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More than an Offender Location Tool: Geographic Profiling and Body Deposition Sites

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Abstract
In homicide cases, it is difficult to provide resolution for the bereaved or to obtain a successful criminal conviction of the guilty party when no body is found. Since the mid-nineteenth century, geographic and environmental patterns have been used to better understand the relationship between crime and its environment. Now known as geographic profiling, practitioners in this field amalgamate criminological, psychological, and geographical knowledge, as well as aspects of mathematics, statistics, and physics to identify spatial patterns associated with criminal behaviour as a means of locating anchor points of an offender (where they live, or work). The same techniques can also be used to locate the covert body deposition sites of their victims. This paper aims to (1) provide a brief summary of criminal behaviour and the environment and how understanding their relationship can be helpful to geographic profiling, (2) amalgamate the available literature on the application of geographic profiling in locating clandestine graves (as most documented uses are to locate offender residences), and (3) include a geographic profile of Ivan Milat, an Australian serial killer (officially) active from 1989 to 1992, demonstrating how geographic profiling techniques can help to identify additional victims and potential body deposition sites. The information in this review will be helpful to law enforcement and practitioners to improve missing persons investigations and searches for clandestine graves.

Keywords Geographic profiling · Clandestine grave · Body deposition site · Missing person · Ivan Milat

Introduction

Since the mid-nineteenth century, geographic and environmental patterns have been used to analyse the relationship between crime and its environment (Nichols 2019; in-depth discussion also in Weisburd 2015). In the 1970s, the term 'geographic profiling' was used to describe the analysis of the spatial patterns of serial offenders to locate a perpetrator's residence (Nichols 2019; Rossmo 1995, 1999; Snook et al. 2005b), later expanded to include an offender's anchor points, such as where they work (Downs 2016). This investigative method was developed to examine the spatial patterns that result from a perpetrator's 'hunting' behaviour and target locations (Rossmo 1995; Ruffell and McKinley 2014). In the 1990s, law enforcement agencies began to use spatial data to see patterns and connections between serial crimes and their geographic locations (Nichols 2019; Rossmo 1995, 1999). Today, geographic profilers, or alternatively geo-environmental profilers, use spatial, temporal, environmental, and geographic (STEG) information to locate body deposition sites (BDSs), as well as the more traditional application of locating a perpetrator's residence (or other anchor points). As such, geographic profiling is a multi-faceted investigative technique, as it calls upon the knowledge of criminology, psychology, and geography, as well as mathematics, statistics, and physics, and can be applied in a legal setting (Barone et al. 2021; Rossmo 1999).

The purpose of this review is to amalgamate the available literature on the application of geographic profiling to clandestine grave location (also referred to as BDSs). This article is novel, not only because geographic profiling is used more often to locate an offender's workplace or residence as opposed to clandestine graves, but also because a review such as this has never been done. This review commences with a brief discussion on criminal behaviour and

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the environment and how understanding their relationship can be helpful to geographic profiling. It then discusses the STEG elements, as well as other important intelligence such as case-specific information, technology, predictive modelling, and offender profiles that can be helpful when locating covert graves. Finally, this information is brought together with a geographic profile of Ivan Milat, an Australian serial killer (officially) active from 1989 to 1992 (Mallett 2019), who is a very good example to illustrate how an offender uses space. Milat was arrested in 1994 and died in prison in 2019 (Mallett 2019) after being found guilty of seven murders, but it is highly likely that he is responsible for additional murders not yet attributed to him. Therefore, creating a geographic profile of this offender has allowed for other potential victims and BDSs to be linked to him, providing a path to resolution to the victims' families as well as to law enforcement (EQ Media & Bannaby Productions 2021).

Clandestine graves (defined as any burial containing one to four human beings that is created to conceal a crime; Christensen et al. 2019; Dupras et al. 2011) are, by design, difficult to find (Keatley et al. 2021). This can be exacerbated by post-burial alterations, destruction, and/or lack of/poor intelligence (Congram 2010), even though data suggests that the majority are only 0.5 m deep (Pringle et al. 2008). The inability to locate those who are missing has important personal and legal ramifications. For family and friends, the psychological and emotional consequences of not knowing what has happened to their loved ones are significant (Lenferink et al. 2019). Even with the presumption that their loved one is deceased, many people find it hard to move on without the confirmation provided by locating a body (Lenferink et al. 2019). From a legal standpoint, it is particularly difficult to achieve a successful conviction in murder cases where no body has been recovered[1] (Keatley et al. 2021), and when this has been achieved, significant additional circumstantial evidence is required.

Historically, it would only be the police who were involved in locating clandestine graves; however, their collaboration with various field experts (usually on a consultancy basis) has become more common since the 1950s and 1960s (Golda 2010; Kania 1983; Ruffell and McKinley 2014). For example, in cases where a search, recovery, and identification of an individual are necessary, a forensic anthropologist or archaeologist may be beneficial (Blau 2009; Christensen et al. 2019; Ubelaker et al. 2019). In recent years, for missing persons' cases, a geographic profiler may be called upon to lend expertise to an investigation. Provided with specific case intelligence, witness statements, and the STEG elements, a geographic profiler can compile a map indicating potential BDSs. These maps should be used as a guiding tool for law enforcement (Rossmo 1999) or relevant experts to increase the chances of locating clandestine graves.

Criminal Behaviour and the Environment

The study of crime site geography (Brantingham and Brantingham 1981) combines the concepts of opportunity, motivation, mobility, and perception and determines that although crime may seem chaotic and unstructured, there is an underlying rationality influencing the geography of its occurrences (Bernasco et al. 2017; Chainey and Muggah 2020; Chainey and Ratcliffe 2013; Curtis-Ham et al. 2020; Harrison and Donnelly 2009; Rossmo 1999; Weisburd 2015). The ability to locate an offender based on their offending habits can be explained by Brantingham and Brantingham (1981) in seven general hypotheses:

1. The source, strength, and character of the motivations that encourage criminals to commit certain offenses will vary.
2. Regardless of the motivations, the actual act of committing a crime is the result of a multistage decision process concerning the environment, target, and time of offence.
3. The environment in which a criminal act takes place will emit cues based on its physical, spatial, cultural, legal, and psychological characteristics.
4. An offender will be informed by those cues to locate victims.
5. As an offender commits more criminal acts, the cues or cluster of cues used to identify a victim will be categorized as 'good' or 'bad' and will become the offender's template.
6. Once the template is established, it becomes fixed.
7. Although victim templates will vary by offender, a specific offender's template can be identified because human environmental perception has universal properties, and the spatial and temporal distribution of offenders and victims is clustered and patterned.

The selection characteristics of both the victim and the environment will be identifiable to each offender (Harrison and Donnelly 2009; Larson et al. 2011; Rossmo 1999). Research has shown that offenders perpetrate criminal activity in an environment that is familiar to them (Curtis-Ham et al. 2020; Lundrigan and Canter 2001a; Rossmo 1999). Offenders often feel most comfortable within the geographic areas in which they reside or work, making this the most likely place for them to perpetrate crime (Rossmo 1999). Despite this, most

[1] As an example, the Australian killer Bradley Robert Edwards, also known as the Claremont killer, was arrested in 2016 after being suspected of killing three women in 1996 and 1997; however, only two of the victim's bodies have been found (Mayes 2020a). As a result, in 2020, Edwards was only found guilty of the murders of the two young woman whose bodies were found (Mayes 2020b).

serial offenders, especially those of violent crimes (like sexual assault and murder), will not offend directly around their residence or workplaces as this may increase their chances of being caught (Lundrigan and Canter 2001a; Rossmo 1995, 1999). This is called a 'buffer zone' or 'safety zone', wherein the perceived risk is too high and victims in this area are therefore seen as undesirable (Rossmo 1999).

