Understanding crime using GIS and the context of COVID-19:

The case of Saldanha Bay Municipality

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South Africa faces high levels of crime. The Saldanha Bay Municipality, the setting of this study, is laden with poverty, unemployment and gangsterism that deprive quality of life and contribute to social ills. While crime management and prevention strategies require information regarding crime trends, this information for the Saldanha Bay Municipality area is limited. Hence, the study aimed to illustrate the spatial distribution and trends of crime in the Saldanha Bay Municipality, focusing on the period January 2017 to June 2020, and to indicate the recent impact of COVID-19 on these crime trends. The results of the study are presented by means of graphs and tables, and hotspot mapping was done using the ArcGIS Getis-Ord Gi statistics tool. These results indicate that crime has increased over the past three years and that criminal activities are linked to urban hubs where most people stay and work. In terms of the effect of the COVID-19 pandemic and the lockdown regulations on crime, it is interesting to note the variations in crime rates during the first 3 months of lockdown (from April 2020 to June 2020) when compared to the rest of the period under investigation. Amongst the five towns investigated, the town of Vredenburg which has the highest population total and was ranked highest in terms of crime rates prior to the lockdown, moved from first to third, behind Langebaan and St Helena Bay. Similarly, Saldanha Bay with the second highest population total moved down to fourth. Hopefield was still the town with the lowest mean crime rate.*

Introduction

Actual crime levels in South Africa and around the world are difficult to present because only crimes reported through official processes are recorded, which does not necessarily provide a true reflection of crime. South Africa records a high rate of murders, assaults, rapes and other violent crimes, ranking third in the world and first on the African continent among the most dangerous countries to visit around the globe.[2] In South Africa, crime statistics and estimations are regularly published by the South African Police Service (SAPS) and Statistics South Africa's Governance, Public Safety, and Justice Survey (GPSJS),[3] which updated the long-running Victims of Crime Survey (VOCS) to include themes on governance. The GPSJS complements the statistics provided by the SAPS by presenting South Africans perceptions about crime, their experiences of crime, and their views on policing and the criminal justice system. These and other sources that report on crime should not be seen as replacements or alternatives to official SAPS crime data, but rather to enrich "the police statistics that will assist in the planning of crime prevention".[4]

Eldred de Klerk argues that "poverty and poor service delivery directly impact crime levels, while disparities between rich and poor are also to blame".[5] Statistics indicate that crime affects mainly poorer South Africans.[6] The Saldanha Bay Municipality (SBM), the setting of this study, is characterised by challenging socio-economic conditions, with 14.1% of households without income.[7] Poverty and unemployment undermine quality of life and contribute to social ills such as crime. The SBM's most prevalent crime types are contact crime and property-related crime, believed to be spurred on by gangsterism.[8] Gangsterism and its close relationship with crime and vandalism in this region is fuelled by illicit drugs, a major crime pull factor among idle, socio-economically disrupted and desperate youth.[9] The reintegration of parolees into the community is problematic, especially since no sustainable, meaningful employment is available, causing parolees to reoffend for survival.[10]

Although much is known about the causes and consequences of crime and the use of geographic information systems (GIS) to map the spatial distribution of crime, not much is known about geospatial crime trends in the SBM area. Existing studies focus on utilising GIS techniques to map and analyse spatial distributions of crime for specific countries, regions and towns.[11] In South Africa, few studies have used geospatial techniques to illustrate and analyse spatial distributions of crime visually, and none have focused on SBM. The SAPS, through a Memorandum of Understanding with Statistics South Africa, publishes the crime statistics for the whole of South Africa on a quarterly basis.[12] Crime is reported in five broad categories, recorded by each police station per province. However, data are not visually illustrated to show spatial distributions and trends.

The Novel Corona Virus Disease 2019 (COVID-19) has added another dimension to crime trends. Some countries, such as South Africa, implemented swift and drastic measures to stop the spread of COVID-19.[13] Since the outbreak of the pandemic, there has been much research about its effects on global crime.[14] However, there has been limited such research in South Africa.[15] Similarly, not much is known about the effects of the COVID-19 pandemic on crime in the SBM, specifically during the first three months of the South African national lockdown.

This study attempted to fill these gaps by pursuing a visual representation of crime data of the SBM area to recognise high crime spots, and to show the relationship between the COVID-19 pandemic and crime in the SBM. The purpose was to illustrate by means of graphs and tables the crime trend in the SBM area over the period 2017 – 2020, and kernel density estimation and the Getis-Ord Gi* statistics tool using a GIS for identifying statistically significant clusters of crime. This study also briefly considered the effect of the COVID-19 pandemic and the resultant first three months of lockdown regulations of South Africa on crime rates in the SBM from April to June 2020.

Describing crime and crime mapping

Criminological theory holds that three things are needed for a crime to occur: a driven offender, an appropriate target, and a location/environment.[16] Crime, according to Wortley, "will be concentrated around crime opportunities and other environmental features that facilitate criminal activity".[17] Crime pattern theory suggests that offenders are influenced by the daily activities and routines of their lives, meaning that offenders in search of a criminal opportunity will tend to steer towards areas that are known to them.[18] Crime patterns can be "analysed in terms of their socio-demographic, temporal and spatial qualities, and may be represented visually using graphs, tables and maps".[19] With these results, crime analysts provide advice to police on criminal investigations, improvement and/or deployment of resources, planning, evaluation, and crime prevention.[20]

Analysts use geographic information system (GIS) technology to map crime locations. A GIS is a conceptual framework or system that is used to capture, store, manipulate, manage, and analyse geospatial data.[21] While the most common use for a GIS is to create maps in the geospatial environment, it is used in numerous sectors such as realty, health, finances, security and communication. GIS integrates data and information from various sources to map crime incidents by using spatial statistics to identity hot spots, track crime incidents, and produce density maps.[22] In policing, GIS represents a data management system which stores, processes, analyses and displays spatial data on crime which might include the types of offences, the spatial location where criminal activities were committed, and the offenders and victims of

criminal acts.[23] These data are important for collecting, analysing and mapping purposes, because they provide support in decision-making and effective deployment of police and resources to increase protection and safety in the community.

GIS techniques are used extensively in crime analysis as a problem solving, crime prevention and crime fighting tool.[24] The importance of geographic data in finding and analysing patterns or models of criminal behaviour has been recognised by modern police organisations to prevent and reduce crime rates, benefitting the citizens.[25] Crime analysis can be used not only to enhance an agency's ability to prevent crime or catch criminals, but also to identify crime patterns, forecast future crime occurrences, target profile analyses, and provide support data to crime prevention programmes.[26] The development of affordable GIS and the increasing technological developments within policing (such as the digitisation and geocoding of crime records) have allowed researchers to exploit the wealth of data recorded by police agencies and to map crime.

