Cape Province of South Africa. Distributed lag non-linear modelling was used to identify temporal relationships between temperature, relative humidity and rainfall, and violent, property and sexual crime over a 10-year period (2006–2016). We found hot days (defined as ≥ 25 °C) increased the cumulative relative risk of violent crime by up to 32% but were also found to be associated with a lagged increase in violent crime for at least a week thereafter. On very cold days (defined as ≤7∘C), the cumulative relative risk of property crime increased by up to 50% whereas on very rainy days (defined as ≥20mm) the risk of property crime surprisingly increased by 40%. These findings provide some additional evidence for the relationship between the atmospheric environment and human behaviour in a developing context.

Keywords: crime; Khayelitsha; climate; distributed lag non-linear modelling; weather

Introduction

There is a long history associating weather with crime. From the early writings of Cicero to empirical observations by Adolph Quetelet (1842), the notion that certain meteorological parameters, most notably temperature, promote aggressive behaviour is well-documented (see e.g. Rotton and Cohn 2000; Hipp et al. 2004; Bushman et al. 2005; McDowall et al. 2012; Gamble and Hess 2012; Mares 2013; Xiaofeng et al. 2017; Stevens et al. 2019). This association has entrenched itself in the English language in phrases such as ‘hot-headed’, ‘hot under the collar’ and ‘seeing red’. Previous studies have used a range of research designs

and statistical techniques to find any significant relationships between temperature specifically and crime at various temporal resolutions ranging from hourly (Rotton and Cohn 2000; Brunsdon et al. 2009; Baryshnikova et al. 2019) to annually (Rotton and Cohn 2003; Anderson and deLisi 2011). The results of these research studies have, however, most often produced inconsistent and often paradoxical results with some studies finding no seasonal fluctuations in crime (Pittman and Handy 1964; Yan 2004), whilst others find an increase in crimes during either the colder winter months or warmer summer months (Morken and Linaker 2000; Breetzke and Cohn 2012). Moreover, the nature of the 'curve' characterising the relationship between temperature and crime has also been the topic of much debate with some scholars advocating for a linear relationship between temperature and crime (Anderson et al. 1995; Cohn and Rotton 1997; Rotton and Cohn 2000) whilst others motivating for a curvilinear effect (Baron and Bell 1976; Gamble and Hess 2012; Schinasi and Hamra 2017; Stevens et al. 2019). With a few notable exceptions, the general consensus among scholars is that crime does increase with an increase in temperature although the degree to which crime increases may depend on the varying geographical locations under investigation.

Whilst various meteorological parameters have long been found to be associated with crime internationally, these associations have not yet been adequately identified and/or quantified in Africa in general and South Africa specifically. The objective of this study is to examine the effect of three meteorological parameters (temperature, relative humidity and rainfall) on the magnitude of crime in Khayelitsha, a large informal settlement located in South Africa.

Theoretical framework

The causal pathway through which weather (and temperature in particular) impacts crime has historically been explained using the temperature–aggression (Quetelet 1842) and the routine

activity (RA) theories (Cohen and Felson 1979). The former more psychologically based theory motivates that uncomfortably hot temperatures increase the frustration, discomfort and irritability levels of individuals which can lead to more aggressive behaviour, which in turn increases the risk of violent crime in particular. The latter offers a more sociological approach to explaining the association between weather and crime and is based on the notion that in order to understand criminal behaviour, one must first understand how individuals routinely use their time. Whilst some of activities are compulsory with a fixed duration (such as school or work), others are more flexible/discretionary (such as socialising on weekends). Changing weather conditions can play an important role in altering the routine activities of individuals, particularly those who are more flexible, which may in turn impact the likelihood of the convergence of the three elements required for a crime to occur according to the RA theory, namely a motivated offender, a suitable target and the absence of a capable guardian.

Prior research—embedded in these theoretical frameworks—have most often found a positive association between temperature in particular and crime across diverse range of contexts. In the United States (US), Cohn (1990) examined the accumulated research on the association between various meteorological parameters and different types of criminal behaviour and found that, in most cases, crime increased linearly with temperatures up to roughly 30 °C. Later, Cohn and Rotton (1997) found a negative linear association between temperature and assault during certain periods of the day such as early in the morning (3:00 am–5:59 am) and during the evening (18:00 pm–11:59 pm). Also in the US, Hipp et al. (2004) modelled seasonal changes in violent crime for all cities, townships and county sheriffs from 1990 to 1992 and found that warmer periods of the year did show overall increases in violent crime, but areas with overall warmer climates did not exhibit overall higher violent crime rates. Moreover, areas that experienced greater seasonal temperature variations (mostly the colder states) had bigger seasonal oscillations in crime, whilst areas with moderate year-round