Canter and Larkin (1993) coined the 'Circle Theory of Environmental Range', which utilizes the geographic locations of an offender's known crimes to predict their residence. The locations of the crimes and the offender's residence are referred to as the criminal range, and the theory has been tested in at least three counties including the UK, Australia, and the USA (Canter and Larkin 1993; Godwin and Canter 1997; Kocsis and Irwin 1997). Research has shown that serial murderers have a criminal range of 9 to 40 km and that the location of BDS is often a greater distance from the offender's residence than where the murder has taken place (Lundrigan and Canter 2001a, b; Rossmo 1995). Other types of offenders, including serial burglars, sexual assault/rapists, and thieves, maintain a mean distance of approximately 5 km between their residence and target offending location(s) (Rossmo 1995; Snook et al. 2005a). The notion that an offender is more likely to select a target close to their residence (or other anchor points) has been strengthened by the replication of similar research around the world, from the early 1930s up to present (Baldwin et al. 1976; Canter and Larkin 1993; Capone and Nichols 1975; Curtis-Ham et al. 2020, 2021; Downs 2016; Godwin and Canter 1997; Johnson 2013; Kocsis and Irwin 1997; Kuralarasan and Bernasco 2021; Menting et al. 2020; Rhodes and Conley 2008; Snook et al. 2005a; Van Koppen and Jansen 1998; White 1932).

Offenders often make choices between their routine activities, such as perpetrating near their residence or workplace, and the rational decisions necessary to avoid detection, such as perpetrating within a larger range wherein their anchor points are outside of the offending/deposition areas (Clarke and Felson 1993; Cornish and Clarke 1987; Lundrigan and Canter 2001a). The routine activities may be more comfortable for them; however, it could also increase their chances of being apprehended. This can also be examined through a routine activity approach, explaining the relationship between geography and crimes rates. In doing so, Cohen and Felson (1979) found that the dispersion of activities away from households may increase an offender's opportunity to commit crime and may explain the (higher) crime rates in certain areas. Understanding the spatial behaviour of a serial offender can help police investigations in many ways, including pinpointing an offender's anchor points (home or work), a prioritization of suspects by residential area, an augmentation of psychological profiles with information on offender movement, geographically directed patrol efforts, computer database searches by address or postal code, information mail outs, and DNA dragnets (Chainey and Muggah 2020; Congram 2016; Rich and Shively 2004; Rossmo 1999, 2005).

Hypothetically, an offender's residence is at the centre of a crime pattern and can be approximated by the spatial mean (i.e. the circle theory; Snook et al. 2005b); however, this is rarely the case in practice due to the influence of a range of variables (Brantingham and Brantingham 1981; Rossmo 1999). Although crime mapping for the purposes of spatial analyses was first introduced by Guerry (1833, 2002) and Quetelet (1842, 1994) in the early 1800s, it was not until 1996 when the National Institute of Justice (NIJ) officially requested a mapping tool to analyse the links between offenders and their crime locations (Nichols 2019). Subsequently, several geographic profiling software programs were created, such as CrimeStat, Rigel Analyst, Criminal Geographic Targeting, Dragnet, and Predator (ECRI 2021; Godwin 2021; Levine 2006, 2017; Nichols 2019; Rich and Shively 2004). Each software program functions slightly differently; however, in general, they create a map depicting the sites of interest and the means and distances to create a circle (relating to the circle theory of environmental range; Nichols 2019). Many factors are taken into account to generate the circle, including the development of the offender's crimes, their age, intellectual capability, employment and marital status, motive, and their mode of transportation (Snook et al. 2005a).

Popular software like Rigel Analyst, CrimeStat, and Dragnet produce similar outputs, as they are based on a distance decay algorithm (Canter et al. 2000; Canter and Hammond 2006; Rich and Shively 2004). After incorporating important offender information (a non-exhaustive list included above), the software places a grid over an area of interest and then calculates the likelihood that the offender's anchor point is within each grid square (Rich and Shively 2004). Some software programs, such as CrimeStat, include an extra step wherein the data is imported into a Geographic Information System (GIS), such as ArcGIS, that can then overlay streets and landmarks, which may be of interest to the investigation (Nichols 2019; Rich and Shively 2004). These software programs can be useful to law enforcement to aid in their investigations (Spaulding and Morris 2021); however, as there are multiple software programs to choose from, with a price range between $0 and $60,000 (USD), there is little information available to assist with a decision as to which program to select (Rich and Shively 2004). To remedy this, Rich and Shively (2004) compiled a report for the NIJ based on the expertise of several geographic profiling experts aiding law enforcement (and other interested parties) in how to best choose a geographic profiling software. The purpose of the expert panel was to develop a method to rigorously test geographic profiling software,

with law enforcement being the main audience (Rich and Shively 2004; Rossmo 2005). This report contains a detailed feature comparison of various software programs and then an evaluation of CrimeStat, Dragnet, and Rigel Analyst based on output accuracy, user feedback, a feature analysis, and a summary of the deliverables (Rich and Shively 2004).

Shortly after this report was released, a well-known expert in the field of geographic profiling, Rossmo (2005), released a response to the NIJ's report highlighting errors involving the output accuracy performance measurements. More specifically, it was stated that of the five measures being tested (error distance, search cost/hit score, profile error distance, top profile area, and profile accuracy), only search cost/hit score (ratio of the area searched prior to locating the offender's anchor point, to the whole hunting area—a smaller ratio means a more focused geographic profile) was suitable to assess the accuracy (Rossmo 2005). It was stated that error distance, a problematic measurement in which the other three performance measurements are based off, is ultimately flawed because it does not capture how geographic profiling software actually works (*ibid.*). Error distance simplifies a geographic profile to a single point in which to base the distance from and does not capture the non-uniform, often eccentric patterns of an offender's search. To get a meaningful output, the software needs to respect the limitations and assumptions of geographic profiling and measure the actual function of a geographic profile (*ibid.*). Ultimately, the statistical model must correspond with the theoretical model, and any deviation can result in decreased profile accuracies and/or or inference validities (*ibid.*).

Geographic Profiling Techniques Used to Locate Clandestine Graves

Geographic profiling combines aspects of environmental criminology, as well as rational choice and routine activity theories. It is traditionally applied to locating an offender's anchor point and abides by four main assumptions (Rossmo 2005):

1. Serial offender with at least five crimes.
2. Offender has single, stable anchor point.
3. Offender follows appropriate hunting method.
4. Target/victim backcloth is mostly uniform.

In recent years however, geographic profiling techniques have been applied to the location of clandestine graves (see Keatley et al. 2021; Lundrigan and Canter 2001a, b; Moses 2019; Somma et al. 2018). This recent application does not strictly abide to the above four assumptions, as the goal is to locate the BDSs and not necessarily where the offender's anchor points are. Instead, it will collate intelligence gathered by the police, in conjunction with STEG[2] logistics of an area of interest, to map potential BDSs. Ultimately, individuals interact with their surrounding environments in patterned, non-random ways (Curtis-Ham et al. 2020), making it possible to predict burial site location (Congram et al. 2017; Lundrigan and Canter 2001a). Key variables in predicting burial location are the motivation behind the crime, the environment, the time spent with the victim(s), and the need to avoid detection (Congram et al. 2017; Lundrigan and Canter 2001a). The environmental aspects and time spent with the victim(s) will be discussed below; however, the motivation behind a crime can dictate how the victim is disposed of. For instance, premeditation can indicate that the BDS will have some type of meaning to the offender or at least planning to minimize detection, whereas in an impulsive crime, the goal is the get rid of the body as quickly as possible.