Hotspot mapping is a popular analytical technique for identifying concentrations of crime and is used as a basic form of crime prediction. Crime hotspots are areas on a map that have high crime intensity. Hotspot mapping has been used in the analysis of residential burglary, street robbery and vehicle crime, gang-related murders, violent crime, and street assaults.[27] This knowledge allows police, crime prevention practitioners and other interested groups to concentrate resources on specific locations.

In South Africa (SA), few studies use GIS techniques to study crime. The main reason for this is limited access to spatial data on crime and location.[28] Most reliable and credible spatial data on crime in South Africa may be downloaded from sources in the public domain, such as the official websites of the SAPS and Statistics SA. But such data lack specific location details (street addresses) of crimes committed. While these data provide general descriptions crime prevalence on national, regional (provincial) or administrative unit (municipalities and towns) levels, formal administrative requests are required to access specific crime data of the kind used this for this study.

Four previous studies have focussed on targeted spatial distribution of crime using GIS techniques in South Africa. Hiropoulos and Porter performed a descriptive and exploratory examination of theft from motor vehicles per 10 000 members of the population in Gauteng.[29] ArcGIS 10.0 software and local indicators of spatial association (LISA) statistics were used in conjunction with crime pattern theory to *"visualise the spatial relationship between property crime rates and major crime attractors and generators"*.[30] The results show that property crimes are centred predominately in and around the urban centres of Gauteng province, more specifically in major retail areas and shopping centres.

Schmitz et al[31] discuss five examples of forensic mapping used as evidence in criminal court cases in South Africa. Although this article focussed more on the way evidence was presented in court cases (examples include the production of a single map, a storyboard, multiple maps, a report, and a map book) and describes the various circumstances involved in each court case, GIS featured in creating the maps for the forensic analysis. However, specific GIS techniques used to produce these maps were not mentioned.

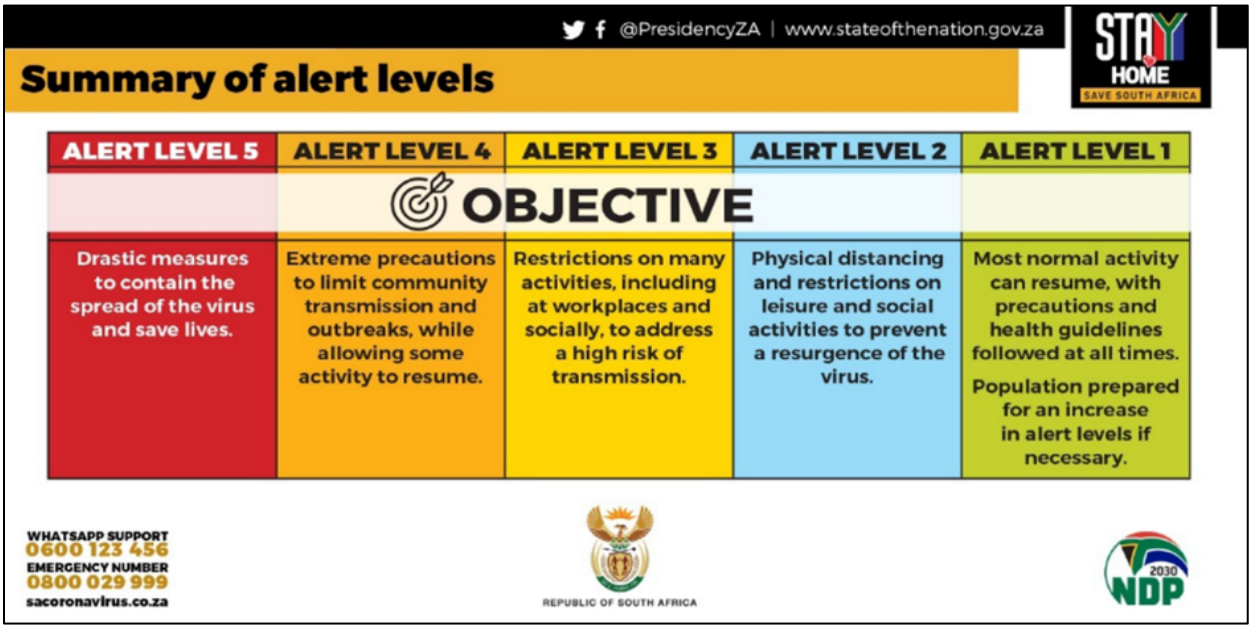
One of the most established academic researchers on crime in South Africa is Associate Professor Gregory Breetzke,[32] whose research focuses on geospatial analysis of crime and criminal offenders. Two of his most recent publications (co-authored) analysed the relationship between temperature and crime on the Cape Flats[33] and the spatial concentration of crime in Khayelitsha township.[34] Both studies use analysis of variance (ANOVA) and multiple regression analysis and small area level and descriptive statistics to analyse the spatial distribution of crime. Results were presented mainly in table format rather than illustrated using GIS techniques, which may have enriched the visual reflection and interpretation of crime trends for general public consumption.

A research gap is evident the use of geospatial techniques to depict present the spatial relationship between crime data and its contributing factors in South Africa. This study uses kernel density estimation and the Getis-Ord Gi* statistics tool available in the ArcGIS software to identify statistically significant spatial associations for high clusters (hot spots) and low clusters (cold spots) of crime in Saldanha Bay Municipality (SBM).

The COVID-19 pandemic and South African lockdown regulations

South Africans were ordered to stay at home beginning 26 March 2020 (lockdown level 5) to fight the spread of COVID-19. Levels gradually eased to lockdown level 4 (1 May 2020), level 3 (1 June 2020), level 2 (17 August 2020), and to level 1 (21 September 2020). Since then, lockdown restrictions have adjusted up and down as infection levels have increased and decrease. Figure 1 summarises these lockdown levels.

Figure 1: Summary of South Africa's lockdown levels (www.stateofthenation.gov.za)



During level 5, only essential services were permitted. No inter-provincial movement of people or goods was allowed, except in extraordinary circumstances for which special permission was required from the local police. Curfews were implemented between 8 pm and 5 am and transport services were only allowed to operate at certain times during the day. People were ordered to stay in their homes and could only leave for specific reasons, for example to buy food or to receive medical care. With the move to lower lockdown levels, restrictions were gradually lifted, and society, services and businesses were allowed more freedom.