temperatures had high overall crime rates but saw little seasonal change in crime. Rotton and Cohn (2003) also examined the effect of increased atmospheric temperature on assault and homicides across the whole US between 1950 and 1999. Results again indicated that temperature was positively and linearly associated with assault crimes. Years which experienced higher average temperatures overall exhibited higher assault rates. More recently, in Cleveland, Ohio, Butke and Sheridan (2010) examined the influence of weather on the magnitude of aggressive crime at the city-wide level whilst controlling for seasonality, time of day and day of week among others. Results also showed that aggressive crimes peaked in summer and reached a minimum in winter, whilst midday and early night hours were the most significant when relating temperature to aggressive crime. McDowall et al. (2012) used 24 years of monthly individual crime (homicide, rape, robbery and aggravated assault) and temperature data for 88 US cities to test for the mechanisms by which seasonal cycles influence crime and found strong evidence for seasonal patterns for most violent crimes, with the exception of homicides, similar to other studies (see e.g. Cohn 1990; Rotton and Cohn 2003). Their findings also suggest that the higher ambient temperatures expected with climate change may result in marginal shifts in violent crime in the short term, especially in already warm regions of the world, but are not likely to be accompanied by markedly higher rates of violent crime in the long term. Other US-based studies include Ranson (2014), Mares (2013), Hsiang et al. (2013), Mares and Moffette (2016), and Schinasi and Hamra (2017).

Outside of the US, several studies have similarly found positive associations between various meteorological parameters and crime. In Norway, Morken and Linaker (2000) found seasonal variation of crime throughout the country with violent crimes reaching a peak in June (summer) and a low in winter whilst in Brazil, Ceccato (2005) found more homicides take place in warm summer months than in cold winter months in Sao Paulo. She did however also find that temporal variables (time of day and day of week) were far more powerful when accounting

for variations in homicide rates, than temperature and relative humidity. In Santiago, Chile, Téllez et al. (2006) examined monthly and seasonal variations in sexual abuse over a 10-year period and found that sexual abuse is seasonal, with the highest incidences occurring in spring (November) and the lowest in winter (June). In China, Xiaofeng et al. (2017) examined the relationship between temperature and six individual crime types (including homicide, assault, robbery and rape) over a 5-year period and found a strong positive association between increasing temperatures and violent crime on a monthly level, with warmer months of the year experiencing higher rates of violent crime.

In Australia, a country with some similar climate zones to South Africa, the relationship between temperature and assault, at both monthly and daily level, was found to be seasonal with roughly 18% more assaults occurring in summer than in winter (see Stevens et al. 2019). At the daily level, assault was also found to increase significantly with temperature; however, the rate of increase slowed when maximum daily temperatures exceeded 30 °C. Studies examining the impact of relative humidity and rainfall specifically on crime rates have been less forthcoming but studies that have been undertaken have most often produced mixed results with some finding an increase in crime during periods of increased humidity and rainfall (Hsiang et al. 2013; Shen et al. 2020) and others finding no such association (McLean 2006; Schutte and Breetzke 2018).

Despite much being known about the relationship between weather and crime elsewhere, few studies have examined crime seasonality in South Africa. In sub-Saharan Africa, a 30-year database of conflict events (not crime) and climate data showed that high temperature extremes were associated with more conflict; however, this varied by conflict type and subregion (O'Loughlin et al. 2014). Rainfall extremes, both low and high, were generally not significant. Recently, homicide, an outcome of crime, was shown to be positively associated with daily ambient temperature (Gates et al. 2019). A 1 °C increase in same-day

maximum temperature was associated with a 1.5% (1.3–1.8%) increase in definite homicides and a 1.2% (1.1–1.3%) increase in total (definite and probable) homicides. Other research by Collings (2008) and Schutte and Breetzke (2018) have similarly found associations between weather and crime. No study has however considered other meteorological variables as predictors of criminal activity and violent behaviour in South Africa and none has examined the lagged effect of weather on crime. This study aimed to fill this gap and provide additional evidence of any weather-crime linkage in a developing context.

Material and methods

Study area

Khayelitsha is located approximately 30 km from Cape Town in the southernmost tip of Africa (see Fig. 1). It is one of the largest townships in the country comprising approximately 400,000 inhabitants (Statistics South Africa 2011), although figures of up to 1.2 million residents have been reported (Cronje 2014). Khayelitsha is one of the poorest townships in the country with almost 40% of residents unemployed whilst just under three-quarters of residents survive on less than R3200 (US$200) per month (Statistics South Africa 2011). In terms of housing, the township comprises both formal and informal housing including informal shack-type housing on its peripheries. Khayelitsha experiences a moderate climate with mild, wet winters and dry hot summers.

