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Understanding the impact of urban heat islands on crime: insights from temperature, population density, and green canopy cover

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Abstract

Emergent literature suggests that micro- and macro-climates influence criminal behaviour; a complex phenomenon that is still incipient in theory development. This mixed-method research starts with a systematic review of the literature on the theoretical premises that urban heat islands amplify aggressive behaviour and crime. Further, it discusses the potential implications of the relationship between the environment and social outcomes on the design and planning of urban environments. A meta-synthesis was conducted to explain the correlations between patterns of criminal behaviour and thermal (dis)comfort. This correlation is to relate fundamental urban design principles to socially sustainable communities that dissuade violence and crime, and otherwise show poorly designed spaces do propagate criminal behaviour. Cross-validation was undertaken using a case study of Midland, a suburb of Perth, Western Australia. Data involves population demographics, temperature, and crime statistics relating to Offences against the Person. Analysis focused on homicide, assault, threatening behaviour, and robbery. The findings imply a positive correlation between long-term temperature, crime, population density, and green canopy cover. Variables of climate (e.g., short-to-long-term climate-related stressors) and crime types also show non-linear association. Nonetheless, forecasting the future of violence and trends of crime through attributes or potential impacts of heat and urban canopy cover on the built environment will inform sustainable social development policy, environmental planning, development strategy, designers, and planners. Recommendations are made around these in relation to making urban communities adaptive to the impacts of global warming and future densification.

Keywords Climate, Criminal behaviour, Sustainable urban design, Urban heat island, Global warming

Introduction

Normative studies agree on how climate change impacts various aspects of city life. Evidence in a study of the Maldives by Moosa et al. (2020) shows there is significant disparity in location-based climate change outcomes. They emphasised the implications of their study to culture, employment, food production, economic output, and mobility patterns (Su et al., 2023), posit that mobility may increase propensity for opportunistic urban crimes resulting from density, mixing, and movement of a diversity of people across public transport nodes (Brantingham & Brantingham, 1995; Felson, 2003; Madensen & Eck, 2012), with existing research finding that the impact

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to the surrounding increasingly urbanised environments was not inconsequential (Loukaitou-Sideris et al., 2002; Moreira & Ceccato, 2021; Newton et al., 2014).

Yet, as urbanisation continues to accelerate to meet the demands of growing populations, frequently they result in unintended and complex consequences. The impact of the constructed environment on the severity of criminal activities is a significant factor (Silva & Li, 2020) and has been the subject of increasing scholarly attention within the realm of crime place studies (Hipp et al., 2018; Sohn, 2016). For example, excessive heat in localised areas, referred to as the urban heat island effect (UHIE),[1] occurs when an urban area has significantly disparate temperatures to that of its surrounding rural belt, caused by heat absorption (Aguiar, 2012). Accordingly, it is incumbent on governments across the world to improve long-term decision making in respect of regional planning and development to mitigate unintended community harms. This must be done with cognisance of paucity of arable land and spikes in resource demand and in relation to population growth.

Moreover, giving up spaces through development and densification pressures agricultural fringes. This also affects the long-term sustainability of natural ecosystems and biodiversity (Armstrong, 2001). In addition, exposed areas required to replenish underground water supplies are impacted, as well as other environmental and socioeconomic issues. Criminal activities are influenced by demographic and socioeconomic variables (Huang et al., 2011) as well as the built environment (Fan & Sengupta, 2021; Jung et al., 2023), which serves as an external factor that impacts an individual's attitudes and behaviours (Cozens, 2011; Davies & Johnson, 2014; Eck & Weisburd, 2015). Thus, under such circumstances, maximising the potential use of all spaces to mitigate HIE, even seemingly insignificant spaces, and pedestrianising hard infrastructure towards active transportation modalities, thus reverting the vehicular-dependence paradigms which fuel current societal norms, may contribute to reducing microclimates, improving the perception of safety, and concurrently reducing the propensity for crime.

Many scholarly works have examined the role of genetics (a person's biological nature) and the environment (the natural and built environment a person exists within, including society and its institutions) in shaping or triggering criminal behaviour (Benson, 2013; Mednick & Volavka, 1980; Rafter, 2016). Most studies suggest that criminality is influenced by both factors, with the environment shaping an individual while their biological nature sets the boundaries of their behaviour (Boyanowsky, 2020; Mehta & Binder, 2012; Wilson and Herrnstein, 1998).

The identification of key factors that contribute to criminality in society has been a focus of previous research. Gaining an understanding of the factors that exert influence on criminal activities is paramount in reducing the detrimental and expensive consequences they can have on society (Twinam, 2017). These factors include population density (Watts, 1931), mental health (Fleischman et al., 2014), substance abuse (Grann & Fazel, 2004), mobility (Kelly, 2000), law enforcement (Fafchamps & Moser, 2003), public perception (Gaubatz, 1995), quality of governance (Curran, 1998), and Oscar Newman's (1977) defensible space theory. The present study aims to evaluate existing literature and theories that relate criminality to climate to determine whether increasing urban expansion and densification,[2], [3] and diversity of people such as that which occur in ecotones (Kark 2013) is likely to lead to opportunities for an increased propensity for crime. Ecotones are where ecological communities overlap in urban areas, promoting diversity and beneficial exchanges. Factors like climate and community structure cause rapid environmental shifts in these overlapping regions (Holland et al., 1991; Kent et al., 1997).

The study aims to guide development policy and enhance urban design, policing infrastructure, and operational planning through a regenerative system thinking approach. It analyses crime types, climate factors, tree canopy cover, and population density, drawing from a systematic literature review and meta-synthesis of select studies. Gaps and limitations in previous research are addressed, emphasising the study's contribution and face validity, particularly in relation to heat and urban crime studies in highly urbanised areas, including Australian environments.[4]

This study contributes to the growing body of work on the climate-weather-crime relationship. This study differs from many other studies in the literature in several ways. It examines the relationship between criminality and climate, with a specific focus on the potential impact of loss of tree canopy due to urban expansion and densification on crime rates while also highlighting variables not yet considered in existing literature. Moreover,

[1] Urban heat island effect (UHIE) may also be referred to as Urban Heat Islands (UHI), or Heat Island Effect (HIE).

[2] Urban expansion and densification are both responses to population growth but can essentially be considered as opposites.

[3] Urban expansion and densification have different effects on climate, hence from this perspective could be expected to have quite different effects on criminality.

[4] Tree canopy is not only a microclimatic factor—there are many other benefits of urban trees which may act as confounding variables in a study focusing on heat.

the study provides a unique perspective on this topic by focusing on a specific case study location, the City of Midland in Western Australia, and analysing the interplay between population growth, crime rates, demography, density, vegetation cover, and temperature. This case study approach offers valuable insights into the complex relationship between urbanisation and crime that are context-specific and could inform more effective urban design decisions and policing strategies.

Finally, the study uses a systematic literature review and meta-synthesis approach, which helps identify gaps and limitations in the existing literature and offers a more comprehensive and integrated view of the current state of knowledge in this field (Pai et al., 2004). Overall, the study's unique focus, methodology, and contribution to the literature make it a valuable addition to the existing body of research on crime prevention and urban design.

Urban heat island studies

Sustainability is a necessity for survival, therefore design strategies that improve sustainability outcomes take precedence over other political and economic motivations. Rad and Afzali (2021) highlight that urban morphology plays an important role in mediating immediate micro-climate and localised thermal comfort. Buildings are an example of this, and their form and orientation can further impact on urban heat island effect. Moreover, materiality, such as extensive masonry and road infrastructure is likely to exacerbate the condition as they add to thermal mass. Applying ENVI-met 3D simulations, Rad and Afzali highlights how different models of urban development provide improved conditions for thermal comfort over other alternatives. They found high-rise buildings affect micro-climate that impact outdoor thermal comfort.

Chakraborty et al. (2019) found green vegetation in urban neighbourhoods moderate HIE. 72% of cities sampled in their study showed disproportionate impact between affluent and vulnerable communities. An inference from this is that climatic events and the HIEs attributed to "urban structures which is then later radiated back into the environment" (Aguiar, 2012, 2), are not equitably distributed amongst communities. Aguiar's description suggests heat island conditions are aggravated in the evening due to thermal lag, or the rate at which heat that was absorbed by a material is released. High thermal mass such as hard surfaces that have absorbed solar radiation will retain the heat for longer and thus have a large thermal lag with implications for social, economic, and health related outcomes. Other studies cited by the author suggest a greener urban environment is gaining popularity amongst prospective urban dwellers.

Dew point is the interface between dry heat and humidity. This is important in the body's ability to cool itself because it is an element of thermal discomfort. Wet-bulb temperature (WBT) is the measure of heat and humidity in keeping with how a human might experience heat.[5] This is also important as it helps to evaluate the relationship between heat and humidity beyond human tolerance, as they interact in some parts of the world much faster than expected under global climate change (Raymond et al., 2020). O'Connor (2020) maintains "most climate scientists believed WBTs never rose above 35 °C, and never would until the effects of global warming grew stronger later in the twenty-first century". Sherwood and Huber (2010) extrapolate this further. They suggest a human body will overheat if heat and humidity combine to stop sweat from cooling the skin below 35 °C irrespective of health, level of activity, or whether in shade or not, and with unlimited drinking water supply. Therefore, WBT at this rate and lower can be uncomfortable and dangerous to health.