While the Western Cape (specifically Cape Town and its suburbs) was initially the COVID-19 infection epicentre, SBM was relatively unscathed likely because of its somewhat remote location about 2 hours outside of Cape Town. The municipality had only one confirmed positive case when level 5 was implemented on 26 March 2020 and 4 cases when the country moved to level 4 on 1 May 2020. By 1 June 2020 when level 3 was implemented, cases had increased to 83 with the first reported COVID-19 death in SBM on 5 June 2020. At the end of the first three months, on 30 June 2020 (lockdown level 3), SBM had 257 active positive COVID-19 cases, 12 deaths and 348 recoveries.[35] By 16 December 2020, there were 1 832 cases -- 209 active cases, 1 570 recoveries, and 54 deaths.[36] The SBM COVID-19 Dashboard shows COVID-19 hotspots clearly centred on the four major towns in the SBM area.[37]

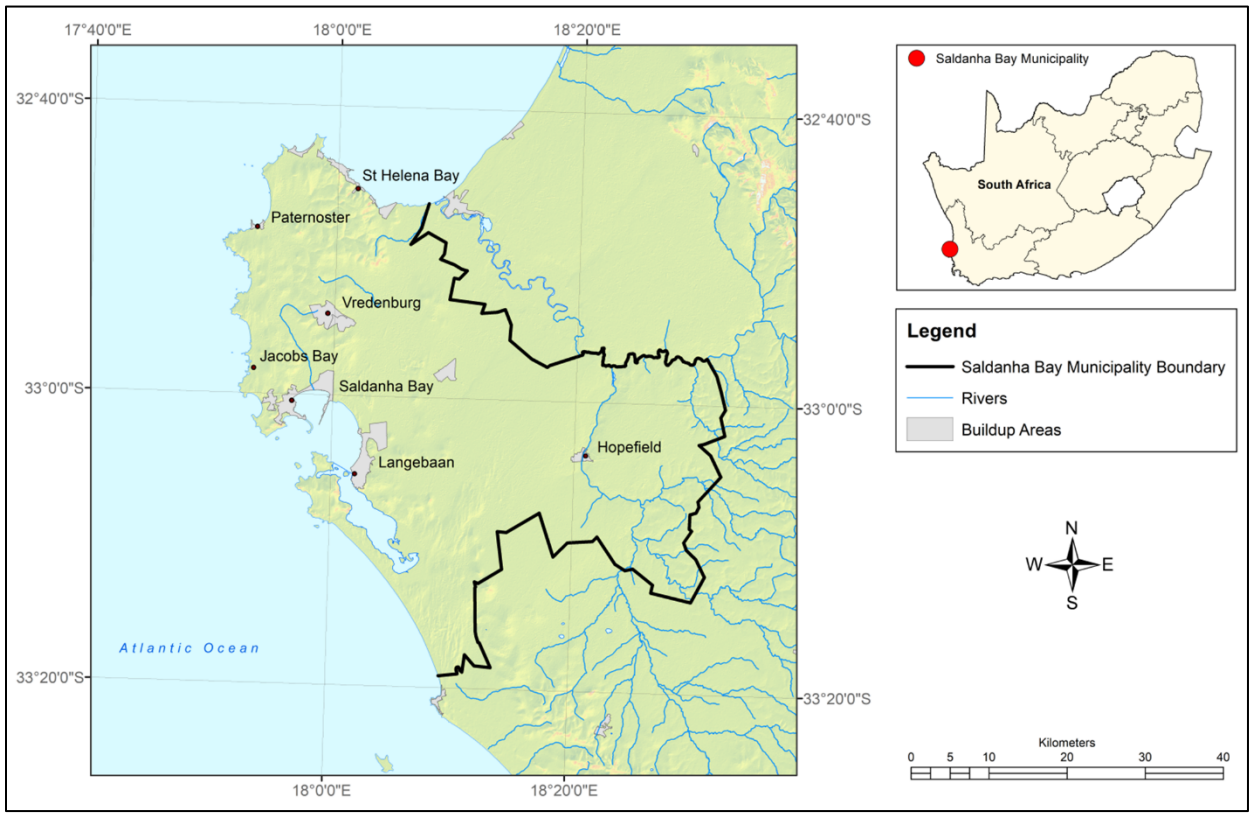
Research on the effect of the pandemic and related restrictions on crime around the world has gained momentum, including region-specific research on the impact of C-19 on crime rates and types. Studies have shown an initial drop in crime in general, with exceptions recorded in some geographical areas[38] and for specific crimes.[39] A significant amount of international research focussed on an increase in gender-based violence and domestic violence.[40]

There are few studies on the impact of the COVID-19 pandemic and related restrictions on crime in South Africa. Conversely, many website and newspaper articles have provided insights into crime trends in general, and COVID-19 related crime specifically. Most of these sources report that crime categories overall decreased initially as a result of the government's swift implementation of strict lockdown restrictions.[41] Studies found a decline in violent crime during the initial 'hard' lockdown, including for domestic violence,[42] but later showed an increase when there was more access to alcohol.[43] Given that South Africa was one of the first countries to implement strict lockdown restrictions, there is an opportunity to explore how this affected the country's crime rates.[44] Visualising where crime tends to be highest and identifying trends at the municipal level can further aid decision-making and direct the deployment of resources to tackle crime more effectively.

Materials and methods

Saldanha Bay Municipality was selected for this study (Figure 2). The SBM is situated approximately 105 km north of Cape Town in the Western Cape. It forms part of the West Coast District Municipality and covers an area of 2 015 km² with a coastline of 238 km. In total, 6.5% of its land is urban, while the remaining 93.5% is rural land. At only 6.4% of the entire West Coast geographical area, SMBM is the smallest municipal area in the district.[45] The Municipality comprises seven towns, namely Hopefield, Jacobs Bay, Langebaan, Paternoster, Saldanha Bay, St Helena Bay, and Vredenburg. Each of these towns, except for Paternoster and Jacobs Bay, has a police station. Paternoster and Jacobs Bay are served by the Saldanha Bay and Vredenburg police stations, respectively.

Figure 2: The extent of Saldanha Bay Municipality and its location within South Africa



Geospatial Data & Crime Hotspot Analysis

This study analysed all crimes that were reported to the five police stations in the SBM between April 2017 to June 2020. Data were collected from the SAPS Western Cape Provincial Commissioner and the SAPS website[46] for the seven towns constituting the Saldanha Bay Municipality.[47] The data were divided into five categories (see Table 2 below):

1) 'contact crimes (crime against the person)';
2) 'contact-related crimes' – described by SAPS as "damage to or destruction of another person's property … or to damage one's own property for the purpose of insurance claims", 'property-related crimes';[48]
3) 'other serious crimes'; and
4) 'crime detected as a result of police action'.

The crime data, which contained the street addresses for each crime, were obtained in MS Excel format[49] and converted to vector points using the ArcGIS software. Using police precinct boundaries as the spatial unit of analysis, the vector point dataset of the location of each crime was used to create the hotspot

analysis. Police stations (vector points) and their respective boundaries (polygons) were downloaded from the SAPS website.[50] The geospatial data utilised for this study were downloaded from the Chief Directorate: National Geo-spatial Information (CD: NGI) portal.[51] The vector data comprised shapefiles (dated June 2020) containing streets and roads (as vector line data), physical addresses where crime occurred (as point data), town boundaries and township and suburb boundaries (as polygon data) of the SBM.