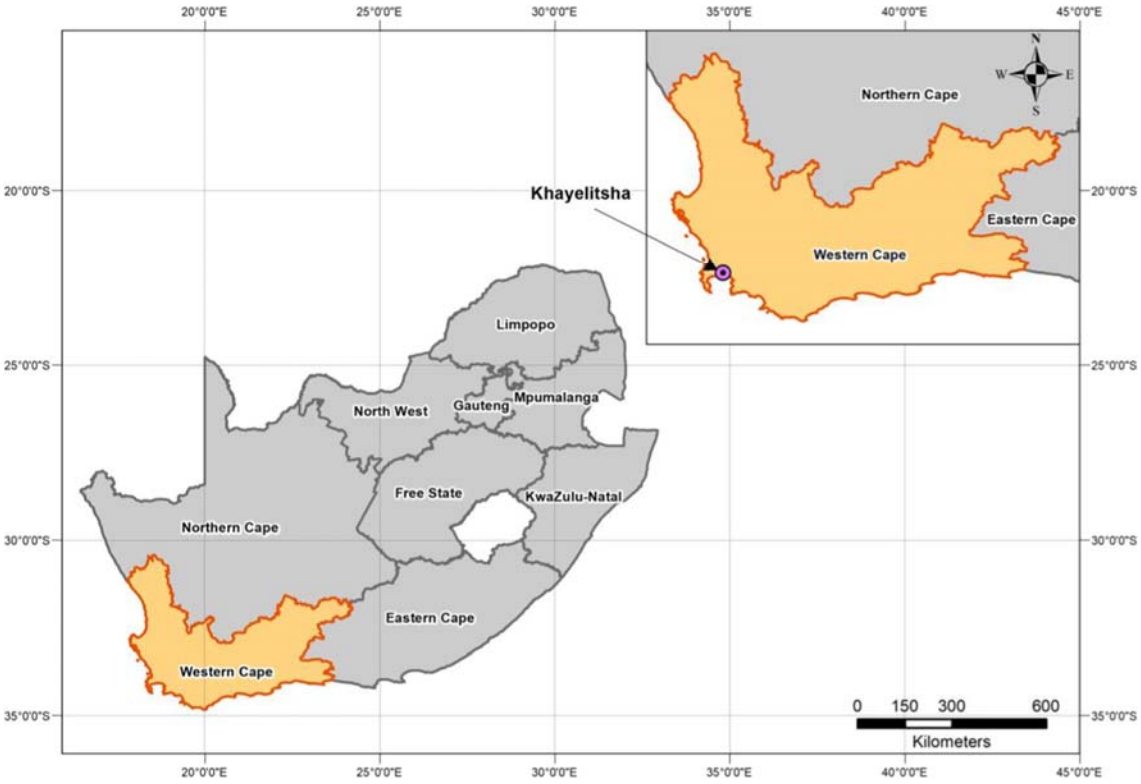

Figure 1. Location of Khayelitsha in South Africa

Crime data

The Khayelitsha police precinct is among the most violent of all 1138 police precincts in South Africa (South African Police Services (SAPS) 2018). Over 40% of all crimes committed in the township are violent; this is above the national average of 34%. Daily number of crimes reported between 1 April 2006 and 31 March 2016 (10 years) data were obtained from the SAPS. The data included the geographic location, date and time of day, as well as type of crime committed in the Khayelitsha policing precinct. The crime data were separated into three broad categories: (1) sexual offences included rape, abduction and sexual assault; (2) property offences included robbery and carjacking; and (3) violent crime included assault, murder and attempted murder. The SAPS gave permission for use of the data. Ethics approval for the study was granted by the University of Pretoria (reference number: NAS366/2019).

Meteorological data – temperature, relative humidity and rainfall

Meteorological data for Khayelitsha were obtained from the South African Weather Service and included hourly temperature records, relative humidity and rainfall across the 10-year duration of the study period (i.e. 1 April 2006 to 31 March 2016 inclusive; total days = 87,672; total hours = 2,104,128). Research examining the association between weather and crime is increasingly occurring at finer and finer temporal resolutions (seeRotton and Cohn 2000; Brunsdon et al. 2009; Baryshnikova et al. 2019). We initially sought to mimic this trend by investigating this potential linkage at the hourly level; however, the available crime data at this temporal resolution was too sparse and zero-inflated (73% of hours had no crimes recorded). Moreover, both the mean and median daily temperature ranges were low for roughly 80% of the dates investigated (< 12 °C) and did not vary significantly. Thus, modelling the data at a daily time interval, we felt, was most appropriate.

Data analysis

Crime-weather analyses

Investigating the curvature of the weather-crime linkage requires a statistical technique that is able to model the effect of an exposure variable (e.g. a hot day) on a response variable (e.g. crime) at multiple points in time. Gasparrini et al. (2010) proposed a distributed lag non-linear modelling (DLNM) framework that does not require the assumption of a linear relationship between the variables of interest. This generalised model enables the simultaneous description of lagged exposure–response relationships that are non-linear and has been used extensively to investigate environmental factors that contribute to other types of behaviours and outcomes (see Schwartz 2000; Ranson 2014; Gates et al. 2019).

DLNMs were therefore fitted to the daily crime counts using a quasi-Poisson distribution. This was done since the variance of daily crime counts far exceeded the mean. AS

previously mentioned, the crime data were modelled at a daily time interval since an hourly time interval led to a large degree of zero-inflation. The number of knots was selected by considering both model flexibility and to avoid potential problems with over-fitting. The final model fit was evaluated based on model residuals and autocorrelation.