Intelligence

Case-Specific Information

Case-specific information is vital when creating an accurate map of potential BDSs. Important information when creating a geographic profile includes when and where the victim was last seen, the victim's last known position, the residences and workplaces of potential suspects (anchor points), locations that the offender and victim frequented, the potential routes taken to and from each point of interest, physical and mental barriers such as highways and rivers, and the activities undertaken by both the offender and the victim on the day of disappearance (Keppel and Weis 1994). This information is typically obtained by the police during the investigation, from as early as the initial missing person's report to interviewing victims, family members/friends, witnesses, and potential suspects (Barone et al. 2021; Broadbent et al. 2018; Gardner and Krouskup 2018; Keatley 2018; Keppel and Weis 1994; Morewitz and Colls 2016). Other relevant information can include a victim profile, which is not used to identify who the victim is (as this is usually known), but to identify what may have happened to them, based on their known psychological well-being and lifestyle choices (Foy 2016; Keatley 2018).

[2] It is important to note that the spatial, temporal, and environmental factors discussed are all influenced and governed by the surrounding geographic area; thus important geographic elements are linked to the spatial, temporal, and environmental elements and will not be discussed on its own.

Spatial

An important consideration when choosing a location for body deposition is finding discrete yet accessible locations, such as secluded areas that are only reachable by artificial light, as well those close to and downhill from a road (Killam 2004). Other spatial variables to be taken into account include the distance from each of the anchor points, the potential travel routes that could have been taken, physical barriers such as rivers or highways, the activity space (area known to offender), the awareness space (area just outside of activity space), and the places that were visited by both the offender and the victim(s).

Temporal

There are multiple factors of time that will impact an offender's choice in where to dispose of a body, including the time of year, month, week, and day (Bernasco et al. 2017); the time since the victim's disappearance; and the amount of time that the offender took to dispose of the body. For time of year, in places that experience adverse weather conditions such as extreme cold, it is unlikely that an offender will be able to bury a body when the ground is frozen. Specific times of the month or week will also be more likely, due to work and personal schedules, such as pay day or days off. As for time of day, there is always a trade-off between the ease of depositing a body in the daytime versus the protection from observation afforded by night-time. The duration of time since the victim(s) disappearance is also important because of the increased opportunity for the environment to change. Finally, the time it takes the offender to deposit the victim(s) is vital because the level of risk will increase when the amount of time spent with the victim increases, as there will be more time that the offender must account for if questioned. The time that the offender spends with the victim will affect the areas of interest for BDSs, as it can dictate the distance from an offender's anchor points—i.e. how far outside of their 'buffer zone' could they have travelled in the unaccounted—for time.

Environmental

Offenders will commonly deposit their victims in areas that are known to them, usually close to one of their anchor points (Lundrigan and Canter 2001a, b) although meaningful areas to the victims may also be important. To locate specific BDSs within an activity space, environmental cues (also known as geomorphological information), such as changes in soil colour, the presence of soil depressions or mounds, the presence of leaves mixed in with the soil, a lack of plant growth in a concentrated area, or a change in the dominant plant species, are important factors (Keatley et al. 2021; Morgan and Bull 2007; Owsley 1995; Pringle et al. 2012; Skinner et al. 2003). Keatley et al. (2021) state that the soil strata or horizons that are disrupted and comingled from digging a grave rarely return to a complete homogeneous mixture, resulting in visible soil colour changes, depressions, mounds, and excess dirt. France et al. (1992) highlight five main points related to the vegetation changes associated with clandestine graves, which include that the act of digging a grave will destroy the surrounding vegetation, plants that are native to the area will grow back first, the vegetation type and growth will change as time goes on, the grave site will look different than the surrounding area (potentially for years, depending on the chosen site and ecosystem), and finally, that knowledge of the native plant species in the area is highly beneficial when searching for clandestine graves, especially when the site looks relatively undisturbed. Molina et al. (2020) were successful in utilizing soil and vegetation indicators (in conjunction with general land reconnaissance and geophysical techniques) to locate a clandestine grave in Colombia (discussed further below). In addition to above ground soil changes, the creation of clandestine graves can also create subsurface soil changes, which are vital not only to the creation of a geographic profile, but to its validation when using technology and various search techniques to locate the BDSs identified in the geographic profile.

Technology and Predictive Modelling

To compile a geographic profile, practitioners can rely on various technologies to locate areas of interest, including BDSs. These technologies include aerial photography, global positioning systems (GPS) data, drone-based photography, infrared photography, satellite imagery, and geophysical techniques. The outputs of these technologies can then be compiled in a Geographic Information System (GIS) that can be visually analysed for spatial patterns, highlighting further BDSs. It is important to note that the above-mentioned technologies can be helpful in both the creation stage of the geographic profile, but also in its validation by law enforcement/search personnel when searching for clandestine graves. Like other scientific applications to investigative work, the quality of the final output will depend on the quality of the information input: In colloquial terms, rubbish in, rubbish out (Congram et al. 2017; Ruffell and McKinley 2014). This concept also applies to the geographic profile final report, as it is entirely dependent on the quality of the information used to compile it (Barone et al. 2021). To ensure the most accurate output, the use of good quality, high resolution, and corroborated data must be used (Congram et al. 2017).

Aerial photographs have been used as a reconnaissance tool by police officers when searching for clandestine burials as the technique is able to highlight and prioritize areas of interest (Donnelly and Harrison 2013; Evers and Masters 2018). Brilis et al. (2000) tested its use, along with topographic mapping and photogrammetry to visualize the spatial relationships between natural and man-made features during environmental investigations including clandestine graves (Morgan and Bull 2007). Grip et al. (2000) furthered this research and created photogrammetric models of the aerial photographs to allow for a detailed interpretation and cataloguing of important features. Along with aerial imaging, Brilis et al. (2001) demonstrated the usefulness of using GIS and GPS in environmental investigations, which are two technologies used in geographic profiling as well.

Pensieri et al. (2020) demonstrated the advantage of using drone-based photography to aid in locating active missing persons (those presumed alive) as well as searching for clandestine burials. This work highlighted that drones have the capacity to search large areas in a short amount of time, reducing the time, person power, and other resources spent searching, especially when there is a risk of harm due to dangerous terrains (Pensieri et al. 2020). Similarly, Evers and Masters (2018) demonstrated the use of a drone-like technique (referred to as an unmanned aerial vehicle), with near-infrared technology attached to search for clandestine burials. In general, infrared photography can highlight heat emissions, which can be helpful when searching for the graves of individuals who have not been missing long and are still in active decomposition (Ruffell and McKinley 2008). The authors found that the combined technique was able to detect soil and vegetation disturbances, compared to non-disturbed areas (Evers and Masters 2018). Although this technique is not commonly used, the results, combined with its low-cost, rapid survey, and non-destructive nature, highlight its merit in forensic investigations (Evers and Masters 2018). Satellite imaging has also proven useful as it can pinpoint areas of interest based on ground topography and vegetation growth, narrowing down large search areas in a short amount of time (Kalacska and Bell 2006; Kalacska et al. 2009; Ruffell and McKinley 2008).