Heat, urban heat islands, crime behaviour, and the built environment

Wolf et al. (2020) conducted a systematic review of 201 studies on the health impacts of urban trees, covering human health, environmental health, and urban forestry. The study highlights the potential of trees to mitigate urban heat island effects and reduce crime rates, particularly in low-income urban areas, especially for young individuals. However, the study acknowledges the presence of multiple variables that should be considered. The authors recommend integrating urban trees into urban planning and management to create health-promoting environments. It is important to note that the study is not specific to the Australian context. Nonetheless, applying the incivility and broken windows theories by Branas et al. (2011) in urban streetscape maintenance can offer advantages by reducing incivility, addressing visible signs of disorder, preventing crime escalation, and enhancing public safety. Municipalities can benefit from implementing these theories in their urban planning strategies.

Wu et al. (2019) investigated the relationship between spatial access to urban parks and residential satisfaction in metropolitan Beijing. Their regression analysis indicated that residential satisfaction decreased with higher crime rates, and the interaction between park access and crime rates also had a negative impact on satisfaction. The study also found a significant association between

[5] WBT informs how a human might experience heat, however, additional factors such as air speed, activity, clothing type influence how WBT is experienced.

distance to parks and perceived satisfaction, particularly in the "greenness domain," suggesting that closer proximity to parks led to higher satisfaction. The analysis considered variables related to residential satisfaction, spatial access to urban green spaces, neighbourhood characteristics, and household demographics, including age, gender, education, income, and family size. However, it is important to note that the study sample was more homogenous than the Australian context. While not directly aligned with the parameters of the current research, this study highlights the presence of other important environmental factors that influence behaviour beyond the scope of other studies.

Baryshnikova et al. (2021) assessed weather–crime relationship at an hourly level rather than daily. At an hourly rate, precipitation was found to be a more significant variable on crime than temperature, and thus should not be disregarded. The research also studied the relationship between four other weather variables (temperature, humidity, precipitation, wind speed) and crime. Crimes included in the study are a select group of violent crimes and property crimes and city-level data, collected over 2014–2017 from Chicago, Indianapolis, Los Angeles, and New York, the largest cities in the USA by population. Findings suggest that the relationship between weather and crime differ significantly and is non-linear when observed at daily versus hourly intervals, and their subsequent impact on results and conclusion are relevant. The study, though not in the Australian context, further supports the notion that other variables are significant and must be considered.

Climate and crime

The literature suggests that the decrease in availability of green spaces leads to increased local temperatures and crime (Baron & Bell, 1976). This study supports the negative affect escape theory proposed by Baron (1972), which suggests a positive correlation between temperature and aggression until discomfort is reached at temperatures exceeding 30 °C. However, the generalisability of studies across hemispheres and socio-demographic groups is inconsistent. For example, recent research conducted in South Africa, a region known for its high crime rates, found that an increase in green space was associated with reduced rates of violent and property crimes, even after controlling for socio-demographic factors (Venter et al., 2022). This highlights the need for more comprehensive studies on the relationship between green space and crime, especially in urban areas of the Global South.

In Australia, the occurrence of major holidays during the summer draws attention to increased alcohol consumption and a subsequent rise in assault rates. It is important to note that the relationship between temperature and assault rates varies spatially and should not be generalised at a state level. This study also considers age and gender of both offenders and victims as variables, highlighting the potential impact of high temperatures on proactive policing due to reduced interactions and arrests.

Some studies highlight a positive correlation between the age of dwellings and suburbs with tree canopy coverage and socioeconomic markers (Donovan & Prestemon, 2010; Stevens et al., 2024; Troy et al., 2012). They also link this to population vulnerability, and propensity for crime. However, other disparate and stratified studies focus on specific locations and homogenous groups. To control variables in these studies, many observed the variables impacting on urban landscape, density, and crime relationships (Nieuwenhuijsen, 2020). Extant literature that examines northern hemisphere case studies suggest vegetation influences crime in both positive and negative ways. Examples of positive impact include mitigating the likelihood of crime through the cooling of the immediate environment and community temperament, the appearance of maintenance, and the perception of care. Examples of negative impact include increasing the likelihood of crime when it provides subterfuge. These are discussed further in this section.

Muggah (2021, 3) reports a non-linear association between variables of climate and crime. Their observations include climate-related stressors that cause significant variances in violent and non-violent forms of crimes "ranging from homicides and assaults to robberies and burglaries". Such weather events have become more commonplace, and although the extent to which these links apply varies, Anderson and Anderson (1984), Anderson et al. (1997) and Rotton and Cohn (2003), who linked climate-related stressors and extreme temperature events with crime, and distinguished between "short-term shocks (cyclones, tornadoes, forest fires and floods), and long-term stressors (droughts and sea level rise)" (Muggah, 2021, 3), generally imply that rising temperatures can cause a significant rise in crime.

Ranson (2012) attests that the profound impact of rising temperatures on criminal behaviour paints a grim picture based on a survey encompassing over 3,000 counties in the United States, forecasting a significant surge in criminal activity by 2100. The study predicts an alarming increase, including an estimated 35,000 additional homicides, 216,000 more rapes, 1.6 million further aggravated assaults, 409,000 additional assaults with a deadly weapon, and 3.1 million annual robberies. Citing the Intergovernmental Panel on Climate Change (IPCC) climate scenario, Ranson argues that the United States is poised to witness a notable rise, encompassing various

offences such as murders, rapes, aggravated assaults, robberies, burglaries, larcenies, and vehicle thefts, compared to the baseline period of 2010. Further, Harp and Karnauskas (2020) evaluated 42 global climate models across 16,000 US cities and estimated an increase of between 2.3 and 3.2 million more violent crimes by 2100. These events can be attributed to high-density populations and locations susceptible to long-term climate stressors.

Many vulnerable communities are already impacted by extreme weather events and are dealing with the resultant severe economic and social impacts. Inequities and the ability to adapt exist across geographic locations. Examples include District 4 Vietnam, Copenhagen, Calcutta, Venice, Vancouver, The Maldives, The Torres Strait, and Australian states such as New South Wales and Queensland (Moosa et al., 2020). These are but a few amongst many more which underscore community divisions relating to approach, response, and adaptation issues, highlighting the challenge of seeking unification in mitigation planning (Jonescu et al., 2024). Notwithstanding this, scalable studies at the individual, local, and regional levels remain critical in Australia, even as most populated metropolitan centres are in proximity to areas most vulnerable to imminent pressures of extreme weather events. To this end, further cross-sectoral leadership will be necessary to coordinate an industry-led collaborative research approach and action a cohesive adoption of adaption strategies to enable a resilient and sustainable approach at local and national levels.

Mares and Moffett (2015) assessed the link between climate change on levels of violence across 57 countries, sampling both western and non-western countries with regression results suggesting an increase in 1 degree Celsius in annual temperatures equated to an approximate 6% average increase in homicides. The authors later examined the impact of climate change on crime at specific times of the year. They utilised monthly crime statistics in the United States set against historical weather data that were collected by the Global Historical Climatology Network. Findings from these highlight a positive correlation between climate and crimes, with evidence supporting monthly variance clearly (Mares & Moffett, 2019).

Stevens et al. (2019) conducted a study in New South Wales, Australia, analysing an 11-year dataset to investigate the influence of season and temperature on crimes such as assault, theft, and fraud. Their linear regression model indicates a positive association between daily assault and rising temperature. The study compares assault patterns with social media anger in response to temperature variations. While the study has limitations, including the comparison of different populations, it concludes that the routine activity theory applies (Cohn & Rotton, 2003), with aggressive crimes increasing in warmer weather, on weekends, and during holidays. The study suggests that increased outdoor socialising may limit opportunities for online presence and vitriol. Further research is needed to explore the relationship between temperature, specific activities, and resulting behaviour (Stevens et al., 2019).

Stevens et al. (2024) investigated the impact of UHIs and green space on violent crime rates in Greater Sydney, Australia, between July 2013 and June 2018. They found that higher surface UHI was associated with increased rates of violent crime committed outside, while greater percentages of vegetation were linked to decreased rates of outdoor violent crime. These findings underscore the significance of addressing both violence and heat exposure, suggesting that expanding green spaces and reducing UHI could help mitigate these challenges exacerbated by urbanisation and climate change.

Amati et al. (2017) undertook a study across 139 metropolitan local government areas in Australia between 2015 and 2016. They established an estimated canopy cover and several socio-economic disadvantage benchmarks. Their calculation highlighted "heat island intensity" using satellite imagery, where they identify "hotspots" or heat islands across Australia through readily available data. The study also developed a vulnerability index that shows areas of socioeconomic and health disadvantage which coincide with a lack of green cover and a high incidence of heat. Notwithstanding this, both global and local analyses have demonstrated that median household income is one of the strongest determinants of urban crime incidence with other demographic variables such as homogeneity, prevalence of specific typologies (such as tobacco retailers), and the number of abandoned properties also positively associated with urban crime (Yu & Fang, 2022).