The association between the meteorological predictors and the relative risk of the three categories of crime was modelled through various natural cubic splines with two degrees of freedom for each predictor and lag space. The maximum lag period considered for each predictor variable was set at 7 days and 21 days for daily mean temperature as well as total daily rainfall and relative humidity. Indicator variables for day of the week and month were also included in the final model.

Models were fitted using RStudio (version 4.0.2) using the dlnm package (version 2.4.2). Results are plotted as predicted relative risks (RR) at different exposure and lag values. Predictions were centred at mean values for predictor variables: mean daily temperature (17 °C), total rainfall (1.3 mm) and relative humidity (72.4%). Relative risks equal to one are considered not to be statistically significant.

Results

Descriptive statistics

Table 1 shows the descriptive statistics of the crime data and meteorological conditions. A total of 29,924 crimes were committed in the township over the 10-year study period (violent crime: 16,416; property crime: 8224; sexual crime: 2284). On average, approximately 18 crimes were committed per day in Khayelitsha with the highest number of crimes committed on any 1 day being 65 which corresponded to mean and maximum temperatures of 22.4℃ and 27.9℃, respectively. Seasonally, the most crimes occurred during spring ($n = 7142$), followed by summer ($n = 6730$), winter ($n = 6707$) and autumn ($n = 6345$).

Table 1: Daily descriptive statistics for crime and weather in Khayelitsha (2006-2016)

	Min	Mean	Max	Variance	25th percentile	Median	75th percentile
Crime							
All crime	1	17	65	80.5	10	15	22
Violent crime	0	10.2	48	48.4	5	8	14
Property crime	0	5.4	21	8.5	3	5	7
Sexual crime	0	1.5	14	2.7	0	1	2
Weather							
Temperature (°C)	7.5	17.1	28.8	15	14	16.9	20.2
Relative humidity (%)	35.5	72.4	98.3	100	65.4	72.7	79.6
Rainfall (mm)	0	1.3	49.2	17	0	0	0.2

Exposure-response estimates

The effects of temperature, relative humidity and rainfall on all crime and for the three categories of crime are provided in Tables 2 and 3. The results predict the meteorological-crime association for the 1st, 25th, 75th and 99th percentiles and suggest that both cold and hot effects may pose an increased risk for the occurrence of all crime (Table 4). However, only cold effects displayed statistically significant positive associations for all crimes combined and for property crime respectively (1st percentile RR = 1.16, CI = 1.03–1.31 and RR = 1.52, CI = 1.35–1.71). Other crime-weather pairings (specifically those involving sexual crimes) produced largely insignificant associations. The most significant results were found for temperature, rainfall and violent and property crime. As a result, in the rest of our results, we expand on these initial findings.

Table 2: Summary statistics for all crimes by month

Month	Minimum	Mean	Maximum
January	1	15	65
February	2	17	46
March	1	17	43
April	2	16	48
May	2	16	42
June	2	17	46
July	3	17	43
August	4	17	46
September	3	18	55
October	5	18	48
November	3	19	54
December	3	19	53

Table 3: Summary statistics for all crimes by day of the week

Day of week	Minimum	Mean	Maximum
Monday	2	14	49
Tuesday	2	12	50
Wednesday	1	11	65
Thursday	3	12	53
Friday	4	17	50
Saturday	8	28	55
Sunday	8	25	48

Table 4: Results of distributed lag non-linear modelling

	Relative risk by percentile			
	1st	25th	75th	99th
Temperature				
All crime	1.16 (1.03 – 1.31) *	1.04 (1.00 – 1.07)	1.02 (0.99 – 1.06)	1.17 (1.00 – 1.37)
Violent crime	1.02 (0.87 – 1.20)	0.98 (0.94 – 1.03)	1.07 (1.03 – 1.12) *	1.32 (1.08 – 1.61) *
Property crime	1.52 (1.35 – 1.71) *	1.16 (1.12 – 1.20) *	0.93 (0.90 – 0.96) *	0.93 (0.74 – 1.09)
Sexual crime	0.94 (0.72 – 1.22)	0.98 (0.91 – 1.05)	1.01 (0.94 – 1.09)	1.02 (0.72 – 1.43)
Relative humidity				
All crime	0.92 (0.72 – 1.16)	1.12 (1.02 – 1.23)	1.00 (0.90 – 1.11)	0.83 (0.70 – 0.99)
Violent crime	0.84 (0.62 – 1.14)	1.13 (1.00 – 1.30)	1.04 (0.91 – 1.19)	0.83 (0.67 – 1.05)
Property crime	0.98 (0.78 – 1.24)	1.12 (1.02 – 1.24) *	0.91 (0.82 – 1.01)	0.80 (0.68 – 0.94) *
Sexual crime	1.29 (0.79 – 2.10)	1.07 (0.87 – 1.31)	0.91 (0.91 – 1.42)	1.00 (0.70 – 1.43)
Rainfall				
All crime	0.99 (0.96 – 1.02)	0.99 (0.96 – 1.02)	0.99 (0.97 – 1.02)	1.04 (0.83 – 1.30)
Violent crime	1.02 (0.98 – 1.06)	1.02 (0.98 – 1.06)	1.02 (0.98 – 1.05)	0.89 (0.66 – 1.20)
Property crime	0.96 (0.93 – 1.00)	0.96 (0.93 – 1.00)	0.97 (0.94 – 1.00)	1.40 (1.10 – 1.68) *
Sexual crime	0.96 (0.90 – 1.03)	0.96 (0.90 – 1.03)	0.97 (0.91 – 1.03)	0.90 (0.55 – 1.47)