Finally, geophysical techniques can also be used to highlight potential areas of interest relevant to a geographic profile. Berezowski et al. (2021) and Moffat (2015) provide a review of various geophysical techniques that can identify the difference between disturbed and undisturbed soils relevant to the creation of clandestine graves. Molina et al. (2020) demonstrate the use of a geophysical technique (electrical resistivity tomography—ERT), in conjunction with geomorphology, and GIS in a real forensic case. The authors utilized witness statements, survivor testimonies, and known areas of activity to narrow down two search areas and then used general land reconnaissance techniques, soil, and vegetation indicators, and ERT to locate clandestine graves (Molina et al. 2020). Although only one of the two sites was successful in locating the missing individuals, this case highlights the merit in using a multi-disciplinary approach that included geographic profiling techniques.

Once all the information has been collected, GIS can be used to compile and collate it. GIS can create analytical models from a wide array of data gathering instruments including aerial photography, satellite imagery, surveying equipment including GPS, and even witness testimony (Congram et al. 2017; Convergne and Snyder 2015; De Vos et al. 2008; Madden and Ross 2009; Molina et al. 2020). GIS (including the freely available platform Google Earth) visually displays multiple sources of data as different layers, which can provide situational awareness and can identify relationships, patterns, and processes by overlaying data and tracking their changes over time (Congram et al. 2017; Convergne and Snyder 2015; McKinley et al. 2009). The organizing principle for all GIS data is their geographic location, and when mapping burials, important features can be plotted as vectors into a geographic reference system (i.e. latitude and longitude), which is linked to the other layers of data within the GIS model (e.g. topographic, roads, land use, hospitals, military facilities, vegetation, and transport networks; Congram et al. 2017; Molina et al. 2020). The information collected from locating areas of interest (listed above) can be used as layers in the GIS model, enhancing not only the predictive site modelling but the final geographic profile as well.

Once the STEG data has been collated (often with the technologies detailed above), predictive modelling techniques, also known as Predictive Spatial and Statistical Modelling or MESP, can be used to predict potential gravesites based on the information included in the GIS model (Molina et al. 2020). Geographic profiling software such as CrimeStat, Dragnet, and Rigel Analyst are capable of this (view Rich and Shively 2004 for a brief overview of how the popular software's function). Certain analytical techniques, such as Maximum Entropy Modelling (Phillips et al. 2021) and distance decay algorithms, will take all variables related to the case and will identify likely areas that may contain gravesites, based on statistical probabilities (Fitterer et al. 2015; Molina et al. 2020; O'Leary 2009; Rich and Shively 2004). These likely sites are then given to those responsible for the search of the missing individual(s) to further guide the investigation.

The accuracy of the predictive models generated from geographic profiling software is difficult to calculate for four main reasons. Firstly, each case is different, and although there are similar types of offenders (i.e. marauders, offender who hunts outward from an anchor point but stays within their activity space, and commuters/travellers, offender who

travels outside of their activity space, creating a buffer zone to avoid detection), software will not always be able to correctly locate an offender's anchor point (Rich and Shively 2004). This is especially relevant for offenders who are considered commuters/travellers because their crime locations will be outside of and away from their anchor points (Canter 2003, 2004; Rich and Shively 2004). Secondly, the software's ability to locate an offender's anchor point is contingent on the quality of the information utilized (Rich and Shively 2004). More specifically, if the program is fed information pertaining to other serial offenders, as linking cases to a single offender is challenging, the program may not be able to correctly identify an anchor point (Rich and Shively 2004; Rossmo 2005). Thirdly, the accuracy of the predicted model will be contingent on the number of data points; therefore if the offender has not committed many crimes, or there are not many points of interest related to the victim or offender, the resulting profile may not be as accurate. Fourthly, if law enforcement has hired a geographic profiling consultant (as opposed to using the software themselves), the investigators may not share the results of the search, thus being unable to corroborate the accuracy of the profile.

Although calculating the accuracy of a specific profile may be difficult, there are two main methods to test the precision of geographic profiling software. Firstly, Monte Carlo simulation techniques test the software's expected performance on simulated point patterns representative of serial crime locations (Rossmo 2005). Although this method can generate high numbers of data cases, the algorithm's underlying assumptions do not reflect those of all serial crimes, and the addition of case-specific information is not incorporated (*ibid.*). Secondly, solved cases can be examined with geographic profiling software, assessing if the anchor points or areas of interest are correctly identified (*ibid.*). Although this is the most common method, there is an inherent sampling bias and requires large amounts of data review (*ibid.*). Rossmo (2005) identified a third method, which entailed using the software on an unsolved case; however, as stated above, this could be problematic if the results of the case are not shared (*ibid.*). It would also be time-consuming, as this method requires the case to be solved, which can range anywhere from weeks to years (*ibid.*).

Offender Profile (Including Victimology)

Creating a criminal profile of the offender (referred to as an offender profile), as well as the specific victimological aspects (referred to as a victim profile), using psychological and criminological techniques, can also make an important contribution to geographic profiling (Kocsis 2006). Understanding the mindset, motivation(s), and lifestyle of the offender can help to identify important aspects of the crime(s), such as potential BDSs (Keatley 2018; Petherick and Brooks 2020). Similarly, understanding how the offender identifies with their victims (lending to levels of remorse felt by the offender) can also help to narrow down potential BDSs (Labuschagne 2006; Salfati et al. 2015). For example, the BDS of a victim where the offender felt zero remorse (i.e. left at a rubbish tip) may be different to that where the offender felt highly remorseful (i.e. buried with a meaningful object or closed the victims' eyes). Victim demographics, such as sex, age, and socioeconomic status will also be helpful when grouping multiple crimes by the same offender (Farrington and Lambert 2018; Harding 2021).

Discussion

In clandestine grave situations, an offender will usually choose a body deposition site that minimizes the likelihood of apprehension (Lundrigan and Canter 2001a, b). The site is not always the same as where the victim was killed, but it may be an important location to the offender (Lundrigan and Canter 2001b). Lundrigan and Canter (2001a) found that although most of the BDSs were within the 'disposal domain' (an area described as bearing a strong relationship to the offender's home), because it is considered a familiar area based on activity patterns, those that were outside were most likely to minimize the risk and maximize the benefit to themselves. Control of the deposition scene is also a potential consideration for the offender, and when an offender disposes of a body, there is a trade-off they must make between control and risk levels. An offender can keep control but at a higher risk, or they can relinquish control to minimize risk. Keeping control means keeping the body close and concealed, but that is at the risk of being caught or associated with it. The offender can give up control and dispose of the body far away; this increases risk in the short term as it may increase the chance of discovery with the body; however, it can reduce the risk in the mid- to long term. The third choice is that they can destroy the body. This idea of risk highlights the benefit of including the offender profile with the geographic profile, as it may indicate where the body has been deposited (i.e. someone who likes control will not likely take the body far away). This trade-off between control and risk is demonstrated in Fig. 1. The column on the left demonstrates the sliding scale pertaining to the level of control, with the column on the right demonstrating the sliding scale of risk level. The resulting body deposition site is demonstrated in the centre column, highlighting that destroying the body denotes the lowest level of control (disassociation) and the lowest level of risk, whereas remaining in possession of important evidence or having the BDS on their residential premises denotes the highest level of control (complete control) and the highest level of risk.