Kuo and Sullivan (2001) also undertook studies on Ida B. Wells, a large highly densified public housing development in Chicago. The case study shows a "homogeneity" representation that is disproportionately high, with a lack of diversity evidenced in female residents (65%), African American (97%) and unemployment (93%). In addition, the study also sought to evidence a link between vegetation and crime, whether the former persuaded criminal behaviour based on passive surveillance and sentiment of ownership and safety. This is an important addition to knowledge as other research has only sought to link vegetation to urban heat islands where the heat itself is the subject of study in its effect on criminal behaviour. Donovan and Prestemon (2010) also consider the impact of vegetation density by relating it to limiting visibility and natural surveillance, in ways that advance the conversation on perceived safety through prevention e.g.,

inclusion of street lighting, security bars and systems, and the physical structures themselves.

The environment, psychological health, and safety are examined in Branas et al. (2011). The authors used incivility and broken windows theories to frame their research. They discovered that health and safety results relate to perceived attitudes of managed urban greening of empty spaces in Philadelphia, cared for and considered as "orderly" (as though someone had "power" over them). Greening's physiological (biophilic) and temperature effects on health and safety were not examined in the study. However, some associations imply major statistical decreases in stress and some crimes, while others show the contrary, such as disorderly conduct, which grew dramatically, and unlawful dumping, which only increased in specific city regions.

Poorly constructed urban places where people are exposed to a full spectrum of human behaviours constitute a safety risk. People avoid poorly lighted, low-traffic places that may attract crime (Jacobs, 1961, 89). Oc and Tiesdell (2007) argue that public spaces become socially sustainable due to increased occupancy and activity, passive surveillance, and extended habitation through "fortification approaches". These involve physical segregation and territorial defence, spatial governance within fortified and controlled spaces, and "regulatory approaches" that regulate public spaces and protect local municipal assets. Jonescu et al. (2018) demonstrate how surveillance technology might be integrated into urban environments to govern public places. These important planning principles reduce crime by encouraging occupancy, territorialisation, and social involvement in urban places. They also deter inhabitants from disruptive behaviours, vandalism, and other minor offences that affect personal and spatial safety. However, permeability, sightlines, and visual access are necessary for beneficial community interactions and social behaviours that improve safety perception and reality (Jacobs, 1961; Newman, 1977).

Newman (1977) argues that a sense of ownership over a person's immediate urban environment empowers them for greater accountability and responsibility. In addition, according to Oc and Tiesdell (2007), in an "animated approach" to urban design, public spaces must be socially sustainable through increased use, passive surveillance, occupation, and activation. When communal places lack critical components of good urban design, lighting and activities that encourage participants to venture outside and stimulate community interaction, safety perception becomes crucial. Passive monitoring of a section of the population will lead to an increased sentiment of safety for communities to act in coordination with collective power to prevent undesirable behaviours (Cozens & Grieve, 2009; Jacobs, 1961; Jonescu, 2013). These elements address observations against key criteria outlined by Gehl (2011). The elements are protection, comfort, environment, urban density, level of activity, increased physical participation, decreased traffic noise, pedestrianisation, and occupation of spaces. Other authors also agree these variables shape fundamental principles for designing urban environments that are socially sustainable (Cozens, 2011; Jonescu et al., 2020).

Case study area and methodology

Case study development

Overall, the case study location was determined by evaluating several key criteria that would provide appropriate data to meet the research question. Criteria included temperature, vegetation cover, population data, crime statistics, and factors such as population, demographic diversity, economic indicators, and the feasibility of conducting the study in the selected location. This study utilised the Australian Real Estate Search, Suburb Reviews, to analyse residents' sentiments in a cross-section of suburbs across Perth (Homely Group Pty Ltd 2023). The consideration of mixed feedback in our study is essential as it provides valuable insights into the multidimensional nature of urban liveability and community well-being.

Residents' sentiments, as highlighted by Branas et al. (2011), serve as a critical indicator of perceived safety and overall satisfaction with the built environment which can significantly impact residents' perceptions of safety and contribute to increased criminal activity. Sentiment serves as a valuable resource for informing targeted interventions and urban development initiatives aimed at fostering resilient and thriving urban environments that encourage urban social interactions that can lead to improved passive surveillance outcomes and perceived safety.

The ideal candidate was required to have a functioning 'township' with inclusion criteria comprised well-established suburbs with a mix of land use, including residential, commercial, industrial, urban spaces, public transport, civic infrastructure, and educational and healthcare facilities. Localities that had a police precinct, a town centre, and other critical infrastructure, such as hospitals and industries were highly regarded. In the process of township development, all suburbs were cleared. The study recognised the significance of reintroducing vegetative growth alongside the criteria outlined in Table 1. This regeneration primarily occurred over time.

Based on the reviews of various suburbs, the study chose Midland over others considered. Although Joondalup, Armadale, and Mandurah met the Township Assessment Criteria, Joondalup's recent establishment limited its vegetation cover maturity. Mandurah's coastal location and cooling effects due to its proximity to the coast

Table 1 Township assessment criteria across six case study candidates

Location	Distance to CBD (km)	Access to all data	Critical infrastructure	Police and justice
Midland	16	Yes	Yes	Yes
Armadale	25	Yes	Yes	Yes
Gosnells	20	No	Partial	Partial
Kwinana	30	No	Partial	Partial
Joondalup	25	Yes	Yes	Yes
Mandurah	70	Yes	Yes	Yes

Criteria that was shared equally among all candidates was not included in the table

made it an outlier compared to other locations. Armadale closely resembled Midland across most criteria but lacked sufficient population density.

Midland received mixed online feedback. Positive aspects mentioned included its scenic location near Swan Valley, historic buildings, proximity to Perth Hills, schools, hospitals, shopping centres, and an efficient public transportation system. However, concerns were raised regarding criminal activity and abandoned places resonate with the notion of environmental incivility, suggesting potential areas of improvement to enhance community safety and cohesion (Churchill et al., 2023; Stevens et al., 2024) and broken windows theory (Branas et al., 2011). Some reviewers expressed reservations about settling down or raising families in Midland due to drug usage and safety concerns during night-time walks.

Midland, established in 1832, experienced rapid expansion following the commencement of operations by the Midland Railway Company in 1886. Various developments were introduced, including the iconic Town Hall in 1923. Midland's revitalisation was influenced by the Midland Redevelopment Authority, which became part of the Metropolitan Redevelopment Authority in 2012 (City of Swan, 2022). At the time of the study Midland had a population of 6,335 and a median age of 39 and is spread across a land area of 4.2 km2 resulting in a population density of 1,508 persons per km2 (ABS, 2022). The Midland CBD has a population of approximately 1,142 people and covers an area of 2.05 km2. The local municipality (City of Swan) projects Midland will experience an 84.6 percent increase in population by 2051 (id Consulting Pty Ltd, 2021). The associated dwellings required is anticipated to increase in step with population growth; density may impact local crime, and increased hardscapes may result at the expense of canopy cover.

Moreover, the feedback from residents also sheds light on the complex interplay between environmental factors, social dynamics, and community outcomes. As demonstrated by Stevens et al. (2020) and Amati et al. (2017), perceptions of safety and the quality of the built environment are closely intertwined, with visible signs of neglect and disorder often leading to decreased community engagement and social cohesion, leading to more time spent outdoors in the urban context leading to improved (Cozens, 2011). Nonetheless, Midland was recommended as an investment hub, particularly for apartments, due to its proximity to amenities and ongoing redevelopment projects (Homely Group Pty Ltd 2023).

By acknowledging and addressing the concerns raised by residents, urban planners and policymakers can work towards creating safer, more inclusive communities that promote positive social interactions and enhance overall quality of life.

The study also reviewed temperature, vegetation cover, population, and crime statistics data for the case study location.

Method design

This study applies three research methods. Figure 1 presents a relationship diagram between the research methods applied in this study. The methodology aligns with current literature, employing a systematic literature review to contextualise the study within existing scholarship (Kitchenham, 2004). Archival analysis is conducted to understand longitudinal context, demographic, and historical data. While the literature acknowledges potential for both linear and non-linear relationships, the data in this study is not normally distributed. Therefore, statistical analysis focuses on identifying non-linear correlations between climate, temperature, vegetation cover, population, and crime statistics.

A review of extant literature reported in this study has provided an understanding of some of the variables to be analysed in the study. City of Midland is the case study location. In addition, the systematic review has presented correlations between published theory, climate, temperature, vegetation cover, population, and crime statistics. An objective of this study is to undertake statistical correlation in relation to patterns of criminal behaviours and deviations from thermal comfort. Such an intersection between heat and urban crime is important in highly urbanised areas generally, not least the Australian environment.[6] Archival data were explored using cross-referenced weather station temperatures near the case study area with ACORN-SAT used by the Australian Bureau of Meteorology to track long-term temperature changes nationwide. Scope of capture includes Perth Metro, Perth

[6] Due to the unavailability of crime data at the desired frequency, it was not possible to compare daily air temperature data with the timing of the crimes.