Note: * denotes statistically significance ($p < 0.05$); reference values 17°C, 75% and 1.35 mm, respectively

The overall relative risk of violent crime and temperature is shown in Fig. 2. Violent crime increased significantly for temperatures above 18°C. Very hot days (28°C, the highest observed temperature) were associated with more than a 50% increase in the relative risk of violent crimes relative to baseline; the highest RR of 1.65 was observed at 30°C (CI = 1.13–2.42). In terms of lag effects, a lag of 7 days of high temperatures (> 20 °C) was found to be associated with a significant increase in the relative risk of violent crime (Fig. 3a); however, after 14 days no significant associations were observed (Fig. 3b).

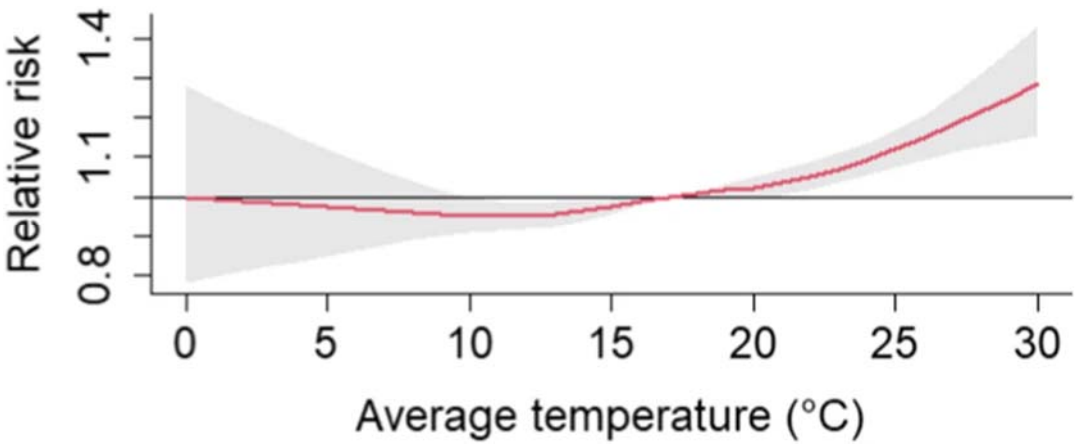

Figure 2: Association between violent crime and mean daily temperature

The overall relative risk of violent crime and temperature is shown in Figure 2. Violent crime increased significantly for temperatures above 18°C. Very hot days (28°C, the highest observed temperature) were associated with more than a 20% increase in the relative risk of violent crimes relative to baseline; the highest RR of 1.286 was observed at 30°C (CI = 1.153 – 1.370). In terms of lag effects, a lag of three days of high temperatures (20°C) was found to be associated with a significant increase in the relative risk of violent crime (see Figure 3a). After seven days, however, high temperatures were found to be associated with a significant decrease in the relative risk of violent crimes (Figure 3b). Finally, after 14 days no significant associations were observed (Figure 3c).