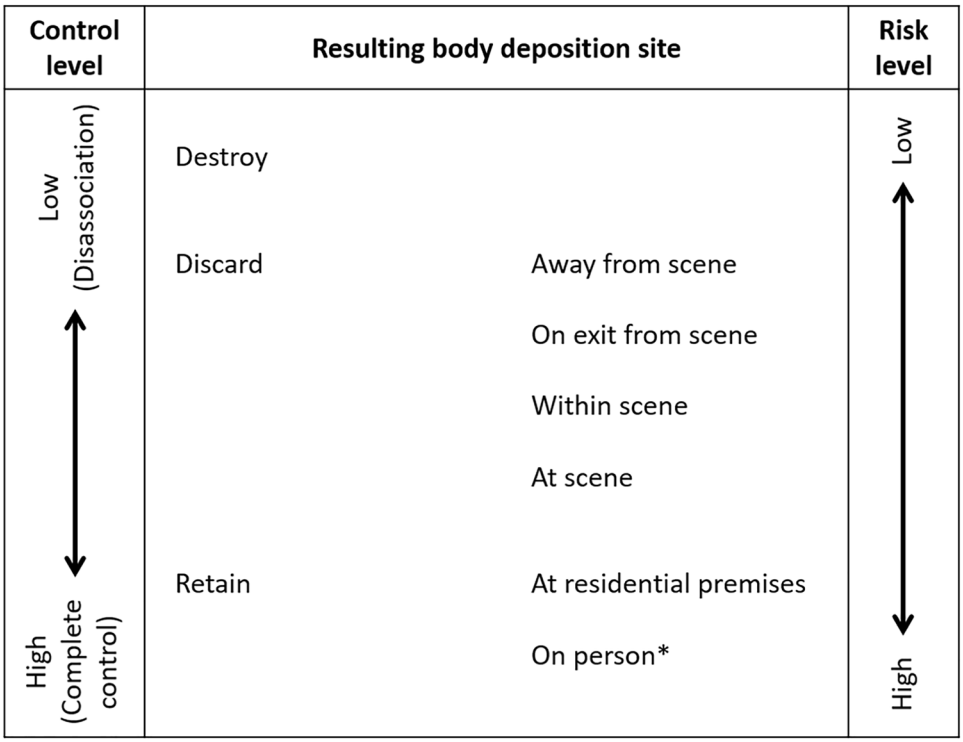

Fig. 1 Depiction of the behavioural trade-off between control and risk levels for offenders depositing their victims in clandestine graves. The left most column identifies the level of control with the corresponding level of risk in the right most column. The centre column highlights the resulting body deposition sites depending on the levels of control and risk. *Although a body deposition site cannot be on the offender, this category was included as some offenders wish to take trophies and may carry them around on their person. Used with permission from (Mattock 2020), with slight changes to include column headings

Although the STEG logistics were discussed separately, it is important to note that they are not mutually exclusive and are often dependant on one another. For example, the time since disappearance is not only a temporal factor, but will affect the spatial and environmental factors as well (all of which are governed by the geographic area). This is evident when working on cold cases, as the factors being included in the geographic profile, such as anchor points, last known locations (of victims and offender), potential routes taken, the specific weather and soil conditions, and the state of the vegetation, will have inevitably changed from when the victim went missing, to many years later when the case is being investigated or revisited. Even in active cases, the STEG logistics are intertwined and unavoidably depend on one another. For example, if an offender kills their victim(s) in the winter (temporal factor), the environmental and geographic factors will be contingent on that, and the potential BDSs will surely indicate that the individual was not buried but disposed of in another manner.

When creating a geographic profile, it is important to note that context is vital, and one single model may not fully depict the intricacies involved in body deposition (Congram et al. 2017). The accuracy of the geographic profile is increased when there are multiple locations and sources of data that can be linked to better locate the BDSs (Barone et al. 2021; Congram et al. 2017). Additionally, the inclusion of the offender profile and victimology will not only increase the accuracy of the geographic profile but will also highlight the fact that each case is different. To this end, each case should be approached with fresh eyes and keen detail on the case-specific information. In that sense, a model that fits for one offender will most likely not fit for another. This notion highlights the importance of amalgamating multiple sources of data, demonstrating how geographic profiling is an interdisciplinary approach that relies on data triangulation.

It is important to make judicious choices when determining what information to include in a geographic profile. Firstly, it is essential to only include accurate information (i.e. from the police investigation or from reliable witnesses; Barone et al. 2021). If there is conflicting information over a certain point in the case, or important location, it should not be included in the final product. It is critical that geographic profilers maintain a suitable balance between the precision and accuracy of a profile. A broad profile (less precise) will be more time-consuming to create but may be more accurate, as it will include more data points. Conversely, developing a narrow profile (more precise), although desirable to investigatory bodies because it decreases the search area, may be less accurate. For example, a broad profile may be that a body was disposed of within 10 m on either side of a roadway that is 30 km in length, whereas a narrow profile may be that the body will be found within 3 km of where the attack occurred. In either situation, the body deposition site may still be found; however, deciding on a broad or narrow profile will be situational and completely dependent on the needs of the investigation and the evidence available.

Although a geographic profile relies on multiple layers of scientific and oral evidence, it is also important to use common sense and avoid external influences. For example, if a 10-year-old girl went missing from a street where a known child sex offender lives, and that same offender visited his cabin in the woods the following day instead of showing up to work, the cabin is a likely place to search. Certain external influences to avoid include theories, such as those held by law enforcement or other relevant experts, and extraneous case details. Exhaustive scenarios that are guided by theories and not evidence, as well as definitive conclusions, should also be avoided.

With any investigative technique, the question of accuracy always seems to be at the forefront. Unfortunately, with geographic profiling, calculating the accuracy, or even a degree of confidence, can be difficult. As discussed above, there are ways to assess the accuracy of a geographic profiling software; however, those techniques do not assess the accuracy of the profile itself. Assessing the profile is more difficult and has not received as much focus as developing accurate software programs (Paulsen 2007). The difficulties in assessing profile accuracy stem from the discipline being both a qualitative and quantitative exercise. Once the STEG elements have been factored in, specifically the spatial elements such as geospatial activity, activity spaces, routes of travel, and anchor points, as well as the offenders MO (based on the offender-victim relationship), the size of the search area and possible BDSs can be highlighted and passed on to law enforcement. Although the potential BDSs can be mathematically calculated by spatial distribution methods and simple heuristics (Harries and LeBeau 2007; O'Leary 2009; Paulsen 2006a, b), being that it is a qualitative exercise based on research into human behaviour and spatial activity, it is not possible to give a degree of confidence in a percentage format.

That being said, retroactively applying geographic profiling techniques to solved cases has shown certain trends that can provide loose degrees of confidence. For example, the average distance to a BDS is 15 km (if the offender has a personal relationship with the victim, they may be found further away), and the average distance from a road is 2 to 3 m. More specifically, in cases of familial homicide (may include children), the victims are more likely to be buried face up, wrapped, and in a meaningful location,[3] potentially on the offender's property. Likewise, in non-familial homicides where the offender has a close relationship with the victim, they are generally found in a meaningful location (but not the property) and at a distance greater than 15 km. These, however, are just generalizations and may change based on the specific case details.

[3] An example of this is the Christopher Watts case from 2018 in Frederick, Colorado, USA. The victims were found at the work site of Mr. Watt's (Morales 2020).