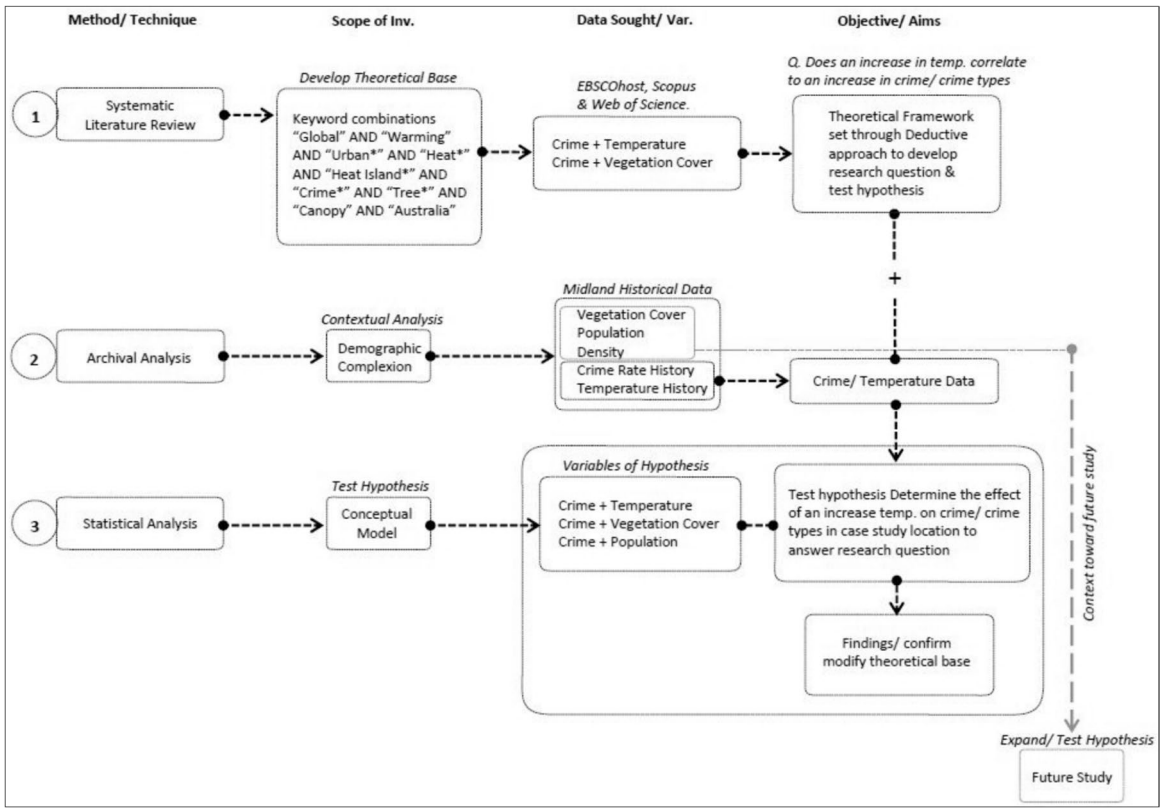

Fig. 1 Diagram of research methods and their relationships

Airport, and Upper Swan, all 4–15 km from Midland CBD.,[7], [8]

CSIRO's Urban Monitor was utilised to measure vegetation coverage, using Mesh Block Vegetation and Tree Canopy Cover. Relying on Caccetta et al. (2015, 2018), this technique uses "grass", "shrubs", and "trees" to characterise vegetation by height: < 0.5 m, 0.5–3 m, and > 3 m. Canopy coverage is provided in square metres. Further contextual studies are conducted of the Midland suburb including population, age distribution, population density and anticipated growth. The overarching purpose of this research is to test a hypothesis on the relationship between temperature and crime behaviours:

H1: higher temperatures increase crime rates.

Midland Police District (Fig. 2) is the defined catchment of the study, consisting of three local government areas: City of Swan, City of Kalamunda, and the Shire of Mundaring. Mean monthly temperature data for the study were extracted from the Bureau of Meteorology (2022), with Perth Airport Station Number 9021 being the closest weather station. Crime statistics from the WA Police archives were extracted from the Western Australian Police (2021). They cover records of offences that are known to Midland Police within the relevant periods, excluding incidents categorised as no criminal offence, offence substituted, false report, mistakenly reported, or entered in error. Monthly crime statistics were taken from January 2007—December 2020 (data for the study including the year 2020 was treated with caution because of COVID-19 pandemic and the social restrictions that came about in controlling it).

All data obtained for the purpose of the study are open source and publicly available from: City of Midland,

Australian Bureau of Meteorology, CSIRO's Urban Monitor, and Western Australian Police Force.

Data classification

Crime classification is by the Australian and New Zealand Standard Offence Classification (2011), WA Legislation, and operational reporting requirements (Western Australian Police, 2021). From WA Police

[7] The air temperature data used is representative of the spatial distribution of air temperatures in the target district.

[8] Instead of using the monthly average temperature data to capture the urban heat island phenomenon, which varies based on season, weather conditions, and time of day, it was employed in the analysis to assess its correlation with crime rates.

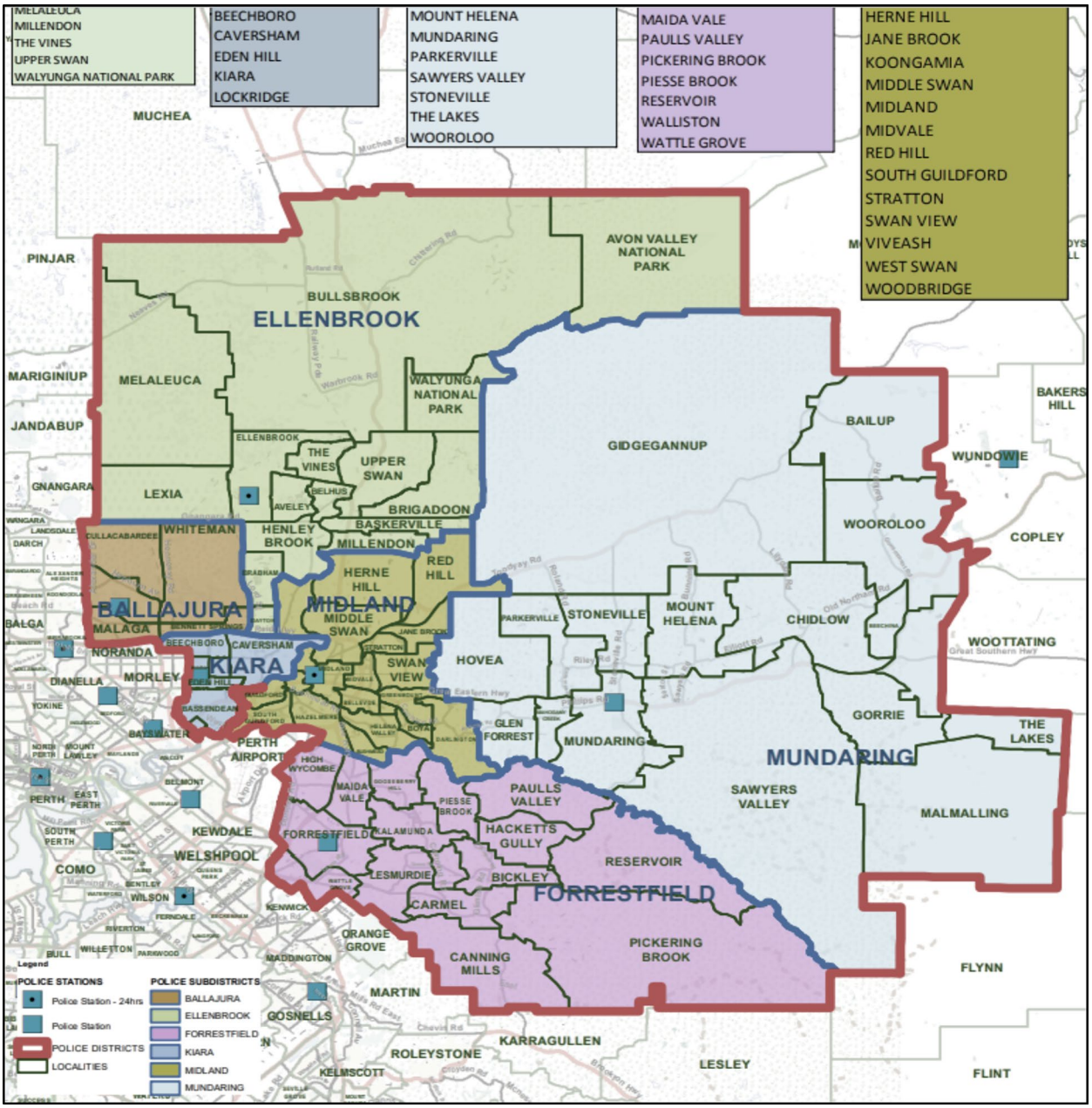

Fig. 2 Midland Police District, Source: Western Australian Police Force, 2021

Crime statistics published online, (see Appendix) current research considered 9 crime groups, including:

1. Offences against a Person (OaP), such as Homicide (Hom), Recent Sexual Offence (RSO), Historical Sexual Offence (HSO), Assault (Family) (A_Fam), Assault (Non-Family) (A_nFam), and Threatening Behaviour (Family) (TB_Fam). Others in this category include Threatening Behaviour (Non-Family) (TB_nFam), Deprivation of Liberty (DoL), and Robbery (Rob).,
2. Selected Offences Against Property (OaPty_Sel),
3. Drugs (Drugs),
4. Receiving and Possession of Stolen Property (RnP_SP),
5. Regulated Weapons (RWp),
6. Graffiti (G),
7. Fraud and Related Offences (Fraud),

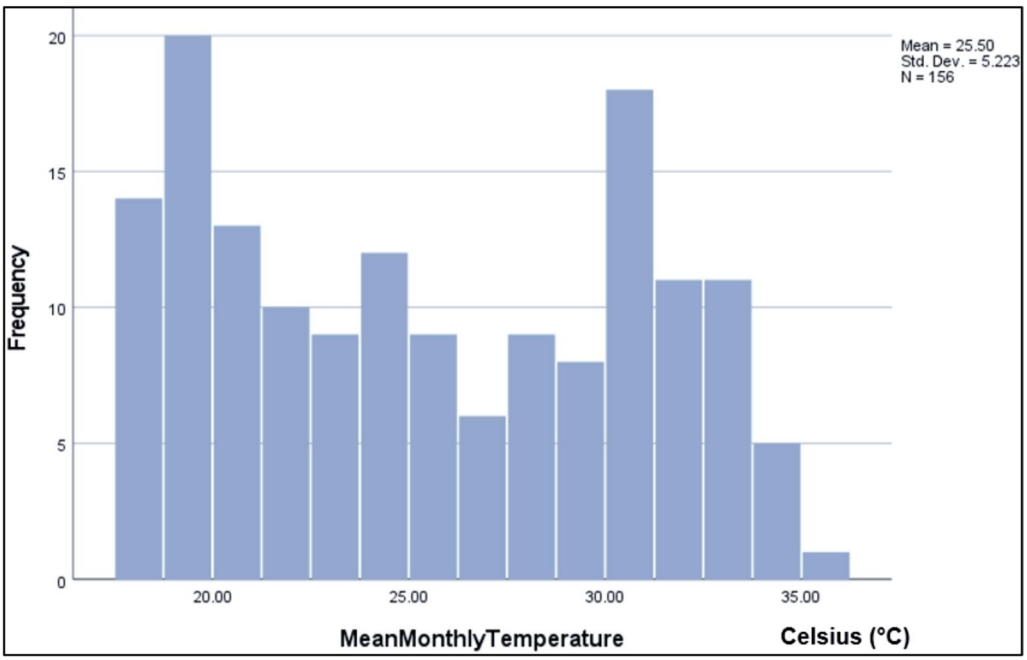

Fig. 3 Mean Monthly Temperature Histogram

8. Breach of Violence Restraint Order (BVRO), and
9. Selected Miscellaneous Offences (MiscO_Sel).

Contextually, Family means partner, ex-partner, parents, guardians of children, and children who reside or regularly stay with involved parties. Non-Family crimes are acts against people that are not included in the Family bracket. In addition, there are sub-category classifications of the WA Police that this current research did consider in its analysis. There were five such sub-categories under OaPty_Sel. They include Burglary (Bug), Stealing Motor Vehicle (S_MV), Stealing (St)—including from motor vehicles, Property Damage (ProDmg) and Arson (Ars).

WA Police's crime categories and sub-categories were analysed by total crime rates per 100,000 people.[9] Total population was based on the annual Estimated Resident Population (ERP) published by the Australian Bureau of Statistics (ABS 2022). The research assumes that population growth was linear between two consecutive years—as shown in Eq. 1.

$$Crime\ per\ 100,000 = \frac{\text{Crime Count}}{\text{ERP} \times 100,000} \quad (1)$$

[9] For category definitions see: Western Australian Police. 2021. "Archived Crime Statistics Reports".

Findings

Mean monthly temperature

From January 2007 to December 2019, there were 156 mean monthly temperature readings with mean (μ) = 25.50 °C and standard deviation (σ) = 5.22 °C. The median was 24.95 °C, and the minimum and maximum temperatures were 17.5 °C (August 2016) and 35 °C (January 2010) respectively.

As shown in Fig. 3, the mean monthly temperature histogram had two peaks, due to the seasonal effects. Since this data distribution was non-normal, non-parametric statistical tools were used to test H1.

Monthly crime rates

Table 2 shows descriptive statistics for monthly crime rates for crime groups and sub-categories. Of the main groups, *OaPty* (μ = 529.22; σ = 71.25) has the highest average crime rates, followed by *OaP* (μ = 128.16; σ = 26.12).

In the sub-categories of *OaP*, *A_Fam* (μ = 49.89; σ = 16.77) and *A_nFam* (μ = 38.07; σ = 7.27) were the major crimes in Midland district. For Properties, stealing (μ = 253.39; σ = 28.47) was the main form of crime between 2007 and 2019.

Monthly mean temperature versus monthly crime rates

To test H1, this research set the null and alternative hypotheses as below:

Table 2 Descriptive statistics for monthly crime rates for crime groups and sub-categories

Crime categories*	N	Mean	Median	Standard deviation	Kurtosis	Skewness
Main categories						
OaP	156	128.16	123.23	26.12	0.6090	0.5534
OaPty	156	529.22	515.28	71.25	0.7408	0.1561
Drugs	156	64.84	61.82	24.69	0.5565	−0.1525
RnP_SP	156	10.27	9.51	5.41	1.3282	2.5762
RWp	156	11.61	11.18	5.06	0.7716	1.1155
G	156	38.31	8.50	54.43	1.7257	2.1405
Fraud	156	48.11	43.23	36.30	1.9564	7.6247
BVRO	156	25.72	23.87	11.98	1.9630	6.8435
MiscO_Sel	156	112.14	101.79	48.79	1.2623	1.9783
Sub-categories—OaP						
Hom	61	0.78	0.52	0.56	4.0569	22.1440
RSO	155	9.64	8.30	7.87	7.9334	83.0057
HSO	156	7.30	5.64	6.80	3.4162	17.4099
A_Fam	156	49.89	48.47	16.77	0.3396	−0.5024
A_nFam	156	38.07	37.55	7.27	0.3819	0.2443
TB_nFam	156	9.75	9.64	3.15	0.3313	0.0466
TB_Fam	155	6.91	5.76	4.21	1.2871	1.9033
DoL	125	1.19	1.03	0.71	1.1729	1.7460
Rob	156	5.40	5.19	1.96	0.6717	0.5956
Sub-categories—OaPty						
Bug	156	124.48	120.89	25.89	0.6347	0.0950
S_MV	156	27.78	26.61	7.02	1.0634	1.9481
St	156	253.39	253.06	28.47	0.3808	−0.0238
ProDmg	156	118.66	114.06	27.62	0.6054	0.0463
Ars	155	4.93	3.99	3.33	1.6182	3.4552

*Offences against a Person (OaP), Homicide (Hom), Recent Sexual Offence (RSO), Historical Sexual Offence (HSO), Assault (Family) (A_Fam), Assault (Non-Family) (A_nFam), Threatening Behaviour (Family) (TB_Fam), Threatening Behaviour (Non-Family) (TB_nFam), Deprivation of Liberty (DoL), Robbery (Rob), Selected Offences Against Property (OaPty_Sel)[sub-categories: Burglary (Bug), Stealing Motor Vehicle (S_MV), Stealing (St)—including from motor vehicles, Property Damage (ProDmg) and Arson (Ars)], Drugs (Drugs), Receiving and Possession of Stolen Property (RnP_SP), Regulated Weapons (RWp), Graffiti (G), Fraud and Related Offences (Fraud), Breach of Violence Restraint Order (BVRO), and Selected Miscellaneous Offences (MiscO_Sel)

Table 3 Spearman's correlation coefficients between mean temperature and crime rates

Categories of crimes	Mean monthly temperature	
	Correlation coefficient (r)	Sig. (2-tailed)
OaP	0.336	< 0.001
Drugs	−0.193	0.016
RnP_SP	−0.166	0.039
Sub-categories—OaP		
A_Fam	0.201	0.012
A_nFam	0.449	< 0.001
TB_nFam	0.167	0.037
Sub-categories—OaPty		
Bug	0.208	0.009
S_MV	0.244	0.002
Ars	0.485	< 0.001

H_0: there is no significant correlation between monthly crime rates and mean monthly temperatures.

H_a: there is a significant correlation between monthly crime rates and mean monthly temperatures.