The crime data were firstly presented in graphs and tables for each crime category per town for each year, from April 2017 to March 2020, to show crime quantities and trends. Secondly, a hotspot map was created using location-specific crime data of all crime categories combined. The research approach and GIS techniques used in this study are well documented in the literature. For example, Jana and Sar,[52] Yang,[53] Schaffter,[54] and Mohammed and Baiee,[55] produced kernel density maps using the Getis-Ord Gi* statistics function available in the ArcGIS software to calculate optimized hotspot analysis. ArcGIS offers spatial statistics tools like Kernel Density Estimation (KDE), Inverse Distance Weight (IDW), Standard Deviational Ellipses (SDE), and Getis-Ord Gi statistics[56] that can be used to identify crime hotspots, trends, and patterns.

Yu and Su investigated the performance of kernel density estimation methods, finding that KDE performed better than empirical methods and could be favourably applied in a complex noise environment.[57] Li and Wang et al. compared various interpolation methods, including IDW and Ordinary Kriging,[58] to determine the most accurate spatial distribution estimations and best interpolation methods. Both studies found that data and location dependant interpolation methods are optimum for density estimations. Regarding the SDE technique, Wang et al. state that standard deviational ellipses are derived under the assumption that observed samples follow the normal distribution, but that SDE should be used with caution when measuring the spatial distribution of concerned features.[59]

This study used kernel density estimation and the Getis-Ord Gi* statistics tool to identify statistically significant spatial associations for high clusters (hot spots) and low clusters (cold spots) of crime in the SBM. The Getis-Ord Gi statistics tool performs two types of calculations, namely Gi* that considers the value of the target point and the values of the neighbouring points in the calculation, and Gi that only considers the values of the neighbouring points and excludes the target point.[60] The Getis-Ord Gi* spatial statics tool creates an attribute for each feature class with a z-score, p-value, and confidence level bin (Gi_Bin).[61]

The Getis-Ord Gi* statistic shows spatial associations when the Gi* values are positive for each point (showing high counts of crime close together – hotspots) and when the Gi* values are negative for each

point (indicating low counts of crime close together – coldspots).[62] Negative Gi* values are also an indication of short incident durations.[63] The z-score is 'used extensively in determining confidence thresholds and in assessing statistical significance'[64] and show the place of the crime value in the dataset relative to the mean with respect to the standard deviation.[65] Songchitruksa and Zeng mention that a z-score close to 0 is an indication that the observed spatial clusters have a random distribution.[66] According to Chainey, when a location displays a 99.9% significance 'something exceptionally unusual has happened at this location in terms of the spatial concentration of crime.'[67] Achu and Rose describe the statistical significance of hotspots and coldspots, using the Getis-Ord Gi* statistic, as an indication that 'the observed spatial clustering of high or low values is more pronounced than one would expect in a random distribution of those same values.'[68] A spatial clustering of high values is indicated by a high z-score and a small p-value and a spatial clustering of low values is indicated by a low negative z-score and small p-value.[69] Achu and Rose also mention that a more intense clustering is linked to higher (or lower) z-scores and that no apparent spatial clustering exists when a z-score is close to 0.[70]

Getis-Ord Gi* in ArcGIS 10.5.1 was selected because it is the most popular method used for crime analysis and involves identifying areas where there is a high concentration of crime, relative to the distribution of crime across the area of interest.[71] The spatial analysis usage of points to analyse and map active crime locations or hotspots has the advanced capacity to predict trends and identify possible locations where crime is more likely to occur. Getis-Ord Gi* hotspot analysis is a highly rated and effective tool for conducting prospective mapping to predict where crime is likely to occur. This tool is especially effective in making highly accurate predictions in small areas with a frequent occurrence of crime,[72] which is a characteristic of the SBM area and related crime that had occurred over the analysis period.

Results

Crime trend in the SBM from April 2017 to March 2020

Table 2 indicates the population size of towns in the SBM and presents a breakdown of the five crime categories, showing totals for each type of crime committed, per town, over the 3-year period. The tables present crude values for crimes committed per crime category and per town, as well as the total for all crimes per town, percentages and the mean crime rate per 1 000 population.

'Property-related crimes' accounted for 29.5% of all crimes committed in the SBM over the period and are ranked the highest crime category in this municipality, followed by 'contact crimes – crime against the person' (23.2%), 'other serious crimes' (21.1%), 'crime detected as a result of police action' (19.1%), and 'contact-related crimes' (6.8%). Table 2 also shows that 'assault with the intent to inflict grievous bodily

harm', 'common assault', 'malicious damage to property', 'burglary at non-residential and residential premises', 'theft of motor vehicle and motorcycle', 'theft out of or from motor vehicle', 'all theft not mentioned elsewhere', 'commercial crime', shortlisting', and 'drug-related crime' accounted for the highest number of crimes committed in the SBM from April 2017 to March 2020. Vredenburg recorded the highest crude number of all crimes combined (n = 11 153; 48.2%), followed by Saldanha Bay (n = 6 658; 28.8%), St Helena Bay (n = 2 179; 9.4%), Langebaan (n = 2 163; 9.3%) and Hopefield (n = 994; 4.3%). The total crude number of criminal activities recorded in the SBM over the period under investigation is 23 147. Comparing the mean crime rate per 1 000 population for each town over the three years, Vredenburg still ranks highest (222), followed by St Helena (210), Saldanha Bay (170), Langebaan (152) and Hopefield (124). The mean crime rate for SBM is 190 per 1 000 population.

Table 2: Individual crime activities in the SBM: April 2017 to March 2020

		Vredenburg	Saldanha Bay	Langebaan	St Helena Bay	Hopefield	Total
Population Total		50 127	39 158	14 322	10 307	8 025	121 939
Contact crimes (crimes against the person)							
Murder		63	31	3	10	5	112
Attempted murder		44	19	1	5	4	73
Sexual offences	Rape	114	59	7	19	10	206
	Sexual assault	57	33	13	8	6	117
	Attempted sexual offences	17	8	0	1	2	28
	Contact sexual offences	13	6	4	0	2	25
Assault with the intent to inflict grievous bodily harm		1 034	376	73	158	53	1 694
Common assault		893	621	176	305	123	2 118
Common robbery		151	131	19	20	4	325
Robbery with aggravating circumstances		285	185	6	13	5	494
Some subcategories of robbery with aggravating circumstances	Carjacking	5	4	0	0	0	9
	Robbery at residential premises	54	46	9	2	1	112
	Robbery at non-residential premises	67	26	4	3	5	105
	Robbery of cash in transit	3	0	0	0	0	3
	Bank robbery	0	0	0	0	0	0
	Truck hijacking	2	0	0	0	1	3
Count Total (n)		2 802	1 545	315	544	221	5 427 (23.2%)