Case Study: Ivan Milat Geographic Profile[4]

The following profile of Ivan Milat was compiled to demonstrate how geographic profiling can contribute to the investigation of serial offenders' activities. Specifically, this geographic profile follows the intelligence gathering and technology model outlined above, with the addition of an offender and victim profile, linking the subject of this case study to other cases and identifying other potential BDSs. Current thinking indicates that there are four additional victims who are likely attributable to Milat.

Executive Summary

Ivan Milat was responsible for the disappearance and murder of seven backpackers, whose bodies he deposited in the Belanglo State Forest (BSF), New South Wales, Australia, as well as the abduction, false imprisonment, and attempted murder of an eighth victim who managed to escape, between 1989 and 1992 (Mallett 2019). He was found guilty in 1996 and sentenced to seven life sentences for the murders, plus 18 extra years for the crimes against the surviving victim (*ibid.*). Milat died in 2019 from stomach and oesophageal cancer. His violent offending started in 1971 after the death of his sister; however, he was never convicted of any criminal activities prior to 1989 (*ibid.*). Although there has been speculation of many other possible victims aside from the confirmed eight, this geographic profile will only discuss his seven murdered victims, as well as four other suspected victims, based on similarities in crime scene details and BDS characteristics. Figure 2 highlights the seven confirmed and the four highly suspected murder victims of Ivan Milat between 1971 and 1992.

Milat's eight known victims were all backpacking (normally in pairs) at the time of their abductions and seven subsequent murders. His victim choice challenges the established notion that the offender selects the time and place for the offence. In this case, his victims dictated many of the spatial and temporal factors, whereas Milat dictated many of the environmental and geographic factors. His employment history allowed him access to many parts of NSW, often travelling along busy highways connecting main cities. This provided him with familiarity with transportation infrastructure and rural access points. Overall, his employment history explains his victim dispersal, points of contact, and BDSs. The distribution of the victim disappearances and BDSs demonstrate that Milat did not like to travel far to pick up and dispose of his victims. This was dictated by his work schedule, travel routes, and residences, providing him with

[4] All information sourced from publicly available information.

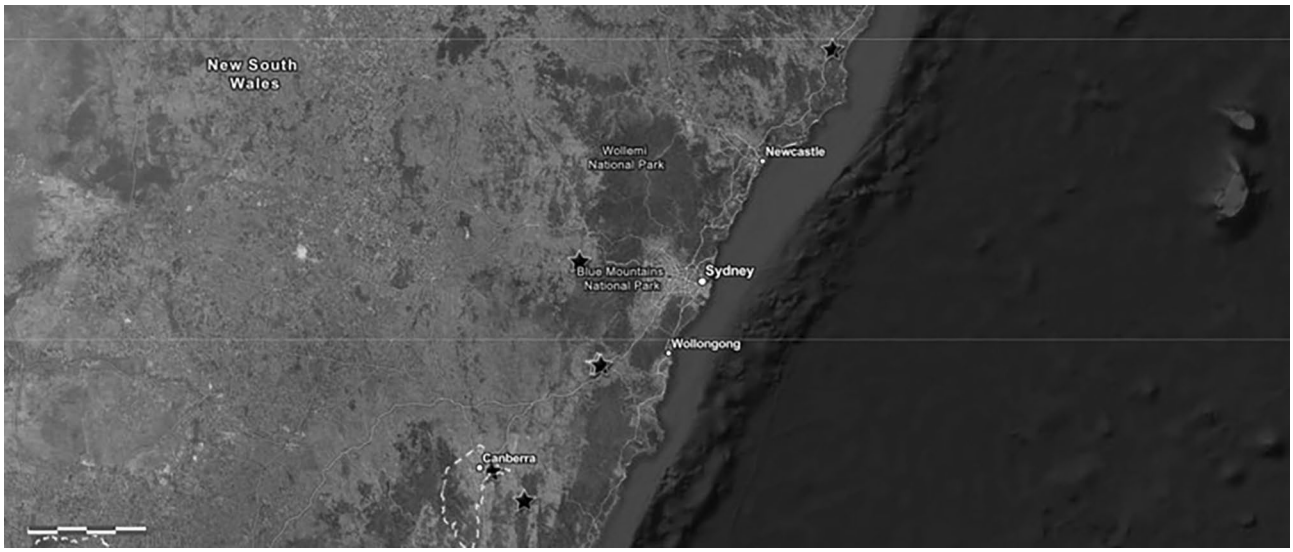

Fig. 2 Map of the BDSs of Milat's known and suspected victims (star pins) found between 1971 and 1992. The seven known victims found in BSF are all denoted in the pins adjacent to Wollongong, and the four highly suspected victims are denoted by the remaining four pins. Throughout this time frame, Milat was known to be active in these areas, travelling for work and to different residences. This map was made in ArcGIS, which is always oriented N-S

the opportunity to commit additional crimes while remaining close to a familiar anchor point or travel route.

Milat was a confident, organized, and ritualistic offender. There was an escalation in criminal behaviour from 1971, when his violent offending started, to 1989–1992, when he abducted and murdered the seven known deceased victims. For these known victims, his confidence is evident in his abduction of and subsequent control over multiple victims simultaneously as he kidnapped three pairs of backpackers (and two single backpackers, including the survivor), spending a protracted amount of time with each deceased victim(s) (evidenced by fire pits and cigarette butts at the crime scenes), and leaving his victims only semi-concealed to facilitate his revisitation. His organization is evident as he had weapons ready in the vehicle (witness testimony from one of his failed abductions), as well as the preselected site (BSF) and extensive knowledge of the area. Milat is considered a ritualistic offender because for each of the seven known murder victims, their ordeals began with a ruse (Milat offering the hitchhikers a ride) and ended with sexual assault, torture, murder, and post-mortem mutilation (victims were used for target practice).

Although there was evidence of sexual assault, Milat's primary focus was to gain power and control over his victims, satiating his violent and sadistic psychopathic personality. Milat's choice of victims demonstrates that he was an opportunistic offender, as he was drawn to a specific type of victim (hitchhikers). Hitchhikers can be considered ideal victims because they are often alone or in pairs, as well as being isolated from others including loved ones for extended periods of time (at the time, cell phones were not largely available prohibiting everyday contact).

Modus Operandi (MO)

Milat's MO was to pick up young hitchhikers, whom he abducted, tortured, sexually assaulted, and murdered and ultimately left in the remote, forested area of BSF. Although he never admitted to his crimes, an analysis of the crime scene, geo-environmental elements, and victimology highlights a potential sequence of events:

1. Friendly, trustworthy, and reliable appearance used to lure his potential victims into his vehicle.
2. Travel in the direction asked by the hitchhikers as to not raise suspicion.
3. Fabricate a reason/excuse to venture away from the main road and get victims to a secluded forested area—potentially involving an official abduction sequence if they became suspicious.
4. Psychological and/or physical control over his victims using threats of violence and restraints. With victims travelling in tandem, he likely subdued/eliminated one victim as to be able to control the other—this is supported by evidence as one victim was often shot with clothes intact, while the other victim was subjected to multiple weapons and sexual assault.
5. Torture, sexually assault, and then kill victims.
6. Post-mortem mutilation and target practice.