Table 3 illustrates only the statistically significant associations at the 95% confidence level ($p \leq 0.05$). Three categories of crimes indicated significant statistical correlations. *OaP* shows the strongest correlation ($r = 0.336$; $p < 0.001$). The R-squared value shows about 12.5% of data fit the trendline. *Drugs* and *RnP_SP* indicate weak negative correlations with mean monthly temperature. Therefore, the association between crime categories and monthly temperatures for Midland District is limited. Following these observations, sub-groups of *OaP* and *OaPty* were analysed further. Table 3 indicates *A_nFam* ($r = 0.449$; $p < 0.001$) and *Ars* ($r = 0.485$; $p < 0.001$) showed moderate positive relationships with monthly temperature. Since data distributions were non-normal,

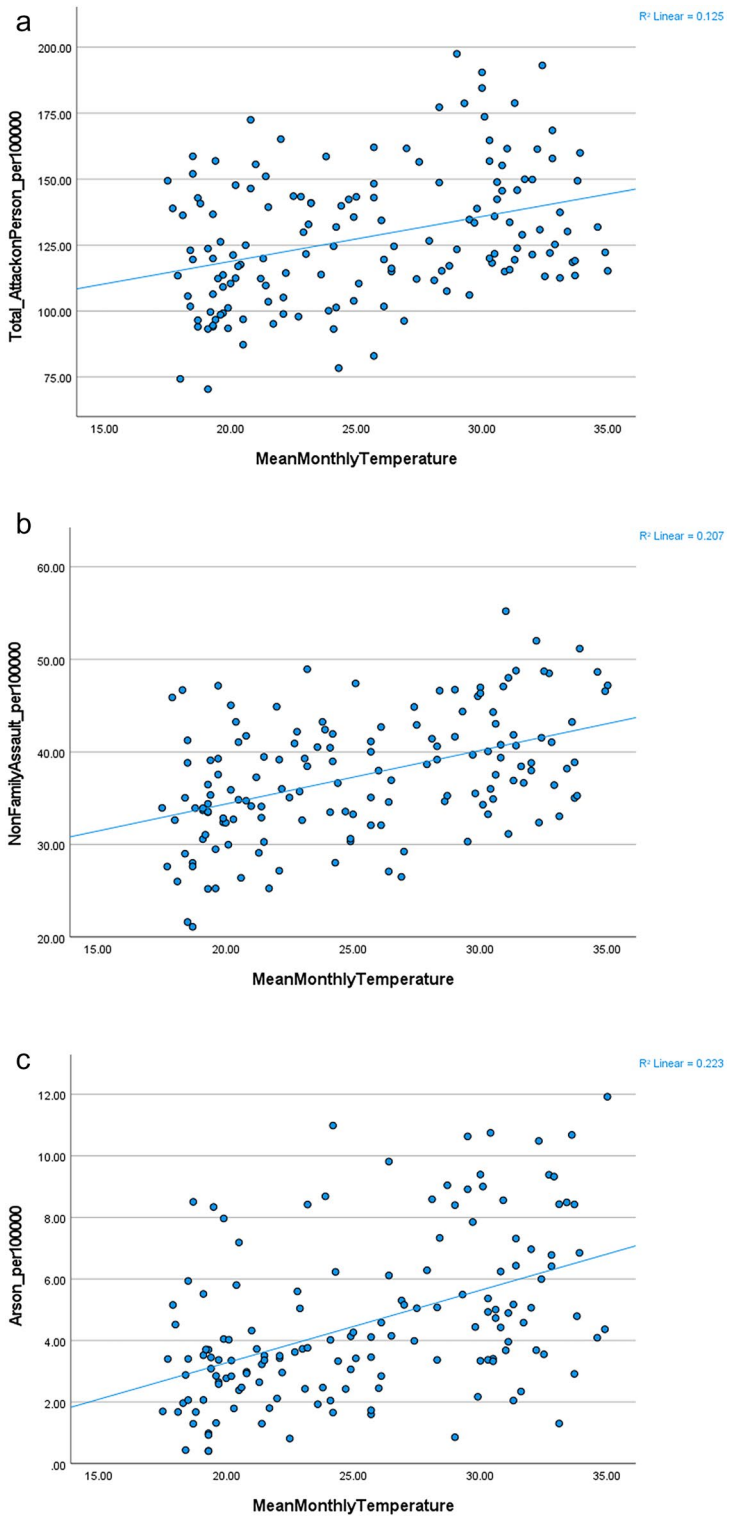

Fig. 4 **a** Scatter plot of *AoP* against mean monthly temperature. **b**, **c** Scatter plots between *A_nFam* and *Ars*, and mean monthly temperature

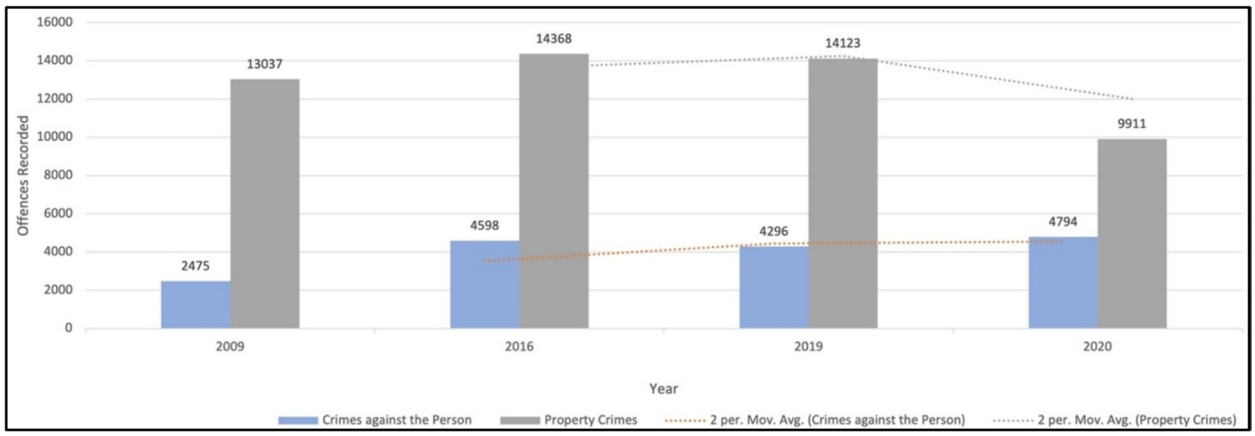

Fig. 5 Midland's Crime Statistics (2009–2020). Adapted Western Australian Police (2021)

researchers relied on Spearman's correlation coefficients, hence the correlations in this study are non-linear. IBM SPSS Statistics 28 was used to test the hypothesis.

Figure 4 shows about 20% of data fit the trendline. The positive correlation between *Ars* and temperature can be understood as hotter days leading to greater fire risks. This finding underlines the need to further study why higher temperatures increase assault rates towards non-family members.

Analysis of midland: vegetation cover, population and crime statistics

A report by the Department of Planning, Lands and Heritage (2021) shows Mesh Block Vegetation Cover and Tree Canopy for Midland in 2009 and 2016 *increased* from 7.98 to 10.39% of landmass. In addition, according to datasets of the ABS (2022), Midland's population of 6,335 (median = 39) is spread over a landmass of 4.2km^2 (density = 1,508 persons/km^2). Midland CBD has a population of approximately 1,142 people over a landmass of 2.05 km^2. The population of the City of Swan municipality, in which Midland exists, is projected to rise by 85% by 2051. The number of dwellings required is predicted to increase sharply over the same period to keep in step with population growth.

Midland crime statistics

AoP statistics are 2,475 (2009), 4,598 (2016), 4,296 (2019), and 4,794 (2020). From these figures, 2009 to 2019 represents an 87% increase. ***AoPty*** statistics are 13,037 (2009), 14,368 (2016), 14,123 (2019), and 9,911 (2020); *AoPty* statistics also rose on long-term trends but decreased significantly between 2019 and 2020. The reduction coincided with the first COVID lockdown in March to April 2020, and the subsequent easing of restrictions ending in June 2020 presents an anomaly. Western Australian Police (2021) Crime Statistics Timeseries Data suggests overall OaP in Midland District increased. Historical sexual assault and Recent sexual assault increased 27.7% and 91.7% respectively. Threatening Behaviour (Family) also rose by 30%. Similarly, AoPty decreased by 29.8% between 2019 and 2020 (Fig. 5).

Statistics show ± 20% or higher between the summer months of December to February, in comparison with the preceding 9-month average. Between 2007 and 2020, Western Australian Police (2021) figures suggest that this occurred on three occasions for ***AoP*** (the average from March 2012 to November 2012 contrasted with December 2012 to February 2013 (+ 25%)). Also, between March 2014 and November 2014, set against December 2014 to February 2015 (+ 21%), and averages across March 2018 and November 2018 compared with December 2018 to February 2019 (+ 22%).

This did not occur for ***AoPty*** but on one occasion, the average of March to November 2010 when compared with December 2010 to February 2011 (+ 19.6%). Across most other similar comparisons in this category, most increases are of less than 5%, and on three occasions had reduced between negative −0.5 to −10% (March 2009 to November 2009 compared with December 2009 to February 2010 (−10%)). It is also important to note that in Australia, December to February coincides with school holidays, which also coincides with increases in some crime categories.

Discussion

This study emphasises the complexity and multitude of variables involved in understanding the relationship between heat, heat-related illness, and crime or violent behaviour. Studies by Stevens et al. () specifically investigates how seasons and temperature impact crime rates, focusing on variables such as assault, theft, and fraud.

Churchill et al. (2023) investigated the impact of temperature and climate change on crime, uncovering possible long-term patterns and consequences for policy development and intervention tactics. Corcoran and Zahnow (2021; 2022) examined the correlation between weather conditions and assault rates in Brisbane, and undertook a systematic review of the empirical literature, offering significant insights into specific patterns of criminal activity. In addition, Auliciems and DiBartolo (1995) conducted important research on the relationship between weather patterns and domestic violence in the same urban setting, emphasising the complex impact of environmental factors on criminal behaviour.