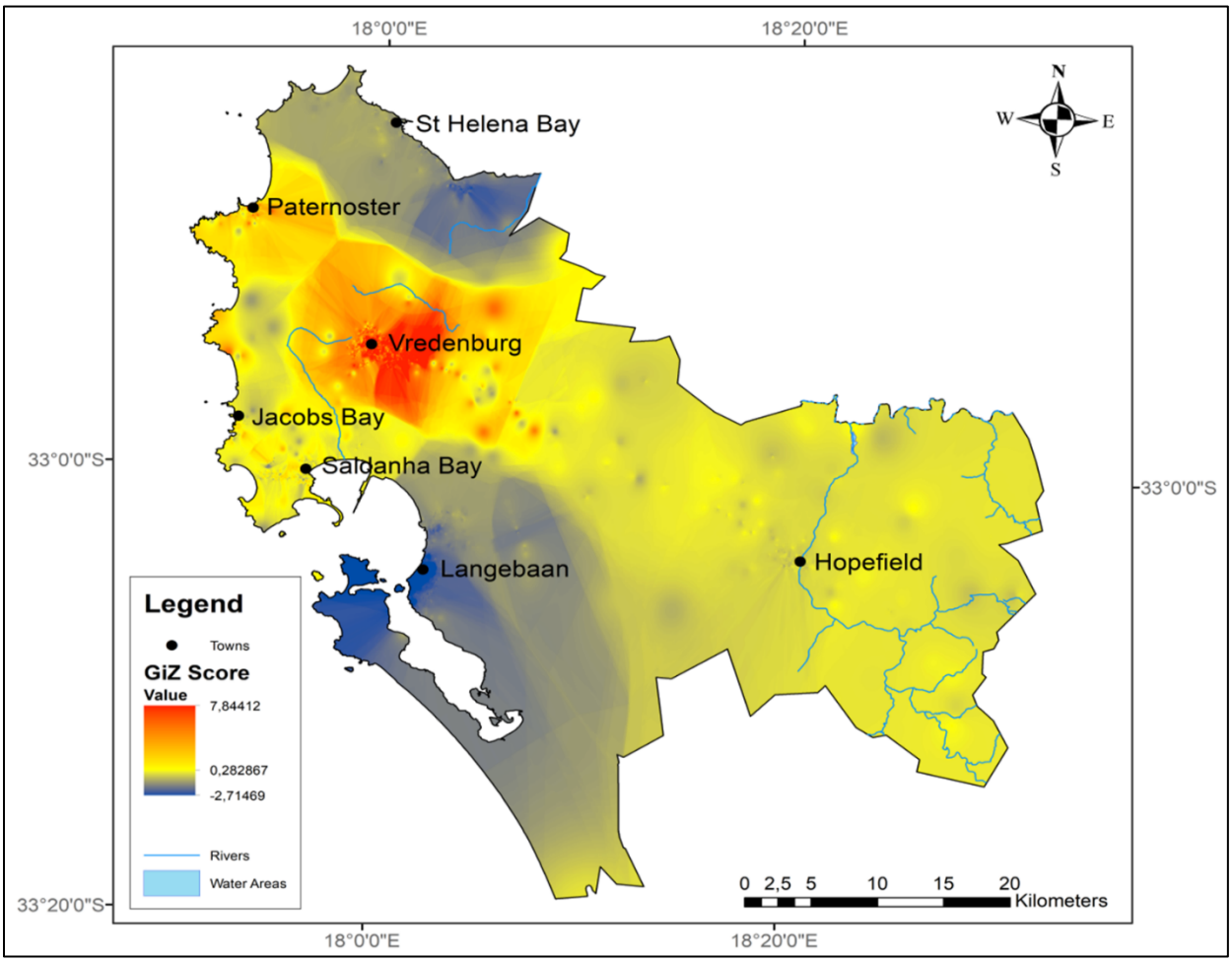
Contact-related crimes						
Arson	36	25	5	7	2	75
Malicious damage to property	699	536	81	154	53	1 523
Count Total (n)	735	561	86	161	55	1 598 (6.8%)
Property-related crimes						
Burglary at non-residential premises	433	410	15	97	60	1 015
Burglary at residential premises	1 731	1 091	519	385	86	3 812
Theft of motor vehicle and motorcycle	63	18	9	8	2	100
Theft out of or from motor vehicle	1 088	539	84	73	34	1 818
Stock-theft	33	18	1	6	15	73
Count Total (n)	3 348	2 076	628	569	197	6 818 (29.5%)
Other serious crimes						
All theft not mentioned elsewhere	1 388	1 041	274	480	108	3 291
Commercial crime	408	171	94	51	22	746
Shoplifting	699	90	32	12	6	839
Count Total (n)	2 495	1 302	400	543	136	4 876 (21.1%)
Crime detected as a result of police action						
Illegal possession of firearms and ammunition	66	37	4	8	5	120
Drug-related crime	1 345	917	674	327	357	3 620
Driving under the influence of alcohol or drugs	361	220	56	27	23	687
Sexual offences detected as a result of police action	1	0	0	0	0	1
Count Total (n)	1 773	1 174	734	362	385	4 428 (19.1%)
Count Total and Percentages per Town - All Crime Categories	11 153 (48.2%)	6 658 (28.8%)	2 163 (9.3%)	2 179 (9.4%)	994 (4.3%)	23 147
Mean Crime Rate per 1 000 Population per Town	222	170	152	210	124	190

Source: SAPS Crime Statistics 2019/2020

Crime hotspot mapping for the SBM

Figure 3 shows the hotspot results for crime committed in the SBM during the 3-year period under investigation. The Inverse Distance Weighted (IDW) interpolation method was used for better visualisation which indicates the continuous estimation of hotspots (red) and coldspots (blue). The Gi* indices represent the physical location of the 23 147 crime incidents. Although this density map is noteworthy, it has the limitation that it indicates crude risk, yet the underlying population is not considered.

Figure 3: Getis-Ord Gi* hotspot map showing clusters of crime activities in the SBM (April 2017 to March 2020)



The main hotspot is in Vredenburg with a high Gi* z-score of 3.436 and p-value of 0.055 and the main coldspot is in Langebaan with a high negative Gi* z-score of 3.787 and a p-value of 0.019. Crime spatial clustering in these two towns indicate an intense concentration at 99.9% significance. The crime in St Helena Bay exhibits low counts of crime that occur in quick succession and with short incident durations, which indicates that crime in this town occurs quickly, and is relatively limited to specific areas. The relative spatial clustering is recorded with a 90% significance (Gi* z-score = 3.787, p-value = 0.019). No significant spatial clustering exists for Saldanha Bay (Gi* z-score = -0.224, p-value = 0.578), Paternoster (Gi* z-score = 1.166, p-value = 0.342), Jacobs Bay (Gi* z-score = 0.231, p-value = 0.537) and Hopefield (Gi* z-score = -0.387, p-value = 0.685). Crime in these towns has a random distribution.