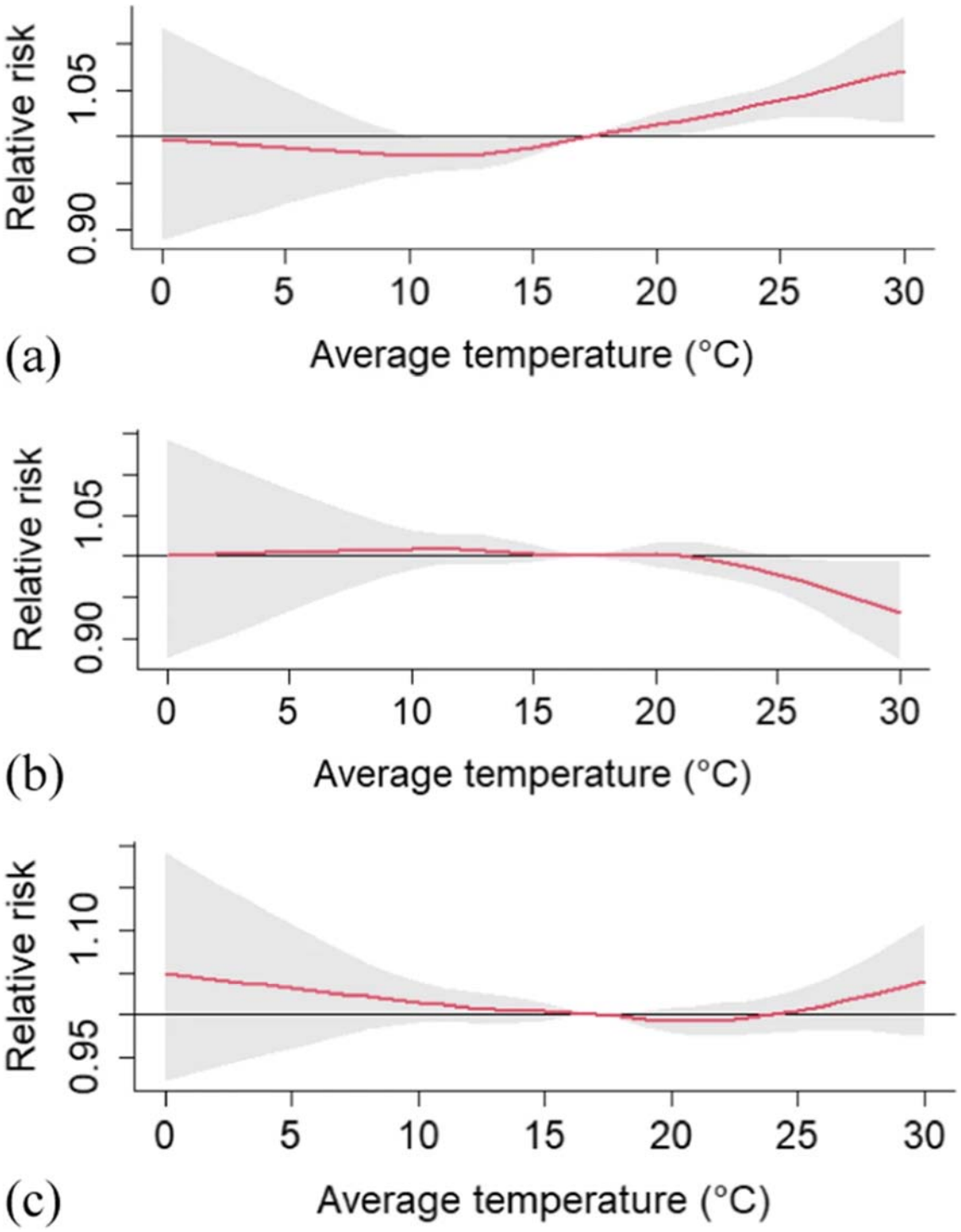

Figure 3a: Lagged associations between violent crime and mean daily temperature (3 days)
Figure 3b: Lagged associations between violent crime and mean daily temperature (7 days)
Figure 3c: Lagged associations between violent crime and mean daily temperature (14 days)

Figure 4 shows the cumulative relative risk associated with violent crime and days with an average temperature equal to the minimum, 25th percentile and 75th percentile as well as

maximum of the observed temperatures over the study period. Average temperatures of 28 °C were associated with a cumulative increase in the relative risk of a violent crime event of roughly 60% whilst average temperatures of 20 °C or more resulted in an increase of approximately 6%. Very hot days (defined as ≥ 25 °C) thus have far greater lasting effects on the relative risk of violent crime events than other days.

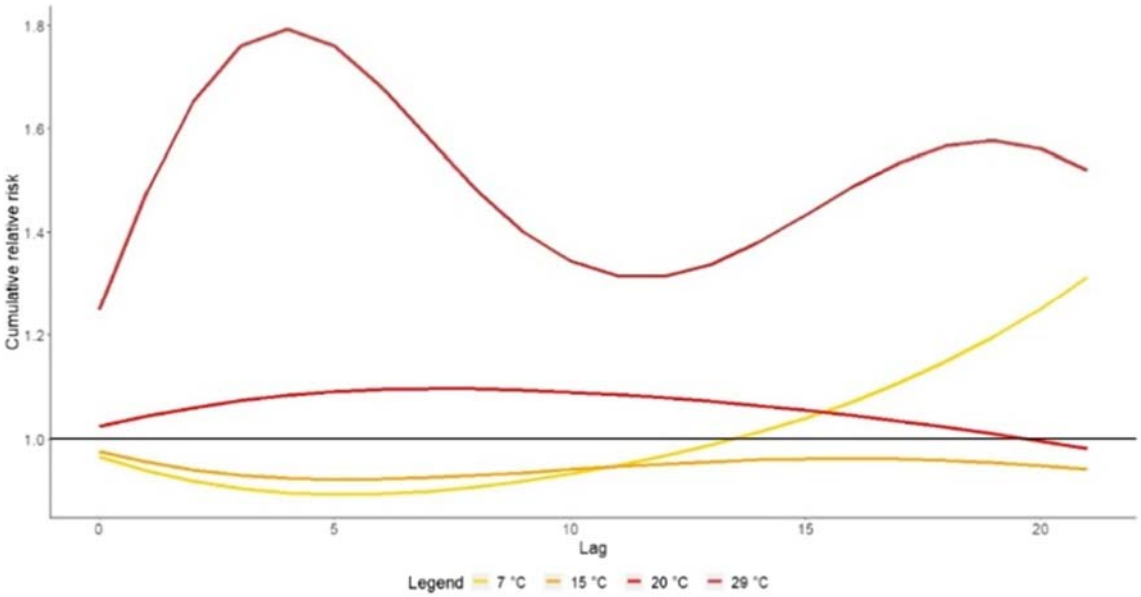

Figure 4: Cumulative association between violent crime and varying mean daily temperatures across different lags