Fig. 3 Map of Milat's seven confirmed victims (star pins) found in BSF. The two most left pins and the most right pin indicate crimes scenes where he subdued, controlled, and murdered two victims at once. This lends to Milat's criminal confidence. The remaining pin was a single victim incident. This map was made in ArcGIS, which is always oriented N-S

7. Bury victims in shallow grave by covering with foliage or existing forest features (tree trunks, branches, etc.).
8. Take clothing and items belonging to his victims as a trophy, as well as to give his family members as souvenirs/gifts.
9. Revisitation of some graves—confirmed as the t-shit of a later victim was found with the remains of an earlier victim (Mallett 2019).

Intelligence

Case-Specific Information

A comprehensive case summary is provided by Mallett (2019).

Spatial

Milat is considered a troller (a newer category of offender, not conventionally taught in geographic profiling—defined as an offender who hunts both within and outside their activity space) whose offending is space-centred, not victim-centred. A troller can be considered a combination of a marauder and a commuter. Milat moved around a lot for work and often hunted close to an anchor point that was either a workplace or his residence.

The gravesites of Milat's known murder victims were in secluded areas in BSF, devoid of artificial light at night. They were all located off fire trails (up to 150 m), thus being out of the way of anyone passing by but easy enough to reach by vehicle and close to an identifiable reference point such as large boulders. This allowed Milat to re-locate the BDSs and spend a considerable amount of time with them without being disturbed. Each gravesite was separated both within and between events, probably as a way for Milat to 'spread out evidence' to avoid discovery. Figure 3 demonstrates where the seven known victims were found in BSF.

Temporal

Some of the temporal factors in the Milat cases are victim driven, whereas others are offender driven. Hitchhikers tend to avoid the busy morning commute, as well as unfavourable night-time risks such as lack of light and a higher potential to get struck by a car; therefore, Milat likely picked up his victims in the late morning or early afternoon. His documented murders took place in the warmer months, which is consistent with an increase in hitchhikers.

Avoiding night-time abductions was also beneficial to Milat, as the gravesites in BSF were devoid of artificial light; therefore the victims needed to be controlled and subdued by nightfall. Milat often worked daytime hours; therefore, the abductions took place on his off days, including weekends and holidays.

Prior to the seven known deceased victims, Milat had three overlapping activity spaces, corresponding with three time periods, including 1971, 1975–1986, and 1987–1992. It is important to note that the 1972–1974 timeframe is excluded from Milat's timeline as he was known to be in New Zealand (NZ). The reason for his time in NZ was because he faked his death to avoid legal matters concerning an armed robbery; however, little is known about his

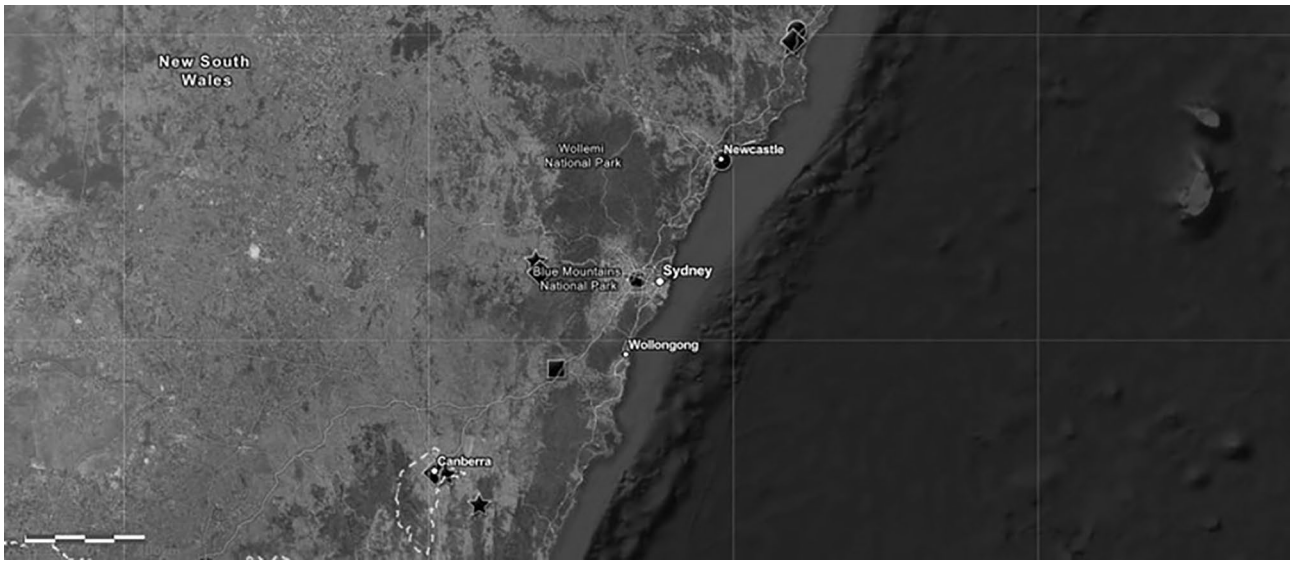

Fig. 4 Map of Milat's four highly suspected victims, including the BDSs (star pins), Milat's work/anchor points (diamond pins), and residences (circle pins), as well as BSF (square pin) for reference. This map was made in ArcGIS, which is always oriented N-S

activities, employment, and relationships there before returning to Australia in 1975. In 1987, Milat and his then wife got divorced, which is thought to be the catalyst for his murdering the seven known victims between 1989 and 1992, as well as an eight victim who was abducted and murdered in 1987 whose remains were found in Jenolan State Forest, a crime widely believed to be attributable to Milat.

Environmental

Milat preferred forested areas as BDSs that were close to main highways but were not popular tourist destinations. He avoided hilly terrain with thick vegetation, allowing him to drive to the gravesites and spend time with his victims, which were placed in shallow graves or hallows and covered with loose leaf litter.

Although Milat gave up some control over the time and place to his victims initially, he did maintain control over his environment. He was well acquainted with the BSF area and may have considered it his sanctuary. He knew the road system well, including where the visitors frequented and how they generally navigated around the area. More importantly though, he knew where to hunt and where he could be alone with his victims for extended periods of time. He used the forest as a visual and sound barrier to conceal his activities.

As for the other four highly suspected victims, Milat was either working or living in close proximity to where the victims were abducted and subsequently found (shown in Fig. 4). The first suspected victim was abducted, and her body disposed of in 1971 in Canberra where Milat was purportedly working. Although Milat's involvement in this murder is inconclusive, the similarities in body deposition characteristics (including the environment of the pine plantation in which the body was found), Milat being in the area, and being one month after his sister died, make him a likely suspect. The second victim was found in 1987 in Kiwarrak State Forest but had been reported missing in 1985 from the Newcastle area. Milat was living in Newcastle at the time of their disappearance and was known to work in the Kiwarrak State Forest. The next victim was found in the Jenolan State Forest, also in 1987 (before the seven known victims). This murder has been connected to Milat for a number of reasons, including the fact that a shell casing that was found with the Jenolan victim was linked to the gun that killed two of the seven Belanglo victims, in addition to which the cause and manner of death and body deposition pattern match the seven known murder victims (Mallett 2019). This victim was known to be hitchhiking from Sydney to Bathurst, a route Milat is witnessed to have taken. The fourth and final suspected victim went missing from Queanbeyan, NSW, in 1991 and was found a few months later in the Tallaganda State Forest, approximately 300 km from her family home in Guilford, and 200 km from BSF.