The hot- and coldspots partially coincided with the urban areas of Vredenburg, St Helena Bay and Langebaan, which are characterised by higher population totals than Paternoster, Jacobs Bay and

Hopefield. The last official population census in South Africa was held in 2011, but it has been estimated that the SBM population has grown at a rate of 1.7%, which calculates to an estimated population size of 121 939 in 2020.[73] The projected population totals for each town were calculated in the same way. The largest population cohort is the age group between 15 and 34 years (37.7%), followed by individuals aged between 35 and 64 years (31.9%).[74] The younger age cohort, those 15 years old and younger, makes up 25.6%. The smallest cohort comprises people older than 65 years (4.7%).[75]

The majority of the population in the SBM are poor by national poverty definition, and forced by circumstance to live in the larger informal settlements located in Vredenburg, Saldanha Bay, St Helena Bay and Langebaan.[76] Informal settlements are low income settlements characterised by poor human living conditions,[77] including *"illegality and informality; inappropriate locations, restricted public and private sector investment; poverty and vulnerability; and social stress"*.[78] Saldanha Bay Municipality has the highest unemployment rate (17.5%) in the West Coast district.[79] In 2019 an estimated 51 433 workers (76.5%) were employed in the formal sector, and 12 090 workers (23.5%) were employed in the informal sector.[80]

The socio-economic conditions in the SBM can contribute to the crime patterns shown in Figure 3, a claim confirmed by various poverty-crime correlation studies.[81] Bhorat et al., investigated the correlation between crime in South Africa and socio-economic factors such as unemployment, poverty and inequality.[82] This study found a strong correlation between increased levels of property crime and robberies and the adverse socio-economic factors. Coccia sampled 191 countries, including South Africa, and highlights that *"income inequality is one of the sources of aggression and violent crime in human society"* and that *"countries' intentional homicides can be explained by the level of income inequality alone"*. The author further states that socio-economic inequality is a major contributing factor not just to homicide, but to other forms of aggressive behaviour and violent crime in society.[83]

The effect of the COVID-19 pandemic and lockdown regulations on the crime rate in the SBM

During the first three months of lockdown (April 2020 to June 2020), 1 266 crimes were reported for the SBM. The mean crime rate per 1 000 population during this period was 10. Table 3 shows the crude values for crimes committed per crime category per town as well as the mean crime rate per 1 000 population per town.

Table 3: Crime categories, count totals and mean crime rate per town (April 2020 – June 2020)

Towns	Contact Crimes Against Persons	Contact Crimes	Property Crimes	Other Serious Crimes	Crime as a Result of Police Action	Total Crime per Town	Mean Crime Rate per 1 000 Population
Vredenburg	129	37	190	135	27	518	10
Saldanha Bay	69	31	136	83	60	379	9
Langebaan	13	6	56	28	53	156	15
St Helena Bay	30	10	59	34	30	163	11
Hopefield	7	5	15	7	16	50	6
Count Total per Crime Category	248	89	456	287	186	1 266	

Source: SAPS Crime Statistics 2019/2020

Vredenburg was ranked highest in terms of crime committed in the SBM and accounts for 40.9% (n = 518) of all crime in the area, followed by Saldanha Bay (n = 379, 29.9%), St Helena Bay (n = 163, 13%), Langebaan (n = 156, 12.3%) and Hopefield with the lowest violent crime rate (n = 50, 3.9%). 'Property-related crimes' were committed most frequently (N = 456, 36%) in this period, followed by 'other serious crimes' (n = 287, 22.7%), 'contact crimes against the person' (n = 248, 19.6%), 'crime detected as a result of police action' (n = 186, 14.7%), and 'contact-related crimes' (n = 89, 7.0%). It is interesting that during the first three months of the lockdown, Langebaan had the highest mean crime rate per 1 000 population (15), followed by St Helena Bay (11), then Vredenburg (10), Saldanha Bay (9), and Hopefield (6).

When one compares the effect of the COVID-19 pandemic and lockdown regulations on crime (Table 3) in the SBM with the crime rate for the preceding three-year period (Table 2), results show no change in crime overall for all towns in the SBM. Table 4 shows the results of this comparison, with decreases shown in green percentages and increases in red. Crime decreased by 7.3% in Vredenburg and by 0.4% in Hopefield during the first three months of lockdown, compared to the three-year period before the lockdown. However, crime increased by 3.6% in St Helena Bay, by 3.0% in Langebaan and by 1.1% in Saldanha Bay during the same period.

Table 4: Differences in crime rates per town between the three-year period before the lockdown and the first three months of the lockdown

	Vredenburg	Saldanha Bay	Langebaan	St Helena Bay	Hopefield	Total Count
Three-year period before the lockdown	11 153	6 658	2 163	2 179	994	23 147
First three months of the lockdown	518	379	156	163	50	1 266
Differences in Crime (%)	7.3%	-1.1%	-3.0%	-3.6%	0.4%	