Finally, the cumulative relative risk of property crime increased for very cold (defined as ≤7∘C) temperatures (10 °C, RR = 1.36, CI = 1.34–1.67) and large amounts of rain (defined as 20 mm) (RR = 1.36, CI = 1.11–1.66) (see Figs. 5 and 6a, b). The results indicate that very low temperatures and very large amounts of rainfall were both associated with an increase in the relative risk of property crime for an extended period).

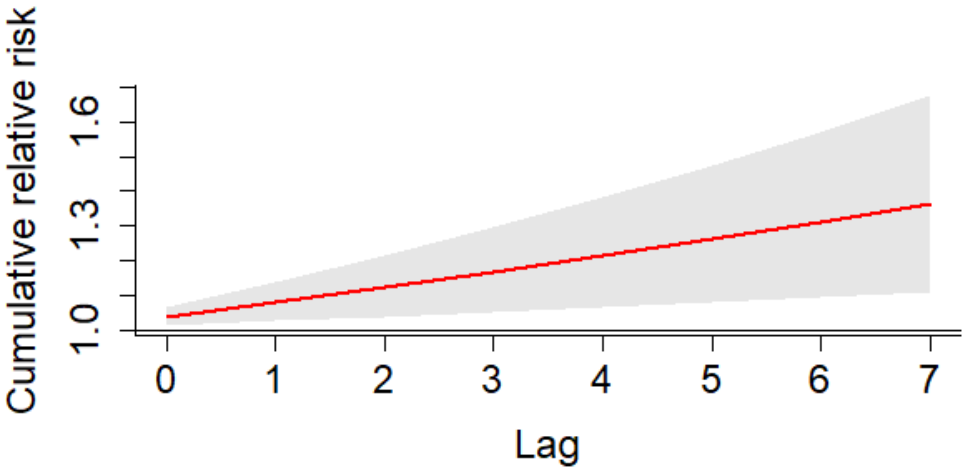

Figure 5: Cumulative association between property crime and mean daily temperature of 10℃ across different lags

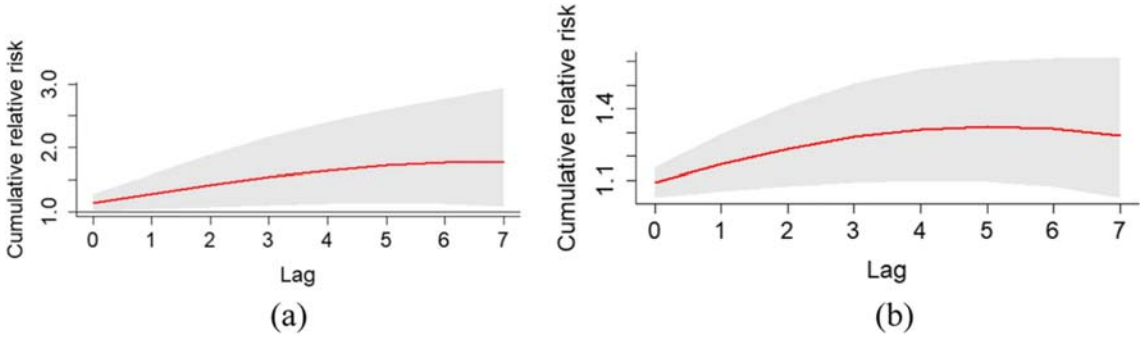

Figure 6: Cumulative association between sexual crimes and total daily rainfall of 20mm across different lags (a) relative humidity of 48%, (b) relative humidity of 80%

Discussion

Our results suggest some significant associations between weather and crime in Khayelitsha, most notably between temperature and violent crime. The risk of violent crime was found to increase with a rise in daily average temperatures, peaking at 30°C (RR = 1.65; 95% CI = 1.13–2.42). This is, to our knowledge, the first time such an empirical observation has been made in South Africa. This finding is supported by both the temperature–aggression and routine activity theories which both predict higher levels of violent crime during warmer periods of time. In