Technology

A drone mounted Light Detection and Ranging (LiDAR) scan was completed in November 2020, for the purposes of an Ivan Milat documentary on Australia's Channel 7, hosted by forensic criminologist Dr. Xanthé Mallett and criminal psychologist Dr. Tim Watson-Munro, and with the contributions of geographic profiler Doug MacGregor and GIS and remote sensing expert Yuri Shendryk (EQ Media & Bannaby Productions 2021). It is important to note that no

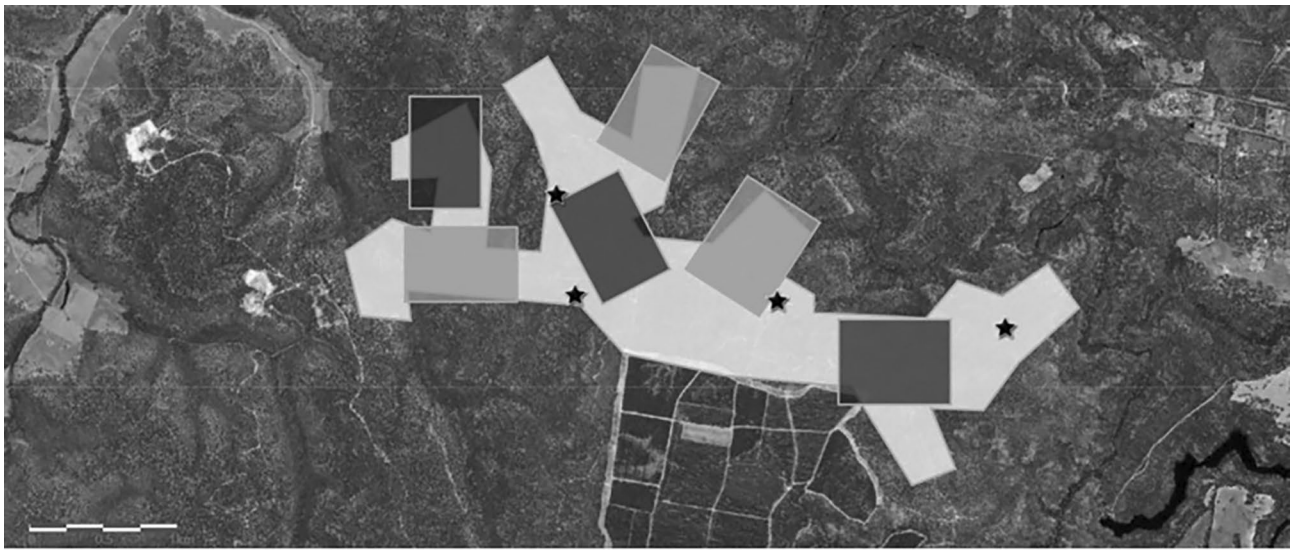

Fig. 5 Map of BSF denoting the BDSs of Milat's seven known murder victims (star pins), as well as the ideal search area for additional victims (white polygon). The ideal search area follows the fire trails and extends 150 m on either side. Primary (light grey) and secondary (dark grey) search areas are highlighted for a subsequent LiDAR scan and foot search. The two most left pins and the right most pin indicate crimes scenes where he subdued, controlled, and murdered two victims at once. The remaining pin was a single victim incident. This map was made in ArcGIS, which is always oriented N-S

new victims were found, as the purpose of the LiDAR scan was to demonstrate the usefulness of this type of technology when searching for BDSs and was not used in an official capacity to locate additional Milat victims. A second LiDAR scan should be undertaken in BSF, following 150 m from the fire trail (shown in Fig. 5), to officially search for additional gravesites.

Although it is possible that Milat deposited his victims in other forested areas (as this type of area seemed to be a preference for him), BSF was the largest forested area off the Hume Highway (where he often abducted his victims). Other potential state forests include Penrose, located off the Hume Highway, which could have been used as a deposition site if he could not access BSF covertly, as well as Jenolan, Kiwarrak, and Tallaganda State Forests.

Offender Profile

Offender Risk Type

Milat can be considered a low-risk or risk-adverse offender due to the circumstances surrounding his choice of victims (e.g. they were all isolated, vulnerable, in ready supply, lacked visibility, and allowed discretion) and weapons. His victims were isolated throughout the ordeal, from being picked up as hitchhikers in Milat's vehicle to their final moments in a secluded, forested area. His victims were considered vulnerable because they required a service that would only be provided by a stranger, as well as the false security that existed because most of his victims travelled in pairs. The stretch of highway (Hume Highway) where Milat hunted was a major road connecting popular parts of New South Wales, meaning that there was likely to be hitchhikers present that could not be selective with their transportation choices. The visibility of his victims was considered low, because although they were subject to human surveillance while hitchhiking, their disappearance would go largely unnoticed (especially because cell phones were not common at the time and contact with family and loved ones would have been minimal). Milat had discretion, as he would have blended in as a driver offering the hitchhikers a ride (like a taxi driver). Finally, the weapons he selected (a hammer and later a 0.22 calibre shotgun with a home-made silencer) were chosen to instil fear in, and control over, his victims, and they were quiet, meaning that the sound would not travel and alarm other people.

Motives

Milat's primary motive was the enjoyment and thrill of hunting and capturing, and subsequent torture of, his victims. As a (undiagnosed) violent and sadistic psychopath, he was known to fulfill his need to kill after being triggered by certain life events. Ivan Milat's documented murders were opportunistic and logical and usually took place when his relationships with his female partners had broken down. Possible secondary motives include trauma (violent offending started after 1971 when he lost his sister in a car accident), loss (sentenced murders started after his wife and

non-biological son left him), a sexual component (evidence of sexual assault on most of his victims), and anger (result of losing control of one person in his life and needing to fulfill that by controlling someone else).

Victimology

Milat's known victims were hitchhikers aged 19–24; however, the age range broadens to 18–29, when suspected victims are included. He is classified as a teleiophile (a sexual preference to adult victims), but his age range and victim choices were more so a product of his MO and not his sexual preferences. The way each of his victims was found denoted no real connection to the victims and rather exemplifies his need for power and control.

Conclusion

In conclusion, this review paper highlighted the benefits of using geographic profiling techniques in missing persons investigations to help locate clandestine graves. This was done by discussing the role of the STEG factors and other intelligence, all of which were useful in the creation of a geographic profile of serial killer Ivan Milat. This profile provided an extensive overview of Milat's history of violent offending, demonstrating that serial offenders usually offend in proximity to an anchor point/points and are governed by the STEG elements of the area. These assumptions can help to locate not only the residence or workplace of the offender, but the BDSs of their victims as well. Although geographic profiling is commonly used on serial offenders, it can also be useful when locating the BDSs of single offence offenders.

It is important to note that geographic profiling does not solve crimes but is instead a tool that can be used to guide investigations by providing investigative strategies or 'areas to search'. As such, the information gained from a geographic profile should not be taken as conclusive fact, because the accuracy of the profile is contingent on the accuracy of the information involved in creating it (Barone et al. 2021). The only definitive way of locating deceased missing persons is by excavation, which is time- and personnel consuming (Berezowski et al. 2018); however, geographic profiling techniques can increase the accuracy of locating BDSs by combining case intelligence with the relevant STEG elements, as well as the offender and victim profiles. The importance of locating clandestine graves has been demonstrated in this article through the legal, social, psychological, and financial implications that unresolved cases can have on individuals, communities, and societies (Congram et al. 2017). Including all, or even some, aspects of geographic profiling as an investigative tool will enhance the likelihood of locating those who are missing and presumed dead.

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Consent for Publication Not applicable.

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