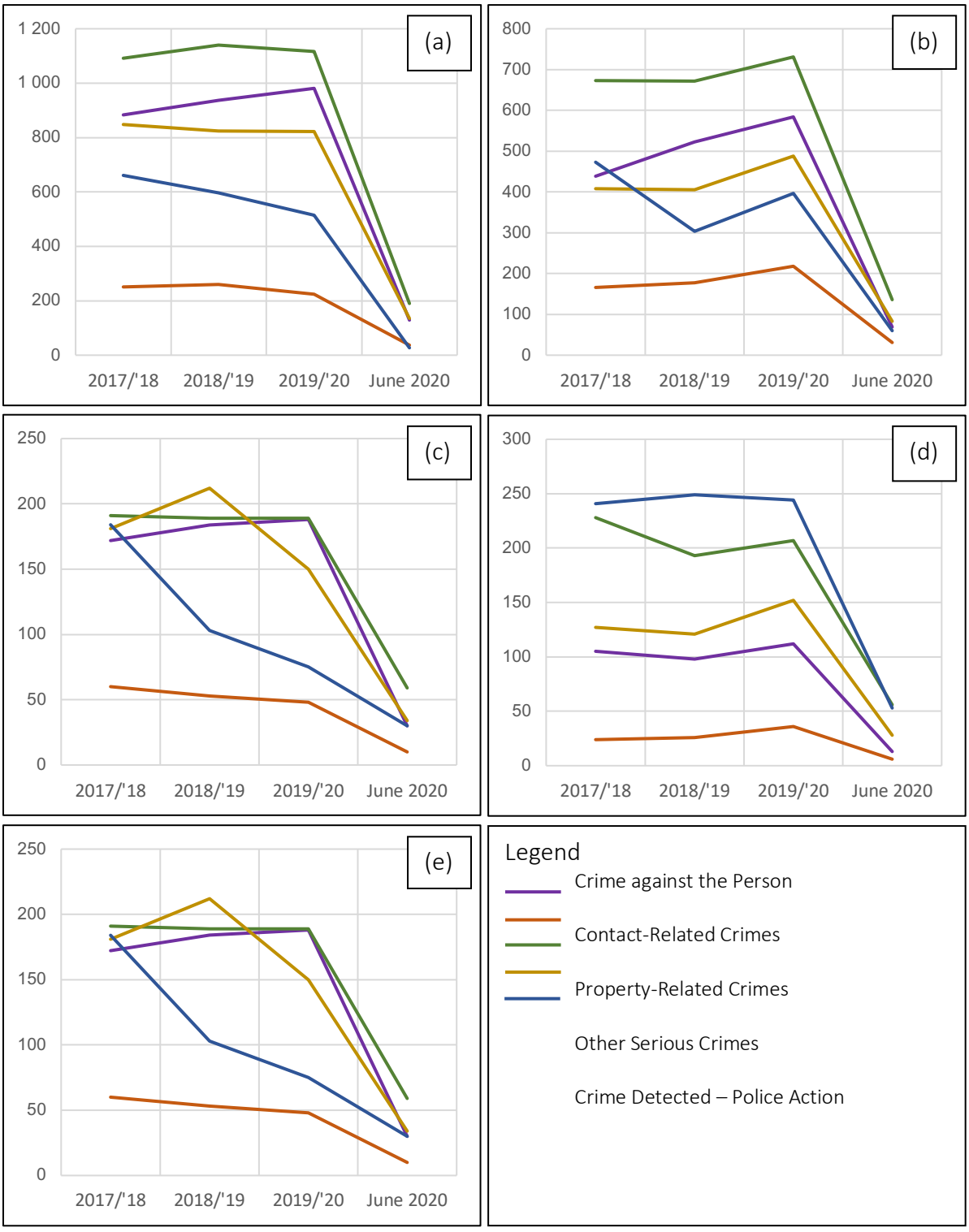
Table 5 shows a comparison between the different crime categories over the two periods under investigation. Three categories showed increases (red) and only two categories recorded a decrease (green). 'Contact crimes (crime against the person)' and 'crime detected as a result of police action' decreased by 3.9% and 4.7%, respectively. But, 'property-related crimes' increased by an exceptional 6.5%, 'other serious crimes' increased by 1.8%, and 'contact-related crimes' increased by 0.2%.

Table 5: Differences in crime rates per town between the three-year period before the lockdown and the first three months of the lockdown

	Crime Categories				
Period	Contact Crime against Person	Contact Crimes	Property Crime	Other Serious Crimes	Crimes as a Result of Police Action
Three-year period before the lockdown	5 427 (23.5%)	1 598 (6.8%)	6 818 (29.5%)	4 876 (20.9%)	4 428 (19.3%)
First three months of the lockdown	248 (19.6%)	89 (7.0%)	456 (36%)	287 (22.7%)	186 (14.7%)
Differences in Crime (%)	3.9%	-0.2%	-6.5%	-1.8%	4.7%

The increase in 'property-related crimes' is unexpected because during C-19 lockdown, especially levels 4 and 5, people's movement was restricted and they were confined to their residence, which might have deterred criminals from committing common property-related crimes, such as domestic burglaries because residents were at home. Conversely, because people were at home places of work were left unoccupied and vulnerable to criminal activities. Around the country businesses and schools were burgled and vandalised during, and as a result of lockdown restrictions.[84] The effect of the COVID-19 pandemic and South African lockdown regulations for all crime activities for each town in the SBM is clearly visible on the graphs in Figure 4.

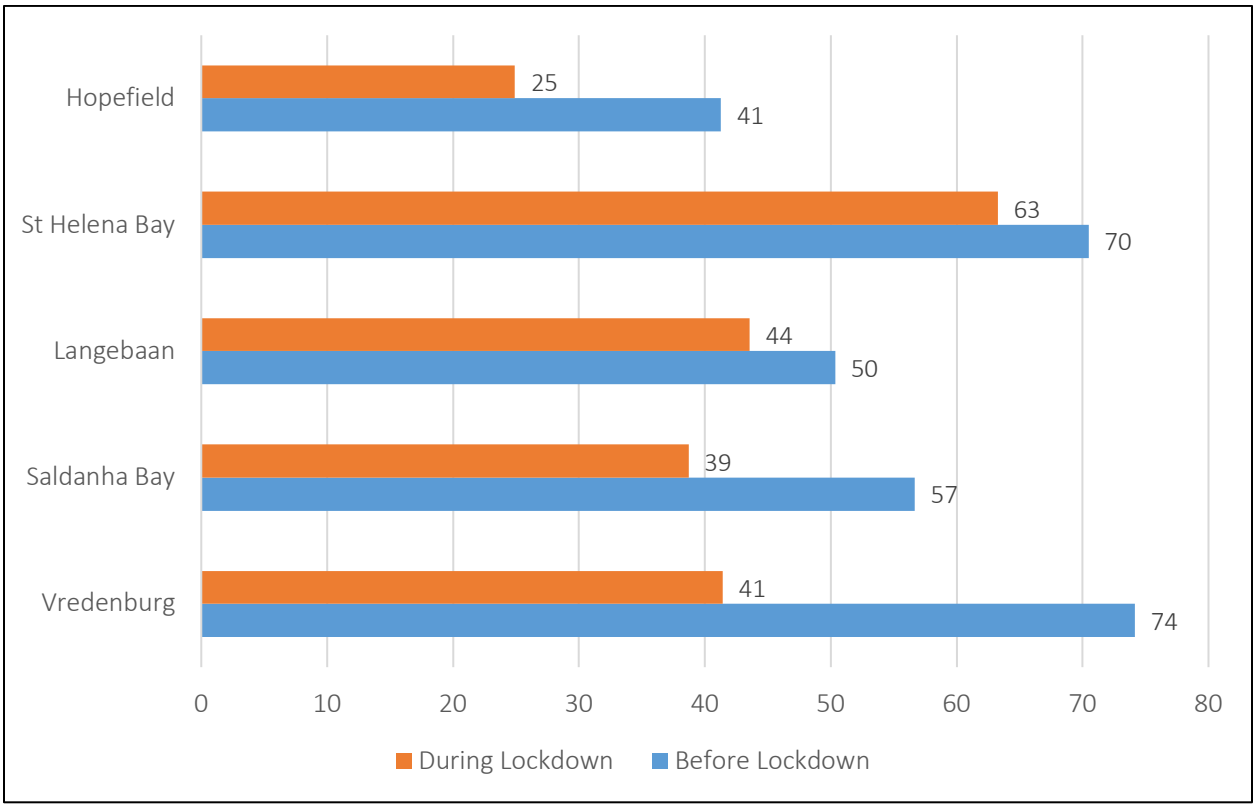
Figure 4: Trends in crime totals for the five different crime categories in the different towns of the SBM: April 2017 to June 2020



(a) Vredenburg (b) Saldanha Bay (c) St Helena Bay (d) Langebaan (e) Hopefield

The decreasing trends illustrated by the graphs in Figure 4 should not be taken at face value. The effect of the COVID-19 lockdown is based exclusively on the three-month totals compared against the total crude numbers for each crime category over the three-year period preceding the lockdown. However, it is interesting to compare the annual mean crime rate per 1 000 population for each town, which is graphically displayed in Figure 5. We observe notable differences across these SBM towns' crime rates before and during the lockdown. Overall, the crime rates decreased across all towns because of the COVID-19 lockdown and a significant decrease is indicated for Vredenburg, which moved from being the highest ranked to ranked third in terms of crime committed in the SBM. St Helena Bay is ranked highest and Hopefield was still the town with the lowest mean crime rate during the said period.