In contrast, other studies have primarily explored the relationship between heat and social media behaviour or health outcomes. Developing on these influential studies with our own research, we enhance our comprehension of the elements that influence crime patterns in urban areas of Australia. This highlights the need for more interdisciplinary research and collaborative efforts to tackle the complex challenges presented by climate variability and its consequences for community safety.

This research suggests that studies conducted beyond the United States and European contexts are relatively limited, making generalisation to other socio-economic, cultural, and ethnic circumstances challenging. Moreover, had significant limitations and fails to consider criminality comprehensively within the broader context of societal dynamics, social norms, and landscape morphology over time.

In Perth, tree canopy area increased by 4% between 2009 and 2016. Tree canopy coverage and suburban maturity have been widely researched (Lowry et al., 2012; Luck et al., 2009; Mockrin et al., 2019). Troy et al. (2007) found that residence age and tree coverage are positively correlated (around 45 years). Mockrin et al. (2019) found different relationships between dwelling age and urban tree canopy. These relationships were non-linear and negative when comparing United State locations. Lowry et al. (2012) added that community and housing age influenced the relationship between urban tree cover and socioeconomic factors of vegetation cover. Luck et al. (2009) found that housing density increases vegetation over time, showing that communities 'green up' after development.

Global studies also neglect "blue" infrastructure like coastal areas and vast bodies of water. Thermal mass and direction are also a vital omission. Most capital cities in Australia are located around the coast, which is colder and wetter than interior places. As air travels from high- to low-pressure zones, cooler ocean air pushes toward warmer air onshore, generating a sea breeze. This cools coastal areas but not interior areas. Blue infrastructure was rarely included in heat-crime research, nonetheless a key variable in HIE. Urban development's influence on cooling channels may have substantial implications for understanding sea breezes in cities.

Research typically correlates environment, vegetation, social, and demographic information. Law enforcement efforts and initiatives are usually overlooked e.g., police "actions" that target certain forms of crime in specific locations. Guerette and Bowers (2009) found this may lower crime in targeted regions while increasing crime in non-targeted areas. Normative literature, e.g., Clarke and Weisburd (1994) has reported on crime implications of displacement and diffusion. Moreover, transit nodes are, and their surrounding environments that the extant literature suggest, are interconnected, and are largely not considered as variables in the heat-crime literature as it is in the urban-crime literature.

Moreover, studies do not typically attribute drug use and seasonal drug use patterns (alcohol) as a variable in the populations studied. For example, the impact of heat on drug-affected persons and crime. Surveys relating to illicit drug use by people aged 14 and over in Australia considered age, geographic area, level of socioeconomic advantage and disadvantage, and a person's education (Australian Government [Australian Institute of Health and Welfare] 2020). In 2019, 43% of people in Australia were reported to have used an illicit drug at some point in their lifetime, whilst 16.4% had used one in the last 12 months. For example, the use of cannabis, cocaine, ecstasy, inhalants, hallucinogens, and ketamine all increased from 2016 to 2019, and so was the non-medical use of pharmaceuticals, painkillers, opioids, and codeine. Future studies may draw conclusions on such increases and their relevance to variables of crime, urban tree canopy, heat and HIE. While our study did not specifically analyse seasons, it is important to recognise their potential impact on crime dynamics, especially in Australia. For instance, the summer season coincides with holidays and increased alcohol consumption, potentially influencing aggressive behaviour. Although a limitation in this study, acknowledging seasonal variations could offers valuable insights and highlights the need for future research to explore this aspect further, particularly in regions like Australia where seasonal patterns differ.

Crime statistics need to be considered proportionately and examined per 100,000. This is to examine the correlation between crime rate and population growth, dwelling growth, and growth in economic activities. In addition, offenders' statistics may include alleged offences that are later retracted or unsubstantiated, which are not redacted from databases and risk biasing results. In Australia, lesser incidents such as disturbances, disorderly behaviour, damage, and other events may be reported

to municipal rangers instead of police. Such occurrences are not included in police crime statistics, and offences of a sexual nature, and domestic violence are more likely to affect women, children, and disadvantaged socio-economic groups, regardless of vegetation density. Such crimes may be underreported due to apathy toward authority and sensitivity of the crime type.

Service and coverage may vary per municipality. The percentage of house ownership and rental might also impact findings; however, they are not uniformly examined among studies. Crime may also change with population density. Radial, suburban, and gridded patterns that create mono-functional zones or segregated precincts may catalyse crimes. High-rise residential with mixed-use, single residences, pedestrianised precincts and public realm, vehicular-dependent cities, rate of movement, and scale also affect sustainable densification and place-making (Jonescu et al., 2018).

Prima facie, the Midland case study indicated a positive correlation between temperature, crime statistics, and green canopy cover (which rose over time) with population density. Thus, longitudinal studies might draw different conclusions across the literature reviewed. Accordingly, future studies could consider recidivism rates [a small fraction of the population overrepresented in crime statistics], in conjunction with population density. Heat, HIE, and canopy cover may not affect recidivism rates, which may have grown independently of population expansion and density.

While this study primarily focused on the relationship between temperature and crime rates, future research endeavours could explore the intricate interplay between rainfall patterns, temperature fluctuations, and their combined influence on criminal behaviour, thus providing a more comprehensive understanding of environmental factors impacting crime rates. This study acknowledges the importance of incorporating contemporaneous vegetation data in alignment with ongoing housing developments that may displace remnant vegetation in future studies, with relevance to presenting a deeper understanding of the multifaceted dynamics of urban development and their effects on vegetation loss and criminal behaviour. Additionally, exploring the potential influence of blue grids, such as water bodies, on temperature reduction and subsequent impacts on crime rates is an area of worthy of future research in this emerging area of study. Lastly, while this study did not incorporate emergent sources of disaggregate data, such as smartphone tracking studies, to analyse UHI exposures through the lens of everyday activity spaces, future research could explore the potential of integrating such data to enhance the scholarly understanding of this relationship.

Conclusion

Existing studies linking temperature and crime rates lack longitudinal analysis. This study highlights anomalies that warrant further investigation, including recidivism, urban composition, and variables beyond temperature, population, and crime. Factors such as economic downturns, unemployment, and apathy in reporting can influence crime rates. It is important to consider the variability in location-based climate change outcomes and the need for more comprehensive studies on the relationship between green space and crime, especially in urban areas of the Global South.

The study emphasises the heat-sink properties of thermal mass which can lead to exacerbated UHIEs, orientation, which can influence passive cooling, and blue grids which, in conjunction with orientation and breezes can be utilised to alleviate heat, are often ignored in normative literature, in the design and development characteristics of cities researched. And further, the potential significance of integrating rainfall analysis into future research endeavours, which could offer valuable insights into the multifaceted influences shaping criminal behaviour. Urban morphology mediates immediate micro-climate heat islands with dramatically different temperatures from surrounding local belts.

Human behaviour and criminality are complex, posing challenges for urban design decisions. The impact is further complicated by changes in macro- and micro-climates. Urbanisation and the loss of green spaces, leading to urban heat islands, are also significant factors. The existing literature is still in its early stages, mainly focused on Northern Hemisphere case studies. However, if hypotheses regarding the interplay between the urban environment, local climate, and criminal behaviour are accurate, it is crucial for built environment specialists to collaborate on evidence-based research to understand the intricacies and determinants of emerging crime and behavioural norms. This collaboration aims to mitigate the consequences of urbanisation.

This study's analysis of growth, crime, demographic, and temperature analysis of Midland, in Perth Western Australia assessed the validity of existing theories that associate criminality and patterns of criminal behaviour. Local crime, temperature, and vegetation cover data were analysed. Validity was done through an evaluation of field literature.

The findings draw to an observable correlation between green canopy cover with temperature, long-term crime, and population density. However, the population for Midland was expected to grow substantially by 2051. The study acknowledges that while the commonly tested variables applied by most other studies did not have a statistically significant impact on crime in the case study area,

there are other variables that may influence crime discussed throughout the paper.

Such prediction of the potential impact of local heat and canopy cover on urban criminal behaviour could benefit the long-term aspirations of designers and policymakers in the (re)shaping of city infrastructure through development policy largely set prior to the eminence of climate change and heat islands. Development policy, for example, could consider alignment, orientation, above and below-ground infrastructure, materiality, blue grid optimisation, vegetation, and greening policies for active cooling. Moving forward, the integration of rainfall analysis as a complementary variable holds promise for refining predictive models and informing policy interventions aimed at mitigating crime rates in urban environments, and further research in police resource planning and resource implementation could benefit from understanding the likely correlations between long-term heat projections and an anticipated increase in crime.

Additionally, this study highlights the importance of considering environmental variables such as vegetation cover and temperature in understanding crime dynamics. We recognise the need for future studies to include more up-to-date vegetation data available, especially in areas undergoing housing development, and suggest prioritizing this in future research endeavours.

Lastly, the potential impact of blue grids, such as water bodies, on temperature reduction and crime rates warrants further investigation. Incorporating such variables into future studies can enhance our understanding of the complex interactions shaping urban crime patterns, offering valuable insights for policymakers and urban planners.