terms of the temperature–aggression theory, these results support the notion that warmer weather may increase frustration and anger among residents of Khayelitsha resulting in an increase in violent behaviour. From a routine activity perspective, our results suggest that warmer weather in the township may lead to a change in the routine activities of individuals in such a way that creates conditions for violent crime to increase. Whilst speculative, the most likely change would be an increase in social interaction among individuals in warmer weather and a concomitant increase in alcohol consumption, possibly leading to more violence. The spatial link between alcohol and crime is well-established both locally (Matzopoulos et al. 2020) and globally (Gruenewald and Remer 2006; Pridemore and Grubesic 2013). Alcohol consumption is particularly high in Khayelitsha with recent studies indicating that more than half of all patients reporting violence-related injuries in the township were under the influence of alcohol at the time of violent incident (Matzopoulos et al. 2017). As part of their analysis, Matzopolous and colleagues (Matzopoulos et al. 2017) mapped the location of over 1400 illegal alcohol outlets or so-called shebeens operating in the township. These are unregulated, and as a result pose an increased risk of safety for patrons as well as those living in the vicinity of these outlets. The results of this research suggest that increased temperatures may exacerbate the existing association between alcohol and violent crime. We also found that the relative risk of violent crime was far greater when temperatures were extreme, particularly when they were extremely high. Previous research has found that when temperatures exceed a certain threshold, the risk of violent crime decreases (Schinasi and Hamra 2017; Stevens et al. 2019)—motivating for the curvilinear effect of temperature on crime. We did not find overwhelming evidence in this study for this trend**.**

Associations between temperature and violent crime have been among the most consistent throughout the literature. Substantial evidence has been found globally for increasing violent crime rates during warmer years, seasons, months and days (Rotton and

Cohn 2003; Butke and Sheridan 2010; McDowall et al. 2012; Stevens et al. 2019). The results of our analysis support this previous international work but supplement it in a number of important ways. First, we show that violent crime and temperature are positively associated in a developing context. Unlike the plethora of past research on this topic, we have shown a linkage in a new context. Second, we found that this association remains true when the area under investigation is uniformly poor, and violent. The World Economic Forum (2016) lists Khayelitsha as one of the world's five biggest slums with an estimated 32 to 46% of households in the township living in severe poverty. Violent crime is also rampant with the township among the most violent in the country with a homicide rate consistently over 80 per 100,000 residents, almost double the national average (Crime Hub 2018). We believe that this is the first study anywhere that has examined weather-crime linkage in an area of extreme poverty, crime and concentrated disadvantage. Third, we found a lag effect for temperature with the highest cumulative RRs (~ 1.4 to 1.6) observed between days 10 and 16. Prevention of potential future spikes in violent crimes during periods of increased temperatures should be addressed by local government and other key stakeholders in the settlement. Last, this study provides preliminary evidence for the successful use of 'Western' crime theories (i.e. T/A and RA theories) to explain the weather-crime linkage in a South African context. We did not find any instances in which either theory could not be used to explain the results we obtained although we caution that the results are applicable to Khayelitsha only. However, the rainfall data were zero-inflated and very few large values were observed. With respect to humidity, extreme (high or low) humidity was associated with a decreased risk of property crime. These observations may be related to the climate in Khayelitsha that experiences most of its rainfall during the winter when humidity is expected to be lower.

We are aware of the limitations in our study. The first, and most notable limitation, relates to the accuracy and precision of reported crime statistics obtained from the SAPS (see

e.g. Leggett 2004; Breetzke 2006). There are a number of limitations in using official crime statistics to measure and monitor crime. Whilst most official crime data globally should be treated with a degree of caution, in South Africa the situation is exacerbated by the deep-seated animosity and mistrust that exists between marginalised communities and the SAPS, which undoubtedly effects crime reporting and recording (see e.g. Breetzke 2006; O'Regan et al. 2014). The crime data obtained for this research might thus not be a complete representation of the crime occurring in Khayelitsha; however, we are relatively confident it does approximate its true number. Second, we do not account for nor incorporate underlying socio-demographic and socio-economic factors into our analysis. These factors undoubtedly play a massive role in shaping the environment and subsequent crime patterns. However, the main aim of this research was to investigate any potential linkages between weather and crime; future research could thus aim to integrate other social, economic and environmental factors into similar research. Third, we did not examine the extent to which the impact of weather impacts crime spatially. It could be that when temperatures rise, for example, so too does crime, but only within certain more at-risk neighbourhoods and not uniformly throughout Khayelitsha. It has recently been shown that within township communities' crime also clusters in specific areas or 'hotspots' (see e.g. Breetzke and Edelstein 2019). Future research could aim to determine whether the trends we find in this study vary spatially. Finally, the study is context-specific. The results are applicable to Khayelitsha alone**.**

These limitations notwithstanding, we believe that this study has contributed to the existing literature on crime seasonality. The results of this research also provide increasing support for a more evidence-based approach to policing in South Africa. Current policing in the country—and in Khayelitsha in particular—has been described as haphazard at best (O'Regan et al. 2014) and more reliant on intuition and gut-feel than data. Emphasising the need for data and evidence to inform policing will enable the development of an accurate

understanding of what factors, both environmental and social, may increase the risk of crime. This is vital if this scourge is to be addressed in the country.

Declarations

Funding: Not applicable

Conflicts of interest/Competing interests: The authors have no conflicts of interest to declare that are relevant to the content of this article

Availability of data and material: The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Code availability: Available on request

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