Figure 5: Annual mean crime rate per 1 000 population, before and during the lockdown per town



Discussion and conclusion

Using crime data and the spatial location of where each crime activity had occurred, this study filled a research gap visually presenting the crime data of the SBM area for easy recognition of high crime spots. The study reported on the crime trends in the SBM area over the past three years and highlighted the locations where the clusters of crime activities were concentrated. It also demonstrated the innovative application of mapping to crime hotspots using the Getis-Ord Gi* statistical tool of the ArcGIS software, to indicate the hotspots and coldspots of crime concentrations.

The results show that the main crime hotspot is located in Vredenburg and the main coldspot is in Langebaan (Figure 3). St Helena Bay exhibits low counts of crime in close succession with short incident durations while Saldanha Bay, Paternoster, Jacobs Bay and Hopefield have random distributions (no significant spatial clustering of crime exists). The hotspot analysis map confirmed the statistically significant cluster of crime in Vredenburg, St Helena Bay and Langebaan, which have higher populations than Paternoster, Jacobs Bay and Hopefield. While one should be cautious of the assumption that high crime activity clusters will always occur in, and are linked to, urban centres, this comports with findings from previous studies that links the increase in urbanisation around the world and crime in these areas.[85] Although this relationship is partially confirmed by the results of this study – Saldanha Bay shows no significant spatial clustering of crime, assumptions still need to be scrutinised to link crime to urban centres. It is therefore important to analyse results by considering the population ratios against total crime for any particular region. Even though the link between crime and population concentrations were made by this study and are indicated by the mean crime rate per 1 000 population for each town, more research on the possible correlation between crime and population concentrations in the SBM is needed.

Analysing the absolute reported crime totals for each town in SBM over the first three-months of the lockdown and comparing these totals to the three-year period totals, a slightly different picture emerges (Tables 4 and 5). Crimes decreased in Vredenburg and Hopefield, but increased in Saldanha Bay, Langebaan, and St Helena Bay. Except for 'contact crimes (crime against the person)' and 'crime detected as a result of police action' which decreased by 3.9% and 4.7%, respectively, all other crime categories increased during the first three-months of the lockdown. 'Property-related crimes' showed the biggest increase at 6.5%, which might be attributed to the reduction in guardianship of businesses because of the restricted movement of people and closure of non-essential businesses during the initial stages of the national lockdown. Residential properties are also considered soft targets for criminals and in SBM many residential properties are holiday homes which are vacant for much of the year, especially in the coastal towns of Langebaan, St Helena Bay, Jacobs Bay and Paternoster. Results confirm that crime trends fluctuated in the SBM during the national lockdown as the nature of social life changed. The results

showed that crime increased and decreased, which opportunity theorists explain as a characteristic of crime that depends 'on the opportunity structure and the character of the exceptional event',[86] such as the COVID-19 pandemic and consequent lockdown restrictions.

The results of this study correspond well with the findings of other national and international studies on the effect of COVID-19-related restrictions on crime rates. Almost all studies show that crime overall decreased in urban centres, which comports with the decrease in crime rates for Vredenburg and Saldanha Bay in this study. Considering the limited national research that exists regarding the effect of the COVID-19 pandemic and consequent lockdown restrictions implemented in South Africa and their effect on crime, opportunities exist to explore this phenomenon much further, not only on a local or regional scale, but within a national context.

The effects of the COVID-19 pandemic and South African lockdown regulations on the crime rate in the SBM, are illustrated explicitly in this study (Tables 4 and 5; Figures 4 and 5). These show that a total of 23 147 crimes were reported for all towns in the SBM for the three-year period before the lockdown, and 1 266 crimes were reported during the first three months of the lockdown. Only Vredenburg and Hopefield recorded decreases in crime rates per town during the first three months of the lockdown, while St Helena Bay, Langebaan and Saldanha Bay recorded increases. Only 'contact crimes (crime against the person)' and 'crime detected as a result of police action' decreased, while 'property-related crimes', 'other serious crimes', and 'contact-related crimes' increased. Notably, in general no change was recorded for crime overall for all towns in the SBM during the first three months of the lockdown when compared to the three-year period before the lockdown.

Drastic decreases are shown in the trends in crime totals as a result of the first three months of the lockdown (Figure 4). Considering the mean crime rate per 1 000 population per town (Figure 5), Vredenburg, which notably has the highest population total and was ranked highest in terms of crime rates prior to the lockdown, moved from first to third (amongst the five towns), behind Langebaan and St Helena Bay. Similarly, Saldanha Bay with the second highest population total moved down to fourth. Hopefield was still the town with the lowest mean crime rate during the said period.

It is worth mentioning that none of the police stations in the SBM were amongst the 30 highest-crime police stations in South Africa.[87] Hence, the SBM can be regarded as a comparatively low crime prevalence area and the effect of the COVID-19 lockdown restrictions on crime might look very different for other medium to high crime prevalence areas in South Africa. It would be interesting to conduct a follow-up study on the impact of the COVID-19 pandemic and lockdown restrictions on crime in elsewhere in South Africa. This will provide a more accurate and comprehensive picture of the effect of the COVID-19

lockdown restrictions on the occurrence of crime. It would also be helpful to conduct a follow-up study after lockdown restrictions have been lifted to investigate the total impact of the pandemic on crime.

In conclusion, this study advanced our knowledge and understanding of the spatial distribution and trends of crime in the SBM area during the period April 2017 to March 2020, and the relationship between the COVID-19 pandemic and crime in the SBM during the first three months of South Africa's national lockdown. Hotspot mapping with the use of the ArcGIS Getis-Ord Gi* statistics tool presented the clusters of crime for this study, and tables and graphs indicated crime trends. The results of this study should be utilised by police, crime prevention practitioners and other interested groups to concentrate resources on crime problems in the region. Through hotspot crime mapping it is easy to recognise, visualise and analyse crime activity patterns and researchers should continue to conduct similar studies by utilising geospatial data for real-world problem solving which could have positive effects on crime management and prevention strategies within society.

Notes

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