Appendix

Offence group	Offence sub-group	Definition
Homicide		Unlawfully kill, attempt to unlawfully kill, or conspiracy to kill another person
	Murder	Unlawfully kill another person where: • there is an intent to kill; or • there is an intent to cause bodily harm of such a nature as to endanger, or be likely to endanger, the life of the person killed or another person; or • the death is caused by an act done in the prosecution of an unlawful purpose, of such a nature as to be likely to endanger life
	Attempted/conspiracy to murder	The attempted unlawful killing of another person or conspiring with others to commit murder
	Manslaughter	The unlawful killing of another person under circumstances that do not amount to murder
	Driving causing death	The unlawful killing of another person, without intent to kill, as a result of culpable, reckless, or negligent driving
Recent sexual offence		Recent Sexual Offence is a sexual offence that is reported within 90 days of the offence occurring
Historical sexual offence		Historical Sexual Offence is a sexual offence that is reported more than 90 days after the offence occurred
Sexual offences		Acts of a sexual nature, or committed with an intent of a sexual nature, against another person, which are non-consensual or where consent is given in proscribed circumstances
	Sexual assault	Physical contact, or the intent of contact, of a sexual nature against another person, which is non-consensual or where consent is given in proscribed circumstances

Offence group	Offence sub-group	Definition
	Non-assaultive sexual offences	Sexual related offences, other than sexual assault. Includes: child pornography, grooming, procuring for prostitution, wilful exposure
Family relationship		The following definition is to be used in conjunction with any reference to 'family' related offences: 'Family' includes: partner, ex-partner, parents, guardians of children, and children who reside or regularly stay with involved parties
Non-family relationship		Every other family or personal relationship which is not listed under the Family Relationship definition
Assault		The use of force against another person, or the threat of the use of force where the threat has a real or perceived ability to be enacted at the time
	Serious assault	• Use of force against another person resulting in injuries such as: - Grievous bodily harm; - Actual bodily harm; - Wounding; - Severe mental behavioural disturbance or disorder; or • Administering drugs to another person with intent to assault; or • Assaulting a Public Officer (Assault Police Officer reported separately)
	Common assault	The use of force, or threatened use of force, against another person, that does not result in bodily harm
	Assault police officer	The direct infliction of force or violence against a police officer, which may involve bodily harm
Threatening behaviour	Threatening behaviour	Declaration, orally via a communications device or recordings, using a computer, or in writing, of intention to punish or hurt; to injure body, property or reputation; or give warning of intention to inflict harm or revenge
	Possess weapon to cause fear	A person who is, or pretends to be, armed with any dangerous or offensive weapon or instrument, in circumstances that are likely to cause fear to any person. Includes discharging of a firearm to cause fear
Deprivation of liberty	Kidnapping/child stealing	The abducting of a person against their will and depriving them of their personal liberty with intent to: • gain a benefit, • cause a detriment, • prevent, hinder or compel an act Includes abduction of a child under the age of 16 years and depriving them of their personal liberty, with the intention of depriving any person with lawful care of the child Includes: fraudulently enticing the child away, receiving/harbouring a child
	Deprivation of liberty	The unlawful detention of a person against their will
Robbery		Uses, attempts to use, or threatens, violence against a person or business to facilitate stealing of property
	Robbery (business)	Uses, attempts to use, or threatens violence, to facilitate the unlawful taking of property belonging to a business
	Robbery (non-business)	Uses, attempts to use, or threatens violence, to facilitate the unlawful taking of property, other than that belonging to a business

Offence group	Offence sub-group	Definition
Burglary		The unlawful entry of a structure with the intent to commit an offence, or committing an offence in a place when in that place without consent A structure is defined as a building that is contained by walls and can be secured in some form. This includes, but is not limited to, a: dwelling (e.g. house, flat, caravan); office; bank; shop; factory; school; and church
	Burglary (dwelling)	To enter, or attempt to enter, any building, structure, tent, or caravan that is ordinarily used for human habitation, without consent and with intent to commit an offence
	Burglary (non-dwelling)	To enter, or attempt to enter, a building, structure, or tent other than a dwelling, without the owner's consent and with intent to commit an offence
Stealing of motor vehicle		The taking of a motor vehicle without consent. Excludes attempts to steal a motor vehicle, damaging or tampering/interfering with a motor vehicle, or the theft of motor vehicle parts or the contents of a motor vehicle. A motor vehicle: • Is built to be propelled by a motor that forms part of the vehicle; • Is self-propelled that is not operated on rails and includes a trailer, semi-trailer or caravan while attached to a motor vehicle; • Does not include a power assisted pedal cycle; and • Must be eligible for registration for use on public roads
Stealing		The unlawful taking or obtaining of money, goods or services, without the use of force, threat of force or violence, coercion or deception. Excludes stealing associated with a burglary
	Stealing from motor vehicle (contents or parts)	To steal or attempt to steal, the contents or parts from a motor vehicle
	Stealing from retail premises (shoplift)	To steal or attempt to steal goods on display for sale from a retail premises (otherwise known as 'shoplifting'). Does not include the theft of property from retail premises where the property was taken from areas not accessible to the public, or where the property is taken in circumstances that would be described as a burglary
	Stealing from dwelling	To steal or attempt to steal property from a dwelling and/or its yard, where the entry was lawfully gained and without violence or threat of violence
	Stealing from other premises or place	To steal or attempt to steal property other than from a dwelling, motor vehicle or retail premises, without violence or threat of violence
	Stealing as a servant	To steal or attempt to steal property by an employee from their employer, without violence or threat of violence
	Stealing (not elsewhere classified)	To steal or attempt to steal property without violence or threat or violence that is not elsewhere classified
Property damage		Unlawful destruction or damage to property. Excludes circumstances where the damage was caused in facilitating another offence, such as breaking a window to commit a burglary

Offence group	Offence sub-group	Definition
	Criminal damage	The wilful and unlawful destruction or damage of the property of another person/entity without their consent
	Damage	The unlawful destruction or damage of the property of another person without their consent
Arson		Wilfully and unlawfully destroying or damaging property by fire or explosion
	Cause damage by fire	The use of fire or explosion to cause damage to property
	Cause bushfire	Wilfully light a bushfire to injure or damage; or placing a match or other inflammable or combustible substance in the open (including during a total fire ban), that then ignites and causes a bushfire
	Other fire related Offences	Other fire related offences not elsewhere classified such as burning during a restricted burning time without a permit
Drug offences		The possessing, selling, dealing or trafficking, importing or exporting, manufacturing or cultivating of drugs or other substances prohibited under legislation
	Drug dealing	The supply of an illicit drug or controlled substance of any quantity; or the purchase or possession of an illicit drug or controlled substance, where the amount involved is deemed to be of a quantity for commercial activity
	Cultivate or manufacture drugs	Actions resulting or intended to result in either the manufacture of controlled substances, or cultivation of plants used to make illicit drugs
	Drug possession	The possession of a non-commercial quantity of an illicit drug or controlled substance of which possession or use is prohibited under legislation
	Possession of drug paraphernalia	The possession of pipes, syringes, or other utensils associated with the use of drugs
	Other drug offences	Other drug offences not elsewhere classified, such as occupier permit drug offence or conspiracy to commit a drug offence
Receiving and possession of stolen property		Receive, handle, process or possess money or goods taken or obtained illegally
	Possess stolen property	Possession of stolen or unlawfully obtained property, or property reasonably suspected of having been stolen or unlawfully obtained
	Receiving stolen property	Knowingly receiving, handling or dealing with property obtained by means of an act constituting an indictable offence
Regulated weapons offences		Offences relating to possessing weapons/explosives, or items intended to be used as weapons, in circumstances that contravene legislative and regulatory requirements Excludes the use of weapons to threaten or injure persons or property, such as discharging a firearm to cause fear which is reported as 'Threatening Behaviour'
Graffiti		Unlawful property damage caused by the application of substances (e.g. paint) or etching or scratching
Fraud and related offences		Offences involving a dishonest act or omission carried out with the intention of deceiving for the purpose of obtaining a benefit, or avoiding some detriment/disadvantage
	Forgery	Forging or uttering records with intent to defraud, counterfeiting currency, or possessing equipment to forge or counterfeit. Includes all attempts

Offence group	Offence sub-group	Definition
	Fraud (credit card)	The use of deception or impersonation with the intent of dishonestly obtaining property, services or other benefit, or to avoid detriment/disadvantage, through the use of unlawfully obtained credit/debit card information
	Fraud (not elsewhere classified)	Fraud not elsewhere classified. Prior to June 2017 this offence type included credit card fraud
Breach of violence restraint order		An act, by an individual, of breaching the requirements of an order of law prescribed specifically for them
	Family violence restraint order	Breaching the requirements of a Family Violence Restraint Order or breaching the requirements of a Violence Restraint Order where a family relationship has been determined to exist
	Violence restraint order	Breaching the requirements of a Violence Restraint Order
	Police order	Breaching the requirements of a Police Order

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Availability of data and materials
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Declarations

Declaration of generative AI and AI assisted technologies in the writing process
Not applicable.

Competing interests
The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential competing interests.

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